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Maxim Bakaev · Radomir Bolgov · Andrei V. Chugunov · Roberto Pereira · Elakkiya R · Wei Zhang *Editors*

Digital Geography

Proceedings of the International Conference on Internet and Modern Society (IMS 2023)

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ISSN 2194-315X ISSN 2194-3168 (electronic)
Springer Geography
ISBN 978-3-031-67761-8 ISBN 978-3-031-67762-5 (eBook)
https://doi.org/10.1007/978-3-031-67762-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

IMS-2023 Editorial

On June 26–28, 2023, the International Conference "Internet and Modern Society" (IMS-2023) was held in St. Petersburg (Russia) and Online (partner universities). The proceedings contain the papers that were selected by the IMS-2023 Program Committee. The selection of papers for publication is based on the results of double-blind review by members of the program committee using the international system for supporting scientific conferences Easychair.

This proceedings book addresses the topical issues of digital geography and geography of information society, providing a platform for discussion and collaboration of experts in the related fields. Participants from all over the world consider the controversies and challenges posed by globalization, focusing, in particular, on the Digital Urbanism, Smart City, Digital Sustainability, Social Media Movements, Digital Divide, Cyber Psychology, etc. The content of the book may be interesting to expert community, academics and popular audience. The Program Committee comprising the recognized researchers had conducted a rigorous peer review. One of the unique characteristics of this proceedings is that it gathers under conceptual umbrella Western and Eastern researchers. Moreover, this book reveals a new topic of geography—Digital Geography.

ITMO University is the main organizer of the event held in cooperation with the partner universities (Birla Institute of Technology and Science, Pilani—Dubai Campus, United Arab Emirates, Huazhong University of Science and Technology, China & Federal University of Paraná, Curitiba, Brazil).

The program of the IMS-2023 conference was based on international workshops:

- Electronic governance (eGov-2023)
- Digital City (DCity-2023)
- Computational Linguistics (CompLing-2023)
- Internet Psychology (IntPsy-2023)

Traditionally, the conference program also included sessions of scientific presentations:

- E-learning and distance educational technologies
- Cultural studies of cyberspace

The program of the conference was expanded by special events aimed not only at researchers but also at the expert community and young scholars:

- International Symposium "Digital Health and Active Aging Development." The symposium is being held for the second year in collaboration with Huazhong University of Science and Technology, Wuhan, China.
- International Workshop "Interactive Systems & Information Society Technologies" (InterSys2023) was held in collaboration with Federal University of Paraná, Curitiba, Brazil, and Birla Institute of Technology and Science, Pilani—Dubai Campus, United Arab Emirates.
- Young Scholars' Poster Session "Digital Transformation in Governance and Society" (Young DTGS-2023).

We would like to thank those who made this event possible and successful. We especially express our gratitude to the Program Committee members for their contribution to the event. We thank the authors for submitting their papers. We are proud to attract a great team of scholars from different countries and disciplines. We will work further to sustain and expand the IMS community through joint research and collaboration.

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Young Scholars' Poster Session "Digital Transformation in Governance and Society"
Yury Kabanov, HSE University, St. Petersburg, Russia

Contents

Part V E-Governance and Political Communication

Part I
Digital City

Ontological Engineering to Support Building, Urban Planning and Environmental Security Solutions

Artem Shcherbakov, Nikolay Rashevskiy, Natalia Sadovnikova, Artyom Chikin, and Danila Parygin

Abstract The chapter is devoted to the issues of decision support systems in the field of construction, urban planning, environmental safety, efficiency and prospects of use of the proposed solutions. The relevance of this study is determined by the automation of the application of regulatory documentation, accelerating the development and saving money at the design stage of urban infrastructure, as well as the subsequent use of the proposed solutions. Decision support systems (DSS) are an integral part of our lives. One way or another, we all make decisions based on analysis, experience or some documentation. The field of urban planning is not spared by this system. In today's world ontologies, namely the representation of knowledge bases in the form of an ontological model, are gaining popularity. There is a popularization of knowledge bases by increasing the volume of information and its complexity. For the intellectualization of DSS (transition to IDSS), ontological engineering is offered—development of an ontological model on the basis of normative documents in parametric modelling: "Set of rules" and "Building codes and regulations". The model applies graphical predicate tools and semantic ontologies of architectural topology. Classes of urban planning objects and their properties, as well as urban planning standards, determine the order of construction of urban infrastructure and urban facilities were compiled on the basis of the analysis of regulatory documents. The structures of normative documents containing heterogeneous nesting, mutual references and contradictions were considered. Based on the results of the study, we compiled an ontological model of a knowledge base to support urban planning decisions, containing five entities: "Buildings", "Private sector", "Schools", "Shopping centres" and "Parks".

Keywords Decision support system · Knowledge representation model · Ontology · Urban planning standards · Ontological engineering · Environmental safety · Construction

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_1

1 Introduction

Every year the pace of construction and urban planning increases. In turn, this is accompanied by increased attention to the development of traditional technologies and methods of urban planning. Thus, "Urban Planning Code of the Russian Federation" related to urban planning activities and the development of territories of cities and other settlements is constantly changing and supplemented. It describes the following activities [1]:

- Territorial planning
- Urban planning zoning
- Architectural and construction design
- Construction of capital construction facilities
- Capital repairs
- Reconstruction
- Operation of buildings and structures
- Landscaping

Despite such a wide range of areas described in this code, they are all based on normative documentation, standards and rules, which, in turn, allow us to clearly distinguish all urban planning processes and make them reliable and safe. But it must not be forgotten that all urban planning processes go through another five stages of legal regulation:

- 1 level: The Constitution of the Russian Federation, the norms of which guarantee a favourable environment (Art. 42) [2].
- 2 level: The Urban Planning Code of the Russian Federation itself. All laws and normative legal acts of the Russian Federation and subjects of the Russian Federation regulating relations in the area of urban planning cannot contradict this code.
- 3 level: Federal laws, such laws include various land codes [3], the federal law "On architectural activity of the Russian Federation" [4], etc.
- 4 level: Subordinate legal acts of the Russian Federation, such as Resolutions of the Russian Federation, the Order of the Government of the Russian Federation "On approval of the action plan ("road map") for the implementation of the mechanism of management of system changes in the regulatory framework for business activity 'Transformation of the business climate' 'Re-engineering of rules of industrial construction'" [5], orders of the Ministry of Construction of Russia, etc.
- 5 level: Legal acts of the subjects of the Russian Federation, they include the Code of Volgograd region on administrative responsibility ("Administrative offences in the field of land use and urban planning") [6], the Law of Moscow "Code of the City of Moscow on Administrative Offences" ("Administrative offences in the field of urban planning and operation of urban infrastructure") [7], etc.

They also reviewed regulatory documents related to the construction and environmental safety:

- 1 level: The Constitution of the Russian Federation, the norms of which guarantee a favourable environment (Article 42).
- 2 level: Urban Planning Code of the Russian Federation, for example, chapter "Automatic Keyword Extraction from German Journalistic Discourse Using Statistical Methods", devoted to construction, architectural and construction design and environmental expertise (Articles 47–55).
- 3 level: Federal laws, that is, Federal Law "On the sanitary and epidemiological welfare of the population" [8], Federal Law "On Environmental Protection" [9].
- 4 level: Secondary regulatory legal acts of the Russian Federation, that is, Decree of the Government of the Russian Federation "On approval of the action plan ("road map") for the implementation of the mechanism for managing systemic changes in the legal regulation of business activity 'Transformation of the business climate' 'Re-engineering of rules of industrial construction'", Regulations on the assessment of the impact of planned economic and other activities on the environment in the Russian Federation, etc.
- 5 level: Legal acts of the subjects of the Russian Federation, that is, Code of Volgograd region on administrative responsibility, etc.

To represent the knowledge of urban planning rules and regulations, as well as their management, it is advisable to consider such a tool as ontology. Ontology is a description of a subject area, taking into account the existing rules and relationships between elements of this subject area. Of course, there are other approaches to store knowledge, for example:

- Thesauri (sets of words, concepts and information having semantic connection between each other)
- Datasets (sets of objects that have specific properties: attributes, connections between each other)
- Taxonomy (knowledge systematized according to the hierarchical structure, each element of the hierarchy is considered as an entity correlated with other entities)
- Controlled vocabularies (systematized knowledge with indexing of each unit of information)

The advantages of the ontological approach are clearly expressed, which is described in Table 1.

Table 1 Advantages and disadvantages of the ontological approach

Advantages of the ontological approach	Disadvantages of the ontological approach
Simplifying system development in perspective	Complexity of perception of the stored data
Obtaining a logical output as a result of a query based on the stored data	Development labour intensity
Ability to dynamically change the data	–
Ability to use one knowledge base in another, by specifying a URL link	–
Ease of modeling complex relationships	–

2 Overview of the Use of the Ontological Approach in Urban Planning Tasks

Some studies examine multidimensional ontological models. The main purpose of such models is to provide semantic descriptions of land use in accordance with four aspects: zoning, services, infrastructure and easement. The regulatory framework used for ontologies was presented within the framework of Moroccan urban planning law. The model is based on a concrete example, comparing the land use planning document on the territory of the Einchok municipality of Casablanca in accordance with the concepts of this ontology [10].

Another example of using ontologies is the integration of spatial information in the construction of the ontology of the urban planning subject area and obtaining spatial information from the Internet as input data of the self-learning method is usually used in the construction of an ontology. Geographical names are an important indicator of understanding spatial information on the Internet. However, the place names expressed in natural language introduce various ambiguities, which would create serious problems for several fields of research, such as Geography Information System (GIS) and Geographic Information Retrieval (GIR). GIR contributes more to the elimination of ambiguities in place names than GIS. However, from the point of view of urban planning, it still lacks practical application. A hierarchical structure of spatial ontology has been developed, which allows designers to deal with ambiguities. The study of Liao & Lin [11] solves the problem of ambiguity in urban planning.

The ontological approach in urban planning is a way to organize knowledge and data, which allows us to define the entities of the urban environment, their relationships and properties, as well as ways of using these data to achieve urban planning goals. Ontologies allow to create general semantic structures to describe the entities and properties that are used in urban planning, construction and environmental safety. These structures can be represented in the form of ontological graphs, where each entity is represented by a node, and relations between them are represented by links between nodes. Let us consider several possibilities for using this approach [12]:

- Knowledge formalization: Creating a structured representation of knowledge about the urban environment, planning participants and decision-making.
- Integration of data and knowledge: Using knowledge in a single system to simplify the analysis and comparison of information in different contexts of urban planning.
- Support of interdisciplinary cooperation: Ontologies can become a unifying tool for specialists of different disciplines, such as architects, urban planners, builders and environmentalists, who work in the field of urban planning.
- Automation and intellectualization of urban planning: The ontological approach will make it possible to develop intelligent decision support systems based on knowledge and regulations in urban planning.
- Improving the quality and reliability of planning decisions: The use of this approach will help to identify in advance possible conflicts, contradictions and deficiencies in urban planning decisions, which contributes to better and more reliable results.
- Improving the sustainability of urban development: The use of the ontological approach can help to develop strategies for sustainable urban development, taking into account environmental, social and economic factors.
- It is possible to distinguish one more variant of use that bears a training function for future specialists: The use of ontologies for the development of educational programmes and trainings courses.

There are already several real solutions to urban planning problems, one of them is CityGML. It is an extensible schematic model for describing urban objects, which stores information about the geometry of urban objects, such as buildings, roads and bridges, as well as the properties of objects, such as building heights and surface types [13].

The next example is LandInfra/InfraGML-standards for the exchange of data on spatial planning and infrastructure, based on geographic information systems (GIS). The standards include objects, projects, trace, roads, railroads, geodesy, land features, land subdivision and drainage infrastructure [14].

Another major solution in urban planning is urban ontologies. Urban ontologies are classification and description systems related to planning, land use, transportation, housing, environment and socio-economic aspects of the urban environment [15].

However, despite the clear success of researchers in the field of urban planning, Russian researchers have created Opensource ontology. The Information Modeling Technology Ontology project is designed to develop a set of ontologies in the field of urban planning in order to support the development of the national standards system "Unified System of Information Modeling" [16]. An example of their visibility of the ontology is shown in Fig. 1.

Of course, as you can see from the ontograph, the model is far from perfect and, unfortunately, the project is abandoned. Therefore, the ontological approach in the direction of urban planning is still in its infancy and does not have a sufficiently well-established base, especially for the Russian Federation.

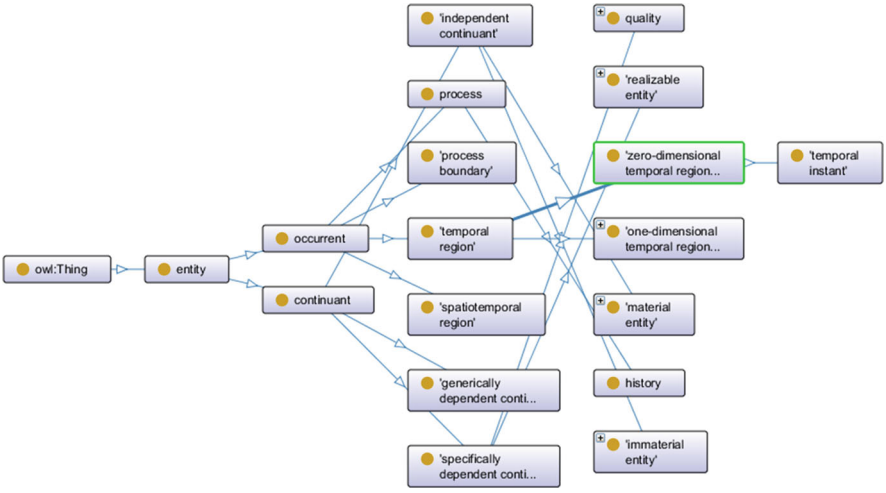

Fig. 1 Ontological model of the unified information modeling system

3 Development

At this stage of ontology model development, we identified five urban entities: "Buildings", "Private sector", "Schools", "Shopping centres", and "Parks". To create each entity and entity instance, we analysed building codes and regulations, as well as codes of practice, sanitary rules, regulations and national standards. The normative documents used for the analysis, as well as the entities formed on their basis, and their instances for specific infrastructure objects are presented below.

3.1 Entity "Park"

One of the highlighted objects of urban development infrastructure is parks. Parks play an important role in the city's socio-economic life. To form an ontological model, the following normative documents were considered:

- "Set of rules 475.1325800.2020. Code of Practice. Parks. Rules of urban planning design and improvement"
- "Set of rules 59.13330.2020 'Building codes and regulations' 35-01-2001. Accessibility of Buildings and Structures for Low Mobility Populations with Amendment No. 1"
- "Sanitary rules and regulations 2.2.1/2.1.1.1200-03. Sanitary Protection Zones and Sanitary Classification of Enterprises, Structures and Other Objects"
- "Sanitary rules and regulations 2.1.3684-21. Sanitary and epidemiological requirements for the maintenance of urban and rural settlements, water bodies,

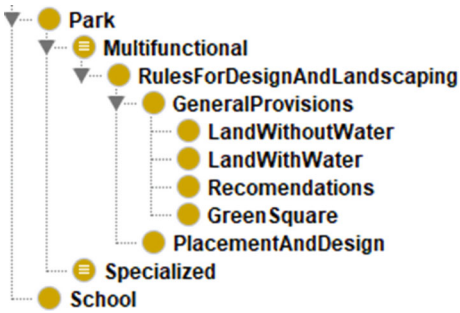

Fig. 2 Ontological model of the "Park" entity

drinking water and potable water supply, atmospheric air, soils, residential premises, operation of industrial and public buildings, organization and conduct of sanitary and anti-epidemic (preventive) measures"

Based on the results of the work, an ontology was formed (see Fig. 2). The instances of the class "Design and landscaping standards" describe the design rules of the park area, the distance from other urban infrastructure, etc. In the same way in the instances "Green space", "Park without water" and "Park with water", the rules of ecological safety of the object and ecological norms were considered.

3.2 Entity "School"

The next highlighted object of urban development infrastructure are schools. Schools have a significant role in the socio-educational life of the city. To form an ontological model, the following normative documents are considered:

- "Set of rules 42.13330.2016 'Building codes and regulations' 2.07.01-89. Urban Planning. Planning and development of urban and rural settlements" with Amendments No. 1, No. 2, No. 3 and No. 4
- "Set of rules 59.13330.2020 'Building codes and regulations' 35-01-2001. Accessibility of Buildings and Structures for Low Mobility Groups of Population with Amendment No. 1"
- "Set of rules 10.13130.2020. Fire protection systems"
- "Set of rules 52.13330.2016 'Building codes and regulations' 23-05-95. Natural and artificial lighting with Amendments No. 1, No. 2"
- "Set of rules 131.13330.2020 'Building codes and regulations' 23-01-99* Construction Climatology with Amendment No. 1"

Based on the results of the work, the ontology shown in Fig. 3 was formed. In the instances of the class "Premises" we have formed the building rules for classes, workshops, corridors, etc. In the instances of the "Territory" class, general urban planning rules were generated. In the instances of the class "Climatic district", the

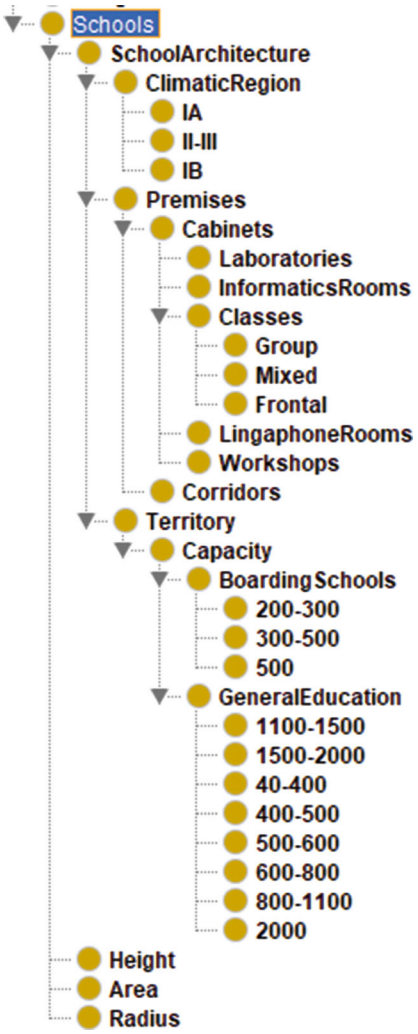

Fig. 3 Entity "School" and its instances

rules establishing the climatic parameters that apply to the design of buildings and structures were considered.

3.3 Entity "Buildings, Apartment Building, Neighbourhood"

The next highlighted objects of the infrastructure of urban development are buildings, residential buildings and neighbourhoods. These infrastructure objects play an important role in urban development. To form the ontological model, the following normative documents were considered:

- "Set of rules 476.1325800.2020. Territories of urban and rural settlements. Rules for planning, development and improvement of residential neighbourhoods"
- "Set of rules 42.13330.2016 'Building codes and regulations' 2.07.01-89. Urban Planning. Planning and development of urban and rural settlements with Amendments No. 1, No. 2, No. 3 and No. 4"
- "Sanitary rules and regulations 2.2.1/2.1.1.1200-03 Sanitary Protection Zones and Sanitary Classification of Enterprises, Structures and Other Objects"
- "Set of rules 59.13330.2020 'Building codes and regulations' 35-01-2001. Accessibility of Buildings and Structures for Low Mobility Groups of Population with Amendment No. 1"

Based on the results of the work, the ontology shown in Fig. 4 was formed. The instances of the class "ArchitectureBuildings" describe the rule of construction of buildings, according to their storeys. The instances of the class "Yard" describe the rules of yard and courtyard territories according to the regulatory documents (Fig. 5). In the copy "Landscaping", according to Set of rules 82.13330.2016 "'Building codes and regulations' III-10-75 Area Improvement" with Amendments No. 1 and No. 2, the rules of landscaping and beautification of the territory were highlighted. Considering the rules of the remoteness of residential buildings from the objects of infrastructure, a subclass "Infrastructure" was formed, describing the rules of the remoteness of the building from these objects (Fig. 6).

3.4 Entity "Private Sector"

The next highlighted object of urban infrastructure is the private sector. These infrastructure objects play an important role in urban development. To form the ontological model, the following normative documents were considered:

- "Set of rules 104.13330.2016 'Building codes and regulations' 2.06.15-85. Engineering protection of the territory against flooding and underflooding with Amendment No. 1"
- "Set of rules 10.13130.2020. Fire protection systems"
- "Set of rules 59.13330.2020 'Building codes and regulations' 35-01-2001. Accessibility of Buildings and Structures for Low Mobility Groups of Population with Amendment No. 1"

Based on the results of the work, the ontology shown in Fig. 7 was formed. The instances of the class "ArchitecturePrivateSector" describe the rule of the construction of buildings, according to their storeys. The instances of the class "SettlementsCityType" describe the general rules for the construction of these settlements according to the regulatory documents. In the copy "Landscaping", according to Set of rules 82.13330.2016 "'Building codes and regulations' III-10-75 Landscaping" with Amendments No. 1 and No. 2, the rules of landscaping and beautification of the territory were allocated (Fig. 8).

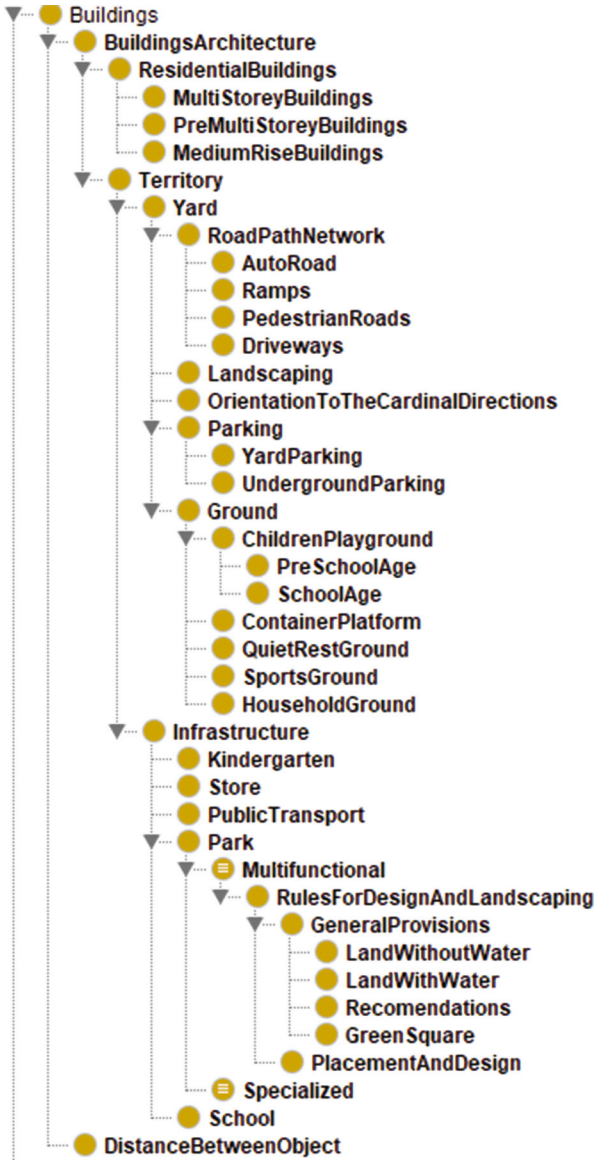

Fig. 4 Entity "Buildings, residential building, neighbourhood" and its instances

3.5 Entity "Shopping Centres"

The next highlighted object of urban development infrastructure is shopping centres. These objects of infrastructure play an important role in the socio-economic life of the city. To form an ontological model, the following regulatory documents were considered:

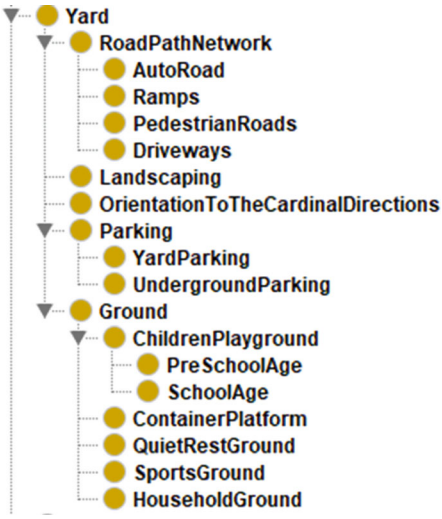

Fig. 5 Instances of the "Yard" entity

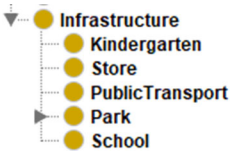

Fig. 6 Instances of the "Infrastructure" entity

- "State standard" 30494-96. Residential and Public Buildings. Parameters of microclimate in the premises
- Sanitary rules and regulations 2.2.1/2.1.1.1076-01. Hygienic requirements for insolation and sun protection of premises of residential and public buildings and territories
- Set of rules 113.13330.2016 "Building codes and regulations" 21-02-99*. Parking lots with Amendment No. 1
- "Set of rules 132.13330.2011. Ensuring anti-terrorist protection of buildings and structures. General design requirements"

Based on the results of the work, the ontology shown in Fig. 9 was formed. The instances of the class "Parameters" describe the rule of building construction, according to their height, area and type. The instances of the "Rules" class describe the general rules of construction of these shopping centres according to the regulatory documents. In the copy of "Landscaping", according to Set of rules 82.13330.2016 "'Building codes and regulations' III-10-75 Landscaping" with Amendments No. 1 and No. 2, the rules of landscaping and landscaping were highlighted (Fig. 10).

Obviously, this is not the entire list of regulatory documents that were used for the analysis.

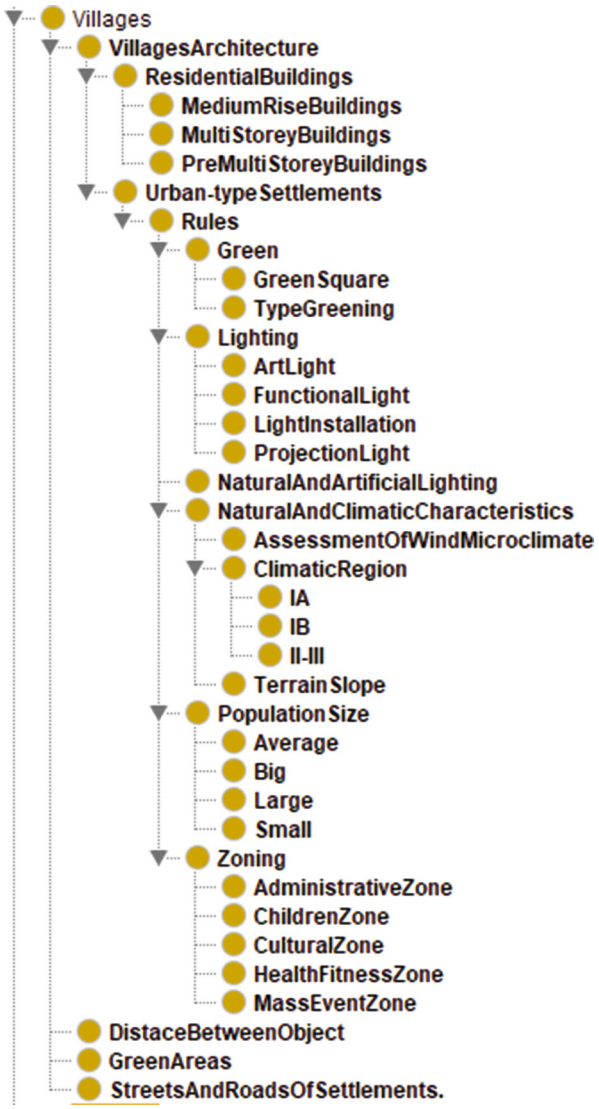

Fig. 7 Entity "Buildings, residential building, neighbourhood" and its instances

3.6 Making Links

The next step towards creating an ontology is descriptive logic, a section of mathematics that describes any information expressed in natural language [17] as a chain of triplets (Fig. 11). For example, School $\sqsubseteq \forall$ hasObject. Classroom—it means that every school has an object "classroom".

Using this logic, ontology was represented as a graph (Fig. 12), the vertices of which represent the entities of the domain and the edges represent the relationships

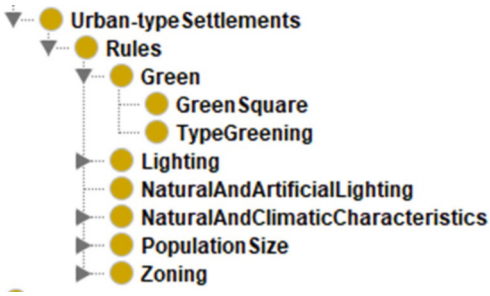

Fig. 8 Instances of the "Greening" entity

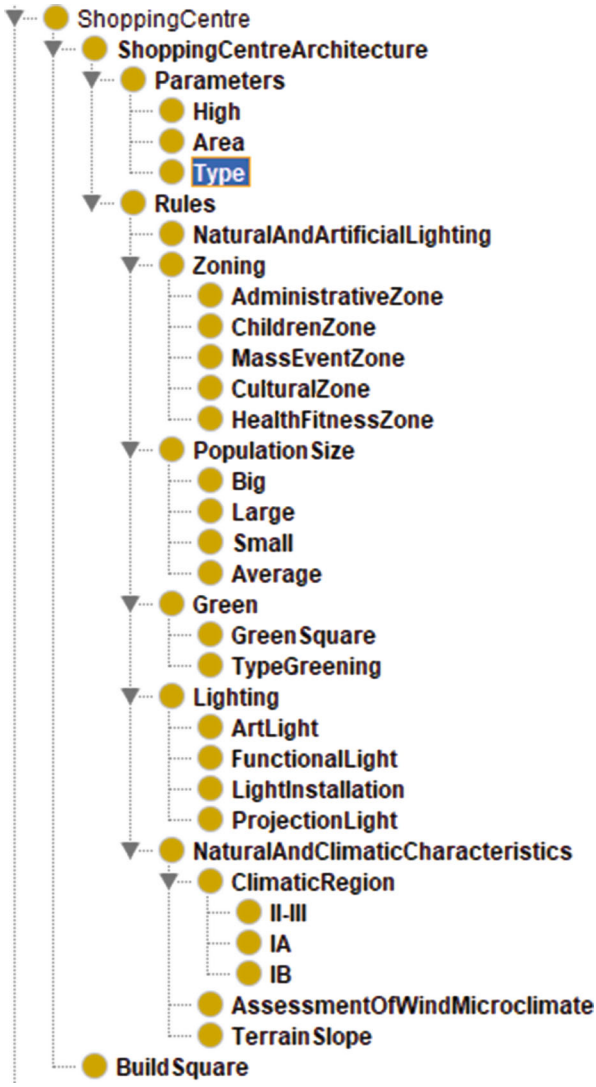

Fig. 9 Entity "Buildings, residential building, neighbourhood" and its instances

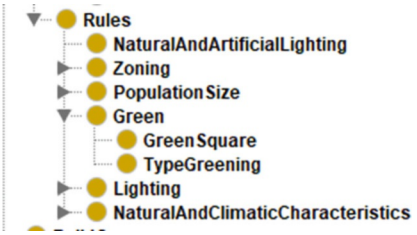

Fig. 10 Instances of the "Greening" entity

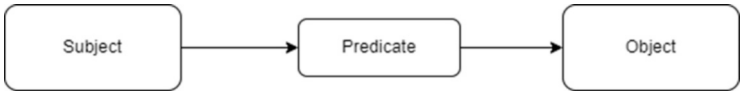

Fig. 11 Chain of triplets based on descriptive logic

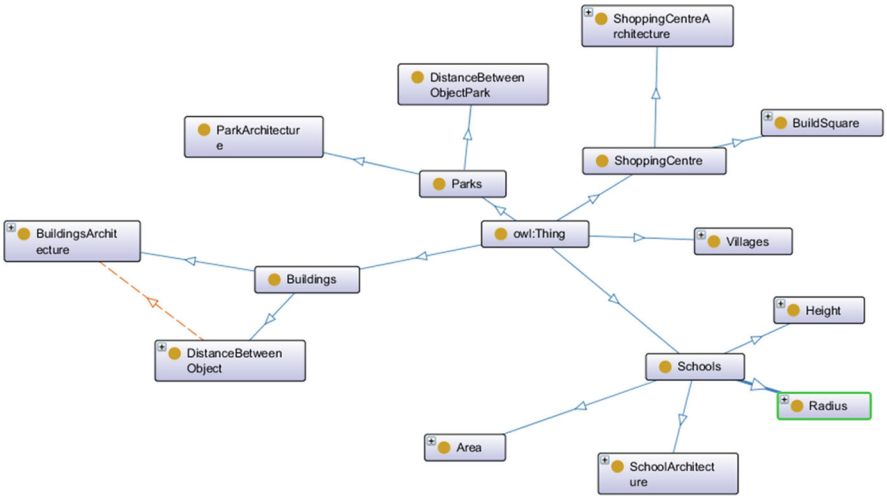

Fig. 12 Ontograph of the ontological model

between the entities. The next step was to define the properties of entities and their constraints, describing the relationship between entities and their characteristics. Subsequently, entity instances representing specific elements of the domain were defined.

"Protégé", which has a free license, was chosen as the environment for implementing the project and compiling the ontology. Decomposition of the ontology is shown in Fig. 13.

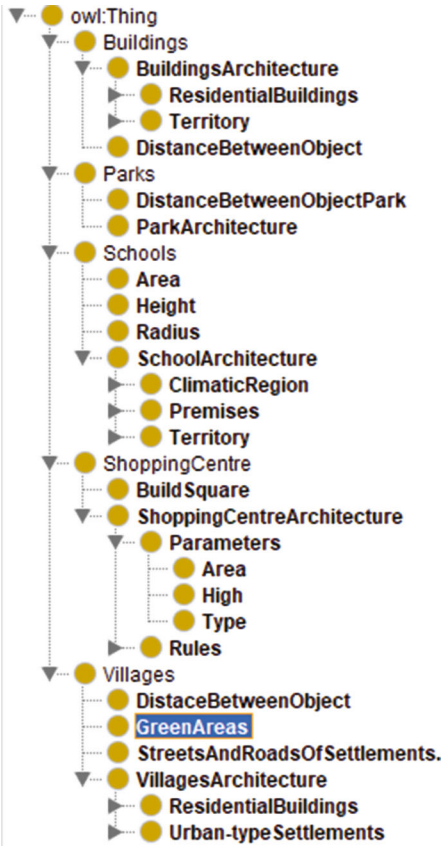

Fig. 13 Decomposition of the ontological model

3.7 Making Ontology Queries

To demonstrate the completeness of the ontological approach, we should show an example of relations between instances of entities. To demonstrate the relationships, it is necessary to refer to the ontology by means of a query. Queries to the semantic web are performed using the SPARQL (Protocol and RDF Query Language) query language. SPARQL is similar to SQL in its origin. The SPARQL language defines four different query variants for different purposes, but the most commonly used variant is SELECT, which allows you to extract raw values from a SPARQL access point and returns results in a table format [18]. Let us reproduce the query based on the normative and legal documentation, namely the distance between houses over nine floors (Fig. 14).

The query outputs the value of the distances between houses over 9 floors, equal to at least 25 m.

Let us reproduce the request on the basis of the normative and legal documentation, namely the distance between the house and the recreation area (Fig. 15).

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
SELECT ?subject ?predicate ?object
            WHERE { ?subject ?predicate ?object.
?predicate rdfs:label "hasADistance".
?subject rdf:type ?class.
?class rdfs:label "distanceBetweenObject"}
```

subject	predicate	object
distanceBetweenHouse	hasADistance	"25"^^<http://www.w3.org/2

Fig. 14 Example of a request for the distance between houses with more than nine floors

SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
SELECT ?subject ?predicate ?object
            WHERE { ?subject ?predicate ?object.
?predicate rdfs:label "hasADistance".
?subject rdf:type ?class.
?class rdfs:label "distanceBetweenHouseAndAdultRecreationArea"}
```

subject	predicate	object
distanceBetweenHouseAndRecreationZone	hasADistance	"8"^^<http://www.w3.org/2001/XMLSchema#int>

Fig. 15 Example of a request for the distance between houses and the recreation area

4 Conclusion

Ontological engineering in construction, urban planning and environmental safety is a powerful tool for organizing knowledge and data in this field. Ontographs allow to create a common system of classification and description of entities, properties and relations between them, which simplifies decision-making, improves planning and increases the efficiency of urban infrastructure use.

The use of ontological engineering to support construction, urban planning and environmental decision-making represents a significant advance in the fields of urbanism, construction and environmental protection. This approach offers benefits that enhance the efficiency of decision-making and optimize the use of resources.

Ontological engineering allows to formalize and structure the knowledge about building, urban planning and environmental safety, thus providing coherence and consistency between the various concepts, criteria, methods and tools used in this

field. This facilitates communication between stakeholders, reduces the risks of misunderstanding and simplifies the decision-making.

In addition, ontological engineering provides the ability to automate the analysis and processing of information, which in turn accelerates the collection, exchange and synthesis of data for construction, urban planning and environmental decisions. This approach simplifies the scaling of projects and the use of advanced methods of analysis and modelling to evaluate alternatives for the development of urban areas.

Nevertheless, it is worth noting that the implementation of ontological engineering requires qualified specialists with competencies in the fields of construction, urban planning, environmental safety and information technology, as well as substantial investments in the development and support of ontologies and related systems and tools.

In general, the integration of ontological engineering into the construction making, urban planning and environmental decisions is a promising direction, which can lead to the optimization and harmonization of construction and urban planning projects, strengthening the sustainability and environmental friendliness of the urban environment and ensuring a high quality of life for the urban population.

Acknowledgements The study has been supported by a grant from the Russian Science Foundation (RSF) and the Administration of the Volgograd Oblast (Russia) No. 22-11-20024, https://rscf.ru/en/project/22-11-20024/. The authors express gratitude to colleagues from the Department of Digital Technologies for Urban Studies, Architecture and Civil Engineering, VSTU, involved in the development of the project.

References

1. Urban Planning Code of the Russian Federation (as amended on December 29, 2022). Available on: https://docs.cntd.ru/document/901919338. Accessed: 2 Apr 2023
2. Constitution of the Russian Federation (adopted by popular vote on 12.12.1993) (with amendments introduced by the RF Laws on Amendments to the Russian Constitution of 30.12.2008 N 6-FKZ, of 30.12.2008 N 7-FKZ, of 05.02.2014 N 2-FKZ, of 01.07.2020 N 11-FKZ, of 06.10.2022) // The text of the Constitution, including the new subjects of the Russian Federation – Donetsk People's Republic, Luhansk People's Republic, Zaporozhye region and Kherson region, is given according to the official publication on the Official Internet Portal of Legal Information (www.pravo.gov.ru), October 6, 2022
3. Land Code of the Russian Federation: [text with amendments and additions on February 6, 2023: adopted by the State Duma on September 28, 2001: approved by the Federation Council on October 10, 2001]. Available on: www.pravo.gov.ru/. Accessed on 2 Apr 2023
4. Federal Law of the Russian Federation: [text with amendments and additions on July 19, 2011: adopted by the State Duma on October 18, 1995. Available on: www.pravo.gov.ru/. Accessed on 2 Apr 2023
5. Decree of the Government of the Russian Federation of 27.09.2021 No. 2692-r (revised on 30.09.2022) "On approval of the action plan (road map) for the implementation of the mechanism of management of systemic changes in the regulatory and legal regulation of business activity "Transformation of the business climate" "Re-engineering of rules of industrial construction". Available on: https://docs.cntd.ru/document/608775688. Accessed on 2 Apr 2023

6. Code of Volgograd Region on Administrative Liability: Law of Volgograd Region of 11.06.2008 No. 1693-OD (as amended on 29 December 2022) // Volgogradskaya Pravda. – 2008. – No. 105. – Art. 7.1–7.4
7. Moscow City Code of Administrative Liability: Moscow City Law from 21.11.2007 No. 45 (as amended on December 14, 2022) // Vedomosti of the Moscow City Duma. – 2008. – No. 12. – Art. 7.30
8. Federal Law of the Russian Federation of 30.03.1999 No. 52-FZ (ed. from 04.11.2022) "On the sanitary and epidemiological welfare of the population" // Sobranie zakonodatel'stva RF. – 07.11.2022. – No. 45. – Art. 7674
9. Federal Law of the Russian Federation from 10.01.2002 No. 7-FZ (ed. from 14.07.2022) "On Environmental Protection" // Sobranie zakonodatel'stva RF. – 18.07.2022. – No. 29. – Art. 5235, Art. 5310
10. Barramou, F., Mansouri, K., Addou, M.: Toward a multi-dimensional ontology model for urban planning. J. Geogr. Inf. Syst. **12**(6), 697–715 (2020)
11. Liao, Y.-P., Lin, F.-T.: Place name ambiguities in urban planning domain ontology. In: Proceedings of the 7th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management 2015, pp. 429–434. SCITEPRESS—Science and Technology Publications, Setúbal, Portugal, Lisbon, Portugal (2015)
12. Parygin, D.: Implementation of exoactive management model for urbanized area: real-time monitoring and proactive planning. In: 2019 8th International Conference System Modeling and Advancement in Research Trends (SMART), pp. 310–316, Moradabad, India (2019)
13. CityGML – Open Geospatial Consortium, https://www.ogc.org/standard/citygml/
14. OGC LandInfra / InfraGML – Open Geospatial Consortium, https://www.ogc.org/standard/infragml/. Accessed on 8 Apr 2023
15. Teller, J., Keita, A.K., Roussey, C., Laurini, R.: Urban ontologies for an improved communication in urban civil engineering projects. Cybergeo: Eur. J. Geogr., art. no. 386 (2007). https://doi.org/10.4000/cybergeo.8322
16. imbok-pro/Information Modeling Technology Ontology, https://gitflic.ru/project/imbok-pro/imt-ontology. Accessed on 11 Apr 2023
17. Hitzler, P., Lehmann, J., Polleres, A.: Logics for the semantic web. In: Handbook of the History of Logic, pp. 679–710. Elsevier (2014)
18. Parygin, D., Sadovnikova, N., Kravets, A., Gnedkova, E.: Cognitive and ontological modeling for decision support in the tasks of the urban transportation system development management. In: 2015 6th International Conference on Information, Intelligence, Systems and Applications (IISA), pp. 1–5, Corfu, Greece (2015)

Monitoring Urban Population's Quality of Life via Digital Footprint: The Case of Novosibirsk

Elizaveta Babaikina, Galina Kurcheeva, and Maxim Bakaev

Abstract Quality of life monitoring used to rely on statistical data and population surveys, but these sources increasingly lag behind the accelerating pace of the social and physical urban environments. In our chapter we put forward a set of ten indicators, each of which is derived from the city residents' "digital footprint": social networks, local web portals, geo-information services, etc., and devise a formula for each of them. The indicators are organized per the four sections: (1) Urban spaces, (2) Road and transport infrastructure, (3) Public and business infrastructure, and (4) Citizens' engagement in the management of the urban environment. With the dedicated data and text mining software (VK.barkov.net, Dostoevsky and DeepPavlov, YMapsReviewsParser), we demonstrate how the indicators can be calculated on the real data for the city of Novosibirsk. The proposed methodology might be of use to municipal authorities and city managers who seek to avoid survey bias and promptly react to the changing conditions and popular sentiments.

Keywords Smart city · Digital footprint · Social data mining · Sentiment analysis

1 Introduction

There are various methodologies used for assessing quality of life indicators. Some rely on statistical indicators, while others are based on sociological surveys of the population, gathering people's responses about their lives. Consequently, numerous reports and compilations of indicators are published. However, these established methods have inherent disadvantages, such as time lag, incomplete coverage, and subjectivity (e.g., social acceptability bias in surveys). As a result, city administrations and government structures may not fully grasp how citizens perceive the urban environment in terms of convenience and accessibility. This can lead to the

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_2

implementation of projects that are negatively assessed by citizens, while their actual needs go unnoticed. To enhance quality of life, close interaction and cooperation between city authorities and citizens are essential. This collaboration will enable more whole consideration of public opinion and empower authorities to leverage modern information and communication technologies (ICT) effectively.

ICT can aid by supplementing the population's quality of life indicators with the data obtained from urban residents' "digital footprint." The concept of "digital" or "online" footprint is not new and has been extensively used in studies of urban development and digitalization of city management [1, 2], labor market [3], tourism [4], general social research [5], etc. Still, establishing a relevant set of quantitative indicators whose values can be calculated automatically is not a trivial task [6].

In our research, we showcase how social networks, review sites, and city portals can provide valuable quantifiable indicators that capture citizens' experiences in the urban environment. Our main contribution is introducing a set of ten new quality of life indicators and developing the practical formulas for their automated calculation. We have demonstrated this through the analysis of data collected in Novosibirsk, Russia in 2021, processed using appropriate software tools. We believe that these indicators and their practical implementation will be beneficial to employees of municipal authorities and to public institutions involved in urban development.

The rest of our chapter is structured as follows. In Sect. 2, we provide a brief overview of digital footprint and the related work in urban studies. In Sect. 3, we outline the monitoring methodology, list the relevant software for data collection and mining, and present the ten new quality of life indicators. Section 4 is dedicated to the practical case of Novosibirsk. In the final section, we summarize and discuss our work and outline directions for further research.

2 Related Work: Urban Studies Relying on Digital Footprint

A digital footprint, which is a set of digital actions that users leave on the Internet, can become a tool for collecting and processing urban data. Social networks are the most important source of digital footprint because it is there that people react to current events and voluntarily express their opinion without any mediators, such as questionnaires or interviews. At the same time, the statements that users leave on social networks are generally more extensive and diverse than the responses that they provide while filling out special questionnaires.

Various methodologies for evaluating and enhancing the quality of life of the Russian population through digital footprints have been proposed by researchers. For instance, in [7], the authors computed the subjective well-being index for most Russian regions by analyzing textual content from regional communities on the VKontakte social network. This index facilitated the assessment of whether residents in different regions conveyed positive or negative sentiments regarding various

aspects, including the advancement of regional infrastructure, the condition of media, the efficacy of law enforcement agencies, and other governmental entities.

In large cities of Russia, digital footprints are used to analyze the popularity of urban spaces among local residents and tourists. For example, prior to the 2018 FIFA World Cup, a consulting company named Strelka KB had been developing design projects for the improvement of public spaces in Kaliningrad. In order to understand which urban spaces young users prefer, an analysis based on digital footprints was carried out in [8]. As a result, a map was created, which showed the number of photos taken in different parts of the city. The analysis of digital footprints aided in understanding which urban spaces were positively perceived by the residents. Digital footprints are also useful in analyzing the effectiveness of urban land improvement activities. For example, in [9] they describe in detail the effectiveness evaluation for the improvement of urban territories within the "My Street" program in Moscow (undertaken from 2015 to 2018). The approach was based on the analysis of geo-located digital footprints, which in the case of that study were user photos collected from social networks. The authors reported that the increased attractiveness of the territory, as well as the safety and comfort of the streets, were indeed associated with the urban land improvement activities.

Geo-located urban digital footprints can also be used for improving the attractiveness of an urban environment for tourists since the most frequently visited locations can be easily identified through the number of check-ins and published photos and reviews. For example, in [10], they studied reviews obtained from Russian-speaking users of the TripAdvisor website. This analysis allowed determining the most important factors in the tourists' choice of a hotel with a certain level of service (2–3 stars and 4–5 stars). Expectedly, the factors were either related to the hotel itself or to its proximity to the popular city locations.

In [11], an analysis of Foursquare check-ins in the Spanish city of Alicante was carried out, which made it possible to measure the "success" of public spaces. In [12], a study of the digital footprint left by residents and tourists of London on Flickr and Foursquare allowed the authors to assess indicators such as street safety, comfort, and crime rates, and to provide recommendations for improvement. The authors of [13] created a map of the urban landscapes' attractiveness in Barcelona based on geolocated photos uploaded from a social network, assessing the impact of the city infrastructure. In [8], the approach was based on the idea that the number of photos reflects the so-called urbanity of the area, i.e., a combination of its esthetic characteristics and the ability to provide services. "Urbanity" can be seen as a characteristic of urban spaces that contain natural recreational areas, architectural landmarks, cultural institutions, etc. Correspondingly, the more attractive a place is for citizens, the more often they take pictures of it and post it on the Internet.

Finally, a federal network of Regional Control Centers was launched in Russia (https://t.me/tsurofficial), whose goal is to provide data for the state authorities. It collects information from social networks, portals, etc. on citizens' satisfaction in different regions of the country. Our research work complements the above approaches and mechanisms, as we see that digital footprints can indeed facilitate the studying of urban environments. Therefore, it can be used to monitor quality of

life indicators of the population in order to make subsequent improvement and assess their effectiveness.

3 The Methodology for Monitoring the Quality of Life

3.1 The Monitoring Process

The proposed methodology relies on social networks, review sites, and city portals as the main sources for digital footprint data. We add a specific stage to the baseline model, which involves the development of management scenarios based on the values calculated for the population's quality of life indicators. This allows taking into account the real needs of citizens and can lead to improvement in the quality of the urban environment. The proposed information model for the process of monitoring the quality of life indicators based on digital footprint is presented in Fig. 1.

Thus, the process of monitoring the quality of life indicators consists of five stages (per the respective sub-processes presented in Fig. 1).

1. *Data collection for the various city areas*. Data were obtained from social networks, city portals, review sites, and other unofficial sources.
2. *The quality of life indicators formulation*. Relative values are generally preferred over absolute ones, for easier comparison and lack of scaling problems.
3. *The quality of life indicators calculation*. The values for the specific cities or city areas are obtained through the formulas (from stage 2) and the current data (collected in stage 1).

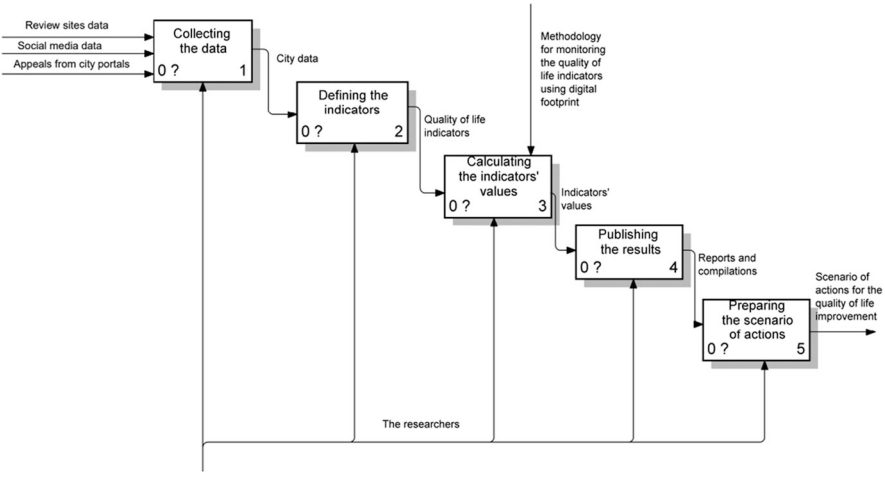

Fig. 1 The information model for monitoring quality of life indicators based on digital footprint

4. *Presenting the results*. These are generally published in open online resources, for easier access by all the stakeholders.
5. *Developing the management scenarios*. This is a synthesis stage, involving qualitative analysis of the results and development of management actions aimed at improving the quality of life and the urban environment.

Next, we consider the first stage of the above process—collecting the data.

3.2 Methods and Tools for Data Collection

Currently, VKontakte is the social network that sees the most extensive usage by the Russians residing in the country. Correspondingly, we see it as the most important source of digital footprint, together with the other nonofficial information sources, such as review sites and city portals. As of 2021, about 22 million people visited VKontakte at least once a day and spent about 31 minutes daily in it [14, 15]. The average number of active authors in this social network was about 23.8 million people per month, and the average number of posts, reposts, and comments was 408.8 million per month.

VKontakte has many urban-themed communities, which contain posts and comments on various topics related to the urban environment. As most other information sources nowadays, VKontakte provides an API—an interface that allows users to receive information from the vk.com database using http requests to a dedicated server. The advantage of such an interface is that one can make requests using the specified methods, without the need to know the exact structure of the database. For the data collection, a Novosibirsk urban community named "AST-54" was used. Part of the required data was obtained with the help of VKontakte API using direct requests with the corresponding methods in Python. The remaining data were collected with a third-party tool named vk.barkov.net, which offers legal ways to mass collect the data from VKontakte.

Another type of digital footprint is the reviews of various organizations and locations published by users of specialized resources. Such resources include geo-information services, such as 2GIS, Google Maps, Yandex.Maps, as well as the services especially dedicated to reviews, such as Flamp. The main problem when using these resources to collect digital footprint data is the technical difficulties with the API. It is worth noting that the abovementioned services have their own APIs, but their main objective is to provide the developers with the map-related data and technologies to use in third-party projects. To collect reviews for the organizations listed in the major Yandex.Maps geo-service, the YMapsReviewsParser program was used.

It should be noted that parsing the publications from social network communities and publicly left comments about organizations and public spaces is not illegal. This information does not qualify as personal data and is in the public domain. Parsing in

this case only simplifies and automates the process of collection of this information, but does not directly affect its usage.

Python programming language and some dedicated libraries were used to collect and analyze the digital footprint needed to calculate the quality of life indicators. These libraries include the Pandas library that is used for collecting and processing data, as well as Dostoevsky and DeepPavlov libraries used for conducting the sentiment analysis of the reviews.

3.3 The Quality of Life Indicators Formulation

While the previous section was dedicated to data sources and methods for collecting the digital footprint, in the current section we move to the next stage of the quality of life monitoring process, which is defining the indicators. The proposed methodology is based on the "Methodology for the formation of the urban environment quality index," which was approved by the order of the Government of the Russian Federation on March 23, 2019 [16]. In order to determine the urban environment quality index, the document puts forward 36 indicators that characterize various types of urban spaces. Our analysis of the document suggests that only two of the indicators involve a digital footprint: "Attractiveness of green spaces" (digital footprint here is the number of publications with photos taken within the boundaries of green spaces) and "Number of points of attraction for the population" (digital footprint here is the number of streets that are most often tagged on the publications with photos).

Correspondingly, we propose a modified set of indicators with a focus on the digital footprint: there are ten of them, divided into four sections (see the formulations and the descriptions in Table 1).

In the next section of our paper, we present the calculation of some indicators of the proposed methodology for monitoring the quality of life of the population using the example of the city of Novosibirsk and analyze the results obtained.

4 Application of the Proposed Methodology: The Case of Novosibirsk

To illustrate the third stage of the quality of life indicators' monitoring process, in the current section we calculate the concrete values for some of the indicators, using the data obtained for the major Russian city of Novosibirsk.

Table 1 Methodology for calculating the quality of life indicators using digital footprint

Name of the indicator	Digital footprint data	Source of digital footprint	The indicator formulation
Section 1: Urban spaces			
1. Use of public spaces by citizens	Number of photos made in the public space	VKontakte social network	$\frac{N_{ph}}{S_{sp}} \times 100,$ (1) where N_{ph}—number of photographs taken within the boundaries of the public space, S_{sp}—area of the public space
2. The quality of services provided in public spaces	Number of positive/negative reviews about public spaces	The reviews section of Yandex.Maps mapping service	$\frac{G_{pos}}{G_{tot}} \times 100,$ (2) $\frac{G_{neg}}{G_{tot}} \times 100,$ (3) where G_{pos}, G_{neg}, G_{tot}—number of positive/negative / total number of reviews about public spaces
3. Availability of illuminated sides of streets, driveways, embankments	Number of photos taken on the territory during daylight hours	VKontakte social network	$\frac{F_L}{P_{tot}} \times 100,$ (4) where F_L—number of photos taken on the territory during daylight hours P_{tot}—total length of the territories under consideration
Section 2: Road and transport infrastructure			
4. Road congestion	Number of publications about traffic jams	VKontakte social network	N_a—number of publications about traffic jams in winter (Dec–Feb), N_b—number of publications about traffic jams in spring (Mar–May), N_c—number of publications about traffic jams in summer (Jun–Aug), N_d—number of publications about traffic jams in autumn (Sep–Nov)
5. Number of road accidents in the city	Number of publications on road accidents	VKontakte social network	N_{publ}—number of publications on road accidents
6. Percentage of fatalities in relation to the total number of road accidents	Number of publications on road accident fatalities	VKontakte social network	$\frac{N_{fatal}}{N_{publ}} \times 100,$ (5) where N_{fatal}—number of publications on road accident fatalities N_{publ}—total number of

(continued)

Table 1 (continued)

Name of the indicator	Digital footprint data	Source of digital footprint	The indicator formulation
			publications on road accidents
Section 3: Public and business infrastructure			
7. Number of streets with a well-developed service sector	Number of reviews on service businesses located within the street	The reviews section of Yandex.Maps mapping service	$\frac{R}{P_{\text{tot}}} \times 100$, (6) where R—number of reviews on service businesses located within the street P_{tot}—total length of the territories under consideration
8. Quality of services provided in social and business districts	Number of positive/negative reviews on organizations located in social and business districts	The reviews section of Yandex.Maps mapping service	$\frac{R_{\text{pos}}}{R_{\text{tot}}} \times 100$, (7) $\frac{R_{\text{neg}}}{R_{\text{tot}}} \times 100$, (8) where R_{pos}, R_{neg}, R_{tot}—number of positive/negative/total number of reviews on organizations
Section 4. Citizens' engagement in the management of the urban environment			
9. Citizens' engagement in solving issues of development of the urban environment	The number of citizens' appeals to city portals	City portals	$\frac{N_{\text{a14}}}{N_{14}} \times 100$, (9) where N_{a14}—number of appeals to city portals from citizens aged 14 years and older N_{14}—population aged 14 and older
10. Percentage of users participating in the discussion of the urban environment, by various characteristics	Information about users who have left comments under publications on urban environment issues	VKontakte social network	Characteristics such as gender, age, and level of education about users who have left comments under publications on the urban environment

4.1 The "Use of Public Spaces by Citizens" Indicator

The "Use of public spaces by citizens" indicator was calculated for several large parks (green zones) in Novosibirsk. The social network VKontakte was used as the source of the digital footprint. Using the photos.search method from the VKontakte API, which searches for images by location, the number of photos made in each park was obtained. The photos by coordinates were collected in the date range from 01/01/2021 to 01/01/2022. The results of the indicator's calculation are presented in Table 2.

We can notice from the table that the largest number of photos was taken in the surroundings of the *Novosibirsk Zoo*. Indeed, animals located in the zoo are of great

Table 2 The result of calculating the "Use of public spaces by citizens" indicator

Name of the park (green zone)	Area (sq. m)	Number of photos	The indicator value
Berezovaya Roshcha	233,176	3137	1.345
Central Park	73,865	4708	**6.374**
Zaeltsovsky Forest Park	350,000	198	0.057
Novosibirsk Zoo	630,000	**10,032**	1.592
Kirov Park	65,982	1567	2.375
Sosnovyy Bor	83,091	442	0.532
Mikhailovskaya Embankment	176,725	4199	2.376
Dzerzhinsky Garden	80,321	704	0.876
Bugrinskaya Roshcha	168,965	599	0.355
U Morya Obskogo Park	433,630	577	0.133
Pervomaisky Park	60,325	674	1.117

interest to visitors and cause many to take and publish photos on social networks. Still, the *Novosibirsk Central Park* has the highest value of the indicator. This can be explained by the convenient location of *Central Park*, which increases the flow of citizens, despite the relatively limited area of this green zone. It is also worth noting that in 2019–2020 *Central Park* had undergone an extensive redevelopment, which has also contributed to the park's high attendance levels in 2021. Similarly, we can explain the value of the indicator for *Mikhailovskaya Embankment*, whose territory saw a large-scale reconstruction several years ago. So, we can suggest that since the recently reconstructed parks show high values of the indicator, the urban land improvement projects were effective. The low values of the indicator for parks such as *Dzerzhinsky Garden*, *Bugrinskaya Roshcha,* and *U Morya Obskogo Park* are likely caused by the remoteness of the parks from the city center, and at the same time call the city authorities for some kind of land improvement. The *Zaeltsovsky Forest Park* gained the lowest value of the indicator because this park was undergoing reconstruction and was closed to visitors throughout 2021.

4.2 The "Quality of Services Provided in Social and Business Districts" Indicator

We collected reviews for the parks of Novosibirsk and analyzed their texts using Python programming language and Dostoevsky and DeepPavlov libraries. Both libraries classified the vast majority of reviews as positive, as the share of negative reviews was only 3–15%. However, when using the DeepPavlov library, the number of reviews classified as neutral was significantly reduced compared to the Dostoevsky library. Thus, the model based on the DeepPavlov library appears to perform the sentiment analysis task better, at least with respect to our purposes. The

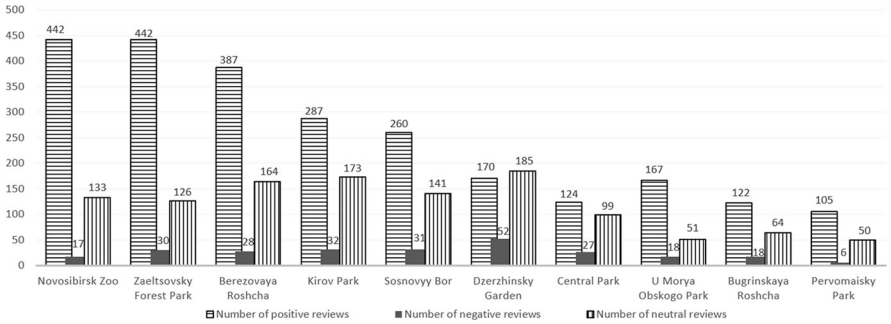

Fig. 2 The results of the sentiment analysis in the reviews

diagram with the results of the reviews' sentiment analysis using the DeepPavlov library is presented in Fig. 2.

It can be seen from the diagram that positive reviews dominate for every park, while the percentage of negative reviews is only 3–13%. About 21–45% of reviews were classified as neutral. The largest number of negative reviews (13%) was written about the *Dzerzhinsky Garden*. Moreover, for this public area, the number of neutral reviews slightly exceeded the number of positive ones. With respect to the management actions, the city authorities could pay increased attention to *Central Park*, which received 11% of negative reviews, despite the renovation that we mentioned previously. The *Novosibirsk Zoo* and the *Zaeltsovsky Forest Park* received the largest percentage of positive reviews (74%), as well as the *U Morya Obskogo Park* (71%).

4.3 The "Road Congestion" Indicator

To calculate the next indicator, the number of publications about traffic jams was obtained. To collect these data, a program was written in Python that allows downloading posts from a user or a community wall using the VK API, as well as searching for keywords using regular expressions. As a result, a dataset containing 8654 publications for the period from 01/01/2021 to 01/01/2022 was obtained. The analysis of this dataset made it possible to calculate the "Road Congestion" indicator, as demonstrated below.

- Number of publications about traffic jams in winter: $N_a = 78$
- Number of publications about traffic jams in spring: $N_b = 70$
- Number of publications about traffic jams in summer: $N_c = 40$
- Number of publications about traffic jams in autumn: $N_d = 67$

The obtained data are in accordance with the reality. The largest number of publications about traffic jams is generally observed in winter, which is caused by

the presence of snow on the roads. The absence of snow can explain the lowest value of this indicator registered in summer.

4.4 The Road Accident-Related Indicators

To calculate the "Number of road accidents in the city" and "Percentage of fatalities in relation to the total number of road accidents" indicators, the number of publications on road accidents and the number of publications on road accidents' fatalities were obtained. The AST-54 community from VKontakte social network was used as the data source and a dataset with posts for the period from 01/01/2021 to 01/01/2022 was collected. The calculated values of the indicator are provided below.

- Number of publications on road accidents: $N_{\text{publ}} = 1282$
- Number of publications on road accidents' fatalities: $N_{\text{fatal}} = 168$
- The percentage of publications on road accidents' fatalities of the total number of publications on road accidents: 13.1%

Publications on road accidents accounted for about 15% of all publications of the AST-54 community in 2021.

4.5 The Citizens' Involvement Indicator

To calculate the "Percentage of users participating in the discussion of the urban environment, by various characteristics" indicator, a list of the 500 most active users in the AST-54 community was obtained—in 2021 they left from 257 up to 4963 comments.

The analysis of the list showed that the vast majority of commentators who actively discuss urban problems are male. Their percentage in the total number of active commentators was 82%. Moreover, 59% of active users listed Novosibirsk as the location in their profile, which confirms that the collected data are correct. About 31% of users did not list the city on their VKontakte profile at all, and 10% of users listed another city. However, it should be understood that these data cannot be completely reliable, since users do not always post complete and accurate information about themselves on social networks. It was also found that the majority of active commentators are between the ages 30 and 50. For the city authorities, this result may mean that the opinion only of a certain group of the population can be taken into account with the help of unofficial sources of information. In order to obtain the widest possible opinion of the entire population on urban environment issues, it is also necessary to involve the groups under the age of 30, as well as those over the age of 50. It may be necessary to use other platforms in order to involve these groups in the discussion of the urban environment issues.

When assessing this indicator, it is necessary to understand that it can give only approximate results since many users in social networks do not provide reliable and complete information about themselves. Most users provide information about their gender and age on their profiles, but far fewer users specify additional information. For example, when trying to calculate the proportion of users who are taking part in the discussion of the urban environment and have a higher education, it was found that information about the university was listed only in 7% of the collected active users' profiles.

5 Discussion and Conclusion

In this work, we proposed the methodology for monitoring the quality of life indicators that contains ten indicators, divided into four sections, and uses unofficial data sources such as social networks and review sites to collect digital footprint data. To illustrate the methodology, six indicators were calculated with the data collected for Novosibirsk city. The VKontakte social network and the reviews section of the Yandex.Maps mapping service were used as the primary data sources.

After calculating the "Use of public spaces by citizens" indicator, an analysis of the attendance of parks in the city of Novosibirsk was carried out. The obtained data made it possible to determine which parks had the most photos published in 2021. Since a large number of publications indicate a high level of public space attendance, the indicator can help the city authorities evaluate the effectiveness of urban land improvement projects. A low value of the indicator, on the other hand, may indicate that a renovation might be needed to attract citizens to a public place.

The value of the "Quality of services provided in social and business districts" indicator allows for analyzing the sentiment of the reviews that residents write for the public spaces of a city. With the help of text sentiment analysis tools, all reviews were divided into three classes: "Positive," "Negative," and "Neutral." The obtained results can help the city administration employees track the citizens' opinions about public areas and quickly respond when the rating of a particular public space downgrades. The disadvantage of some models applied within this method is their low accuracy in recognizing subtle intonations and meanings that are typical for texts in Russian. It can lead to inaccurate results, e.g., when a large number of reviews are classified as neutral.

Indicators of the "Road and transport infrastructure" section, such as "Road congestion," "Number of road accidents in the city," and "Percentage of fatalities in relation to the total number of road accidents" can characterize the state of a city's roads, as well as their safety level. These indicators allow the city authorities to monitor the state of a city's transport infrastructure, and rapidly take action if critical values of indicators have been reached.

The analysis of the "Percentage of users participating in the discussion of the urban environment, by various characteristics" indicator can allow the city authorities to find out which group of the population is the most involved in the discussion

of urban environment issues. This should help them to take into account the real needs of citizens and lead to an improvement in the quality of the urban environment. This has the potential to decrease the level of dissatisfaction among the population and the number of conflicts between citizens and the government structures.

One of the important limitations of the current work is that we did not perform validation of the proposed indicators. Our future plans involve calculating the indicators on a per-month basis and correlating them to each other and comparing them to a sort of the "ground truth," i.e., the values obtained with traditional and approved quality of life monitoring methodologies. For this, we plan to introduce an integral indicator with calibrated weights. Also, in further studies, we plan to focus on the subsequent stages of the proposed quality of life monitoring process (Fig. 1)—particularly, the development of the management actions scenarios based on the calculated indicators.

The proposed methodology for monitoring the population's quality of life indicators based on a digital footprint is primarily designed for municipal authorities, in order to improve decisions related to urban development. The methodology also allows taking into account the opinions and trends in the population based on data from "unofficial," presumably more unbiased, sources of information.

References

1. Kurcheeva, G.I., Klochkov, G.A.: Smart rural settlement: digitalizing the quality of life. IOP Conf. Ser. Earth Environ. Sci. **666**(3), 032040 (2021). IOP Publishing
2. Kurcheeva, G.I., Bakaev, M.A., Klochkov, G.A.: Analysis of tools and data sources for assessment of digital city development. J. Phys.: Conf. Ser. **1661**(1), 012179 (2020). IOP Publishing
3. Bakaev, M., Avdeenko, T.: Intelligent information system to support decision-making based on unstructured web data. ICIC Express Lett. **9**(4), 1017–1023 (2015)
4. Salas-Olmedo, M.H., Moya-Gómez, B., García-Palomares, J.C., Gutiérrez, J.: Tourists' digital footprint in cities: comparing big data sources. Tour. Manag. **66**, 13–25 (2018)
5. Golder, S.A., Macy, M.W.: Digital footprints: opportunities and challenges for online social research. Annu. Rev. Sociol. **40**, 129–152 (2014)
6. Przybyłowski, A., Kałaska, A., Przybyłowski, P.: Quest for a tool measuring urban quality of life: ISO 37120 standard sustainable development indicators. Energies. **15**(8), 2841 (2022)
7. Shchekotin, E., Goiko, V., Myagkov, M., Dunaeva, D.: Assessment of quality of life in regions of Russia based on social media data. J. Eurasian Stud. **12**(2), 182–198 (2021)
8. Strelka Mag: There Is Such a Profession: A Digital Anthropologist (2019). URL: https://strelkamag.com/ru/article/est-takaya-professiya-cifrovoi-antropolog (In Russ.)
9. Radchenko, D.A.: After the ball: how to evaluate effects of urban improvement with anthropology. Urban Folklor. Anthropol. **II**(3–4), 270–291 (2019). (In Russ.)
10. Kaspruk, N., Silyutina, O., Karepin, V.: Hotel value dimensions and tourists' perception of the city. The case of St. Petersburg, international conference on digital transformation and global society. In: Alexandrov, D., Boukhanovsky, A., Chugunov, A., Kabanov, Y., Koltsova, O. (eds.) Digital Transformation and Global Society, DTGS 2017 Communications in Computer and Information Science, vol. 745, pp. 341–346. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-69784-0_29

11. Martí, P., Serrano-Estrada, L., Nolasco-Cirugeda, A.: Using locative social media and urban cartographies to identify and locate successful urban plazas. Cities. **64**, 66–78 (2017). https://doi.org/10.1016/j.cities.2017.02.007
12. Quercia, D., Aiello, L.M., Schifanella, R., Davies, A.: The digital life of Walkable Streets. In: Proceedings of the 24th International Conference on World Wide Web (WWW '15), pp. 875–884. International World Wide Web Conferences Steering Committee, Republic and Canton of Geneva (2015). https://doi.org/10.1145/2736277.2741631
13. Langemeyer, J., Calcagni, F., Baró, F.: Mapping the intangible: using geolocated social media data to examine landscape aesthetics. Land Use Policy. **77**, 542–552 (2018). https://doi.org/10.1016/j.landusepol.2018.05.049
14. On Approval of the Methodology for the Formation of the Urban Environment Quality Index, 2019. URL: https://docs.cntd.ru/document/553937399. (In Russ.)
15. Live Dune: Social Network Statistics in Russia in 2021 (2021). URL: https://livedune.ru/blog/statistika_socsetej_v_rossii. (In Russ.)
16. Brand Analytics: Social Networks in Russia: Figures and Trends, Autumn of 2021 (2021). URL: https://br-analytics.ru/blog/social-media-russia-2021. (In Russ.)

Planning of the Species Composition of Urban Green Spaces Using Network Modeling and Comments from Users of Social Networks

Boris Nizomutdinov and Nikita Kopyt

Abstract The chapter presents a method for determining the permissible species composition of plants for a given territory, taking into account environmental factors, factors of ecological and anthropological impact, growing conditions, and the values of the inhabitants of a given territory. The developed model can be used to plan the breed composition in a new territory without existing vegetation cover, to create biodiversity in existing conditions. The model uses information about the compatibility of species, polluting objects, noise sources, and shadows created by buildings. At the output, the model offers compositions of plant species under specified conditions in a limited area that will be as stable as possible under specified conditions. The formation of a stable biotope from various representatives of the species diversity of the flora consists of a composite combination of several plant species in a certain area with close or possible close contact during growth. Additionally, the model uses the experience of the inhabitants of the area, their historical experience, and in the form of comments on green areas (parks, gardens, and squares closest to the site of the species composition). The assessment of the communicative practices of the Google Maps geoinformation network was carried out using classification and classification methods to search for mentions of problems related to landscaping. To collect feedback, a database was collected for all districts of the pilot city, all parks were selected, then, with the help of a parser, comments were collected. With the help of machine learning methods, those reviews were selected that described the problems associated with landscaping and trees. The information obtained is used in the model to plan the breed composition in the new territory.

Keywords Species composition · Planning · Landscaping · Parks · Social network data

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_3

1 Introduction

During the period of intensive development and expansion of cities, green spaces are under stressful conditions and become vulnerable. It is necessary to regularly replenish the species composition of green spaces or the creation of new recreational areas.

The species composition of green spaces is a complete list of plant species that exist in a certain region or a specific place. It includes trees, shrubs, and other species that grow in the region and create green spaces. The species composition of green spaces is important for the study and assessment of the ecosystem. It allows you to conduct an overview and detailed study of the area, assess its biological diversity, and make maps of vegetation distribution [1].

The species composition of green spaces can also be important for planning urban development and landscaping [2]. It determines the nature of the landscape and can be used as a basic resource for the development of landscape projects and the management of green spaces in cities and territories for various purposes. Also, the species composition of green spaces is an important factor for the preservation and protection of the ecological system and natural biodiversity in a particular area.

Plant species diversity is a measure of the number of different plant species that live in a particular region or on the planet as a whole. This includes factors such as the richness of the flora of a certain territory, the number of species in a given ecosystem, and the level of threats to which they are exposed.

Higher plant species diversity means more diverse ecosystems that support the life of many animal species and are key to ecosystem productivity and sustainable development of human society. However, in recent years, due to human activity, the species diversity of the plant world has been significantly reduced, which has led to the loss of biodiversity worldwide. Therefore, it is important to continue to maintain species diversity, while using the most correct selection of breeds.

Landscaping works in the city included in the landscaping complex, consisting of a large number of activities, are aimed at creating a comfortable, favorable, and safe environment for humans. Landscaping is carried out in compliance with the norms and requirements.

Regulatory legal acts of the federal level and regional legal acts of cities establish both general and special requirements in terms of the formation of the road network and landscaping, there are regulatory legal acts regulating the conduct of works on complex landscaping of territories. However, these documents do not take into account the compatibility of species, the presence of limiting factors, climatic, and anthropogenic factors affecting the growth of trees and shrubs.

For example, woody and shrubby plants growing in urban green spaces represent a biotope where there is direct interaction, limited only by territorial remoteness. Neighborhood within the same territory with possible close contact during growth entails influence in various aspects and also contributes to the spread of diseases associated with the spread of fungal and viral infection [3]. There are many such factors, and they all need to be taken into account.

For effective planning of green spaces, as well as the creation of sustainable species compositions we offer a method for optimal planning based on network modeling, as well as using the knowledge and experience of citizens, expressed in comments on social networks.

In this chapter, the hypothesis is considered, according to which, for the method of species composition planning, it is possible to use the knowledge of citizens in the form of reviews on social networks.

2 Materials and Methods

During the period of intensive development and expansion of cities, green spaces are under stressful conditions and become vulnerable. It is necessary to regularly replenish the species composition of green spaces or the creation of new recreational areas.

In the first stage, a literature analysis was carried out to search for thematic publications and a review of existing planning methods. A search in Scopus, limited to journals, by the word in the title and keyword fields revealed several thousand publications on the topic of gardening planning.

The search was performed using the formula (TITLE (telegram) OR KEY (telegram)). Analyzing the publication activity, we can conclude that every year, the interest of scientists in planning green spaces is growing.

The VosViewer tool was used for further processing of the literature. The VosViewer is a popular software tool for visualizing and analyzing bibliometric networks, which are networks that represent relationships among scientific publications. The software allows researchers to create maps of scientific fields based on co-citation or bibliographic coupling of articles, and to explore these maps using various visualization techniques, such as clustering, zooming, and filtering.

VosViewer has been widely used in scientometric research to study the structure, development, and impact of scientific fields, as well as to identify key authors, journals, and institutions in these fields.

A network analysis of the joint appearance of thematic keywords (co-keywords) extracted from the records of publications found in Scopus showed the most developed industries in which gardening planning is studied (see Fig. 1).

At the same time, in our opinion, automated models for selecting the optimal species composition of green spaces can become a new generation tool for sustainable development and modeling. Therefore, it is important to analyze the potential of this development and use of the platform.

In the past, when planning landscape plants for an urban ecological garden environment, planning often focused on the plants themselves, rather than on the environment and compatibility.

Modern methods have different approaches to planning. In [4] a new method of spatial planning of plants for urban ecological landscape environments is proposed. Based on a detailed study of the characteristics of spatial planning of plants for the

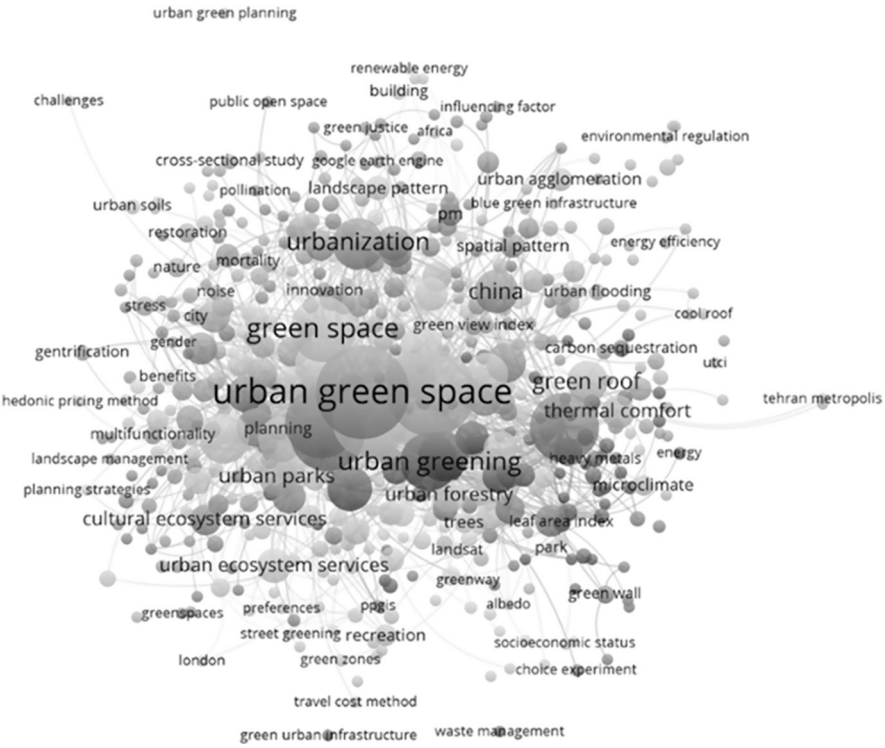

Fig. 1 An example of popular research areas on urban landscaping

urban ecological landscape environment, spatial planning of plants is planned based on the site conditions, functional planning, spatial sequence, and thematic plot. In accordance with the principle of plant selection, plant placement and landscaping are completed in the form of a point, line, and surface, and the impact of spatial planning of plants on the urban ecological landscape environment is assessed comprehensively by combining the process of analytical hierarchy and weighted average.

Researchers will gradually adopt information and analytical systems for species composition planning. A group of scientists has developed a methodology [5] designed to help landscape architects, plant designers, and urban gardeners in the process of plant selection. Tehran was chosen as an example because of its arid and semi-arid climate, which poses more challenges for the expert. After grouping the plants, selection parameters were determined for each group of plants.

A group of eight specialists conducted a comparative assessment of plant species for each parameter. The analytical hierarchical process (AHP) method and hierarchical cluster analysis were used to search for the most adaptable plant species for a given area in accordance with the main selection parameters: zonal tolerance, urban conditions, aesthetics, care, growth characteristics, and specific features.

Several new plants received high marks in the final tables, which suggests that the urban landscape of Tehran has great potential to become more attractive, less allergic, and less expensive, as well as consume less water.

The paper [6] describes an attempt to comprehensively classify and evaluate urban tree species from the point of view of usability after predicted climate changes. A new Climate-Species matrix has been developed for this purpose.

The compatibility of plants is being studied at different levels and according to different parameters. In [7], researchers study the compatibility of plants with contrasting root systems in terms of obtaining limited nutrients from the soil. Paired combinations of proteus and cereal species were grown in a pot experiment using soil from a site with poor vegetation and degraded soil.

Network modeling methods are widely used in landscaping issues [8]. The planning of the ecological network of Xiamen Island (China) is described in detail, based on these analyses, a number of alternative planning scenarios were developed using network analysis methods to improve the ecological network of Xiamen Island.

The combined and integrated application of remote sensing, landscape indicators, least-cost analysis, gravity models [9], and graph theory analysis represents an innovative approach to the development of urban green space networks for biodiversity conservation.

However, we still see that there are no ready-made solutions or open-source models available to a wide range of researchers for designing the composition of green spaces. There is no single system that takes into account limiting factors, compatibility of species, and stability in one model. Our research is devoted to the creation of an optimal planning method followed by the creation of an Open-Source product that will take into account the compatibility of species, limiting factors, as well as user assessments of a specific area for the prompt search for problems with growing new plants.

This method will allow you to build species sets for optimal planning of sustainable green areas.

3 Results

To solve the problem of creating a sustainable composition of green spaces, we have developed an algorithm for planning the species composition of plants for the most effective landscaping of urban areas, taking into account the compatibility and compositionality of species, as well as the conditions of their growth based on the use of network analysis and graph modeling methods.

The algorithm allows you to get recommendations on the species composition for a predetermined territory, or, if there is a second use case, to supplement the existing composition with new breeds. Modeling of interrelation and combination of plant species are carried out by forming a matrix of interrelation and combination of plant species (see Fig. 2).

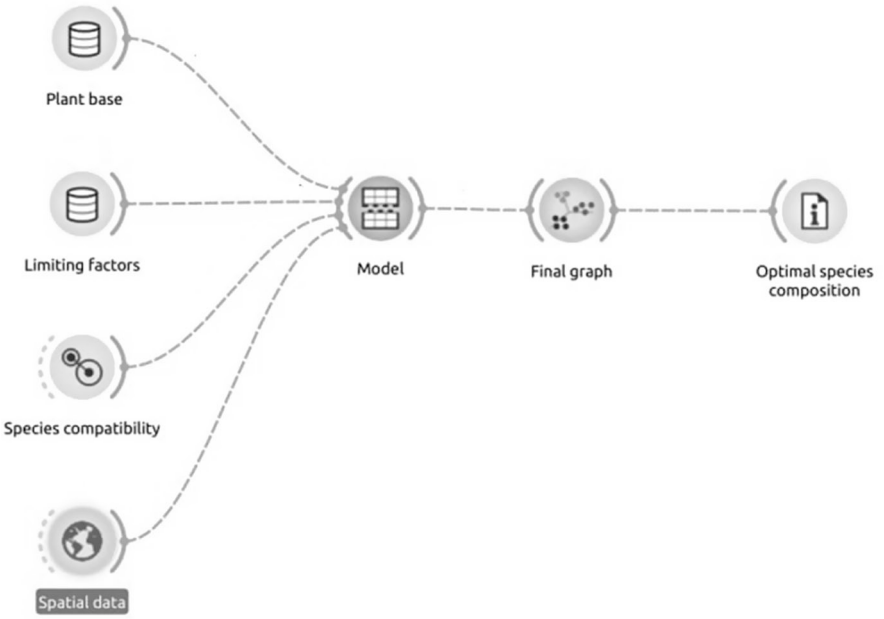

Fig. 2 General scheme of species composition formation based on network modeling

Modeling of combinations of plant species has a nondirectional character and reflects the presence of successful practices of joint planting of plants of the corresponding species for compositional or functional purposes.

The generated model can be used to plan the species composition of plants in the tasks of landscaping territories when the growing conditions are known.

The method described above has given good results, it allows you to get recommendations for a predetermined territory with a list of trees, shrubs, and other plants that are well combined and can grow specifically in this territory. However, we decided to supplement the model with the opinion of residents, their knowledge, and experience.

In the second stage of the work, it was proposed to supplement the model with geolocated data that users leave on the network in order to identify problem areas, search for new limiting factors, for example, flooding zones that are not indicated in GIS systems and other problems.

The purpose of this direction is to identify what information users write about the current state, for example, of the park, this will allow you to quickly identify problem areas, for example, to learn about soil contamination, to quickly identify that pests have got into the park. These are just a few examples of how you can work with reviews from residents of cities. To solve this problem, first, you need to collect all the reviews about the parks, then, from all the reviews, you need to identify only those that are related to green spaces.

4 Data Collection

Google Maps was chosen as a source of information. It is a free online service that allows users to view a map of the world, build routes, and search for places and businesses on the map. In general, the Google Maps service allows users to quickly and conveniently obtain cartographic data about places that interest them and receive detailed information about them. Google Maps allows users to post reviews about objects, for example, shops, but, among other things, this system also has maps of recreation facilities—parks, gardens, and squares, and users can also leave their reviews and ratings on them.

Using the example of St. Petersburg, we examined the park cards in the Google Maps service. In addition to the description and address, such cards contain user reviews, this information was studied in our study. Recreational objects were collected by districts, there are 18 districts in the city, landscaping objects were selected for each of them using an internal Google Maps search, the words "park," "garden," "square," "alley," "forest," and "field" were used for the search, then each object was saved as a link to the object card in the system. All the objects were saved in the final table, in addition, the total number of reviews and ratings were recorded for each map.

The rating is a score from 1 to 5. Reviews were collected for each card of the park, further, all reviews were combined by districts, a total of 18 groups were obtained, according to the number of districts in St. Petersburg. In total, more than 360 thousand comments from citizens were collected.

Furthermore, with the help of a predefined dictionary, comments related to the topic of gardening were selected, more than 1000 entries were found in which residents discuss gardening issues. Preliminary text processing has been carried out. Reviews have been identified that signal problematic trees, there are records indicating drainage problems and other valuable information about recreational areas.

5 Depersonalization of Information

An important aspect of data processing is personal data, the legislation of many countries clearly states that personal data cannot be used.

For example, the GDPR text, through which the European Parliament, the Council of the European Union, and the European Commission strengthen and unify the protection of personal data of all persons in the European Union.

In our work, it is important for us to follow the ethics of scientific research. In order to solve this problem, we refuse to save any names, contacts, and other personal information. Some users sometimes, in the text of comments, they may mention names, and address other participants or public persons through reviews. The collection of such information is not included in the subject of our research. To

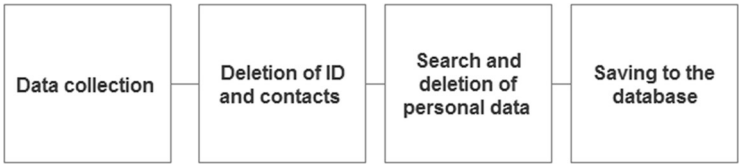

Fig. 3 General scheme of depersonalization of comments

solve the problem, all real IDs were not saved. In the work, only the texts of reviews were used, which were assigned an ordinal number. To further strengthen it, it was decided to develop a script that would remove any mention of surnames, names, and contacts from the text.

This script was implemented based on the Yargy parser and the Natasha library. Yargy parser is a library for extracting structured information from a natural language text based on rules. This library is used to perform operations such as extracting dates, names, addresses, organizations, and other named entities from the text in Russian and English. Yargy works by generating parser combinators from rules describing the structure of data in the text. It can be used in various natural language processing tasks, such as analyzing news articles, machine learning texts, or building business logic through text query processing.

The Natasha library is a set of tools for natural language processing. In particular, it allows lemmatization, morphological analysis, extraction of named entities, and other operations with the text. Natasha uses the pymorphy2 library for the morphological analysis of words. The processing procedure takes place immediately after data collection, the deleted information is not duplicated anywhere.

The general scheme of depersonalization of comments is shown in Fig. 3. The result justified the efforts, all the reviews remained depersonalized, firstly, we deleted all the contact information provided by the geoinformation network itself, and in the second step, with the help of our script, we got rid of any mentions of personal data, thereby not violating the requirements.

6 Data Mining

In our work, we used a pre-loaded dictionary, which we compiled together with ecologists, it included the main terms applicable to green spaces, for example, “tree, shrub, landscaping, swamp, botany, branches, wind-resistant, forest, vines, leaf, weeds,” in total, more than 200 words in addition, we supplemented the dictionary with names of plants. So, according to World Flora Online, there are over 350,000 plant species growing in the world, however, we used only the species composition of a specific area that can grow in a specific area, taking into account limiting factors.

Before starting, text processing is performed. Text preprocessing creates tokens by converting text to lowercase, splitting it into words, normalizing words, and removing stop words.

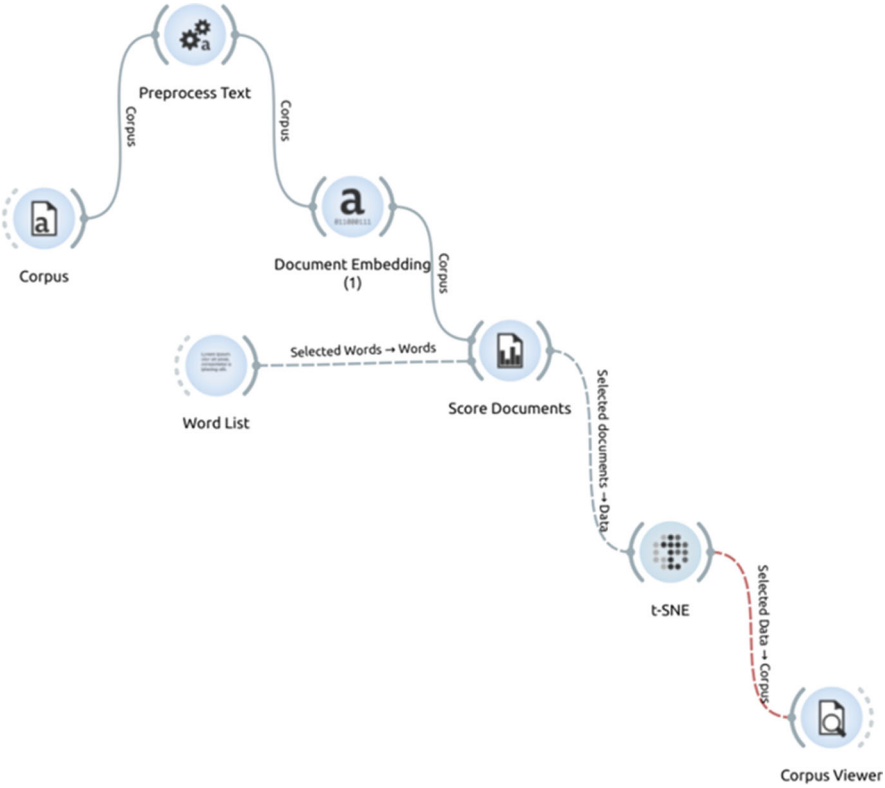

Fig. 4 Scheme of work for data mining

Finally, we send the entire list of words to the Semantic Viewer and also add the corpus output from the preprocessing text. Semantic Viewer now evaluates documents based on a list of input words. The higher the score, the more matches there are in the document. This is a good way to find interesting content on the topic of gardening.

The final scheme of work is shown in Fig. 4. Orange Data Mining software was used for text processing. It is an open-source software designed for data analysis and machine learning. It allows users to perform various tasks, such as classification, clustering, regression analysis, and data visualization. The program has a graphical user interface. Orange Data Mining uses algorithms such as random forest, logistic regression, neural networks, support vector machines, and many others to process data. In this paper, Orange was used to search for thematic comments.

In total, more than 1000 reviews were revealed on the topic of gardening. Examples of the reviews found are given in Table 1. The examples obtained demonstrate that residents pay attention to the problems of green spaces and react to them. For example, they report withered or unstable trees.

Table 1 Examples of reviews that mention gardening problems or issues

No.	Review text
1	They cut down all the birches, now it is too windy in this place. Previously, it was possible to take a break from the hustle and bustle, but now it's noisy and windy
2	While they were doing drainage for the more expensive, a very large number of roots were damaged, some trees began to wither
3	In good weather, there are a lot of people, when it is cloudy, then as a rule there is a very strong wind and it is cool The playground is constantly broken by drunk teenagers at night, and some thieves stole the tui. Those that were not stolen dried up themselves. The trees were planted at the wrong time, just to plant, for show. So almost everyone did not start. And the idea itself was good—to refine the lake.
4	There are few paved paths, one alley, the rest of the paths are wet and dirty, chernozem, clay. It is necessary to develop a network of paths of the park, at least to sprinkle them with granite chips. It is necessary to remove lawns, there are not enough shrubs
5	Better than nothing. But! As a park, it is completely not thought out. It feels like it's just a birch forest with cut paths
6	Bad park: garbage, dirt, not a single pine or Christmas tree. Everything is gloomy and unsightly. New thuja planted in 2020 dried up, absolutely not watered and planted in clay

Preliminary analysis showed that it is possible to extract relevant geolocated information about landscaping problems from residents' comments. It is planned to use the received information in the work of the model.

Following the results of the collection of text processing, all thematic comments were collected into a single database, which contained the text of the review and its geolocation. Then, with the help of thematic modeling, the analysis of the selected reviews was carried out.

Thematic modeling is a great way to reveal hidden topics in a large collection of documents. The method is extremely popular in the digital humanities, so it is not just about performance, but also explainability. Thematic modeling detects abstract topics in the corpus based on clusters of words found in each document and their corresponding frequency. A document usually contains several topics in different proportions, so the widget also reports the weight of the topic for each document. Among the methods of thematic modeling, many researchers [10] still use latent Dirichlet allocation (LDA), a generative model that observes the frequency of words in the corpus and iteratively builds a thematic model for a given number of topics. LDA (latent Dirichlet allocation) is a statistical modeling technique used in natural language processing and machine learning to identify topics within a large corpus of text data. At a high level, LDA assumes that each document in the corpus is a mixture of multiple topics and that each word in a document is associated with one of those topics.

The goal of LDA is to automatically detect those underlying topics and to determine how prevalent each topic is in each document. The LDA algorithm works by iterating through each word in each document in the corpus and attempting to assign it to a topic. Over multiple iterations, the algorithm fine tunes the topic

Table 2 Results of thematic modeling on Gensim

No.	Topic words
1	Trees, grass, bloom, park, beautiful, trees, cozy, apple trees, garbage, bad
2	Zone, walk, green, park, huge, green, in general, trees, cities, one
3	Green, greenery, green, uncut, park, place, ducks
4	Trees, more, park, not enough, place, grass, beautiful, clean, little, greenery
5	Park, not enough, flowers, green, trees, trees, hope, tulips, nice, birds
6	Trees, exhaust, flowers, air, lawn, park, green, plantings, dirty, squirrels
7	Park, beautiful, trees, greenery, place, sit, trees, walk, garbage, cool
8	Garden, old, branches, among, greenery, withered, cities, excellent, trees, jungle
9	Green, center, greenery, green, park, corner, city, island, place, big
10	Dark, park, square, nice, nice, evening, paths, shade, place, shade

assignments by considering the probability of each word occurring in each topic and the probability of each topic occurring in each document.

LDA is often used for tasks such as document classification, topic modeling, and sentiment analysis. It has been applied in a wide range of fields including social media analysis, customer feedback analysis, and scientific literature analysis.

The Gensim library was used in working with LDA. Gensim is an open-source library for unsupervised thematic modeling, document indexing, similarity search, and other natural language processing functions using modern statistical machine learning.

As a result, ten thematic clusters were identified, after the analysis of which it was possible to identify common problems with aridity, shadows, and poor care (Table 2). These simulations indicate that comments can be used in the planning and modeling of buildings of green spaces, to account for specific nuances that are not in GIS databases.

In the future, an analysis using other techniques is planned to identify the optimal approach to analysis. At the current stage, the main task was to prove the applicability of the method of automated collection and processing of comments for species composition planning.

7 Discussion and Limitations

The results obtained allow us to conclude that the research hypotheses have found support. The results obtained demonstrate that data from social networks can complement the model for planning the species composition for a specific area. If we collect all the reviews in advance about the location where landscaping is planned, and about the nearest objects, we can get additional variables for our model.

At the next stage, it is planned to carry out thematic modeling using clustering by other methods, to speed up the analysis of specific objects, the presence of clusters will allow identifying predefined problems.

The practical novelty of the project lies in the development and testing of tools for interdisciplinary scientific research, which allows planning the breed composition for the most effective landscaping of urban areas, taking into account the compatibility and compositionality of species, their growing conditions, and the experience of the inhabitants of the area in the form of comments on the social network.

Based on the obtained model, a service is being developed for the formation of recommended compositions of plant species for landscaping urban areas.

This method cannot replace the classical methods of observation, questioning, and focus groups, however, it can allow for an operational analysis of the situation.

References

1. Gulgun, B., et al.: Role of the landscape architecture in interdisciplinary planning of sustainable cities. J. Environ. Prot. Ecol. **15**(4), 1877–1880 (2014)
2. Sjöman, H., Nielsen, A.B.: Selecting trees for urban paved sites in Scandinavia–a review of information on stress tolerance and its relation to the requirements of tree planners. Urban For. Urban Green. **9**(4), 281–293 (2010)
3. Shirgapure, K.H., Ghosh, P.: Allelopathy a tool for sustainable weed management. Arch. Curr. Res. Int. **20**, 17–25 (2020)
4. Li, S., Peng, Z., Huang, Z., Qin, J.: Plants spatial planning method of urban ecological landscape environment. Ekoloji. (107), 2905–2916, Article No: e107325 (2019)
5. Asgarzadeh, M., Vahdati, K., Lotfi, M., Arab, M., Babaei, A., Naderi, F., Soufi, M.P., Rouhani, G.: Plant selection method for urban landscapes of semi-arid cities (a case study of Tehran). Urban For. Urban Green. **13**(3), 450–458 (2014). ISSN 1618-8667
6. Roloff, A., Korn, S., Gillner, S.: The climate-species-matrix to select tree species for urban habitats considering climate change. Urban For. Urban Green. **8**(4), 295–308 (2009). ISSN 1618-8667
7. Wei, Z., et al.: Plant species complementarity in low-fertility degraded soil. Plants. **11**(10), 1370 (2022)
8. Zhang, L., Wang, H.: Planning an ecological network of Xiamen Island (China) using landscape metrics and network analysis. Landsc. Urban Plan. **78**(4), 449–456 (2006). ISSN 0169-2046
9. Kong, F., Yin, H., Nakagoshi, N., Zong, Y.: Urban green space network development for biodiversity conservation: identification based on graph theory and gravity modeling. Landsc. Urban Plan. **95**(1–2), 16–27 (2010). ISSN 0169-2046
10. Sievert, C., Shirley, K.E.: LDAvis: a method for visualizing and interpreting topics. In: Proceedings of the Workshop on Interactive Language Learning, Visualization, and Interfaces, pp. 63–70, Baltimore, Maryland, USA (2014)

Development of a Network Model for Urban Greening Based on the Characteristics of Plant Growth

Nikita Kopyt and Boris Nizomutdinov

Abstract The development of landscaping and the creation of a comfortable urban environment are priority tasks for urbanists and city planners today. It is through landscaping that decisions are made to ensure that new construction sites are comfortable for visitors.

Landscaping is carried out by selecting an assortment of plants. It is possible to automate this process, but it is essential to use the characteristics of the plant species. A good selection of high-quality plants affects the future viability of the landscaping and the performance of its functions. These conditions are reflected in the work on the development of a network model of landscaping, a database of plants by the characteristics of growth.

The database of species composition was compiled with mandatory consideration of the characteristics of plant growth on the factors limiting their full development and distribution. As proof of this, an experiment on the application of the development is described.

Keywords Selection of species composition · Plant database · Network model of landscaping · Urban plantations · Growing characteristics · Urban plants

1 Introduction

Urban greenery is one of the foremost themes in the creation of an improved and comfortable urban environment of our time. It is the plants in the "stone jungle" that can have a positive effect on the psycho-emotional state of urban dwellers, reducing the negative impact of the poor urban environment and the negative factor of an active society. The creation of green areas requires a judicious selection of plant species so that they come into contact with one another and can grow on the chosen

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_4

site according to their growth characteristics. In order to find out if they can grow, you need to consult plant databases [1, 2].

2 Current Data Situation

Databases are a source of information on the characteristics of species composition. Many databases have been compiled to date, each aimed at different tasks and with a variety of architectures. In the course of the study, seven existing species composition databases were reviewed (Table 1).

We highlighted the main points of comparison: Date of the last update as the plant world's ability to adapt to environmental conditions; location of growth the availability of internationally recognized Latin names as an opportunity for the international use of the database, validation and testing by the international scientific community to avoid misunderstandings and discrepancies in the naming

Table 1 Database

Criterion	Update year	Region	Utility	Latin name	API	Limit factor	Absence of most endemic species
Name							
Search by Genus or Cultivar	**1996**	**All world**	**Website**	**—**	**+**	**—**	**+**
Plant Select Plant Smarter	2022	North America	Website	–	–	–	+
Australian Native Plants Society (ANPSA)	**2022**	**Australia and Oceania**	**Website**	**+**	**—**	**—**	**—**
Plants of the World Online (POWO)	2021	All world	Website	+/–	+	–	–
База данных геоботани□еских описаний растительных сообществ Европейской России	**2000, now in progress**	**Russia and Eastern Europe**	**Excel file**	**+**	**—**	**+/—**	**+**
North Carolina Extension Gardener Plant Toolbox	2022	North America	Website	+	+	–	+
База данных породного состава	**2022**	**European Russia and Eastern Europe**	**Excel file**	**+**	**+**	**+**	**+**

conventions, the possibility of writing a query to the database as the main tool for using the information and the availability of limiting factor parameters for the introduction of plant species as part of the introduction of new plant species into the list. Availability of common species, as the prevalence of endemic plant species can be detrimental to the quality of the results of the compiled species list in the future use of the database as the introduction of endemics is a complex scientific process [3, 4].

3 Plant Composition Database

Consider the excerpt from the breed composition database in (Fig. 1)

The most important parameter for ensuring the viability of planting stock is to take into account the characteristics of the plant species when selecting plants. For this reason, the first step in developing the plant selection service was to compile a "Plant Breed Composition Database". The database is based on data about the climatic range of species. The frost-resistance zones of the USDA are the main selection criterion and correlation of the selection result in the created database. Secondary, but inherently important characteristics, are the limiting factors for plant growth. These are soil conditions, wind resistance, smoke and gas resistance, waterlogging tolerance and plant growth characteristics in terms of distribution typology and expansion patterns. Tertiary characteristics include the life form and size characteristics of the average mature model plant of the species. Tertiary characteristics exist to provide summary information on the developmental structure and appearance of the selected plant [5].

The main characteristics of plant growth that are recorded in the database are as follows:

	Наименование	Латинское название	Зона USDA											Высота	Размер кроны	Лимитирующие факторы						Состав почвы: Кислотность							ородие			Разновидности почв								Агресс-ть развития	Живучесть	Инвазивный вид	Свет			Влажность		
			USDA1	USDA2	USDA3	USDA4	USDA5	USDA6	USDA7	USDA8	USDA9	USDA10	USDA11			к переуплотнению	зость к засолению	ст. к пересыханию	ст. к подтоплению	Газостойкость	етроустойчивость	Сильнокислые (4)	Кислые (5)	Слабокислые (6)	Нейтральные (7)	лабощелочные (8)	Щелочные (9)	ьнощелочные (10)	Плодородная	дне плодородные	Бедные почвы	Песчаная	Супесчаная	Суглинистая	Глинистая	Каменистые	Щебнистые	Тяжёлая	ю дренированная				олное освещение	Полутень	Тень	Ксерофит	Мезофит	Гигрофит
1	2	3												15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
222	Микробиота перекрёстнопа	*Microbiota decussata Kom.*			1	1	1	1	1	1	1	1	1	1	1	-1	-1	0	-1	0	1	1	1	1	1	1	-1	-1	0	1	-1	-1	1	-1	-1	0	0	0	1	0	0	0	1	1	0	-1	1	-1
223	Миндаль трехлопастной	*Louiseania triloba (Lindl.) Pachom.*					0	1	1	1	1	1	1	3	3						0				1	1	1		1				1	1								0	1				1	
224	Можжевельник виргинский	*Juniperus virginiana L.*			1	1	1	1	1	1	1	1	1	20	7	0	-1	1	-1	1	1	1	1	1	0	-1	-1	-1	1	1	0	-1	0	1	1	0	0	-1	1	-1	1	0	1	1	-1	-1	1	-1
225	Можжевельник высокий	*Juniperus excelsa M. Bieb.*		1	1	1	1	1	1	1	1	1	1	10	5	0	-1	1	-1	1	1	1	1	1	1	-1	-1	-1	1	1	0	-1	0	1	1	0	0	-1	1	-1	1	0	1	1	-1	-1	1	-1
226	Можжевельник горизонталь	*Juniperus horizontalis Moench*						1	1	1	1	1		0.5	1.5			0		0	1		1	1	1				0	1	0		1			1	1		1		1		1	1	0		1	
227	Можжевельник казацкий	*Juniperus sabina L.*			1	1	1	1	1	1	1	1	1	1	1	0	-1	1	-1	1	1	1	1	1	0	-1	-1	-1	1	1	0	-1	0	1	1	0	0	-1	1	-1	1	0	1	1	-1	-1	1	-1
228	Можжевельник китайский	*Juniperus chinensis L.*						1	1	1	1	1		25	7	0	-1	1	-1	1	1	1	1	1	0	-1	-1	-1	1	1	0	-1	0	1	1	0	0	-1	1	-1	1	0	1	1	-1	-1	1	-1
229	Можжевельник красный	*Juniperus oxycedrus L.*								1	1	1		6	1	0	-1	1	-1	1	1	1	1	1	0	-1	-1	-1	1	1	0	-1	0	1	1	0	0	-1	1	-1	1	0	1	1	-1	-1	1	-1
230	Можжевельник обыкновенн	*Juniperus communis L.*		1	1	1	1	1	1	1	1	1		5	3	0	-1	1	-1	1	1	1	1	1	0	-1	-1	-1	1	1	0	-1	0	1	1	0	0	-1	1	-1	1	0	1	1	-1	-1	1	-1
231	Можжевельник сибирский	*Juniperus sibirica Burgsd.*	0	1	1	1	1	1	1	1	1	1	0	1	2	-1	-1	1	-1	1	1	1	1	1	0	-1	-1	-1	1	1	0	-1	0	1	1	0	0	-1	1	-1	1	0	1	1	-1	-1	1	-1
232	Можжевельник твёрдый	*Juniperus rigida Siebold & Zucc.*	-1	-1	0	1	1	1	1	1	1	1	0	8	2	0	1	1	-1	1	1	1	1	1	1	-1	-1	-1	1	1	0	-1	0	1	1	0	1	1	1	-1	1	0	1	1	-1	-1	1	-1
233	Облепиха крушиновидная	*Hippophae rhamnoides L.*	0	0	1	1	1	1	1	1	0	-1	-1	6	3	1	0	-1	-1	0	1	-1	0	0	1	1	0	-1	1	1	0	1	1	0	-1	1	1	1	1	1	1	1	1	1	0	-1	1	-1
234	Ольха бородатая	*Alnus barbata C.A. Mey.*	0	0	1	1	1	1	1	1	1	0	-1	30	10	1	1	0	1	1	1	-1	0	1	1	1	1	0	0	1	1	-1	1	1	1	0	0	0	1	1	1	0	1	1	-1	-1	1	0
235	Ольха серая	*Alnus incana (L.) Moench*	0	1	1	1	1	1	1	1	1	0	-1	20	5	1	1	0	1	1	1	-1	0	1	1	1	1	0	0	1	1	-1	1	1	1	0	0	0	1	1	1	0	1	1	-1	-1	1	1
236	Ольха чёрная	*Alnus glutinosa (L.) Gaertn.*	0	1	1	1	1	1	1	1	1	0	-1	25	5	-1	1	0	1	1	1	-1	1	1	1	1	1	0	0	1	1	-1	1	1	1	0	0	0	1	1	1	0	1	1	-1	-1	1	1
237	Орех айлантолистный	*Juglans ailanthifolia Carriere*	-1	-1	-1	0	1	1	1	1	1	1	0	20	10	-1	-1	0	-1	1	1	-1	-1	1	1	0	-1	-1	1	0	-1	-1	1	1	0	-1	-1	-1	1	-1	1	0	1	1	0	-1	1	-1
238	Орех грецкий	*Juglans regia L.*	-1	-1	-1	-1	-1	0	1	1	1	1	0	20	10	-1	-1	0	-1	0	1	-1	-1	1	1	1	1	-1	1	1	0	-1	1	1	-1	0	0	-1	1	-1	0	0	1	1	-1	-1	1	-1
239	Орех Маньчжурский	*Juglans mandshurica Maxim.*	-1	-1	-1	0	1	1	1	1	1	1	0	25	10	-1	-1	-1	-1	1	1	-1	-1	1	1	1	-1	-1	1	0	-1	-1	1	1	0	-1	-1	-1	1	-1	1	0	1	1	0	-1	1	-1
240	Орех серый	*Juglans cinerea L.*	-1	-1	-1	0	1	1	1	1	1	1	0	30	10	-1	-1	1	-1	1	1	-1	-1	0	1	1	0	-1	1	1	0	0	1	1	-1	-1	-1	-1	1	-1	1	0	1	1	0	-1	1	-1
241	Орех чёрный	*Juglans nigra L.*	-1	-1	-1	0	1	1	1	1	1	1	0	30	10	-1	-1	0	-1	1	1	-1	-1	1	1	1	0	-1	1	1	0	0	1	1	-1	-1	-1	-1	1	-1	1	0	1	1	0	-1	1	1
242	Павловния войлочная	*Paulownia tomentosa (Thunb.) Ste*	-1	-1	-1	-1	0	1	1	1	1	1	0	20	10	-1	-1	0	0	1	1	-1	-1	0	0	0	-1	-1	1	1	0	-1	1	1	-1	-1	-1	-1	1	-1	0	0	1	-1	-1	-1	1	-1
243	Парротия персидская	*Parrotia persica (DC.) C.A. Mey.*	-1	-1	-1	-1	0	1	1	1	1	1	0	20	7	-1	-1	1	-1	1	1	-1	-1	1	1	0	-1	-1	1	1	0	1	1	-1	-1	0	0	-1	1	-1	1	0	1	0	-1	-1	1	-1
244	Персик обыкновенный	*Persica vulgaris Mill.*	-1	-1	-1	-1	0	1	1	1	1	1	1	4	2	-1	-1	0	-1	0	0	-1	-1	1	1	1	-1	-1	1	0	-1	-1	1	1	-1	-1	-1	-1	1	-1	1	0	1	-1	-1	-1	1	-1
246	Пихта бальзамическая	*Abies balsamea (L.) Mill.*	-1	0	1	1	1	1	1	1	1	1	0	15	5	-1	-1	-1	0	0	1	0	1	1	0	-1	-1	-1	1	1	0	-1	1	0	0	-1	-1	-1	0	-1	0	0	0	1	0	-1	1	-1

Fig. 1 Fragment from the breed composition database

Climate zone Data based on USDA frost tolerance zones, listing the zones with temperatures that are the limiting factor for the spread of vegetation species and the zones chosen to characterize the species enable them to grow without any difficulty or special care. It is worth noting that in many cases species can survive and emerge from hibernation at lower temperatures, e.g. blackcurrant can survive temperature drops as low as −230 °C, but will die in a sudden frost in early summer at −5 °C. It all depends on the drop in temperature and the developmental phase of the plant.

A list of zones reflected on the territory of Russia, formed on the basis of the average value of the annual minimum temperature on the basis of many years of statistical observations, is given.

The temperature is given in degrees Celsius.

Zone 1: less than −45
Zone 2: from −45.5 to −40.1.
Zone 3: −40.0 to −34.5.
Zone 4: −34.4 to −28.9.
Zone 5: −28.8 to −23.4.
Zone 6: −23.3 to −17.8.
Zone 7: −17.7 to −12.3.
Zone 8: −12.2 to −6.7.

Crown size A generalized characteristic of the species for understanding the developmental pattern and projecting mature growth of the plant on the ground when designing planting locations.

Average height A generalized characteristic of the specific features of the species to understand the developmental pattern and projection of mature plant growth on the ground when designing the planting location.

Aggressiveness of development The style of spread and occupation of the surrounding vegetation around the species. This characteristic strongly influences the choice of species in certain compositions and the selection of neighbouring species to avoid crowding out and overshadowing within the species composition of a particular biotope.

Smoke and gas tolerance This characteristic of the species is based on observations in relation to general environmental pollution by smoke and gas pollution. Influences the location when the species is planted.

Vulnerability A figurative characteristic responsible for the vandal resistance of the species and the response to the effects of anthropogenic as well as natural factors associated with the suppression of the species' development. Many species can easily tolerate the breaking or suppression of the main shoot, for example: Thuja westerly, Tatar maple and common lilac, all due to their development and branching characteristics, but there are species for which the impact on the main shoot has a detrimental effect not only on the full development but also on ornamental value, for example, common fir and common horse chestnut.

Soil suitability This characteristic refers to the growing conditions and the best decorative development of the plant on certain soil characteristics in relation to soil composition and pH value.

Relation to moisture Characteristic of the type of vegetation in relation to water nutrition and the ability to grow in a certain relationship with water. There are three types of plant characteristics in relation to water: hygrophytes, mesophytes, and xerophytes. Most of the plants in the study are mainly mesophytes, this is due to the geographical latitude taken in the final qualification work.

The flowering period The time interval of the most ornamental development of the plant, the emergence of flower stems or the seasonal colouring of the leaves or shoots. Many plants can be highly ornamental throughout the year, not only evergreens, especially spruces, but also, for example, oak, in winter it has bright architectonics of the crown texture, in spring a faintly visible but decorative thread-like light yellow flowering with bright salad leaves, in summer a rich dark green colouring and an openwork massive crown, bright green acorns, in autumn a green to bright yellow colouring of the leaves and an abundance of ripe acorns.

Light tolerance A characteristic that describes the ability of the plant to grow under different light conditions. This characteristic influences the ornamental development of the varieties, namely the colour of the leaves, as well as their healthy and full development.

Light-loving or shade-tolerant These characteristics significantly affect the life and health of the plant and, secondarily, the ornamental development of the habitus. This characteristic does not describe the light regime of cultivation of the plant; the light regime is conditioned by the geographical growth on a certain parallel, for example, the dwarf birch will hardly grow on the parallels south of the northern latitudes of the Karelian isthmus due to the different light regime in summer and the absence of "white nights" as in its usual habitat.

Wind resistance A characteristic describing the development of the root system and the ability of the plant species to persist and survive on loose, sloping, loose and windswept surfaces. Root systems of plants are of two types: taproot and lodgepole. The taproot system is due to the presence of a strong main root running perpendicular to the growth of the plant and small adventitious roots. This root system is formed mainly in plants growing on sandy soils or soils with deep groundwater. Most trees have a taproot system; this can often be seen on forks in the forest, where the pronounced taproot and many adventitious roots at the periphery are exposed. A taproot system consists only of a number of adventitious roots; this root system is mainly found in monocotyledonous plants, but only in trees of the palm family.

Purpose and nature of use All types of vegetation are divided into different conditions and uses. The soil-holding capacity or the buffer-protective function are all described in this characteristic.

4 Experiment

As part of the experiment, consider an example of selecting a species composition to complement the existing range of plants using the example of an existing public green space, Murinsky Park, St. Petersburg (Fig. 2).

The existing species composition of Murinsky Park consists of 82 plant species, according to the public green space object passport: Japanese quince, black chokeberry, Chinese astilbe, common barberry, Thunberg's barberry, overhanging birch, birch, common privet, hawthorn red, early weigela, veronica spiky, common cherry, elm, gaylardia hybrid, maiden vine, five-leafed, white currant, white wood "sibirica", English oak, European spruce, spruce, Serbian spruce, tatar honeysuckle, white willow, Babylonian willow, willow goat, brittle willow, willow twig willow, willow aphyllum, willow Schwerin, iris sibirica, prickly pear, arborvitae, cotoneaster, ginnala maple, marigold maple, tatar maple, ash maple, horse chestnut, coreopsis large flowered, shrubby noodle, linden chenopodium, tiny-leaved linden, linden heart, European larch, Siberian larch, mixed loch, magonia holly, cossack juniper, grey alder, common mountain elder, Hungarian lilac, snowberry white, ascolithium hybrid, mountain pine, pinus, spiraea bumalda, spiraea vangutta, oak-leaved spiraea, willow-leaved spiraea, heath bunting, Japanese spiraea, Japanese spiraea "golden princess", white poplar, poplar shivering, poplar Leningrad, Italian poplar, black

Fig. 2 The location of Murinsky Park in St. Petersburg

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✓ 0.1s
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	name_ru	limitation_factor_id	is_stable
83	Ольха бородатая	3	3
84	Ольха серая	3	3
85	Ольха чёрная	3	3
131	Тополь чёрный	3	3
141	Шиповник колючейший	3	3
142	Шиповник коричный	3	3
143	Шиповник морщинистый	3	3
144	Шиповник французский	3	3
145	Яблоня лесная	3	3

Fig. 3 Selected list of species diversity

poplar, thuja westerly, European forsythia, dangling forsythia, plantain hosta, wild cherry, maaca cherry, bird cherry, horseroot, rosa prickly, cinnamon rose, fragrant rose, apple tree hybrid, apple tree, berry apple tree and tall ash.

By downloading the information from the species composition database, the network model proposes to add the following species to the range of the park: bearded alder, grey alder, black alder, black poplar, prickly rose hips, cinnamon rose hips, wrinkled rose hips, French rose hips and forest apple trees (Fig. 3). With manual processing of data on climatic, soil conditions and other characteristics of the park, this selection list of plants was confirmed as viable and was a positive evaluation for the criterion of the veracity of the use of the selection through the network model.

5 Conclusion

The feasibility and plausibility of creating a plant species composition for existing public green space areas was confirmed through a selection experiment. This method based on network modelling can be used for further research and plant selection for specific natural and climatic conditions. The feasibility and plausibility of creating a plant species composition for existing public green space areas was confirmed through a selection experiment. This method based on network modelling can be used for further research and plant selection for specific natural and climatic conditions

In the future, it is planned to develop the technology, to model more experiments, to conduct research in the field of allelopathic interspecific influence of plants on each other and to complete the database of species composition, which at the moment of the publication contains more than 500 plant species.

References

1. Sjöman, H., Nielsen, A.B.: Selecting trees for urban paved sites in Scandinavia–a review of information on stress tolerance and its relation to the requirements of tree planners. Urban For. Urban Green. **9**(4), 281–293 (2010)
2. Outcome of the HABITAT III Scientific Conference. https://habitat3.org/wp-content/uploads/11-Habitat-III-Issue-Paper-11_Public-Space_rus-AI_fin.pdf. Last accessed 16 May 2023
3. Asgarzadeh, M., Vahdati, K., Lotfi, M., Arab, M., Babaei, A., Naderi, F., Soufi, M.P., Rouhani, G.: Plant selection method for urban landscapes of semi-arid cities (a case study of Tehran). Urban For. Urban Green. **13**(3), 450–458 (2014). ISSN 1618-8667
4. Gulgun, B., et al.: Role of the landscape architecture in interdisciplinary planning of sustainable cities. J. Environ. Prot. Ecol. **15**(4), 1877–1880 (2014)
5. Wei, Z., et al.: Plant species complementarity in low-fertility degraded soil. Plants. **11**(10), 1370 (2022)

Part II
Computational Linguistics & Machine Learning

A Corpus Study of the Russian Locative Variability

Timur Galeev, Anna Shevlyakova, Vladimir Bochkarev, and Vera Kosova

Abstract The chapter considers the problem of variability of Russian masculine nouns used in the locative singular. The study was performed on the basis of an extra-large text corpus Google Books Ngram using computer methods. We identified the frequency characteristics of the competing noun forms used in the locative case, determined the dynamics of their use, and revealed the factors that influence the choice of one form or another.

Keywords Russian grammar · Corpus linguistics · Locative · Variability · Google Books Ngram

1 Introduction

The problem of language evolution and the variability of its components are relevant for modern linguistic research. The emergence of large text corpora and development of new computational methods have greatly improved the study of linguistic variability by making it more reliable.

The frequency studies of the evolution of competing word forms have been carried out for different languages. For example, the analysis of the features of competing English verbs was presented in [1]. A similar study was also performed based on the analysis of the competition between German verbs of strong (regular) and weak (irregular) conjugation in [2, 3].

The quantitative aspect of the competing word forms of the Russian language was considered in [4–9].

The objective of the present work is to study the frequency characteristics of the competing forms of the locative singular of masculine nouns in the Russian language using an extra-large text corpus Google Books Ngram, as well as revealing the factors that influence the choice of one or another competing form.

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_5

In Russian, the locative case used with the preposition *v/vo* (in) serves to indicate a place, space, or some event within which or where an action takes place: *dom v derevne, vo vtoroi mirovoi voine* (a house in a village, during World War II); used with the preposition *na* (on/in) indicates the surface where something is located or happens: *na rukakh, na spine, na pleche, na iuge Rossii* (in/on the arms, on the back, on the shoulder, in the south of Russia; in the village). The locative case with the preposition *na* (on/in) also indicates the circumstances of an action, state, and location of an object near some other object or place: *otdykhat' na iuge* (to rest in the south) [10].

In Russian, locative singular endings are *-u(iu)* or *-e*. Variants with *-u* are often used with the prepositions *v* (in) and *na* (on) when designating a place; and less often employed when designating a state or time of an action: *v shkafu, na beregu, v tsvetu* and *v godu* (in a wardrobe, on the shore, in blossom, and in a year).

There is a semantic and stylistic distinction between the noun forms with the endings *-u* and in *-e* (*u*-form/*e*-form). The competing variant with *-e* sounds bookish and obsolescent, while the form with *-u* is stylistically neutral or refers to colloquial, professional, or special speech. The *e*-form is preferable when the noun is attributed with the agreed definitive [11].

Only a few words allow free variation of the endings *-e* and *-u*: *gaz, riad, chas* (gas, row, and hour), etc.

Studies of the locative case variability by corpus methods were performed in previous works. For example, D. Brown pointed out that the choice of the *e*-form variant is influenced by the syntactic distance between a preposition and a noun [12]. The pioneering research was carried out on the material of the Uppsala corpus of Russian texts (created in the 1960s) and the MSU Russian text corpus created in the 2000s and served as a prototype of the modern Russian National Corpus (RNC) [13].

Using RNC and the frequency dictionaries, an international team of researchers studied the influence of the verb prefix on the verb government and, consequently, the choice of the case form [14].

The present study is also based on modern text corpora. Transliteration is performed using the ALA-LC system.

2 Data and Method

The study was conducted employing the Russian subcorpus of Google Books Ngram (GBN) [15]. In addition, we used RNC data when analyzing some complicated cases. At the first stage of the study, variants of the competing pairs of nouns were extracted from the texts presented in the GBN corpus.

To obtain a list of the competing pairs, we created patterns for each of the variations of the locative singular of masculine nouns:

{v(o) N-e|N-y},

{na N-e|N-u},
{X + v(o) N-e|N-u},
{X + na N-e|N-u},
{v + ADJ + Ne|N-u},
{vo + ADJ + Ne|N-u},

where X is the same word for the two competing word forms ((*seichas* + *v otpusk-e*|-*u* (now + on vacation)), ADJ is the same adjective for the two competing pairs, and N is a noun with one of the endings. Having obtained the quantitative data, experts analyzed them and excluded all irrelevant forms.

Homonymous forms *banke* and *dushe* (jar and soul), forms that do not meet grammatical criteria, and words that are not competing variants *na voine*|*u* (at the war) were excluded.

In addition, for each of the variants, we calculated the number of its occurrences in the corpus (e.g., 49,060//22,691), as well as the percentage of the compared variants in the corpus (e.g., 68%/32%). The data are visualized in tables (see Table 1).

Table 1 presents quantitative data for the {X + in N-e|N-u} pattern after manual cleaning. The first two columns (columns 1–2) show the competing variants. We compared the absolute (columns 3–4) and relative (columns 5–6) frequencies of the competing variants in regard to the total frequency of the lemma (column 7) and concluded the frequency predominance of one variant over the other (columns 8–9). As a result of the analysis of the quantitative data and the resulting graphs (see Fig. 1), a conclusion was made about the frequency dynamics of the competing variants throughout the target period and the prevalence of one of them at present (column 10).

Figure 1 shows the typical frequency behavior of the competing variants (pattern {X + v(o) N-e|N-y}). It is seen that the initially predominant variant continues to be preferable with time (1-a) or can be gradually substituted by the competing variant.

Furthermore, the frequency ratios were summed up and the arithmetic mean and median for the entire group were calculated (e.g., 71.54%//28.46% for the entire period and 71.41%//28.59% for the last 100 years).

We also built a general graph with the median values for all selected variants.

One can see approximately equal proportions of the absolute and median values for the patterns {na N-e|N-u} (2a) and {v N-e|N-u} (2c). The graph for the pattern {in N-e|N-u} (2e) is slightly different due to a small number of occurrences of the preposition vo (in) in such constructions.

Graphs of frequency dynamics of the variants for the patterns {v N-e|N-u} (2b) and {v N-e|N-y} (2d) show the following trends: (1) the number of the variants becomes equal due to an increase in the frequency of the variant with the ending *-e* and the preposition *na*, (2) forms with the ending *-e* start prevailing when used with the preposition *nesmotria na* (despite of), and (3) *u*-forms of the {v N-e|N-u} pattern

Table 1 Results of the analysis (pattern {X + v N-elN-u})

Variant 1	Variant 2	Frequency 1	Frequency 2	Frequency 1, %	Frequency 2, %	Lemma Frequency	Difference 1	Difference 2, %	Dominant Variant
grobe	*robu*	9420	85,448	9.93	90.07	94,868	−76,028	−80.14	y
dolge	*dolgu*	1741	105,493	1.62	98.38	107,234	−103,752	−96.75	y
krae	*kraiu*	263,117	52,192	83.45	16.55	315,309	210,925	66.89	e
pote	*potu*	49,051	29,244	62.65	37.35	78,295	19,807	25.30	e
rode	*rodu*	189,439	37,170	83.60	16.40	226,609	152,269	67.19	e
tsvete	*tsvetu*	46,196	39,326	54.02	45.98	85,522	6870	8.03	e

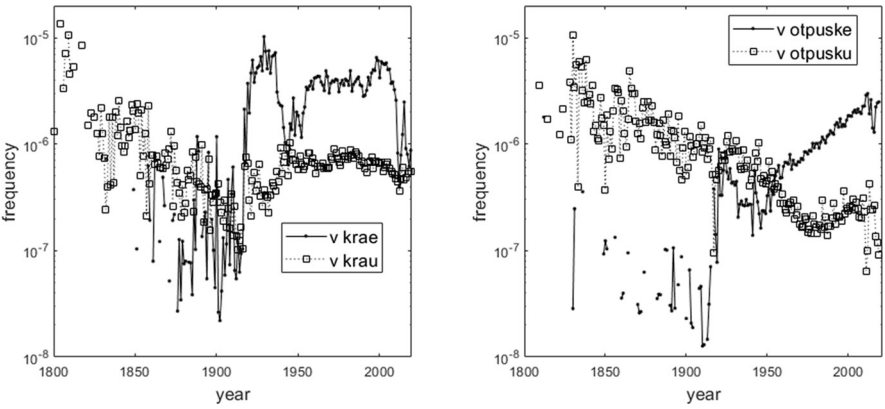

Fig. 1 Frequency graphs of the competing variants *v krae/v krau* and *v otpuske/v otpusku* (pattern {X + v N-elN-u})

prevail in the graphs (2f). The percentage of the variants with the preposition *vo* of the total number of the locative case constructions is ten times lower and does not affect the general trend.

3 Results

We performed a corpus study of more than 100 competing nouns by analyzing the frequency of mascular singular nouns with a stem with a hard consonant used in the locative case. The following results were obtained.

The absolute frequency of the ratio of the variants demonstrates a significant influence of the preposition *v* on the outcome of the competition *v* + *e* | *u* and the equalization of the number of variants in constructions with *na* + *e* | *u*.

That is the variant with the ending *-u* (*u*-form) in constructions with the preposition *na* is still quite frequent; the variant with the ending *-e* (*e*-form) is more common in combination with the preposition *v* (*na slabom svetu* but *v iarkom svete*).

Nouns with a clear predominance of one of the variants are determined:

- *u*-form predominance: *bal, byt, veter, vosk, gaz, glaz, god, gorb, don, dym, lad, led, les, lesok, log, mel, mekh, povod, (aero)port, pukh, sad, sneg, khlev, chas,* and *shkaf* (ball, life, wind, wax, gas, eye, year, hump, don, smoke, fret, ice, forest, forest, log, chalk, fur, reason, (air) port, fluff, garden, snow, barn, hour, and cupboard).
- *e*-form predominance: *vek, grunt, dom, zhir, mir, ostrov, otpusk, rog, spirt, stan, stolb, terem, kholm, tsekh, chin,* and *shag* (century, soil, house, fat, peace, island, vacation, horn, alcohol, camp, pillar, tower, hill, workshop, rank, and step).

An exception is a polysemantic word *krug* (circle). It is used with the ending *-e* (*na poslednem kruge*) in combination with the preposition *na* and with the ending *-u* combined with the reposition *v* (*v takom krugu*).

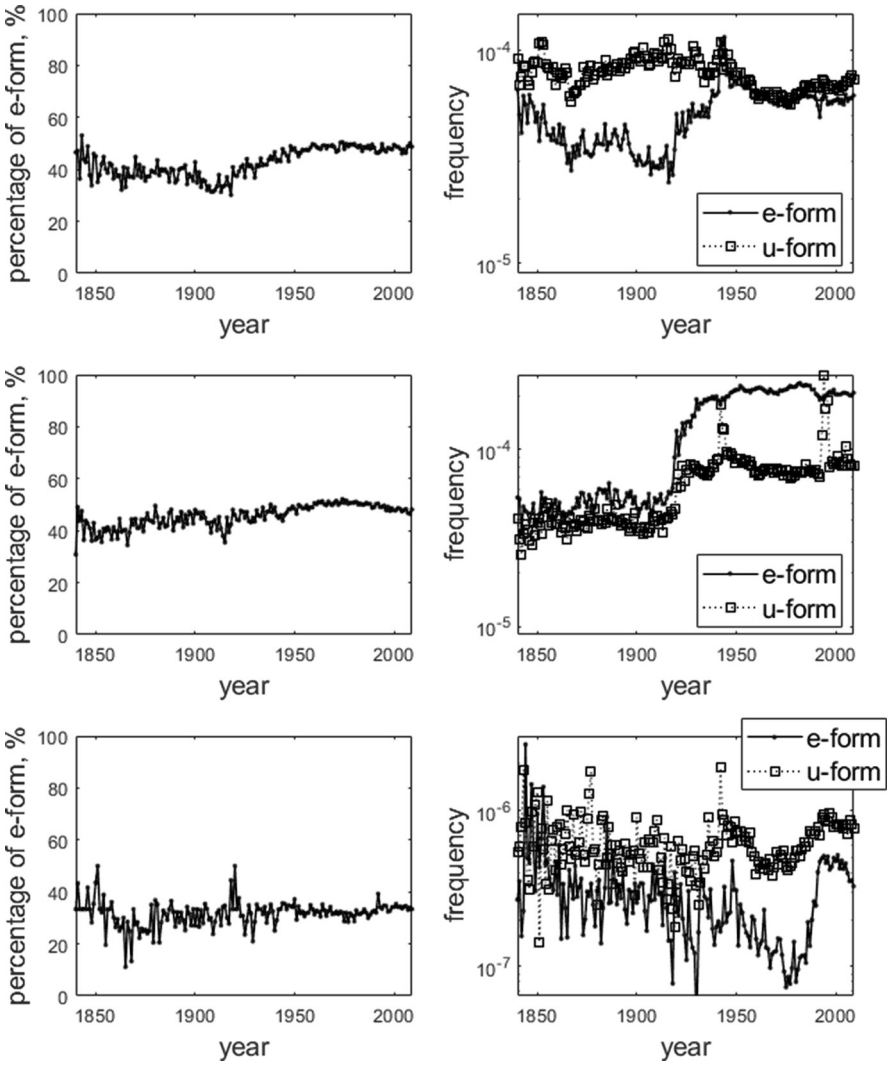

Fig. 2 Graphs for the patterns {na N-elN-u} (**a**), {v N-elN-u} (**b**), and {vo N-elN-u} (**c**)

The analysis of 3-grams including nouns attributed by an agreed definitive showed that semantic factor influences the choice of the preposition: *e*-form is more often used in a direct meaning (*na povorotnom kruge*) and *u*-form is more frequently used in a figurative meaning (*v semeinom krugu*) (Fig. 2).

By and large, the absolute frequency of the lemma in the construction *na* + *elu* does not affect the outcome of the competition because the ratio of the dominant variants with *-e* and *-u* is approximately the same among the highest-frequency and lowest-frequency words. However, the more frequent the word, the more convincing

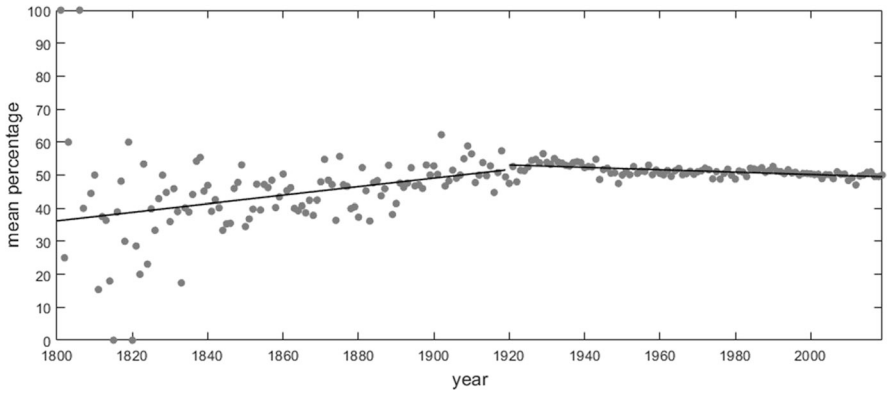

Fig. 3 Average percentage of the second variant (*u*-form) in 3-grams (in 1920–2019, it decreased by approximately 3.6%, i.e., the process is very slow)

the dominance of one variant over the other (*na svete, na beregu,* and *na khodu* (in the world, on the shore, and on the move)—95% of cases and more). The less often the noun is used, the more "equal" the variants are in number (*na stogu, na tazu, na ruch'e* (on a haystack, on a basin, on a stream)—58–70%).

Thus, the high frequency of the word combination reduces the variability (Fig. 3).

The following nouns show almost equal frequency: *klin, korm, krug, list, mozg, par, prud, rod, riad, svet, smotr, sok, ugol, tsvet,* and *shelk* (wedge, feed, circle, leaf, brain, steam, pond, genus, row, light, review, juice, angle, color, and silk).

Words from all groups have hard consonants of different places and manner of production at the end of the stem. This fact shows that the manner of articulation of the final consonant sound of the stem does not play a role in the choice of the ending.

As mentioned above, to search for factors that influence the choice of the ending, we used 3-grams with an agreed definitive (adjective, pronoun, or ordinal) in the preposition. These phrases helped to understand the mechanism of distribution of the variants because the lexical meanings of the competing polysemantic words used in the locative case became clear. For example, the noun *mozg* (brain) is more often used with *-e*, if it is attributed to a medical term (*golovnoi* and *kostnyi*). However, if the definitive is of neutral style (*moi, tvoi,* and *sobstvennyi*), then the *u*-form is more frequent.

Among the variants equivalent in number, there is a large percentage of two—or polysyllabic words with a mobile vowel (*na krepkom vetre* / *na krepkom vetru, na besplodnom peske* / *na besplodnom pesku,* and *v belom pushke* / *v belom pushku*).

To analyze some complicated cases, we used stylistic and sociolinguistic data from RNC.

Thus, statistics on the area of functioning, type, and theme of the text along with frequency graphs of the word forms allow us to assert the gradual archaization either of the *e*-form (*na vetrelu, na balelu*) or the *u*-form (*v gruntelu*).

Let us consider in more detail the frequency behavior of the variants in some word pairs according to the graphical data and the annotations from RNC.

Comparison of the frequency graphs of some word forms reveals gradual archaization of either the *u*-form (*na vetrelu* and *na balelu*) or the *e*-form (*v gruntelu*).

Another case is a long-term competition of the variants *na dube* // *na dubu* (52 and 46 occurrences, respectively) that was graphically confirmed both by the GBN and RLC data. Analysis of the texts showed that different variants of these word forms used in the locative case were fixed in the Russian language under the influence of two different literary traditions: Pushkin's (*na dube*) and folklore (*na dubu*).

The form *v otpusku* as a vernacular is used mainly in fiction.

The phraseological nature of the word expression, direct or figurative meaning of the word and context of use (*v samom soku* and *v kletochnom soke*) play a role when choosing one of the competing forms.

4 Conclusion

Language constantly evolves, therefore, studies of the variability of linguistic units are an acute issue. We studied frequency characteristics of the competing forms of the locative singular of masculine nouns in the Russian language using an extra-large text corpus Google Books Ngram and analyzed factors that trigger and influence the competition of the prepositional case forms. We revealed the following factors.

1. The use of a certain ending (*e*-form or *u*-form) is determined by the preposition. *E*-forms prevail being used with the preposition *v*. *U*-forms are still more often used with the preposition *na*.
2. Noun semantics predetermines the use of the preposition and the ending (*v svete* and *na svetu*).
3. Highly frequent words are less variable than ones with low frequency.
4. Some prepositional variants are preserved in the language being borrowed from well-known works of fiction.
5. The presence of a mobile vowel does not affect the outcome of the competition.

It was also revealed that the choice of the variant is determined by the semantics of a word, its stylistic characteristics, and the context of use.

Acknowledgments The work is carried out in accordance with the Strategic Academic Leadership Program "Priority 2030" of the Kazan Federal University of the Government of the Russian Federation.

References

1. Lieberman, E., Michel, J.-B., Jackson, J., Tang, T., Nowak, M.A.: Quantifying the evolutionary dynamics of language. Nature. **449**, 713–716 (2007). https://doi.org/10.1038/nature06137
2. Carroll, R., Svare, R., Salmons, J.: Quantifying the evolutionary dynamics of German verbs. J. Hist. Linguist. **2**, 153–172 (2012). https://doi.org/10.1075/jhl.2.2.01car
3. Piperski, A.: Ch.: Cheredovanie v korne kak zalog ustoichivosti: iz istorii sil'nykh glagolov v nemetskom iazyke [Alternation in the root as a pledge of sustainability: from the history of the strong verbs in German language]. Acta Linguistica Petropolitana. Trudy Instituta lingvisticheskikh issledovanii. **10**(1), 821–831 (2014)
4. Graudina, L.K., Itskovich, V.A., Kotlinskaya, L.P.: Grammaticheskaya pravil'nost' russkoi rechi: Stilisticheskii slovar' variantov, 2nd. edn. Nauka, Moscow (2001)
5. Gorbachevich, K.S.: Variantnost' slovai i azykovaia norma: Na material sovremennogo russkogo iazyka [Variability of the Word and the Language Norm: On the Basis of the Modern Russian Language]. Librokom, Moscow (2009)
6. Smirnov, I.N.: Izbytochnost' v sfere glagol'nogo slovo- i formoobrazovaniia [Redundancy in the sphere of verbal word- and form-building]. Acta Linguistica Petropolitana. Trudy ILI RAN. **6**, 272–298 (2010)
7. Tatevosov, S.G.: Mnozhestvennaia prefiksatsiia i ee sledstviia. Zametki o fiziologii russkogo glagola [Multiple prefixation and its consequences. Notes on the physiology of the Russian verb]. Voprosy iazykoznaniia. **3**, 42–89 (2013)
8. Gorbova, E.V.: Vtorichnaia imperfektivatsiia russkogo glagola po dannym korpusnogo issledovaniia [Secondary imperfection of the Russian verb according to the corpus study]. Językimetoda. **3**, 149–158 (2016)
9. Galeev, T.I., Le, T.L.: Opyt kolichestvennogo opisaniia evoliutsionnoi dinamiki glagol'noi paradigmy v russkom literaturnom iazyke na etape smeny normy [The experience of quantitative description of the evolutionary dynamics of the verbal paradigm in the Russian literary language at the stage of changing the norm]. In: Slavianskie iazyki i kul'tury v sovremennom mire: III Mezhdunarodnyi nauchnyi simpozium: Trudy i materialy, pp. 133–135. MAKS Press, Moscow (2016)
10. Balalykina, E.A.: Sovremennyi russkii yazyk. Morfologiya, [Modern Russian language. Morphology]. Izd. Kazan. un-ta, Kazan (2003)
11. Shvedova, N.Y., Avilova, N.S., Bondarenko, A.V., Bryzgunova, E.A. (eds.): Fonetika. Fonologiya. Udarenie. Intonatsiya. Slovoobrazovanie. Morfologiya [Phonetics. Phonology. Emphasis. Intonation. Word formation. Morphology], Vol. 1 of Russkaya grammatika [Russian Grammar]. Nauka, Moscow (1980)
12. Brown, D.: Peripheral functions and overdifferentiation: the Russian second locative. Russ. Linguist. **31**(1), 61–76 (2007)
13. The National Corpus of the Russian Language. http://ruscorpora.ru. Last accessed 2023/04/14 (2003–2023)
14. Sokolova, S., Lyashevskaya, O., Janda, L.A.: The locative alternation and the Russian 'empty' prefixes: a case study of the verb gruzit' 'load'. In: Divjak, D., Gries, S.T. (eds.) Frequency Effects in Language Representation, vol. 2, pp. 51–86. De Gruyter Mouton, Berlin, Boston (2012). https://doi.org/10.1515/9783110274073.51
15. Lin, Y., Michel, J.-B., Aiden, E.L., Orwant, J., Brockman, W., Petrov, S.: Syntactic annotations for the Google Books Ngram Corpus. In: Proceedings of the 50th Annual Meeting of the Association for Computational Linguistics Vol. 2: Demo Papers (ACL '12) Jeju Island. Korea (2012)

Automatic Keyword Extraction from German Journalistic Discourse Using Statistical Methods

Maria Khokhlova and Mikhail Koryshev

Abstract Most studies that deal with keyword extraction focus on English texts and do not pay much attention to the role of significant lexemes and their intersection with topics. This chapter presents the results of automatic keyword extraction from a German journalistic articles (about 500 thousand tokens) using the following three statistical methods: log-likelihood, RAKE and YAKE algorithms. The authors identified the most frequently used keywords that can shed light on the topics that attract journalists' utmost attention. The technique allows tracing transformations in topic selection over time and analysing similarities between articles. The scope of topics that were traced based on the selected keywords includes matches with the topics identified by experts. The results reveal the heterogeneous nature of texts published in different years (not only in their structure but also in content), suggesting shifts in the thematic focus of articles change over time.

Keywords Keyword extraction · German language · Log-likelihood · RAKE · YAKE

1 Introduction

Topic modelling is a most promising area of computational linguistics. In a certain broad sense, automatic keyword selection can also be considered as topic modelling. The variety of applications includes automated keyword and thematic marker analysis mainly from English texts. Keywords describe the meaning of the text and reveal hidden semantic structures. The technique is mostly used to analyse news and publications in social networks to identify illicit communities, as well as for other purposes. Political discourse analysis based on the selection of thematic markers allows the identification of the most popular topics for discussion, understanding of the public perception of an author's position and describe the main ideas

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_6

contained in the text. For example, the paper by fellow colleagues [1] studied US Senate proceedings in order to identify keywords, topics under discussion and their clusters, as well as to show transformations over time. Another paper [2] uses non-negative matrix decomposition (NMF) to analyse speeches delivered at the European Parliament plenary sessions. The authors provide findings regarding discussion dynamics for various topics from 1999 through 2014. In addition, a regression model was developed that took into account party membership, the number of speeches delivered, voting preferences for or against a party group, etc. Recently, topic models have also been used for clustering of fiction texts (see, for example, [3, 4]).

Our study is incorporated in a broader project focusing on German journalistic discourse, which, unlike English discourse, has been critically understudied so far. Our hypothesis is that extracted markers allow tracing changes in matters of public interest and values shared by different communities, as well as to outline the most relevant problems and attitudes over time, taking into account historical and cultural realities as the enablers of such changes. The chapter reports the results of keyword extraction from publications of a German journal, based on a variety of statistical algorithms. Thus, topics of utmost frequency and relevance for journalists were identified, as well as modifications in topic selection over time and similarities across different articles.

The chapter's structure is as follows. Section 2 outlines related studies; Sect. 3 describes the collected data and presents methods; Sect. 4 examines the results, followed by the Conclusion that contributes to future perspectives.

2 Background

Extraction of relevant words and word combinations from texts is closely linked to computational linguistics and automated term and collocation extraction, as well as named entity recognition. The simplest way to find important word combinations in a document is by making a list of n-grams for either lemmas or word forms and ordering them by occurrences. A set of tools allows a comparison of reference and focus (or domain-specific) corpora. Such a statistical approach is implemented in Wordsmith Tools [5] and has been further applied in dictionaries and software systems (such as Sketch Engine and AntConc).

More elaborate statistical methods go beyond a single text, involving the calculation of frequencies in a collection of documents (e.g. TF-IDF). Statistical measures and well-known tests (such as chi-squared or Student's *t*-test) can also be effective for extracting significant lexemes. In [6], the authors implement the log-likelihood ratio, the t-test and the Wilcoxon–Mann–Whitney test to compare frequencies in the academic and fiction subcorpora from the British National Corpus and hence to extract keywords that are relevant for academic discourse. The first two measures prove to be more effective for the task and yield better results. Log-likelihood and

TF-IDF are the focus of attention in [7] and are used for keyword extraction for Twitter data dealing with music. Different purposes of keyword analysis and hence suitable statistical measures are discussed in [8].

The RAKE algorithm (Rapid Automatic Keyword Extraction) was introduced by Rose et al. [9] to extract multi-lingual keywords represented by n-grams. Based on frequencies and scores for word co-occurrences and multi-word phrases, the method estimates the sampling weight for each candidate, ranking them according to the obtained values. YAKE is a corpus- and language-independent algorithm that employs a rich set of linguistic and statistical features such as casing, word position and relatedness to context, frequency, as well as lexical dispersion in sentences [10, 11]. YAKE automatic extraction is based on assumptions concerning contextual features of candidate terms. Relevant keywords are assumed to concentrate closer to the beginning of a document. Alternatively, excessive co-occurrences of the candidate word with different terms allow the elicitation of meaningless terminology.

3 Data and Methodology

3.1 Data

The study analyses publications in Germany's magazine *Merkur* [12] which include articles on politics, aesthetics, social science, economics, art and literature—i.e. the issues of utmost concern for the professional German university community. We have selected articles published from 2017 to 2022 and available in open access for nonsubscribed readers (therefore for the discrepancy in the amount of data, see Table 1). These publications reflect the most fundamental ideas that shape the common European humanitarian landscape and the mindset of the contemporary German community.

In total, 171 texts were selected (about 500 thousand tokens). Notably, articles published in different years demonstrate heterogeneity and diversity of genre (the selection includes diaries, reviews or conversation recordings). *Merkur* texts are specific for a stark variety of sizes (in contrast to news or posts on social networks, such as Twitter, that show greater uniformity).

Table 1 Sizes of text collections

	2017	2018	2019	2020	2021	2022
Number of texts	54	18	26	33	22	18
Number of tokens	99,906	37,519	68,629	131,266	84,040	73,797

3.2 Methods

The purpose of our study was to utilize automatic procedures for keyword extraction and identification of major topics in German journalistic texts and compare the output with what experts had earlier identified manually, as well as across different time periods.

The HanTa tagger [13] was used for text preprocessing (as this package is known to show the best performance for German corpora), i.e. lemmatization and POS-tagging. Our study employed log-likelihood, YAKE and RAKE methods to obtain statistical values. To verify the results, the first 100 candidates were evaluated by experts.

4 Results

4.1 Log-Likelihood

The measure extracts only bigrams and allows us to identify the largest number of proper names, as well as examples in English.

1. 2017: *hohe Kultur* 'high culture',[1] *neue Rechte* 'new rights', *popular culture*, *kulturelle Norm* 'cultural norm', *Bündnis 90* 'Union 90', *populäre Kultur* 'popular culture', *Michaela*, *Eichwald*.
2. 2018: *Ilse Braatz*, *Nina Simone*, *Schreibszene 1987*, *Französische Revolution* 'French Revolution', *erste Vorlesung* 'first lecture', *Anne Weil*, *Clemens Setz*.
3. 2019: *Erhard Schüttpelz*, *Thilo Sarrazin*, *Dieter Schönecker*, *Thomas Thiel*, *Universität Siegen* 'University of Siegen', *Vereinigte Staaten* 'United States', *Marc Jongen*.
4. 2020: *Max Frisch*, *Digital Native*, *frühe Neuzeit* 'early modern age', *20 Jahrhundert* 'twentieth century', *Gerhard Richter*, *politischer Raum* 'political space', *Gender Trouble*.
5. 2021: *die Linke* 'the left', *Vereinigte Staaten* 'United States', *Zweiter Weltkrieg* 'World War II', *Gabi Delgado-López*, *Vereinte Nationen* 'United Nations', *deutsche Freunde* 'German friends', *20 Jahrhundert* 'twentieth century'.
6. 2022: *Lost Daughter*, *Sankt Petersburg* 'St Petersburg', *Christiane Hoffmann*, *Gruppe 61*, *Botho Strauß*, *Nord Stream*, *Babyn Jar*.
7. 2017–2022: *New York*, *hohe Kultur* 'high culture', *erste Linie* 'first line', *Thilo Sarrazin*, *Erhard Schüttpelz, letzte Jahre* 'last years', *neue Rechte* 'new rights', *Max Frisch*.

[1] We provide translation for the extracted keywords except for proper names and loanwords originally given in English.

4.2 YAKE

In contrast to other algorithms, YAKE ranks candidate terms in ascending order, i.e. the lower the score, the more relevant the keyword. The algorithm extracts unigrams, bigrams and trigrams, with unigrams assigned a top ranking among all candidates.

1. 2017: *hohe Kultur* 'high culture', *Kultur* 'culture', *populäre Kultur* 'popular culture', *Kunst* 'art', *Frau* 'woman', *Welt* 'world', *Frage* 'question'.
2. 2018: *Sprache* 'language', *Kracht*, *schreiben* 'to write', *Text* 'text', *Anfang* 'beginning', *Frankfurt*, *Kritik* 'critics'.
3. 2019: *Universität Siegen* 'University of Siegen', *Thilo Sarrazin*, *Universität* 'University', *Meinungsfreiheit* 'freedom of speech', *Wissenschaft* 'science', *Sarrazin*, *Wissenschaftsfreiheit* 'freedom of science'.
4. 2020: *politischer Raum* 'political space', *Welt* 'world', *Leben* 'life', *Geschichte* 'history', *politisch* 'political', *Sontag* 'Sunday', *Piketty*.
5. 2021: *Deutschland* 'Germany', *Partei* 'party', *Deutsches Theater Berlin*, *deutsche Freunde* 'German friends', *SPD*, *Frage* 'question', *Erinnerung* 'memory'.
6. 2022: *Krieg* 'war', *Graeber und Wengrow* 'Graeber and Wengrow', *Ukraine*, *Wallraff*, *Gesinnung* 'attitude', *Politik* 'politics', *politisch* 'political'.
7. 2017–2022: *Kultur* 'culture', *Frage* 'question', *Welt Deutschland* 'World Germany', *hohe Kultur* 'high culture', *Geschichte* 'history', *Deutsches Theater Berlin*.

The list of extracted candidates includes nouns, as well as verbs and adjectives. In addition, high-frequency word units are also present in the selection, which may pertain to the language in general, rather than exclusively to the subject of texts.

4.3 RAKE

We used multi-rake implementation [14] that supports German texts and sets a minimum keyword frequency equal to 5. The algorithm extracted the following candidates:

1. 2017: *Bündnis 90/die Grünen*, *neue Rechte* 'new rights', *hohe Kultur* 'high culture', *populäre Kultur* 'popular culture', *kulturelle Norm* 'cultural norm', *klassische Musik* 'classical music', *Lena Vöcklinghaus*. Top-15 results were represented by bigrams, while the rest examples were unigrams.
2. 2018: *Dinge* 'things', *überhaupt* 'at all', *immer* 'always', *erste* 'first', *anfangen* 'to begin', *Zeit* 'time', *Geschichte* 'history'. Due to the small number of texts, all examples are presented by unigrams.
3. 2019: *Dir weh tun* 'hurt you', *Thilo Sarrazin*, *Dieter Schönecker*, *Thomas Thiel*, *sexuelle Gewalt* 'sexual harassment', *Chelsea girls*, *Universität Siegen*

'University of Siegen'. In this case, we find proper names among the most frequent candidates.

4. 2020: *digital native*, *politischer Raum* 'political space', *liberale Demokratie* '', *Max Frisch*, *andere Seite* 'other side', *neue Rechte* 'new rights', *Ordnung* 'order'.
5. 2021: *deutsche Freunde* 'German friends', *Erinnerung* '', *neu* 'new', *dieser* 'this', *deutsch* 'German', *lassen* 'let', *erhalten* 'to receive'.
6. 2022: *neuen Mittelklasse* 'new middle class', *erste Linie* 'first line', *mommy culture*, *alte Mittelklasse* 'old middle class', *dieser* 'this', *deutsch* 'German', *politisch* 'political'.
7. 2017–2022: *Bündnis 90/die Grünen*, *Dir weh tun* 'hurt you', *New York*, *letzte Jahre* 'last years', *Dieter Schönecker*, *Thilo Sarrazin*, *Vereinigten Staaten* 'United States'. In this case, the top list is represented by bigrams and includes almost all the phrases that were typical for each year separately.

The evidence shows the ability of the algorithm to extract collocations, free phrases and proper names, as well as keywords.

4.4 Discussion

We asked two experts in German studies to suggest labels that can describe the content of articles. Their manual analysis identified the following topics referred to in the texts published from 2017 to 2022: (1) books (book reviews and discussions); (2) sexism; (3) social and political life; (4) literary reviews; (5) fiction; (6) university life (lectures, freedom of speech); (7) culture and art and (8) performance art (theater productions).

Log-likelihood produced the poorest results, while the lists extracted using YAKE and RAKE overlap to a certain extent.

Despite the homogeneity of text corpora, articles are largely heterogeneous in structure and, when compared, have little in common. The extracted keywords allowed us to outline the following topics, characteristic of the magazine in general: (1) German politics and political life (*Politik* 'politics', *politisches Leben* 'political life', *Partei* 'party'); (2) elite culture (*hohe Kultur* 'high culture') and (3) universities and university life (*Universität* 'university', *Meinungsfreiheit* 'freedom of speech' and *Wissenschaft* 'science'). Thus, the scope of topics includes matches with the topics identified by experts but also lacks a number of them (for example, book reviews, sexism, fiction, theatre and culture).

Notably, more extensive investigation is needed in case of text corpora scarcity for a particular year of publication. Elaborate year-specific analysis showed that most sampled keywords coincide with the content of texts and high-frequency vocabulary.

5 Conclusion

The study is an attempt to identify high-frequency lexemes in the articles published in Germany's *Merkur* magazine over different years, as well as to trace the thematic content of the sampled corpus overall. These methods allowed us to identify important thematic markers, which generally match initial assumptions and the content of the articles. The analysis reveals fairly low similarity between texts published in different years, suggesting shifts in the thematic focus of articles change over time.

In conclusion, the implemented algorithms have yielded valuable results. However, such complicated mass media texts require more profound investigation, involving more extensive text corpora and topic modelling based on other algorithms.

Acknowledgment The study was supported by the grant 'Literary texts and their language vs quantitative, corpus and computational methods: mutual testing (Nabokov and comparative material)' (St Petersburg State University, ID 94033710).

References

1. Quinn, K.M., Monroe, B.L., Colaresi, M., Crespin, M.H., Radev, D.R.: How to analyze political attention with minimal assumptions and costs. Am. J. Polit. Sci. **54**(1), 209–228 (2010)
2. Greene, D., Cross, J.P.: Unveiling the political agenda of the European parliament plenary: a topical analysis. In: Proceedings of the ACM Web Science Conference (WebSci'15), Oxford, UK (2015)
3. Mitrofanova, O.: Topic modeling of special texts based on LDA algorithm [Modelirovanije tematiki special'nyh tekstov na osnove algoritma LDA]. In: XLII International philological conference [XLII Mezhdunarodnaya filologicheskaya konferencija], pp. 220–233 (2014)
4. Sherstinova, T.Y., Moskvina, A.D., Kirina M.A., Karysheva A.S., Kolpaschikova A.E.: Thematic modeling of the Russian short story 1900–1930: the most frequent topics and their dynamics [Tematicheskoe modelirovanie russkogo rasskaza 1900–1930: naibolee chastotnye temy i ih dinamika]. In: Computational Linguistics and Intelligent Technologies: Proceedings of the International Conference "Dialogue 2022", vol. 21, issue 21, pp. 512–526. Russian State University for the Humanities (2022)
5. Scott, M.: WordSmith Tools Version 8 (64 Bit Version). Lexical Analysis Software, Stroud (2022)
6. Paquot, M., Bestgen, Y.: Distinctive words in academic writing: a comparison of three statistical tests for keyword extraction. In: Corpora: Pragmatics and Discourse. Papers from the 29th International Conference on English Language Research on Computerized Corpora (ICAME 29), pp. 247–269. Rodopi, Amsterdam (2009)
7. Abid, M., Mushtaq, M., Akram, U., Abbasi, M., Rustam, F.: Comparative analysis of TF-IDF and loglikelihood method for keywords extraction of twitter data. Mehran Univ. Res. J. Eng. Technol. **42**(1), 88–94 (2023)
8. Pojanapunya, P., Watson Todd, R.: Log-likelihood and odds ratio: keyness statistics for different purposes of keyword analysis. Corpus Linguist. Linguist. Theory. **14**, 133–167 (2018)
9. Rose, S., Engel, D., Cramer, N., Cowley, W.: Automatic keyword extraction from individual documents. In: Text Mining: Theory and Applications, vol. 1–20. Wiley (2010)

10. Campos, R., Mangaravite, V., Pasquali, A., Jorge, A.M., Nunes, C., Jatowt, A.: YAKE! Collection-independent Automatic Keyword Extractor. In: Pasi, G., Piwowarski, B., Azzopardi, L., Hanbury, A. (eds.) Advances in Information Retrieval. ECIR 2018 (Grenoble, France. March 26–29). Lecture Notes in Computer Science, vol. 10772, pp. 806–810 (2018)
11. Campos, R., Mangaravite, V., Pasquali, A., Jatowt, A., Jorge, A., Nunes, C., Jatowt, A.: YAKE! keyword extraction from single documents using multiple local features. Inf. Sci. J. Elsevier. **509**, 257–289 (2020)
12. Merkur: https://www.merkur-zeitschrift.de. Last accessed 2023/04/15
13. Wartena, C.: A probabilistic morphology model for German lemmatization. In: Proceedings of the 15th Conference on Natural Language Processing (KONVENS 2019): Long Papers, pp. 40–49. German Society for Computational Linguistics & Language Technology, Erlangen, Germany. https://doi.org/10.25968/opus-1527 (2019). Last accessed 2023/04/15
14. Multi_rake Package: https://pypi.org/project/multi-rake/. Last accessed 2023/04/15

The Cross-Evaluation Crux for Computational Phylogenetic Linguistics

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Abstract The flourishing of computational phylogenetic linguistics increased the pressing need for cross-evaluation between the existing classification approaches, which are often imperfect, whether performed by a human or a computer. We present a study of cross-evaluation approaches for both methods (including an interdisciplinary approach to test the linguistic findings against) and data (complementing traditional word lists by linguistic atlases, surveys, and databases). The focus of the research is on insufficient cross-evaluation, which leads to misleading conclusions about methods. We perform a case study of cross-evaluation misuse in computational phylogenetic linguistics research of South American languages based on Levenshtein distance measurement between Swadesh list items. The conclusion presents the prospects of language outgroup comparison implementation. It is a new possible cross-evaluation approach that joins method cross-evaluation and data cross-evaluation.

Keywords Cross-evaluation · Language classification · Computational phylogenetic linguistics · Levenshtein distance · Automatic language classification

1 Introduction

Cross-evaluation is an evaluation of different approaches against each other to discover their possible advantages and fallacies, even if one of the approaches is considered the gold one. Cross-evaluation may be performed for method, data, or both.

In this chapter, we emphasize the utmost importance of cross-evaluation for the automatic language (or lect) classification. We believe that it is crucial to test new methods on existing data, check new data with the old methods, and thoroughly

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_7

analyze the outcomes, as even the human-performed classifications are not reliable enough [1, 2], and results require thorough examination. We use the term "lect" as a neutral umbrella term for any possible variety of a language.

Modern computational historical linguistics is influenced by evolutionary biology (now the common trends in linguistics in general [3]) and computational phylogeny [4], currently forming the discipline of computational phylogenetic linguistics [5: 153]. This connection can be traced back to Schleicher [6]. The use of phylogeny-based methods in modern computational historical linguistics is thoroughly reviewed [4: 13, 5, 7: 143], with some new issues arising for particular language families' studies, such as the subgrouping of South Asian languages, their binary and tertiary branching [7: 148].

Building phylogenetic trees (the genetic classification) is one of the major tasks of computational phylogenetic linguistics, which is currently an indispensable part of computational historical linguistics [5: 152–155]. This work provides a detailed description of transferring phylogeny, including the concepts of rootedness (having one node in a graph as the last common ancestor for others, *root*), leaves (named languages), diversification events (the times when languages split), and an amount of change, the measure for branch length [5: 165–166]. In this chapter, we review the works that employ a cladistics-based approach, as the cladistics v. phenetics v. taxonomy debate is a complicated topic that requires its own research [8].

We argue that automatic language classification methods should be cross-evaluated by both the method and the data when possible. Through a review of the existing body of work, we discover that automatic language classification works already employ cross-evaluation. A case study of a cross-evaluation paper underlines the pressing need for increased attention to cross-evaluation use, which is crucial for correct decision-making on further method implementation.

In Sect. 2, we present a review of the current work on (automatic) language classification. We dedicate Sects. 3 and 4 to the survey of the existing methods and data cross-evaluation approaches, respectively. This lays foundation for Sect. 5 which discusses a paper in which the possible shortcomings of incorrectly applied cross-evaluation manifest themselves. Section 6 wraps up the chapter and provides the direction for the future development of cross-evaluation methods.

2 Related Work

The task of classification via clustering is one of the apparent differences between natural language processing (NLP) and computational historical linguistics, with NLP studying texts and computational linguistics—the lects of these texts.

NLP for historical texts, as any kind of low-resourced NLP, is generally overshadowed by its counterpart, the modern resource-rich NLP [9]. It is making the first steps in the starting tasks of part-of-speech tagging, morphological tagging, lemmatization, and parsing. Clusterization in NLP is the domain of synchronic [10] text-based studies [11–13], focused on the topic variation for various doculects [14:

3975]. However, the latest surveys show an increasing interest in such methods in historical NLP [15]. The adaptation of document clustering methods, such as spectral clustering based on a keyword correlation graph that represents the collection as a set of weighted graphs of topical keywords [14: 3974], may aid the methods of historical NLP and, later, computational historical linguistics. The possible bridge between NLP and computational historical linguistics is a language identification task [10], which is connected to the distance measurement between languages, a basis for performing language classification.

Another opportunity to join the disciplines is introducing the linguistically explainable criteria into the historical NLP task of text clusterization. This approach was applied by Pistorelli [16] to study variation between the idiolects of different Latin scribes in certain types of Latin texts, namely the witnesses of John's Gospel and Korkiangas and Lassila [17]. Contrary to the traditional methods that revolve around the binary agreement between the documents, they use statistical methods based on multiple agreements and disagreements between the manuscripts, which they call "variation units" [16: 1]. These "variation units" can be split into particular variables: spelling correctness, classical prepositions, genitive plural, and diphthong *ae* [17]. Korkiangas and Lassila propose a clustering method of language-agnostic Hierarchical Ascendant Clustering with the aggregation criterion of Ward, generally used in a combination with Euclidean distance [16]. Korkiangas and Lassila build a graph with idiolects as nodes and the relationships between them as edges. The edges display geography-based connections, not language-based ones, so the visualization overall does not provide a substantial understanding of language features in the research of idiolects. However, text clusterization studies under consideration [16, 17] present language-aware research, in contrast to their predecessors.

Computational historical linguistics and its subfield of computational cladistics [18: 83], which this study focuses on, are now rapidly developing. This leads to the appearance of new methods, such as distance-tree matrix-based classification [19], advanced lexicostatistics [20], pointwise mutual information (PMI) [5: 159], pairwise [5: 161], and multiple [21: 199] sequence alignment, and automated similarity judgment program (ASJP) [22]. At the same time, methods of linguistic-aware analysis for classification, such as the analysis of *jeter* pronoun occurrence in ancient Slavic manuscripts, remain widely used [23]. The reviews of the most frequently applied algorithms for genetic classification, Neighbor Joining, FastMe, Fitch-Margoliash, Maximum Parsimony, Maximum Likelihood, Unweighted Pair Group Method with Arithmetic Means (UPGMA), and Bayesian Phylogenetic Inference are given in Jäger [5], Rama and Kolachina [7], and Rama et al. [4].

Large databases such as the one used for the classification of the Northern Eurasia languages emerge [24]. This database contains a comprehensive (1016 items) basic vocabulary list for 107 languages of Northern Eurasia. Yet, many languages do not possess enough data for collecting 210, and often even 100-item Swadesh lists, which leads to attempts at shortening the minimal Swadesh list, as summarized in Holman et al. [22]. Currently, a 40-item Swadesh word list is considered the necessary minimum for a lexicostatistics study [22: 9]. Some researchers, however,

switch to semantic-based research, using semantic-restricted word lists instead of Swadesh lists [25].

The study of the Indo-European family, from which historical linguistics emerged, continues, with case studies of the Romance [5] and the Anatolian [18] languages. Indo-European scholars generally divert from new approaches to Indo-Aryan historical linguistics [26: 621].

New issues inevitably appear if the group of languages under study is no longer restricted by the Indo-European family. There are general questions and issues of classifications of various language genetic groups, such as different South American [27], Arawakan [28], Athapaskan [25, 29: 246–247], Austronesian [2], Dravidian [7, 30], and Bertha, including the areal and genetic connections of the former [1]. Different levels of classification are studied: from the territorial lects of Gondi spoken in India [31], and Udmurt dialectal continuum spoken in Russia [32], up to the Bantu language clusters [33] and the whole linguistic areas, for instance, South Asian languages [34]. For the latter, the study of Indo-Aryan languages' research history leads to the question of whether the South Asian languages form a sprachbund [34: 207].

Several works discuss the precise grouping and possible structure of proto-languages, for instance, Eastern Athapaskan for Apachean and North Atapaskan [35]. Crucial methodological problems that lead to the reevaluation of the whole research paradigms are pointed out [2, 27]. Among those problems are the use of Levenstein distance as the language classification basis and the detection of early-stage borrowings [1]. Some researchers question the possibility of linguistic classification based on both lexicon and grammar [32]. The emergence of such papers indicates the pressing need to develop new methods that balance lexical and grammatical features.

Computational turn in historical linguistics led to the rapid divergence of visualization methods, often previously connected with dialectometry. New packages, such as dialectR [36], include the methods for hierarchical clustering visualization, building a dendrogram that is a graphical representation of phylogenies [5]. There are packages that specialize in language classification spatial visualization with Google Maps, for instance, Gabmap reviewed by Snoek [21]. The studies state Gabmap's potential uses for dialectometry purposes and emphasize its abilities to produce distribution maps [21: 197] and difference maps based on the multiple sequence alignment and Levenshtein distance (a string similarity measure that counts additions, deletions, and insertions between two strings [37]; a hypersensitive method that captures the slightest differences between lects) scoring results [21: 199]. Reviews highlight Gabmap's implementation of multidimensional scaling [21: 201]. In addition to this functionality, Gabmap provides possibilities in clusterization via building dendrograms and maps [21: 203–204]. Researchers report on its efficient use [25, 29]. In the future, we may expect the spread of interactive visualizations. The graphs by Sigma.js (and similar tools) present a lect as a node, and the relationship between lects as an edge connecting the two nodes. This technique helps to illustrate the research in a more transparent manner. Text clusterization studies show its efficiency [17].

3 Method Cross-Evaluation

The new material is a *tabula rasa* for the researcher. Therefore, its study by the well-established methods poses an additional question of whether those existing methods are scalable for that new material. Computational historical linguistics shares this approach with text clusterization, which does not concentrate on the language structure features but relies on collations and differing places in the text [38]. The authors thoroughly review cladistics-based, stemmatology-based [39, 40], and clustering-based classification methods [15: 34–36]. For Church Slavonic clustering, the simplicity and verifiability of Alexeev's method are a deciding factor [15], the only relative disadvantage of which is the appearance of isolated texts [15: 42–43].

Conflicts in previous classifications such as geolinguistics-, genetics-, dialectometry-, and referential-based [33: 384] that appear due to different complications, including closer contact over a long period [26: 620], lead to the introduction of new methods to double-check the issues that confused the previously used. For instance, the neural approach helps to address the indeterminacy in Indo-Aryan subgrouping [7, 26]. The vagueness of the previous classifications [30: 13–14] may cause the researchers to use new Swadesh lists collected by interviewing native speakers [30: 4]. This introduces joint data and method cross-evaluation, with phylogenetic analyses by the evolutionary biology-based tool BEAST [30: 6] and visualization via Neighbor-Net [30: 7–8] and cladogram trees [30: 9–11]. Among the most widely used methods is the phylogenetic classification based on word lists, such as a 40-item Swadesh list [22] or a basic vocabulary 200-item word list [33: 383], visualized via unrooted Neighbor-Net or Bayesian consensus tree [33: 401–402].

The introduction of a new method also requires double-checking with the existing methods. When Bayesian phylogenetic inference is introduced to Gondi lects classification [31: 26] by the materials of 210-item word lists [31: 27], the possible bases for it are multiple, including language distance measurements, language models, and automatic cognate detection with subsequent pointwise mutual information (PMI) comparison [31: 28–30]. The study compares the method to the existing Glottolog classification [31: 27] and proves its efficiency, with only occasional slips for some parts of the Gondi lects classification [31: 34]. The use of databases, such as Glottolog and WALS, to double-check the new method is gaining recognition [41: 8].

Dravidian lects classification requires the comparison between the traditional bases of clustering, such as edit distance, parallel corpora embeddings hierarchical clusterization [26: 621], and generated embeddings classified with LSTM Encoder-Decoder [26: 622]. For the classification, the neighbor joining-based language trees are built and compared by the generalized quartet distances [26: 626]. Cross-evaluation shows that new methods need enhancement, as embedding-based classification methods are outperformed by the Levenshtein distance-based ones [26: 626]. Levenshtein distance, especially its modification, normalized (by the length

of the biggest string in comparison) divided (by the number of word pairs between two pairs), is yet again used as a control method [7].

There are classification and visualization methods that require the simultaneous use of different methods. Among the most vivid examples is CLANS, a graph layout algorithm that was designed for finding similarities in genome sequences [42: 305]. CLANS is built around the p-value of differences between sequences: the lesser the possibility these sequences are similar by chance, the closer they are in the final tree. It uses string similarity distances such as Levenshtein distance on the word lists and Hamming distance on the morphological features [42: 305].

Cross-evaluation may also be innate, with methods not competing but complementing each other. Traditional lexicostatistics may benefit from the introduction of the stability metric to classify the Swadesh list items into the more and less historically fixed within the language lexis, and forming the joint function of lexical similarity and spatial distance as a classification method [22: 13]. This function is effective for distantly related languages, though the closer the distance, the less sensitive the metric becomes [22: 16]. Typological methods, based on morphology and syntax, may enhance the performance of lexicostatistics-based methods [18: 83–84, 22: 17, 28: 44]. However, their use requires caution, as they tend to be heavily influenced by areal contacts, which are harder to detect in grammar than in lexis [42: 305].

Understanding the broader context of language evolution may also be achieved by comparing the results of linguistic methods to the nonlinguistic ones, making the case for interdisciplinary research. A pioneering work that employed Levenshtein distance for language classification via dendrograms used the comparison between geographical and language classification [43]. Later, a dendrogram clusterization of Arawakan languages based on the 100-item Swadesh list was joined with the archaeological data and GIS visualization [28: 39–42]. This helps to build not just an effective linguistic classification but also a wider ethnolinguistic image. This is the case of the contemporary West Himalayish and, much broader, Sino-Tibetan language studies [44]. Common classification of West Himalayish languages, Kanashi prehistory [44: 238], genetics [44: 245–246], geographic [44: 246], and data about migrations [44: 250] are used to test the West Himalayish classification hypotheses, one of which was partially proven via these data [44: 250].

Cross-evaluation may be applied not only to the methods used for the classification of languages [41: 6], such as Levenshtein distance and other language distance measurements, but also to the metrics utilized to test these methods, with each metric providing a different approach to the method results' evaluation [41: 12].

We provide a short summary on the method cross-evaluation in Table 1.

Table 1 Summary of method cross-evaluation in computational phylogenetic linguistics

Reason for method cross-evaluation	Methods that require cross-evaluation	Methods that ensure cross-evaluation
The material is new	Different cladistics, stemmatology, clusterization methods	Alexeev's clusterization method
Conflicts between the existing methods (generally, geolinguistics-, genetics-, dialectometry-, and referential-based methods)	Neural approach, BEAST, Bayesian phylogenetic inference	Glottolog and WALS databases-based comparison, Levenshtein distance, CLANS
Need to combine different methods to achieve the best possible result	Lexicostatistics	Linguistic typology methods
Necessity to put language evolution in the broader context	Levenshtein distance-based lexicostatistics	GIS, geographic, archeological data

4 Data Cross-Evaluation

Data cross-evaluation is used relatively rarely in computational historical linguistics studies than method cross-evaluation. There may be some possible explanations for that issue. The most influential factor is that a lot of lects do not possess multiple kinds of resources such as corpora or grammar descriptions. At the same time, the resources for different lects may be incomparable: while for one there is a Swadesh list, the other is presented by a raw corpus only. To investigate the efficiency of computational methods on a particular lect, a human researcher should possess expertise in it, and being an expert in more than two or three groups of lects is hard for most researchers. Methods are generally not universal, and data cross-evaluation requires some adaptation [2]. However, if at least a part of the pre-requisites matches, researchers implement data cross-evaluation to increase the efficiency and transparency of their study.

Data cross-evaluation may enhance the data set and compare the sources to get a more precise picture of the lects under consideration. In the study of the Dutch territorial lects, the material from the *Reeks Nederlands(ch)e Dialectatlassen* is enhanced with actual data collected from the lects' native speakers [43: xvii].

Sometimes traditional word lists are abandoned: the researchers use semantic-restricted word lists, for instance, names of human body parts [25: 232]. They state that this is preferable to the Swadesh list, as it relies on a set of terms that are almost guaranteed to be met and to remain in the lexicon of any human language for a long time [25: 233]. It requires taking word lists from different sources, such as Pan-Athapaskan Comparative Lexicon [29]. The methods generally do not change. The studies employ dendrograms and maps to visualize classification based on dialectometric methods, such as Levenshtein distance [25: 240, 29: 248].

Data cross-evaluation often helps to investigate why different classifications do not agree: see, for instance, the classifications of diverse South Asian language families [34: 210–211], including Tibeto-Burman [45]. Borin and colleagues explore connections between genealogy, geography, and features of the languages being

examined [34: 217]. The preferred kind of visualization is pairwise distance-based graphs [34: 219].

Cross-evaluation is used to compare the previously used Swadesh list and a new, normalized [45: 182], thoroughly investigated Swadesh list for this group [45: 178]. This research is data-centric, it underlines the advantages and disadvantages of the Swadesh-style lexicostatistics, including complexities, caused by semantics drift and Levenshtein distance-based methods [45: 179–180].

The other data set type is surveys, such as the Linguistic Survey of India, a large survey conducted by the British colonial administration in the nineteenth century [34: 214]. These data sets require preprocessing, manual retrieval of information in binary form (whether the feature exists or not) for each of the analyzed languages [34: 216–217]. However, they help to examine the results of clusterization from both a genetic and an areal point of view [34: 221–222]. They allow one to conduct a more thorough investigation into the linguistic features of the South Asian languages via dimensionality reduction that aids in understanding which features contribute to the classification the most [34: 223]. The surveys facilitate the implementation of map visualization methods to represent the linguistic feature distribution in the languages of South Asia [34: 227].

Sometimes the data set quantity and quality affect the classifications that adapt the Bayesian phylogeny tree approach [46]. To get insights into these effects, scholars utilize a heterogeneous cognate data set, inter alia including Austronesian, Mayan, Mon-Khmer, and Uzo-Aztecan language families' data [46: 1581]. The comparison between the different subsets of these data, based on GQD between trees as metrics [46: 1580], suggests the crucial dependency between an increase in the number of analyzed languages and an increase in the size of the cognate list [46].

Data cross-evaluation that relies on an increase in the number of studied languages to resolve the existing classification issues may lead to a change in the method. If the researcher suspects the areal and not the genetic connection between two languages, they may introduce new languages into an equation. These languages should be related to the language, which is suspected to influence the other via areal contact. It transforms a prototypical language classification into something more similar to the outgroup comparison method heavily used in evolutionary biology [47]. The task may be defined as *linguistic triangulation*, a method that introduces a new language into an analysis of two, providing a wider picture and being beneficial overall for language genetic classification [1]. The outgroup comparison analogy is explicit in other studies. The possibilities of the outgroup comparison introduction to linguistics, though, are not comprehensively realized and discussed in these works [2: 45–46].

In contrast, data cross-evaluation is caused by employing new methods, for instance, a grammar-based classification that relies on a different kind of material, such as grammar data. The latter becomes necessary when a lexicostatistics study based on the lexical data of a dialectology atlas is cross-verified by morphology- and syntax-based classification and dialectometric method, featuring distance matrix [32]. The classification of generated embeddings requires etymological dictionaries [26: 626]. To check the efficiency of distance measurement based on syntax

Table 2 Summary of method cross-evaluation in computational phylogenetic linguistics

Reason for data cross-evaluation	Data that require cross-evaluation	Data that ensure cross-evaluation
Enhancing data set	Dialect atlas, Swadesh list	Dialect recordings, mass linguistic surveys
Insufficiency of the previous data	Traditional Swadesh list	Semantic-based word lists, Swadesh lists, adapted for specific languages
Disagreements between classifications	Existing classifications	Genealogy, geography, and features of the languages
Investigation into methods failings	Bayesian-based phylogenetic trees	Cognate data sets
Employing new methods	Results of raw data classification with CLANS, lexicostatistics data, embeddings	Results of tagged data classification with CLANS, grammar data, etymological differences

variation with the tool CLANS, a comparison between tagged and raw data with software GIZA++ is implemented [42: 305].

We provide a short summary of the data cross-evaluation in Table 2.

5 Levenshtein Distance: Black-Box or Language-Agnostic?

The survey that we presented in the previous sections demonstrates that the fundamental stage of implementing cross-evaluation is the carrying out of its cross-part. The cross-evaluation, in contrast to simple comparison, drives a researcher to evaluate not only the novel method or data but the old ones as well. If the researcher does not adhere to this principle, their conclusion may be distorted.

Levenshtein distance is a widely used basis for language classification [7, 41, 43]. However, some researchers argue against its use [27]. In the latter paper [27], the proposed approach is to employ Levenshtein distance for the classification of 69 South American languages; these are chosen because they are linguistically less studied than the Indo-European family. To visualize the results, Prokić and Moran [27] implement unrooted Neighbor-Net graphs. The results are compared to simpler methods, n-gram analysis, and compression methods [27: 431–433], with human-performed classification as gold data. n-gram analysis is a comparison of n (1 and 2 are used)-grams (sequences of symbols of length n) frequencies for classification [27: 431]. The compression method relies on measuring the distance between compressed (encoded to take less space in the computer memory) representations of words in the provided list [27: 433]. Prokić and Moran conclude that, like the more similar methods, Levenshtein distance captures only high-level splits and fails to meet the requirements of transparency, explainability, and language sensitivity for the classification basis.

This kind of harsh criticism seems slightly unjust, from the starting conditions of the experiment to the conclusion. The data are not suitable. Levenshtein distance shines in the closely related lects distance measurement [7, 25, 43]. Levenshtein distance is not just a sensitive method, it is a hypersensitive method. To use it for the classification of distantly related idioms means to guarantee its failure because it was designed for the opposite task. The paper by Prokić and Moran [27] also contradicts the practice of using well-studied families to examine possible metric failures. Indo-European languages, the most suitable candidate [2: 45–46], are mentioned but not used. The picture may have also been clearer with an alternative understudied data set, highlighting the reasons for Levenshtein distance's poor performance on the main data set. This option is not utilized as well.

Method cross-evaluation is an essential part of the paper. The n-gram and compression-based classification methods are discussed as alternatives to Levenshtein distance [27: 431–433]. There are, however, some issues. Instead of utilizing the modified versions that started to appear in the late 2000s to early 2010s (Levenstein distance between sequences normalized by the longest of sequences [7, 41], phonetics-aware string similarity measures [48], etc.), or enhancing Levenshtein distance with other methods [29], Prokić and Moran use classic Levenshtein distance, which may cause some fallacies in their conclusions about the overall efficiency of a method. The string similarity measures are a very heterogeneous class, and while Levenshtein distance is a well-known and most often used representative, it is probably a good idea to include others, such as Jaro-Winkler distance [49, 50]. String similarity measures, in turn, are treated as the representative of the whole family of the so-called black-box methods (an incorrect definition, as we understand the mechanics of string similarity measures, and easily modify it: something that is hardly possible for true black-box methods), which they were not intended to be, so their implementation should be cautious. The researcher should understand the mechanics of the interaction between the method and data, for a method to capture the key features in data. This principle is followed not only in genetics studies, from which the method came into linguistics [51]. Other linguistic studies generally adhere to the same policy [7, 43]. Comparing string similarity measures to methods like n-gram analysis is not comparing two similarly designed methods of the same type. This certainly means that language-agnostic methods-based classifications should not be considered the ultimate solution when applied to a completely new material. However, they present a good starting point, as the first classifications by human researchers do [52: 62]. And even if we consider string similarity measures to be the black-box methods, all the methods perform pretty well and they achieve 65% of genealogical relationship prediction while being used zero-shot [27].

The problematic point of Prokić and Moran [27] is human-performed classification treated as the gold data. This approach seems justified for the well-studied language groups with achieved consensus among the researchers, developed for centuries: realistically, for Indo-European languages only. However, this is not the case for understudied language groups. In their case, the human-performed classifications are as far from perfection as the black box methods based are [1, 29]. The

issue of different approaches leading to a model seemingly failing in evaluation is already well known in historical NLP, as demonstrated by de Graaf [53]. The differences between results based on human research and the results based on well-established automatic methods are more of a reason to investigate both, and not just those presented by the computer [2, 53]. This is illustrated by the treatment of suspicious inaccuracies in the Austronesian languages' automatic classification by Levenshtein distance normalized divided results [2: 39–40]. Here, it caused an investigation into the possible mistakes of gold data, Ethnologue, with Jackknife Gamma [2: 48]. It turned out that some languages, such as South Sulawesi, pose a particular challenge for both the manually constructed gold data and the automatic methods [2: 55].

Probably in the case of the research in discussion [27], using the same approach of double-checking the human classification after the automatic classification failed can provide even better insights than the ones Prokić and Moran present. These observations include reasons why Levenshtein distance-based classification fails, and whether it is due to the shortcomings of a particular method or challenging data. We also believe that comparing automatic classification with different human classifications (treating each not as a gold, but rather a *gilded* one) may be beneficial for evaluation. This is an approach that is not exclusive to computational phylogenetic linguistics but also to natural language generation (NLG) [54]. We assume that the discussion and adoption of Novikova et al. [55]'s methods from this domain could be helpful for computational phylogenetic linguistics. Using different explainability methods when applying machine learning classification methods may also be beneficial [56].

Overall, the critique of Levenshtein distance [27] is more connected to its implementation of bad practices and does not manage to investigate the possible shortcomings of the method itself—the discussion on the latter remains the topic of future research. The later research does not only achieve this goal but it also demonstrates that Levenshtein distance normalized divided, a modified version of Levenshtein distance, is efficient for closely related lects classification. The following study demonstrates that Jaccard's index normalized divided, another string similarity measure, complements Levenshtein distance normalized divided, providing the latter with high-level classification [41: 16].

6 Conclusion

Our review demonstrates that cross-evaluation is an essential element of automatic language classification research. The dominant trends in text clusterization and genetic language classification highlight the key differences between the two tasks. However, these two directions of historical NLP and computational historical linguistics can be joined by introducing language variation-aware methods into the text clusterization systems.

Method and data cross-evaluation are two key directions of cross-evaluation in automatic language classification. Method cross-evaluation allows double-checking the performance of old approaches on new material, underlining the conflicts between the existing approaches and testing the new ones. Data cross-evaluation enhances the existing sets and methods while allowing for the emergence of completely new methods.

The results of the method and data cross-evaluation, performed in Sects. 3 and 4 of the current work, lead to Sect. 5. The latter demonstrates that cross-evaluation, despite the advantages, should be used carefully, otherwise decently performing methods get unjust criticism. As shown in the works of Rama and Borin [41], Wichmann and Rama [2], and de Graaf et al. [53], cross-evaluation in automatic language classification should examine the human gold classification data as well because these are not error-proof. Cross-evaluation should consider every method and piece of data used.

One of the possible approaches to both data and method cross-evaluation is borrowing and adaptation of outgroup comparison from evolutionary biology [47]. The earlier research underlines the potential of this method in computational historical linguistics [1, 2]. Future research should test its efficiency.

Acknowledgments We would like to thank anonymous reviewers for their comments. We also thank the participants of PhD seminar, led by A. Podobryaev, for the insightful discussion on the topic of automatic classification evaluation methods.

References

1. Starostin, G.: The value of "triangulation" in determining phylogenetic relationship: on the areal and genetic connections of the Bertha languages. Lang. Africa. **3**(2), 352–367 (2022)
2. Wichmann, S., Rama, T.: Jackknifing the black sheep: ASJP classification performance and austronesian. In: Kikusawa, R., Reid, L.A. (eds.) Let's Talk about Trees, Volume 98 of Genetic Relationships of Languages and Their Phylogenic, pp. 39–58. Senri Ethnological Studies, National Museum of Ethnology, Japan (2018)
3. Ladoukakis, M., Michelioudakis, D., Anagnostopoulou, E.: Toward an evolutionary framework for language variation and change. BioEssays. **44**, 210–216 (2022)
4. Rama, T., Kolachina, S., Bai, B.L.: quantitative methods for phylogenetic inference in historical linguistics: an experimental case study of South Central Dravidian. CoRR, arXiv, abs/1401.0708 (2014)
5. Jäger, G.: Computational historical linguistics. Theoretical. Linguistics. **45**(3–4), 151–182 (2019)
6. Schleicher, A.: Die Darwinsche Theorie und die Sprachwissenschaft – Offenes Sendschreiben an Herrn Dr. Ernst Haeckel. H. Boehlau, Weimar (1863)
7. Rama, T., Kolachina, S.: Distance-based phylogenetic inference algorithms in the subgrouping of Dravidian languages. In: Borin, L., Saxena, A. (eds.) Approaches to Measuring Linguistic Differences, Volume 265 of Trends in Linguistics. Studies and Monographs, pp. 141–174. Walter De Gruyter GmbH, Boston/Berlin (2013)
8. Michalove, P.A., Peter, A., Georg, S., Ramer, A.M.: Current issues in linguistic taxonomy. Annu. Rev. Anthropol. **27**, 451–472 (1998)

9. Piotrowski, M.: Natural Language Processing for Historical Texts, Volume 17 of Synthesis Lectures on Human Language Technologies. Morgan & Claypool, Kentfield, CA, USA (2012)
10. Zampieri, M., Nakov, P., Scherrer, Y.: Natural language processing for similar languages, varieties, and dialects: a survey. Nat. Lang. Eng. **26**, 595–612 (2020)
11. Miranda, M., Znotiņš, A., Cohen, S.B., Barzdins, G.: Multilingual clustering of streaming news. In: Proceedings of the 2018 Conference on Empirical Methods in Natural Language Processing, pp. 4535–4544. Association for Computational Linguistics, Brussels, Belgium (2018)
12. Shaffer, K.: Language clustering for multilingual named entity recognition. In: Findings of the Association for Computational Linguistics: EMNLP 2021, pp. 40–45. Punta Cana, Dominican Republic, Association for Computational Linguistics (2021)
13. Walkowiak, T., Gniewkowski M.: Evaluation of vector embedding models in clustering of text documents. In: Proceedings of the International Conference on Recent Advances in Natural Language Processing (RANLP 2019), pp. 1304–1311. INCOMA Ltd., Varna, Bulgaria (2019)
14. Chiu, B., Sahu, S.K., Thomas, D., Sengupta, N., Mahdy, M.: Autoencoding keyword correlation graph for document clustering. In: Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics, pp. 3974–3981. Association for Computational Linguistics, Online (2020)
15. Mironova, D.M.: Avtomatizirovannaja klassifikacija drevnih rukopisej (na materiale 525 spiskov slavjanskogo Evangelija ot Matfeja XI-XVI vv.), Ph.D. thesis. SpbU, Saint Petersburg, Russia (2018)
16. Pistorelli, D.A.: Classification of manuscripts based on a new quantitative method. The old Latin witnesses of John's Gospel as text case. J. Data Min. Digit. Humanit. Spec. Issue Comput. Aided Process. Intertextuality Anc. Lang., 1–48 (2017)
17. Korkiakangas, K., Lassila, M.: Visualizing linguistic variation in a network for Latin documents and scribes. J. Data Min. Digit. Humanit. Spec. Issue Comput. Aided Process. Intertextuality Anc. Lang., 1–26 (2017)
18. Josephson, F.: How aberrant are divergent Indo-European subgroups? In: Borin, L., Saxena, A. (eds.) Approaches to Measuring Linguistic Differences, Volume 265 of Trends in Linguistics. Studies and Monographs, pp. 83–106. Walter De Gruyter GmbH, Boston/Berlin (2013)
19. Wattel, E.: Clustering stemmatological trees. In: van Reenen, P., van Mulken, M. (eds.) Studies in Stemmatology, pp. 123–134. John Benjamins Publishing Company, Amsterdam (1996)
20. Starostin, S.A.: Sravnitel'no-istoricheskoe jazykoznanie i leksikostatistika. In: Vardul, I.F. (ed.) Volume 1 of Lingvisticheskaja rekonstrukcija i drevnejshaja istorija Vostoka, pp. 407–447. Nauka, Moscow (1989)
21. Snoek, C.: Review of Gabmap: doing dialect analysis on the web. Lang. Doc. Conserv. **8**, 192–208 (2014)
22. Holman, E., Wichmann, S., Brown, C., Velupillai, V., Müller, A., Bakker, D.: Explorations in automated language classification. Folia Linguist. **42**, 331–354 (2008)
23. Pichkhadze, A.A.: Slav. jeter: to the question of Old Slavic manuscripts grouping. In: Krivko, R., Orlov, A. (eds.) Ars Christiana: In Memoriam Michail F. Murianov (21.XI.1928 – 6. VI.1995), pp. 219–236. Gorgias Press, Piscataway, NJ, USA (2012)
24. Dellert, J., Daneyko, T., Münch, A., Ladygina, A., Buch, A., Clarius, N., Grigorjew, I., Balabel, M., Boga, H.I., Baysarova, Z., Mühlenbernd, R., Wahle, J., Jäger, G.: NorthEuraLex: a wide-coverage lexical database of Northern Eurasia. Lang. Resour. Eval. **54**, 273–301 (2019)
25. Snoek, C.: Using semantically restricted word-lists to investigate relationships among Athapaskan languages. In: Borin, L., Saxena, A. (eds.) Approaches to Measuring Linguistic Differences, Volume 265 of Trends in Linguistics. Studies and Monographs, pp. 231–248. Walter De Gruyter GmbH, Boston/Berlin (2013)
26. Cathcart, C., Rama, T.: Disentangling dialects: a neural approach to Indo-Aryan historical phonology and subgrouping. In: Proceedings of the 24th Conference on Computational Natural Language Learning, pp. 620–630. Association for Computational Linguistics, Online (2020)

27. Prokić, J., Moran, S.: Black box approaches to genealogical classification and their shortcomings. In: Borin, L., Saxena, A. (eds.) Approaches to Measuring Linguistic Differences, Volume 265 of Trends in Linguistics. Studies and Monographs, pp. 429–446. Walter De Gruyter GmbH, Boston/Berlin (2013)
28. Carling, G., Eriksen, L., Holmer, A., van de Weijer, J.: Contrasting linguistics and archaeology in the matrix model: GIS and cluster analysis of Arawakan languages. In: Borin, L., Saxena, A. (eds.) Approaches to Measuring Linguistic Differences, Volume 265 of Trends in Linguistics. Studies and Monographs, pp. 29–56. Walter De Gruyter GmbH, Boston/Berlin (2013)
29. Snoek, C., Cox, C.: Measuring linguistic distance in Athapaskan. In: Proceedings of the 39th Annual Meeting of the Berkeley Linguistics Society, pp. 245–258. Linguistic Society of America, New York, NY, USA (2013)
30. Kolipakam, V., Jordan, F.M., Dunn, M., Greenhill, S.J., Bouckaert, R., Gray, R.D., Verkerk, A.: A Bayesian phylogenetic study of the Dravidian language family. R. Soc. Open Sci. **5** (2018)
31. Rama, T., Çöltekin, Ç., Sofroniev, P.: Computational analysis of Gondi dialects. In: Proceedings of the Fourth Workshop on NLP for Similar Languages, Varieties and Dialects (VarDial), pp. 26–35. Association for Computational Linguistics, Valencia, Spain (2017)
32. Arkhangelskiy, T.: Application of dialectometric method to the classification of Udmurt dialects. Ural-Altaic Stud. **2**(41), 7–20 (2021)
33. Marlo, M.R., Grollemund, R., Nguyen, T., Platner, E., Pribe, S., Thein, A.: A phylogenetic classification of Luyia language varieties. In: Sibanda, G., Ngonyani, D., Choti, J., Biersteker, A. (eds.) Descriptive and Theoretical Approaches to African Linguistics: Selected Papers from the 49th Annual Conference on African Linguistics, Volume 6 of Contemporary African Linguistics, pp. 383–407. Language Science Press, Berlin (2022)
34. Borin, L., Saxena, A., Comrie, D., Virk, S.M.: A bird's-eye view on South Asian languages through LSI: areal or genetic relationships? J. South Asian Lang. Linguist. **7**(2), 203–237 (2021)
35. Snoek, C., Stang, M., Rice, S.: Linguistic relationships between Apachean and Northern Athapaskan: on the possibility of 'Eastern Athapaskan'. In: Ives, J.W., Janetski, J. (eds.) Holes in Our Moccasins, Holes in Our Stories: Apachean Origins and the Promontory, Franktown, and Dismal River Archaeological Records, pp. 8–26. The University of Utah Press, Salt Lake City (2022)
36. Shim R.S.-E., Nerbonne J.: dialectR: doing dialectometry in R. In: Proceedings of the Ninth Workshop on NLP for Similar Languages, Varieties and Dialects, pp. 20–27. Association for Computational Linguistics, Gyeongju, Republic of Korea (2022)
37. Levenshtein, V.I.: Binary codes capable of correcting deletions, insertions, and reversals. Soviet Physics Doklady. **10**(8), 707–710 (1966)
38. Alexeev, A.A.: EVM i problemy tekstologii drevneslavianskih tekstov. In: Alexeev, A.A., Kuznetsova, E.L. (eds.) Lingvisticheskije zadachi I obrabotka dannyh na EVM, pp. 111–121. Institute of Russian Language of USSR Academy of Sciences, Moscow (1987)
39. Camps, J.-B., Cafiero, F.: Stemmatology: an R package for the computer-assisted analysis of textual traditions. In: Proceedings of the Corpus-Based Research in the Humanities CRH-2, pp. 65–74. Academy Corpora of the Austrian Academy of Sciences, Vienna, Austria (2018)
40. Hoenen, A.: From manuscripts to archetypes through iterative clustering. In: Proceedings of the Eleventh International Conference on Language Resources and Evaluation (LREC 2018), pp. 712–718. European Language Resources Association (ELRA), Miyazaki, Japan (2018)
41. Rama, T., Borin, L.: Comparative evaluation of string similarity measures for automatic language classification. In: Mikros, G.K., Macutek, J. (eds.) Sequences in Language and Text, pp. 171–200. De Gruyter Mouton, Berlin/München/Boston (2015)
42. Buch, A., Erschler, D., Jäger, G., Lupas, A.: Towards automated language classification: a clustering approach. In: Borin, L., Saxena, A. (eds.) Approaches to Measuring Linguistic Differences, Volume 265 of Trends in Linguistics. Studies and Monographs, pp. 303–328. Walter De Gruyter GmbH, Boston/Berlin (2013)

43. Nerbonne, J., Heeringa, W., Kleiweg, P.: Edit distance and dialect proximity. In: Sankoff, D., Kruskal, J. (eds.) Time Warps, String Edits and Macromolecules: The Theory and Practice of Sequence Comparison, 2nd edn, pp. v–xv. CSLI, Stanford, CA (1999)
44. Saxena, A., Borin, L., Comrie, B.: Kanashi and West Himalayish: genealogy, language contact, prehistoric migrations. In: Saxena, A., Borin, L. (eds.) Synchronic and Diachronic Aspects of Kanashi, pp. 237–254. De Gruyter Mouton, Berlin/Boston (2022)
45. Saxena, A., Borin, L.: Carving Tibeto-Kanauri by its joints: using basic vocabulary lists for genetic grouping of languages. In: Borin, L., Saxena, A. (eds.) Approaches to Measuring Linguistic Differences, Volume 265 of Trends in Linguistics. Studies and Monographs, pp. 175–198. Walter De Gruyter GmbH, Boston/Berlin (2013)
46. Rama, T., Wichmann, S.: Towards identifying the optimal data size for lexically-based Bayesian inference of linguistic phylogenies. In: Proceedings of the 27th International Conference on Computational Linguistics, pp. 1578–1590. Santa Fe, New Mexico, USA (2018)
47. Nixon, K., Carpenter, J.: On outgroups. Cladistics. **9**, 413–426 (1993)
48. Normanskaya, J.: Is Komi-Yazva separate language or Komi-Permian's dialect? Yearbook Finno-Ugric Stud. **14**(4), 628–641 (2020)
49. Jaro, M.: Advances in record-linkage methodology as applied to matching the 1985 census of Tampa, Florida. J. Am. Stat. Assoc. **84**, 414–420 (1989)
50. Winkler, W.: String comparator metrics and enhanced decision rules in the Fellegi-Sunter model of record linkage. In: Proceedings of the Section on Survey Research Methods, pp. 354–358. American Statistical Association, Boston, MA, USA (1990)
51. Mohammadi-Kambs, M., Hölz, K., Somoza, M.M., Ott, A.: Hamming distance as a concept in DNA molecular recognition. ACS Omega. **2**(4), 1302–1308 (2017)
52. Wills, J.: Sorting out Proto-Bantu *j. In: Bostoen, K., de Schryver, M., Guérois, R., Pacchiarotti, S. (eds.) On Reconstructing Proto-Bantu Grammar, pp. 59–101. Language Science Press, Berlin (2022)
53. de Graaf, E., Stopponi, S., Bos, J.K., Peels-Matthey, S., Nissim, M.: AGILe: the first lemmatizer for Ancient Greek inscriptions. In: Proceedings of the Thirteenth Language Resources and Evaluation Conference, pp. 5334–5344. European Language Resources Association, Marseille, France (2022)
54. Howcroft, D.M., Belz, A., Clinciu, M.-A., Gkatzia, D., Hasan, S.A., Mahamood, S., Mille, S., van Miltenburg, E., Santhanam, S., Rieser V.: Twenty years of confusion in human evaluation: NLG needs evaluation sheets and standardised definitions. In: Proceedings of the 13th International Conference on Natural Language Generation, pp. 169–182. Association for Computational Linguistics, Dublin, Ireland (2020)
55. Novikova, J., Dušek, O., Curry, A.C., Rieser, V.: Why We need new evaluation metrics for NLG. In: Proceedings of the 2017 Conference on Empirical Methods in Natural Language Processing, pp. 2241–2252. Association for Computational Linguistics, Copenhagen, Denmark (2017)
56. Munn, M., Pitman, D.: Explainable AI for Practitioners. O'Reilly Media, Inc, Sebastopol (2022)

Word Sense Induction in Russian: Evaluation of Corpora Preprocessing Techniques and Model Selection

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Abstract The chapter proposes a solution to the problem of word sense induction (WSI) in Russian. WSI refers to the task of resolving ambiguity by deriving features from corpora without using knowledge bases, dictionaries, and predefined lists of word senses. This study examines the impact of data preprocessing on the performance of WSI techniques using clustering algorithms for context vector representations based on a series of BERT models for the Russian language. Various methods of data preprocessing were analyzed, including tokenization, lemmatization, stop words' removal, and selection of pre-trained models of context vector representations. Experiments have shown that the presence or absence of lemmatization does not affect clustering results, while other factors such as the removal of stop words and the choice of the data vectorization model can significantly affect clustering. The results of the study can be applied to the procedures of semantic annotation of text corpora.

Keywords Word sense induction · Russian text corpora · Distributional semantic models · BERT · Data preprocessing

1 Introduction

Ambiguity is an immanent property of a natural language text: texts generated with the help of a finite set of lexical units and morpho-syntactic rules for combining them are potentially intended to describe the infinite content of extralinguistic reality. Ambiguity, in this case, can be caused both by the multifunctionality of linguistic mechanisms and items and by the similarity or proximity of information transmitted

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_8

by language. In terms of communication, the speaker and the listener choose the combination of conceptual features of texts and the linguistic means, which is most likely related to a particular speech situation and in a specific speech context [1–3]. At the same time, resolvable and unresolvable ambiguity cases should be contrasted. Restrictions on the scope of disambiguation can be associated with communicative functions of speech acts (e.g., puns and allegorical statements) and with the essential impossibility of choosing a single interpretation from a set of acceptable ones in a given context (e.g., diffusion of the meaning of a word or expression, and limited context) [4–6]. The causes of ambiguity are diverse in nature; it is customary to talk about morphological, syntactic, lexical-semantic, and pragmatic ambiguity. As a rule, ambiguity manifests itself simultaneously at several levels of context representation, and this complicates modeling of this phenomenon of NLP.

The reproduction of natural mechanisms of ambiguity resolution in language processing is of research interest in most projects dealing with automatic text understanding systems. This reproduction is based on generalized structural models that reflect the observed linguistic entities and relationships in an abstract form far from linguistic reality. The given divergence is the focus of formal procedures for text analysis, synthesis, and transformation. Therefore, automatic text understanding systems offer a solution to the problem of ambiguity in the form of a set of conventional procedures applied at separate levels (morphological, syntactic, semantic, etc.).

The following procedures can be applied in the studies of lexical-semantic ambiguity: (1) automatic lexical-semantic annotation, e.g., [7–9]; (2) lexical-semantic differentiation of a meaning of a word or expression in contexts, e.g., [10, 11]; and (3) automatic inference of the meaning of a word or expression from contexts, e.g., [12, 13]. All these approaches are based on the assumption that ambiguities may be registered in the text. In our work, we follow the assumption of the joint analysis of polysemy and homonymy which are weakly differentiated in computational semantic procedures (cf. the ideas of semantic annotation and disambiguation in the Russian national corpus (RNC) [7]).

Lexical-semantic annotation solves the problem of correlating a linguistic expression with a certain category or group of categories, however, the markup itself (for example, a group of semantic tags) does not allow it to represent the meaning of a word or expression completely. The markup performs the function of identifying and differentiating meanings rather than their detailed description. A text with lexical-semantic markup does not contain all possible tags for describing a particular meaning, but only those that, in combination with a lemma or contextual markers, make it possible to differentiate the meaning of a polysemous word. The consistency of lexical-semantic markup as a procedure is based not only on the fact that it is possible to compose an adequate markup scheme and also on the fact that the text itself can be reduced to its unambiguous representation. The semantic annotation does not necessarily imply total ambiguity resolution (e.g., if an unambiguous fragment of the corpus is marked), but it also does not exclude it (e.g., in the case

of assigning all possible combinations of tags to a word or expression that is ambiguous in a particular context).

The procedure for automatic word sense disambiguation (WSD) is based on dictionary data and/or context markers of different types and is applied precisely to those parts of the corpus that, when annotated, can receive an ambiguous interpretation. The initial hypothesis on which this procedure is formed is related to the fact that filiations of lexical meanings are predefined in the dictionary as well as the elements of contexts associated with these meanings are identified. WSD is carried out in the course of classifying contexts with respect to lexical-semantic patterns which store features that are characteristic of the use of a word in a particular meaning.

The procedure for deriving word meanings from the WSI corpus is based on the assumption of the ambiguity of words in the lexicon and at the same time it is possible due to another assumption—that semantic ambiguity in the corpus is removed by linguistic insights (context) or algorithmically. During WSI, contexts or context elements are clustered, and the resulting clusters are identified with values. For example, if there are the following contexts of the polysemous word *лук* (*onion/bow*): as a result of the task execution, the contexts should be grouped as follows: contexts 1, 4, and 5 will fall into one cluster, and 2 and 3 into another.

1. *Лицо женщины было испуганным, из груди торчала красная стрела, а над головой женщины, в небе, летал голый маленький мальчик с крылышками, с* ***луком*** *в руках, и специальными черточками было нарисовано, что тетива на* ***луке*** *дрожит. [Евгений Гришковец. ОдноврЕмЕнно (2004)] (The woman's face was scared, a red arrow was sticking out of her chest, and a naked little boy with wings was flying in the sky above the woman's head, with a* ***bow*** *in his hands, and it was drawn with special dashes that the bowstring was trembling.)*
2. *А он рисовал эту картину, у него мерзли руки, и он грел свои руки. . ., дышал на них. . ., а изо рта, возможно, пахло* ***луком****, потому что он поел* ***луку****. . . [Евгений Гришковец. ОдноврЕмЕнно (2004)] (And he painted this picture, his hands were freezing, and he warmed his hands ..., breathed on them ..., and his breath probably smelled of* ***onions****, because he ate* ***onions****. . .)*
3. *Частым блюдом была фасоль с* ***луком*** *и постным маслом. [Эдуард Лимонов. У нас была Великая Эпоха (1987)] (A frequent dish was beans with* ***onions*** *and vegetable oil.)*
4. *Стреляли птиц из самодельных* ***луков****. Кое-кто ловил в море рыбу наволочкой. [И. Грекова. Фазан (1984)] (They shot birds from hometade* ***bows****. Someone was fishing in the sea with a pillowcase.)*
5. *Я не удивился, если бы вдруг тут сию минуту увидел запыленный пурпуровый плащ выходящего из каменной щели кудрявого бога в венке из виноградных листьев, с убитой серной на плече, с колчаном и* ***луком*** *за спиной, с кубком молодого вина в руке—прекрасного и слегка во хмелю, как сама поэзия, которая его породила. [В. П. Катаев. Алмазный мой венец (1975–1977)] (I wouldn't be surprised if I suddenly saw a dusty purple cloak of a curly-haired god emerging from a stone crack in a wreath of grape leaves, with a*

*dead chamois on his shoulder, with a quiver and a **bow** behind his back, with a goblet of young wine in his hand—beautiful and slightly hops, like the very poetry that gave birth to him.)*

Lexical-semantic disambiguation is one of the tasks of automatic language processing which is to be solved to improve results in the fields of machine translation, question-answering systems, and information extraction [14]. Current baselines providing effective decisions of several tasks (supervised–knowledge-based, monolingual–multilingual, coarse-grained–fine-grained, all-words–target words disambiguation, WSD–WSI, etc.) were worked out for English and some other languages in course of SemEval competition series [15]. Russian data were thoroughly investigated within RUSSE competition [16] and semantically annotated corpora development [17]. The Russian language has rich morphology, and, in this regard, text preprocessing can have an impact on the result of context clustering.

The purpose of this work is to consider the influence of data analysis (tokenization, lemmatization, punctuation marks removal, and vector representation) on the results of automatic sense induction in Russian. We focus our attention on the choice of contextualized distributional embedding models, preprocessing techniques, and clustering algorithms which provide an increase in the quality of ambiguity resolution and make up for the lack of knowledge in this field of research.

2 Related Work

WSD is the subject of many studies, the first of which appeared in the 1960s. The majority of modern solutions are based on machine learning and statistical methods. Marking up data, compiling annotated corpora, and creating inventories of values for disambiguation is an extremely resource-intensive task, and therefore methods of unsupervised WSD have become very popular.

The core ideas of this method are exposed in several statements: (a) each ambiguous word is represented as a set of context vectors with a given word, (b) the contexts for each ambiguous word are grouped into clusters using one of the clustering methods, and (c) for each cluster there is a centroid, on the basis of which further disambiguation is performed for new examples of the use of the target word.

Within the competition, SemEval 2013 solutions to the problem of the English language were presented. The participants were asked to cluster the search results for an ambiguous query into semantically related groups in accordance with their values. The data set consisted of 100 ambiguous queries with a length of no more than 4 words and 6400 results [18]. Several models were presented in the competition, including [19–21].

To solve this problem for the Russian language in 2018, the RUSSE'2018 competition was held as part of the Dialogue conference [22]. Participants presented clustering models trained on three data sets containing ambiguous words and

contexts of their use. The models presented at the competition are described in the works [23, 24].

The results of the competition showed that modern systems still cope with the task of deriving values from contexts with great difficulty on the material of polysemants with high detail of values, however, at the same time, they show high results for homonyms (wiki-wiki corpus).

For example, Kutuzov [23] presented a solution based on the clustering of "semantic fingerprints" of contexts using the Affinity Propagation algorithm. So, as a result, the highest *ARI* score reached 0.77 for the wiki-wiki corpus.

Later, this algorithm was modified by using the BERT model to obtain vector representations [25], which allowed increasing the accuracy to an *ARI* value equal to 0.81.

In another paper [24], a similar algorithm is considered, vector representations of the context were calculated as an average-weighted vector from vector representations of words obtained using word2vec. In addition, other clustering algorithms were used: in addition to Affinity Propagation, experiments were carried out using DBSCAN, OPTICS, Spectral clustering, and Agglomerative clustering algorithms. The maximum accuracy on the wiki-wiki corpus was 0.81 *ARI* value.

Many papers devoted to the problem of disambiguation describe data preprocessing, but the authors rarely justify the choice of their method. For example, in the works of [19–21, 23, 26] words in contexts are preliminarily lemmatized, while in the work of [25] there is no lemmatization.

Contextualized word embedding models based on BERT show high efficiency in obtaining semantic vectors of linguistic units on the material of the Russian language, which is confirmed in the works [19, 25]. Such models are based on the BPE (Byte-Pair Encoding) algorithm, so it is considered that lemmatization is not an obligatory step in data preprocessing when using these models.

The study [27] considers the influence of lemmatization on the results of the problem of disambiguation using ELMo embeddings. The experiments have shown that the absence of lemmatization did not affect the classification accuracy for English, while there was a small but stable increase in accuracy for Russian. The authors suggest that this is due to the rich morphology of Russian. Our experiments must confirm or refute the observations on WSI conditions for Russian.

3 Experiments on WSI

3.1 Research Corpus

The experiment described in this study was performed on the Russian data set prepared for the Dialogue Evaluation RUSSE'2018 competition devoted to WSI [16]. The choice of the given data set is justified by the fact that it was developed as a gold standard for WSD/WSI procedures in Russian. The data set was involved in the evaluation of static distributional semantic models, but the full-scale research for a

set of contextualized embedding models have not been not performed yet. Thus, our work fills in the gap. The corpus for training and testing WSI algorithms was compiled on the basis of Wikipedia data. It contains nine polysemous/homonymous nouns (*'бор' (pine forest/boron)*, *'суда' (ships/court)*, *'лук' (onion/bow)*, *'замок' (castle/lock)*, *'банка' (bank/pot)*, *'бит' (bit/beat)*, *'горе' (grief/mountain)*, *'граф' (Earl/graph)*, and *'душ' (shower/soul)*) as target words, as well as contexts containing target words used in one of the two meanings provided. In total, 1056 contexts are included in the corpus (some contexts may include several occurrences of the target word). The contexts in the corpus are preprocessed—all digits are removed and all characters are reduced to lowercase. Data example is given in Table 1.

Unlike the rest of the corpora presented in this competition, the wiki-wiki corpus contains mostly homonymous words, not polysemous ones. In this case, the meanings of words are more clearly distinguished, so automatic sense induction is more justified in this experimental setting.

3.2 Experimental Setup

Our experiment aims to determine the impact of the following data processing factors on WSI results:

- Removal of punctuation marks
- Tokenization (Python libraries NLTK [28], Stanza [29], Razdel [30], Segtok [31], Spacy [32], and Moses [33])
- Lemmatization (cf. Python libraries above)
- Removing duplicate words
- Context embeddings (transformers ruBERT-tiny [34], LaBSE [35, 36], and RuBERT [37])

Distributed vector representations for WSI were obtained on the basis of pre-trained BERT models for sentence embeddings. The input contexts preprocessed in various ways were clustered using the following clustering algorithms: KMeans, Affinity Propagation, DBSCAN, and OPTICS. The range of algorithms was expanded in comparison with RUSSE protocols, thus, we obtained novel results concerning the choice of clustering techniques suitable for WSD/WSI. The results were evaluated by using an Adjusted Rand Index.

Tokenization To consider the impact of tokenization, several existing algorithms implemented within libraries for natural language processing were selected. The following libraries were selected: NLTK, Stanza, Razdel, Segtok, Spacy, and Moses [28–33]. The difference in the accuracy of these tokenizers was analyzed within the framework of the Naeval project [38] while developing a tool for natural language processing Natasha [39]. As part of the study, differences in the tokenization of the experimental data set using these libraries were analyzed.

Table 1 Data example

Index	context_id	word	gold_sense_id	predict_sense_id	Position	Context
1	2	замок	1	NaN	11–16, 17–22, 188–193	*шильонский* ***замок замо́к*** *шильо́н (), известный в русскоязычной литературе как шильо́нский* ***за́мок****, расположен на швейцарской ривьере, у кромки женевского озера, в км от города монтре.* ***замок*** *представляет собой комплекс из элементов разного времени постройки. (the chillon castle ( ), known in russian literature as the castle of chillon, is located on the swiss riviera, at the edge of lake geneva, km from the city of montreux. the castle is a complex of elements of different construction times.)*
2	3	замок	1	NaN	299–304	*проведения архитектурно – археологических работэстонским реставрационным управлением под руководством архитектора х. и. потти, искусствоведа е. а. кальюнди и при научной консультации доктора исторических наук п. а. рапопорта. с года музей называется государственным музеем выборгский* ***замок****. (carrying out architectural and archaeological works by the estonian restoration department under the supervision of architect h. i. potti, art critic e. a. kaliundi and with the scientific advice of the doctor of historical Sciences p. a. rapoport. since the year the museum has been called the vyborg* ***castle*** *state museum.)*
3	4	замок	1	NaN	111–116	*топи с., л. белокуров легенда о завещании мавра с., н. юсупов день рождения с., р. янушкевич янтарный* ***замок*** *с. (topi s., l. belokurov legend of the will of the moor s., n. yusupov birthday s., r. yanushkevich amber* ***castle*** *S.)*

- *Features of the processing of the stress sign (´).* The NLTK and Spacy tokenizers highlight an accent if it is on the last letter of a word. The Segtok and Moses tokenizers always separate an accent mark into a separate token. If this symbol is in the middle of a word, it is divided into three tokens according to stress (e.g., *междунаро, ´, дного*). The Razdel tokenizer never allocates an accent mark into a separate token.
- *Features of processing words written with a slash (/).* All tokenizers, except for NLTK and Stanza, allocate the slash sign into a separate token, Stanza divides such words into two tokens, the slash is part of the second token (for example, *км (km), /ч (/h)*), and NLTK defines them as one token.
- *Features of processing the degree sign (°).* The NLTK and Razdel tokenizers do not separate this character into a separate token, the other tokenizers do.
- *Features of processing time intervals written with a dash (e.g., xi—xii).* The Segtok, Spacy, and Moses tokenizers allocate the dash sign as a separate token, in other cases such an entry is processed as a single token.
- *Features of processing some characters.* The Spacy tokenizer allocates a nonbreaking space as a separate token, replacing it with the HTML code of the given character. Moses replaces the meaning of some characters with their HTML code during tokenization (e.g., quotation marks, square brackets, and apostrophe sign).

Lemmatization As part of the experiment, four processing options were considered: corpus data with Pymorphy2 [40] lemmatization without stop words' removal, with Pymorphy2 lemmatization with stop words' removal, without lemmatization without stop words' removal, and without lemmatization with stop words' removal. A list of words based on Yandex Wordstat [41] was used as a stop-word dictionary.

Removing duplicate words During preprocessing, two options for representing contexts were considered. In the first case, contexts were represented as a list of unique words included in the sentence; in the second case, all occurrences of words were saved.

Embeddings The embedding method used in this study is aimed at obtaining a contextualized embedding of the whole sentence. According to our assumption, different meanings of target words are implemented in contexts whose vectors will be further apart than the vectors of contexts in which a polysemous word is used in the same meaning.

BERT is a language model which is defined as a neural network encoder based on the transformer architecture. When calculating the embedding of a language unit, the model takes into account the right and left contexts.

In this experiment, we use contextualized models of vector representations. When using such models, the context can be represented in two ways:

- Sentence embedding
- Target word embedding

To obtain a vector representation of contexts, the following pre-trained BERT models were used:

- *ruBERT-tiny* [34]: This model represents a sentence in the form of a vector with a dimension of 312; the BERT-multilingual model was taken as the basis, additional training was carried out on the texts of parallel corpora from Yandex. Translate [42], OPUS-100 [43], and Tatoeba [44].
- *LaBSE* [35, 36]: Language-agnostic BERT Sentence Embedding model supports 109 languages, representing the sentence as a vector of 768 dimensions.
- *RuBERT* [37]: The Russian BERT model trained on Russian-language Wikipedia and news data represents the context as a vector of 768.

Clustering algorithms This study was conducted using several clustering algorithms: KMeans, Affinity Propagation, DBSCAN, and OPTICS [45].

- *KMeans* is a stochastic algorithm that requires a predetermined number of clusters, which can be a limitation for its use and opposes it to the other three algorithms, which allow not to set the number of clusters in advance but calculate it dynamically. In addition, the KMeans algorithm is sensitive to the choice of initial cluster centroids which are initiated at random.
- *Affinity propagation* is based on the idea of evaluating message passages between data points and requires damping (from 0.5 to 1, by default 0.5) and preference (by default None) as hyperparameters. In our experiment, we considered the values 0.5, 0.6, 0.7, 0.8, and 0.9 for the damping parameter and values from -6 to 20, including none for the preference parameter. The final evaluation of the algorithm quality was considered as the average of the algorithm results with values of 0.6 and 0.7 for the damping parameter and None for the preference parameter since the algorithm with these parameters showed the best results.
- *DBSCAN* algorithm performs density-based spatial clustering of noisy data. It requires ϵ and min_samples value selection. In our case, values from 0.1 to 1 for the ϵ parameter and values from 2 to 9 for min_samples were considered. These parameters regulate cluster density. The final results were considered as the average between the clustering score with values of 2 and 5 for the min_samples parameter and a value of 0.1 for the eps parameter.
- *OPTICS* algorithm is similar to DBSCAN, but it allows detecting meaningful clusters in data of varying densities. In experiments with OPTICS clustering, values for the min_samples parameter from 2 to 15 were considered, and the final results were considered as the average of the performance estimates of algorithms with values of this parameter equal to 5 and 8.

Evaluation metrics The Adjusted Rand Index was applied to evaluate clustering results. The Rand Index (*RI*) of clustering C is a measure of clustering agreement that determines the percentage of correctly distributed pairs of elements in two clusterings C and G. *RI* is calculated by the formula:

$$R(C,G) = \frac{TP + TN}{TP + FP + FN + TN},$$

where *TP* is the number of true positives, i.e., pairs of elements that are in the same cluster both in clustering *C* and in clustering *G, TN* is the number of true negatives, i.e., pairs that are in different clusters in both clusters, and *FP* and *FN*, respectively, the number of false positives and false negatives. *RI* ranges from 0 to 1, where 1 indicates a full match of clusters up to a permutation.

The Adjusted Rand Index (*ARI*) is a modification of the Rand Index that adjusts the *RI* for a random match and makes it vary as expected:

$$ARI(C,G) = \frac{RI(C,G) - E(RI(C,G))}{maxRI(C,G)},$$

where $E(RI(C,G))$ is the expected value of *RI*.

Thus, the Adjusted Rand Index has a value close to 0.0 for random labeling regardless of the number of clusters and samples, and exactly 1.0 when the clusters are identical (before permutation). The quality scores of each algorithm were calculated as the average of *ARI* over all target words in the data set.

4 Experimental Results

In the course of experiments we managed to reveal the influence of various data preprocessing factors on the results of clustering context embeddings, cf. Table 2. Experiments have shown that lemmatization does not have a stable positive effect on clustering results; on the contrary, quite often it affects negatively. So, in 42% of cases, lemmatization has a positive effect, in 57%—negative, and in 1% it does not affect the results of clustering in any way. The biggest increase is 0.30 points (*ARI* from 0.37 to 0.68). The average *ARI* value for all experiments without lemmatization is 0.40, with UD-Pipe lemmatization is 0.40, and with Pymorphy2 lemmatization is 0.39. The highest results are obtained by experiments with the KMeans algorithm: the average *ARI* value with Pymorphy2 lemmatization is 0.70, with UD-Pipe lemmatization is 0.70, and without lemmatization is 0.71.

At the same time, when using word embedding, the effect of lemmatization is much more distinct—in most cases, lemmatization affects the results negatively. Thus, the highest increase in accuracy is 0.47 points (0.40 when using lemmatization Pymorphy2, 0.87—without lemmatization). The highest results are obtained by experiments with the KMeans clustering algorithm, for example, the average *ARI* value with Pymorphy2 lemmatization is 0.69, with UD-Pipe lemmatization is 0.78, and without lemmatization is 0.88.

Removing stop words in most cases (62%) shows an increase in clustering accuracy, in 3% of cases it has no effect. The most stable option is preprocessing

Table 2 Estimating the accuracy of algorithms with and without lemmatization

	With lemmatization				Without lemmatization			
Clustering algorithm	RuBERT-tiny	LaBSE	RuBERT sentence	RuBERT word	RuBERT-tiny	LaBSE	RuBERT sentence	RuBERT word
NLTK tokenizer, without removing punctuation, only unique words, without removing stop words								
KMeans	0.333	**0.785**	0.325	0.438	0.348	0.778	0.332	**0.848**
Affinity propagation	0.120	**0.214**	0.167	0.060	0.125	0.221	**0.245**	0.073
DBSCAN	0.148	0.447	**0.018**	0.0	0.185	**0.511**	−0.012	0.0
OPTICS	0.073	**0.174**	0.081	−0.032	0.108	0.160	**0.156**	0.148
NLTK tokenizer, with the removal of punctuation, not only unique words, without removing stop words								
KMeans	**0.401**	0.524	**0.613**	**0.713**	0.326	0.790	0.381	**0.977**
Affinity propagation	0.122	**0.230**	0.198	0.070	0.142	0.227	**0.209**	0.070
DBSCAN	0.163	**0.475**	−0.015	0.0	0.156	**0.381**	−0.005	**0.0**
OPTICS	0.072	**0.206**	0.120	−0.034	0.069	0.143	**0.222**	0.168

with the removal of stop words and without lemmatization—such preprocessing does not guarantee the highest performance, but it shows a low result less often than others. The configuration of the Affinity Propagation algorithm and the LaBSE model consistently shows the highest result in lemmatization and the removal of stop words compared to other preprocessing options.

Removing punctuation in 55% of cases has a positive effect on clustering results, in 43% it has a negative effect, and in 2% of cases it has no effect. The most significant increase is 0.29 points. The removal of punctuation has a particularly significant effect on the configuration of the DBSCAN algorithm and the RuBERT embeddings—the indicators are consistently higher in experiments in which punctuation is not removed.

Among the methods of vector representation of contexts, the LaBSE model showed the highest results.

Figure 1 shows graphs of context vectors for the word *бор (pine forest/drill)* obtained using different vector representation models.

Clustering algorithms for any preprocessing options in 87% of cases showed the best results on data vectorized using the LaBSE model, in the remaining 13% using RuBERT sentence embedding. Thus, the average *ARI* value when using the LaBSE model is 0.52, when using the RuBERT sentence embedding it is 0.46, when using RuBERT word embedding it is 0.33, and the ruBERT-tiny model—0.27. Table 3 presents the results of the algorithms for pre-tokenization using NLTK, with the removal of punctuation and stop words, and with lemmatization.

The highest results are shown by the configuration of the LaBSE model and the KMeans clustering algorithm (*ARI* from 0.5245 to 0.8074). The next most effective are the DBSCAN clustering algorithm and the LaBSE vector representation (*ARI* from 0.3751 to 0.5354) and the KMeans clustering algorithm and the RuBERT model (*ARI* from 0.3179 to 0.6203).

The highest result was shown by the system implemented using NLTK/Stanza/Razdel/Segtok/Moses tokenizers, without lemmatization, without removing stop words, removing punctuation marks, and duplicate words with the KMeans clustering algorithm—the average *ARI* value for all words of the corpus was 0.97 (up to 1.0 on individual words). However, word embeddings only perform well with the KMeans clustering algorithm, which requires a number of clusters as input. The configuration with the KMeans algorithm also shows the highest result for sentence embeddings: the average corpus *ARI* value is 0.82 (up to 1.0 on individual words) with any tokenizers, with Pymorphy2 lemmatization, with stop word removal, without punctuation removal, with or without removing duplicates.

5 Conclusion

In this chapter, we discussed the influence of data analysis on the results of automatic sense induction for Russian. Experiments were carried out to reveal the impact of tokenization, lemmatization, punctuation marks, duplicates, etc. on WSI.

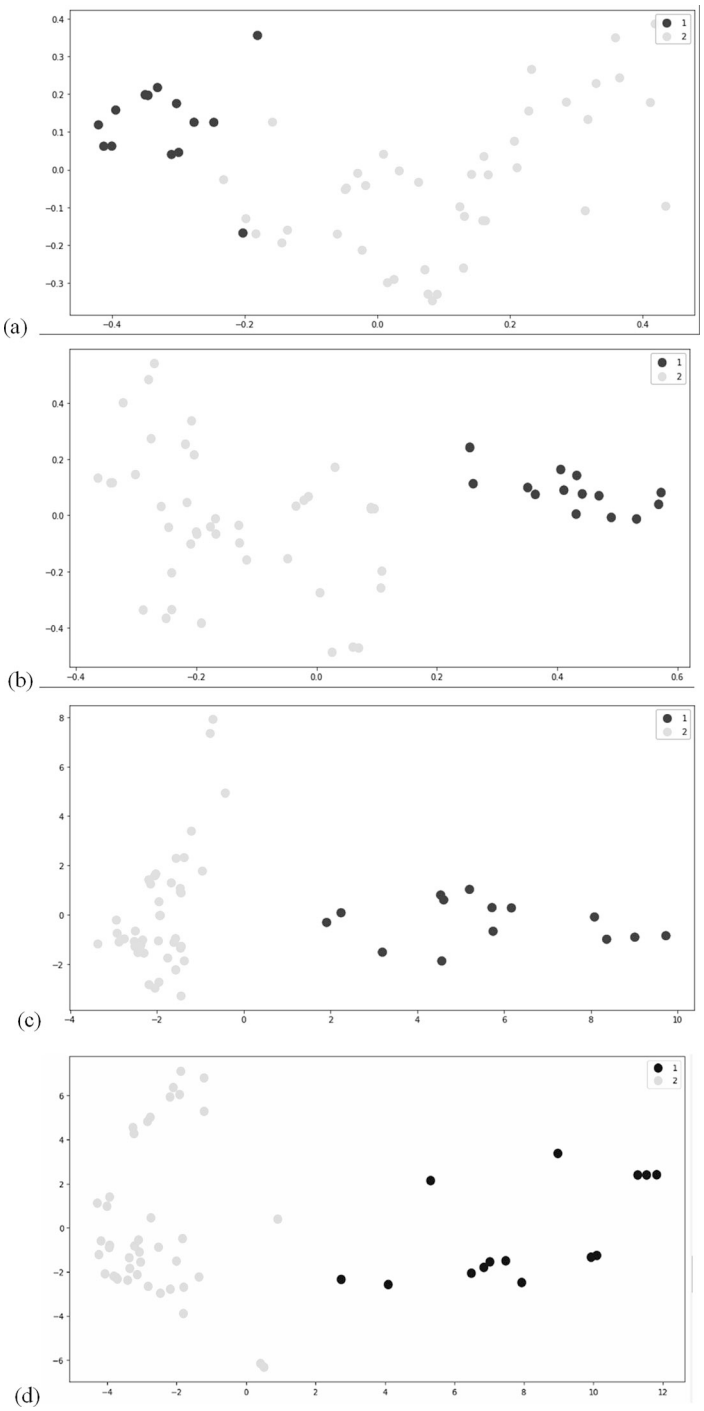

Fig. 1 Graphs of context embeddings for the word *бор*, embeddings obtained using (**a**) ruBERT-tiny, (**b**) LaBSE, (**c**) RuBERT sentence embeddings, and (**d**) RuBERT word embeddings, all other parameters being equal. The gold standard labels are marked in color

Table 3 Estimating the accuracy of algorithms. Pre-tokenization: NLTK, removal of punctuation and stop words, lemmatization with Pymorphy2

Clustering algorithm	ruBERT-tiny	LaBSE	RuBERT	
KMeans	0.3537	**0.7956**	0.6025	0.6292
Affinity propagation	0.1280	**0.2526**	0.1952	0.0665
DBSCAN	0.1635	**0.4384**	−0.0210	0.002
OPTICS	0.07978	**0.2513**	0.2111	−0.0365

Table 4 Estimating the accuracy of algorithms

	ARI score for wiki-wiki corpus
Kutuzov [23]	0.77
Arefyev et al. [24]	0.81
Slapoguzov et al. [25]	0.81
RUSSE'18 baseline [22]	0.62
Our system	**0.97**

Embeddings for WSI were obtained on the basis of pre-trained BERT models: ruBERT-tiny, LaBSE, and RuBERT. The input contexts were clustered by KMeans, Affinity Propagation, DBSCAN, and OPTICS algorithms. The results were evaluated by an Adjusted Rand Index.

The implemented systems showed results exceeding the accuracy of existing systems tested on the same data described in [23–25]. (Table 4).

Experiments have shown that lemmatization overall does not improve WSI results, however removing stop words and punctuation provides an increase in ARI. We found optimal configurations for WSI as regard the choice of embedding models and clustering techniques: LaBSE model and KMeans clustering showed the highest results.

Our next work deals with the expansion of experiments to all-words WSD and working out a flexible procedure of semantic annotation.

Acknowledgments Research is performed with partial support of SPbSU Scientific Project № 75254082 "Modeling the communicative behavior of residents of a Russian metropolis in the socio-speech and pragmatic aspects with the use of artificial intelligence methods," RSF grant № 21-78-10148 "Modeling the meaning of a word in individual linguistic consciousness based on distributive semantics."

References

1. Apresyan, Y.D.: Selected Works, vol. 1. Lexical Semantics, Moscow (1995)
2. Zaliznyak, A.A.: The phenomenon of polysemy and the ways of its description. Issues Linguist M. **2004**(2), 20–45 (1995)
3. Vinograd, T.: Understanding Natural Language. Academic Press (1972)

4. Apresyan, Y.D.: On regular polysemy. In: Proceedings of the Academy of Sciences of the USSR, Department of Literature and Language, vol. XXX, issue 6, pp. 509–523 (1971)
5. Kopotev, M.: Introduction to Corpus Linguistics, Prague (2014)
6. Shmelev, D.N.: Essays on the Semasiology of the Russian Language, Moscow (1964)
7. Rakhilina, E.V., Kustova, G.I., Lyashevskaya, O.N., Reznikova, T.I., Shemanaeva, O.Y.: The tasks and principles of lexical-semantic annotation in RNC. In: The Russian National Corpus: 2006–2008. New Results and Perspectives, pp. 215–239. Nestor-Istoriya, St.-Petersburg (2009)
8. Mudraya, O.V., Babych, B.V., Piao, S., Rayson, P., Wilson, A.: Developing a Russian semantic tagger for automatic semantic annotation. In: Proceedings of the International Conference "Corpus Linguistics-2006", pp. 290–297. St.-Petersburg, Russia (2006)
9. Palmer, M., Kingsbury, P., Gildea, D.: The proposition bank: an annotated corpus of semantic roles. Comput. Linguist. **31**(1), 71–106 (2005)
10. Agirre, E., Edmonds, P. (eds.): Word Sense Disambiguation: Algorithms and Applications. Springer, New York (2006)
11. Navigli, R.: Word sense disambiguation: a survey. ACM Comput. Surv. **41**(2), 1–69 (2009)
12. Nasiruddin, M.: A state of the art of word sense induction: a way towards word sense disambiguation for under-resourced languages (PDF). In: TALN-RÉCITAL 2013, pp. 192–205. Les Sables d'Olonne, France (2013)
13. Panchenko, A., Lopukhina, A., Ustalov, D., Lopukhin, K., Arefyev, N., Leontyev, A., Loukachevitch, N.: RUSSE'2018: a shared task on word sense induction for the Russian language. In: Computational Linguistics and Intellectual Technologies: Papers from the Annual International Conference "Dialogue", pp. 547–564. RSUH, Moscow (2018)
14. Moro, A., Navigli, R.: SemEval-2015 Task 13: multilingual all-words sense disambiguation and entity linking. In: Proceedings of the 9th International Workshop on Semantic Evaluation (SemEval-2015), pp. 288–297. Association for Computational Linguistics, Denver, CO (2015)
15. https://en.wikipedia.org/wiki/SemEval
16. https://russe.nlpub.org/2018/wsi/
17. Bolshina, A.S., Loukachevitch, N.V.: Weakly supervised word sense disambiguation using automatically labelled collections. Trudy ISP RAN/Proc. ISP RAS. **33**(6), 193–204 (2021)
18. Navigli, R., Vannella, D.: SemEval-2013 Task 11: word sense induction and disambiguation within an end-user application. In: Second Joint Conference on Lexical and Computational Semantics (*SEM), vol. 2: Proceedings of the Seventh International Workshop on Semantic Evaluation (SemEval 2013), pp. 193–201. Association for Computational Linguistics, Atlanta, GA, USA (2013)
19. Amrami, A., Goldberg, Y.: Towards better substitution-based word sense induction. ArXiv. https://arxiv.org/abs/1905.12598 (2019)
20. Amplayo, R.K., Hwang, S., Song, M.: Autosense model for word sense induction. In: Proceedings of the AAAI Conference on Artificial Intelligence, vol. 33, №. 1, pp. 6212–6219 (2019)
21. Amrami, A., Goldberg, Y.: Word sense induction with neural biLM and symmetric patterns. ArXiv. https://arxiv.org/pdf/1808.08518.pdf (2018)
22. Panchenko, A., Lopukhina, A., Ustalov, D., Lopukhin, K., Arefyev, N., Leontyev, A., Loukachevitch, N.: RUSSE'2018: a shared task on word sense induction for the Russian language. ArXiv. https://arxiv.org/vc/arxiv/papers/1803/1803.05795v2.pdf (2018)
23. Kutuzov, A.: Russian word sense induction by clustering averaged word embeddings. ArXiv. https://arxiv.org/ftp/arxiv/papers/1805/1805.02258.pdf (2018)
24. Arefyev, N., Ermolaev, P., Panchenko, A.: How much does a word weigh? Weighting word embeddings for word sense induction. In: Computational Linguistics and Intellectual Technologies: Proceedings of the International Conference "Dialogue-2018", pp. 68–84, Moscow (2018)
25. Slapoguzov, A., Malyuga, K., Tsopa, E.: Word sense induction for Russian texts using BERT. In: Conference of Open Innovations Association. FRUCT, №. 28, pp. 621–627 (2021)

26. Eyal, M., Sadde, S., Taub-Tabib, H., Goldberg, Y.: Large scale substitution-based word sense induction. ArXiv. https://arxiv.org/abs/2110.07681 (2022)
27. Kutuzov, A., Kuzmenko, E.: To lemmatize or not to lemmatize: How word normalisation affects ELMo performance in word sense disambiguation. In: Proceedings of the First NLPL Workshop on Deep Learning for Natural Language Processing, pp. 22–28. Linköping University Electronic Press, Turku, Finland (2019)
28. https://www.nltk.org/
29. https://stanfordnlp.github.io/stanza/Stanza
30. https://github.com/natasha/razdel?ysclid=lgmjj9t4cn752154674
31. https://pypi.org/project/segtok/
32. https://spacy.io/
33. https://pypi.org/project/mosestokenizer/
34. https://huggingface.co/cointegrated/rubert-tiny
35. Feng, F., Yang, Y., Cer, D., Arivazhagan, N., Wang, W.: Language-agnostic BERT sentence embedding. ArXiv. https://arxiv.org/abs/2007.01852 (2020)
36. https://huggingface.co/sentence-transformers/LaBSE
37. Kuratov, Y., Arkhipov, M.: Adaptation of deep bidirectional multilingual transformers for Russian language. ArXiv. https://arxiv.org/abs/1905.07213 (2019)
38. https://natasha.github.io/naeval
39. https://natasha.github.io/
40. https://pymorphy2.readthedocs.io/en/stable/
41. https://wordstat.yandex.ru/
42. https://translate.yandex.ru/
43. https://opus.nlpl.eu/opus-100.php
44. https://tatoeba.org/ru/
45. https://scikit-learn.org/stable/index.html

Topic Label Generation in the Popular Science Corpus

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Abstract This chapter presents the results of experiments on topic label generation from web data and distributional semantic models. The procedure in question is required for topic label assignment in Russian popular science corpora. Topic modeling is performed by means of a series of algorithms, including Nonnegative matrix factorization, Latent Dirichlet Allocation, and Biterm topic modeling. Our approach allows for reducing the shortcomings of conventional topic label assignment by choosing the first topical term as a topic label. We introduce an improved version of topic label generation as an ensemble of heterogeneous methods. Candidate labels are evaluated in the course of human assessments. The results of our research allow us to verify the structure of scientific media sites and thus to improve their quality.

Keywords Topic modeling · Topic label assignment · Russian corpora · Scientific texts · Human assessments

1 Introduction

Topic modeling is a way of building a semantic model of text corpora that determines the interrelations of topics, documents, and topical words. Topics are treated as hidden factors represented by clusters of topical words. Each document is associated with one or more topics with some probability or weight, and the topics themselves may intersect: a certain word can be attributed to several topics [1]. Topic

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_9

models help to improve the efficiency of procedures for extracting information from natural language texts, such as automatic headline generation, document clustering, and classification, sentiment analysis, and make a significant contribution to the training of AI systems [2, 3]. The scope of topic models is wide; they cover text corpora of different types and genres, among which are news [4, 5], social media texts [6–8], medical texts [9], financial texts [10], scientific texts [11], and fiction [12–15]. Our study is designed to solve the problem of studying the topical structure of popular scientific texts, which are in great demand in social media and the educational sphere.

Frequently used topic modeling techniques include a group of algebraic models such as Latent Semantic Analysis (LSA), Nonnegative matrix factorization (NMF), and probabilistic models such as probabilistic Latent Semantic Analysis (pLSA), Latent Dirichlet Allocation (LDA), Pachinko Allocation, and Hidden Markov topic model. In practice, their multimodal extensions are often used to introduce additional corpus parameters. Such are authorship in author-topic model, addressee in author-recipient-topic model, relations between topics in hierarchical topic models, the presence of predefined topical words in Guided LDA, linguistic structures within topics in n-gram topic models, the possibility of generalization by introducing labels, and changes in topical structure over time in Dynamic topic models [1, 5, 7, 12, 15–17]. In recent years, a new class of topic models has emerged that combines probabilistic processes and distributed vector models, for example, LDA2Vec, Top2Vec, embedded topic model, contextualized topic model, and BERTopic [18, 19]. The advantage of combined topic models is that they improve the quality of semantic representations and reduce the losses associated with the use of the bag-of-words approach.

As a rule, topic modeling does not necessarily include topic label assignment as an obligatory procedure. Traditionally, topics are presented as a number and the first word or words with the highest probability or weight represent their attachment to the topic. There may be difficulties in understanding the output of topic modeling algorithms, especially for a nonspecialist; labels are used to make topics easier to interpret. A label is a sequence of words that can capture the general meaning of a given set of topical words. The relevant labels are often manually assigned to topics based on subjective criteria. However, automatic selection of topic labels not only makes it easier to interpret the extracted word distributions but also saves time and effort spent on manual indexing.

NLP provides several automatic methods for topic labeling; these methods are divided into three classes depending on label sources, types of algorithms involved, and label structure. The source for labels can be either internal so that the labels are taken directly from the research corpus, or external so that they are extracted from reference corpora, search engine output, or knowledge bases (Wikipedia, WordNet). Algorithms of topic label assignment can be supervised or unsupervised. As regards their structure, labels can be unigrams, bigrams, etc. Label assignment through internal sources includes determining Kullbach-Leibler distance between word distributions and maximizing mutual information between candidate labels and topics [20]; rearrangement of relevant words in terms of their attachment to the

topic [21]; ranking candidate labels using summarization algorithms [22]; extracting candidate label n-grams from documents most relevant to the topics, matching candidates to word vectors and letter trigrams, ranking candidates by similarity between topics and tag vectors [23]; and finding documents closest to the topics, extracting individual terms and set expressions, and ranking them according to information measures [24]. Among different approaches to assigning labels using external sources are term extraction from Google directory hierarchy (gDir) [25]; title extraction from Wikipedia or DBpedia and candidate label ranking candidate [26, 27]; using the web as a corpus for extracting candidate labels using Google search and ranking candidates with PageRank [28]; using Wikipedia titles as candidate labels and ranking candidates through neural embedding operations for words and documents [29]; incorporating a formal ontology into a topic model for knowledge extraction (KB LDA) [30]; and using k-nearest neighbors clustering and hashing for quick label assignment to newly emerging topics [31].

In [5, 32, 33], the authors presented two approaches to topic label assignment for Russian corpora, namely candidate labels extraction from Yandex search engine (Labels-Yandex) and candidate labels extraction from Wikipedia by operations on word vector representations in explicit semantic analysis (Labels-ESA). The evaluation procedure showed that in most cases Labels-Yandex algorithm predicts correct labels and frequently relates the topic to a label that is relevant to the current moment but not to a set of keywords, while Labels-ESA works out labels with generalized content.

In this chapter, we propose a novel approach to topic label assignment, which is applicable in processing a popular scientific corpus that covers a wide range of topics. First, we discuss the problems of corpus building, filtering, and annotation. Second, we compare a set of topic modeling algorithms (LDA, NMF, and BTM) that reveal the topical structure of the corpus and analyze training hyperparameters and evaluation procedures. As the topical structure of the research corpus may not coincide with Wikipedia, we focus our attention on candidate label extraction from the search engine and expand it by adding distributed vector representation model predictions and summarization procedures for topic label generation and ranking. Topic label verification is performed in the course of a perceptual experiment, the results of which are compared with the baseline worked out in previous research.

2 Topic Modeling in the Popular Science Corpus

2.1 Research Corpus

The corpus developed within our study is a compilation of Russian texts sampled from *Elementy bolshoi nauki* [34], an online media outlet covering various aspects of natural sciences and technology. It contains 2289 popular science articles published between 2010 and 2023, or approximately three million words.

As topic models typically need the data to be preprocessed, the necessary steps to be taken included lowercasing, tokenization with NLTK [35], lemmatization using pymorphy2 [36], and collocation extraction with Gensim module Phrases [37]. The latter was used as a means of improving topic coherence and overall topic distinctiveness as it keeps multiword expressions in the corpus instead of breaking them down into separate tokens. A total number of 5389 unique noun phrases were extracted at this point. In addition, we removed all punctuation marks, digits, and words, including only Latin characters, as well as stop words based on a custom list of 1000 items. Only nouns and adjectives made it to the final version of the corpus as the most informative parts of speech regarding a document's content [38], with the size of the corpus reduced to 1.5 million tokens. Aside from the text itself, some metadata were also retrieved, including the title, name of the author, outlet, publication date, and topics provided by the author. In each outlet, the in-built topics are essentially keywords describing the contents of the article and making navigation across the site easier. Next, we filtered out tokens that are too frequent or too rare to be informative, removing words that occur in less than 1% or more than in 20–70% of the documents depending on the model. As a result, the number of unique tokens ranged from 5570 to 47,270.

2.2 Topic Modeling Results

The models built for the corpus were Latent Dirichlet Allocation (LDA), Nonnegative matrix factorization (NMF), and Biterm topic model (BTM) [1, 3, 5, 16, 17, 39]. The intuition behind these algorithms is that no prior knowledge is needed for topic extraction, although LDA typically requires detailed assumptions regarding the hyperparameters [40].

More specifically, LDA is a generative probabilistic model that uses word distributions for topic extraction. It is considered a three-level hierarchical Bayesian model comprising document level, topic level, and word level. At the document level, each document is represented as a finite mixture over a set of topic probabilities. At the topic level, each topic is represented as a finite mixture over an underlying set of words, and at the word level, each word is modeled as a distribution over topics. LDA typically requires three hyperparameters, or initial beliefs about the distribution: a number of topics, beta, and alpha. The alpha parameter represents document-topic density—with a higher alpha, documents are assumed to contain more topics, which results in a more specific topic distribution per document. The beta parameter represents topic-word density—with a higher beta, topics are supposed to be made up of more words in the corpus, which results in a more specific word distribution per topic.

To determine the optimal values for the hyperparameters, we performed a grid search until reaching the highest coherence score, also referred to as the quality of the extracted topic, with a value of 0.9 for both alpha and beta. The number of topics

for LDA was chosen empirically beforehand and stood at 16. A fragment of the output is given below:

Topic 1: *частица, энергия, физика, электрон, измерение, детектор, атом, нейтрино, масса, фотон, ядро, протон, поле, коллайдер, квантовый (particle, energy, physics, electron, measuring, detector, atom, neutrino, mass, photon, nucleus, proton, field, collider, quantum)*

Topic 8: *ребёнок, аллель, отбор, выборка, страна, женщина, показатель, население, смертность, полиморфизм, корреляция, генофонд, индивид, старение, численность (child, allele, selection, sample, country, woman, rate, population, mortality, polymorphism, correlation, gene pool, person, aging, number)*

Topic 3: *самец, самка, птица, яйцо, потомство, пол, гнездо, муха, колония, спаривание, половой, размножение, сперматозоид, птенец, отбор (male, female, bird, egg, offspring, sex, nest, fly, colony, mating, reproductive, reproduction, sperm, hatchling, selection)*

Alternatively, NMF is a nonprobabilistic algorithm that employs a linear algebra approach for topic extraction. It breaks down (or factorizes) high-dimensional vectors into a lower-dimensional representation. The vectors can be represented by words, their raw counts, or TF-IDF weights—a measure evaluating the statistical importance of a word in a collection of documents. In contrast to the simplistic bag-of-words approach used in LDA, which counts word occurrences disregarding any semantic information, TF-IDF weighting generally assigns lower values to more frequent words in the corpus; a word is also considered important when it occurs rarely in the whole collection but frequently in a given document or a set of documents. Moreover, unlike LDA, NMF does not normally require hyperparameter tuning since the only parameter that needs to be specified explicitly beforehand is the number of topics. In our case, the topics generated for NMF were more numerous, equaling 26.

Topic 6: *мантия, порода, земля, кратер, поверхность, млрд_год, минерал, марс, планета, образование, магма, базальт, слой, алмаз, древний (mantle, rock, earth, crater, surface, million_a_year, mineral, mars, planet, formation, magma, basalt, bed, diamond, ancient)*

Topic 20: *опухоль, рак, метастаз, раковый_клетка, клетка, мутация, пациент, раковый_опухоль, терапия, лечение, ткань, ингибитор, опухолевый_клетка, рост, железа (tumor, cancer, metastasis, cancer_cell, cell, mutation, patient, carcinoma, therapy, treatment, tissue, inhibitor, tumor_cell, growth, gland)*

Topic 4: *самец, самка, спаривание, потомство, сперматозоид, ухаживание, яйцо, пол, поведение, половой_отбор, половой, особь, репродуктивный_успех, партнёр, популяция (male, female, mating, offspring, sperm, courtship, egg, sex, behavior, sexual_selection, reproductive, specimen, reproductive_success, partner, population)*

According to [39], BTM explicitly models the word co-occurrence patterns (i.e., biterms) in the whole corpus. In particular, it is most effective when performed on short texts, as word co-occurrence patterns are sparse and not reliable. The documents used in our study were not short, with an average word count of 1434, yet the model has been shown to outperform LDA even on normal texts [39]. A few of the 17 topics produced by BTM are listed below:

Topic 1: *галактика, масса, частица, звезда, энергия, физика, ядро, чёрный_дыра, вселенная, модель, нейтрино, детектор, наблюдение, эксперимент, вещество (galaxy, mass, particle, star, energy, physics, core, black_hole, universe, model, neutrino, detector, observation, experiment, matter)*

Topic 4: *физика, научный, человек, наука, университет, эксперимент, журнал, проект, теория, открытие, вопрос, институт, начало, решение, сша (physics, scientific, person, science, university, experiment, journal, project, theory, discovery, issue, institute, beginning, solution, usa)*

Topic 12: *самец, самка, особь, потомство, эксперимент, поведение, яйцо, популяция, птица, спаривание, пол, пара, муха, признак, маленький (male, female, specimen, offspring, experiment, behavior, egg, population, bird, mating, sex, pair, fly, feature, small)*

The output reveals a seemingly equal degree of topic interpretability across the models; all topics contain both common and technical terms, which are commonly found in popular science texts. Most of the terms within each topic seem to describe the same concept such as “cancer,” “geology,” or “elementary particles.” Moreover, many topics in all three models contain roughly the same set of words or overlap (cf. the last topics in each model). The only major difference is the number of collocations, or n-grams, presented in a topic. In this respect, NMF appears to be the most sensitive to n-grams out of the three and thus potentially produces better results. To test this assumption, we then evaluated each model’s performance in terms of topic coherence, which is based on the premise that words co-occurring more frequently are more likely to belong to the same topic [39]. Specifically, it measures the degree of semantic similarity between high-scoring words in the topic, often using a PMI score. For BTM, we used the UMass coherence metric proposed by [41], which equaled -125.4 (considerably better than the baseline of -167.1, representing a “good” topic according to the authors). For LDA, the UMass measure was implemented from [42], where it takes values between -14 and 14. and in our case it was -1.75. In both cases, numbers closer to zero indicate higher coherence. As for NMF, we implemented a custom approach using a Word2Vec model and word similarities. The coherence score thus obtained was 0.46 out of 1.0. Unfortunately, while all these results by themselves indicate a rather high semantic interpretability of topics, the lack of a common, out-of-the-box evaluation technique makes it impossible to compare the models directly, leaving human judgment as the only reliable option.

3 Our Approach to Topic Labeling

In this study, we used the following set of techniques for topic label generation: search engine topic labeling, topic labeling using Word2Vec, summarization-based topic labeling, and topic labeling with ChatGPT.

3.1 Search Engine Topic Labeling

In this part of our work, we modified the approach introduced in [5, 32, 33]. The proposed idea is to use web-scraping techniques to generate candidate labels by extracting data from the Internet. Scraping is possible with either WebScraper [43] or Selenium [44]; in both cases, a robot-browser imitates human behavior by navigating through web pages [45]. Some other options for web scrapers include Nutch [46], Pyquery [47], Import.io [48], and Beautiful Soup [49]. Beautiful Soup is essentially the most notable of them as it is one of the basic Python libraries; however, it cannot navigate through web pages or type in input spaces [45].

Selenium is undoubtedly the simplest and most effective Python library for web scraping. The procedure starts with initializing Google Chrome Webdriver—a specific driver sharing all functions and capabilities with the Google Chrome browser. This robot is then tasked with searching for the topics obtained through traditional topic modeling techniques. The whole sequence of tokens, for example, the whole topic, is directed into the search query. The robot looks through the first three pages of search results, collecting approximately 30 titles, with the number varying depending on the topic's content. In Selenium, web page elements can be detected in multiple ways using XPATH, CSS selector, class name, text, and others. XPATH and CSS selector are precise since each web page element has its own address [50]; however, XPATH has been proven to be more efficient and stable for processing Google result pages. XPATH models each web page, which by default is an XML document, as a tree of nodes; there are different types of nodes, including element nodes, attribute nodes, and text nodes. XPATH defines a way to compute a string value for each type of node [51, 52]. In our research, titles were retrieved using the XPATH detector, which is built into the Webdriver.

After collecting the titles, we employed cleaning and lemmatization techniques; the former was necessary because the titles contained many redundant characters such as nontextual symbols and digits. All accented characters were transformed into their unaccented variants. The titles were lemmatized using pymoprhy2. Generated labels were n-grams up to 5 units, although unigrams were also present. Some of the examples are *задание по химия*, *мозг от аксон до нейрон (chemistry homework, the brain from axon to neuron)*. Thus, a label was represented as a set of lemmatized tokens, while in reality, it is an independent utterance. In order to get elaborate labels, a search engine was applied for a second time. Search engines often offer corrections to search queries in case there are misspellings or typos; this function is

useful when obtaining grammatically correct phrases without having to examine them manually. However, since Google offers corrections for Russian queries only if there are personalized settings in the browser, and Google Chrome web browser is not personalized, we had to choose another search engine with Russian as the default language. Although there are many Russian-based search engines (Yandex, Mail.ru), the most efficient for our task was Rambler. We easily reproduced the algorithm originally implemented in relation to Yandex search engine (Labels-Yandex) as Rambler employs Yandex.XML technology. However, Yandex linguistic procedures fail to reconstruct the original grammatical forms of lemmatized phrases; consequently, Yandex ranking results are corrected using Rambler linguistic plug-ins.

The algorithm is similar to that of label generation described in [5, 32, 33]: all topical n-grams (10 items by default) are put into a search query in the Rambler search engine. The output is transmitted to TextRank calculator; further, candidate labels (both unigrams and lexical-grammatical constructions corresponding to frequent patterns) are selected according to TextRank values. The main change is that instead of collecting titles, the algorithm collects the corrected query, which is usually placed just below the search icon. The corrected query was taken with XPATH method, as Beautiful Soup (a standard library for searching elements on the page) does not see the element. The algorithm allowed us to get the following labels: *задание по химии*, *мозг от аксона до нейрона* (*chemistry homework, brain from axon to neuron*). However, it is necessary to note that the proposed method sometimes leaves the labels unchanged. Examples are *животное в сон*, *птица от яйца до взрослый* (*animal to sleep, bird from egg to adult*). Examples of topic generation for the BTM model are given in Table 1. The labels we deemed acceptable are marked in bold.

3.2 Word2Vec Topic Labeling

Following [5, 7, 29], we used distributed semantic modeling for topic labeling. In this case, we trained a Word2Vec model [53] on our corpus to find the n most similar words to the highest scoring words in a given topic. For each topic, a distributed representation of words was obtained using continuous bag-of-words (CBOW), one of the two model architectures available for Word2Vec (along with Skip-gram), which does not account for context or word order. A mean of the projection weight vectors of the given words was calculated and then compared to the word vectors in terms of cosine similarity. The words with sufficiently high values were ranked from highest to lowest, and the three most similar words were considered potential topic labels. Some of the topics and their respective labels are listed in Table 2.

It is clear that the labels thus obtained are words synonymous with the original topical terms, yet they ultimately fail to describe the overall content of a given topic, making it more difficult to interpret. Instead, we searched for a method that would yield a general word or phrase summarizing the meaning of the entire topic.

Table 1 Labels generated by Search Engine output processing

Topic	Search engine topic labeling
физика, научный, человек, наука, университет, эксперимент, журнал, проект, теория, открытие, вопрос, институт, начало, решение, США (physics, scientific, person, science, university, experiment, journal, project, theory, discovery, question, institute, start, solution, USA)	***наука в США и России, наука в США, метафизика и наука,*** *методология и метод,* ***метод и технология*** *(****science in the USA and Russia, science in the USA, metaphysics and science,*** *methodology and method,* ***method and technology****)*
человек, мозг, нейрон, животное, эксперимент, поведение, сигнал, мышь, испытуемый, песня, птица, информация, уровень, обучение, социальный (human, brain, neuron, animal, experiment, behavior, signal, mouse, test subject, song, bird, information, level, learning, social)	*сознание и мозг как мозг, нейронаука для медицина и психология, нейрон и душа, образование и наука, медицина и психология (****consciousness and brain*** *as a brain,* ***neuroscience for medicine and psychology****,* ***neuron and soul****, education and science,* ***medicine and psychology****)*
галактика, масса, частица, звезда, энергия, физика, ядро, чёрный_дыра, вселенная, модель, нейтрино, детектор, наблюдение, эксперимент, вещество (galaxy, mass, particle, star, energy, physics, core, black_hole, universe, model, neutrino, detector, observation, experiment, matter)	***нуклон синтез в вселенная, дыра в ентре,*** *портрет в интерьере,* ***вселенная и еловек, физика и астрофизика*** *(****nucleon fusion into the universe, hole in the center****, portrait in the interior,* ***universe and man, physics and astrophysics****)*

Table 2 Labels generated by Word2Vec model

Topic	Word2Vec topic labeling
мутация, хромосома, ***аллель****, старение, ребёнок, частота, днк, изменчивость, выборка,* ***генотип****,* ***фенотип****, потомок, мать, полиморфизм, вредный (mutation, chromosome,* ***allele****, ageing, child, frequency, dna, variability, sample,* ***genotype****,* ***phenotype****, descendant, mother, polymorphism, detrimental)*	***фенотип, аллель, генотип (phenotype, allele, genotype)***
днк, мышь, опухоль, рнк, ***фермент****,* ***белок****, ткань, рак, клеточный, мутация, синтез, заболевание, аминокислота, кровь, иммунный (dna, mouse, tumor, rna,* ***enzyme****,* ***protein****, tissue, cancer, cellular, mutation, synthesis, disease, amino acid, blood, immune)*	***фермент, белок,*** *вирус (****enzyme, protein,*** *virus)*

3.3 Summarization-Based Topic Labeling

In this section, we propose summarization as a new way to generate topic labels. For this purpose, a set of labels was obtained through an abstractive summarization T5 model for Russian. The model is based on Google's mT5-base [54]; it was fine-tuned by David Dale (known as "cointegrated" on HuggingFace Hub). The summarization model is a useful tool for finding the most important labels out of 10 or more items. The

main problem is that any summarization model is by its nature a text2text-generation model; therefore, it generates text with sentences, not just a set of n-grams [55]. To tackle the issue, one can put a comma or a period after each n-gram, for example,

галактика, масса, частица, звезда, энергия, физика, ядро, чёрный_дыра, вселенная, модель, нейтрино, детектор, наблюдение, эксперимент, вещество (galaxy, mass, particle, star, energy, physics, nucleus, black_hole, universe, model, neutrino, detector, observation, experiment, substance)

This significantly reduces the chance that the summarization model will generate a full sentence. The structure, such as the one presented above, was passed to the model. The model generates the most important n-grams, separating them by commas —the way it was in the input. Thus, putting a comma between is a successful strategy to prevent a model from generating a full sentence. The other problem is that some n-grams are repeated several times: in the previous example (see Table 3), the unigram "ядро" (core) occurs twice. This problem can be solved by increasing a repetition penalty in the Transformers pipeline, but in this case, one would need to customize it; adjusting settings for each topic individually is generally not a good idea. The other possible solution, the one that was chosen for this research, is transforming a Python list into a Python set. It is also worth mentioning that the summarization model might generate a label that is not initially presented in the topic, although this was extremely rare. Acceptable labels in Table 3 are marked bold.

Table 3 Labels generated by an abstractive summarization model

Topic	Summarization-based topic labeling
галактика масса частица ***звезда*** *энергия физика* ***ядро*** *□****ёрн****ый_****д****ыра вселенная модель нейтрино детектор наблюдение эксперимент вещество (galaxy mass particle* ***star*** *energy physics* ***nucleus black_hole*** *universe model neutrinos detector supervision experiment substance)*	***звезда, ядро,*** *ядро,* ***□ёрный_дыра,*** *все (****star, nucleus,*** *nucleus,* ***black_hole,*** *all)*
клетка *белок* ***нейрон*** *рецептор организм тип белка молекула животное* ***ядро*** *ген вещество ткань сигнал клеточный (****cell*** *protein* ***neuron*** *receptor organism protein type molecule animal* ***nucleus*** *gene substance tissue signal cellular)*	***□еловек, клетка, нейрон,*** *нейрон,* ***ядро*** *(****human, cell, neuron,*** *neuron,* ***nucleus****)*

3.4 ChatGPT Topic Labeling

Finally, ChatGPT topic labeling was employed to verify and generalize topic labels obtained at previous stages. For this purpose, a set of labels was generated with ChatGPT, a chatbot developed by OpenAI [56]. Specifically, the bot was asked to (a) produce one or more general expressions that would cover the meaning of a given topic and (b) choose the most important word within the topic. The same was asked regarding the labels obtained via search engines; additionally, if there were more than one general expression, the bot was tasked with selecting the most important one. At this point, a total of 59 topics provided by LDA, BTM, and NMF as well as 59 labels for each of them were given to the bot. As a result, a set of three different labels was assigned to each topic. Some examples are presented in Table 4.

Generally, the more plausible labels were obtained by retrieving the most important word or word phrase within the general expressions produced by ChatGPT. To verify the results, we used an evaluation procedure based on [5] by asking 19 human assessors to rate the generated labels on a scale from 0 to 2, where 0 indicates that a label does not cover the content of a topic, 1 indicates that a label somewhat covers the content of a topic, and 2 indicates that a label covers the content of a topic completely. Average weights were calculated for each group of labels; labels with a mean rating $\geq$1.5 were considered good while those $\leq$0.5 were considered bad. The results are shown in Table 5. As expected, the labels were generally deemed satisfactory, with the most important words among the general expressions receiving the highest values. The expanded topic labeling procedure with the best weight 1.52 outperforms the one introduced in [5], where Labels-Yandex gets a high weight of 1.4 and Labels-ESA gets a medium weight of 0.98 (with a maximum threshold of 2).

4 Conclusion

In this chapter, we present modifications of previously developed techniques for topic label assignment and demonstrate the applicability of these techniques in the task of structuring popular science texts in corpora obtained from web sources. In our case, topic modeling was performed by means of Nonnegative matrix factorization, Latent Dirichlet Allocation, and Biterm topic modeling. The topic labels generated with the help of search engine topic labeling, topic labeling with Word2Vec, summarization-based topic labeling, and topic labeling using ChatGPT complement each other, as there are few intersections in the sets of topic labels. Thus, our work introduces an improved version of topic label generation as an ensemble of methods combining inner and outer sources of labels. Further development of our research deals with the application of multimodal topic modeling with label assignment for online scientific resources.

Table 4 Labels generated by ChatGPT

Topic	Topic labels (Google)	The most important word within the topic	The most important word within the labels	The most important word for general expressions
физика, научный, человек, наука, университет, эксперимент, журнал, проект, теория, открытие, вопрос, институт, начало, решение, США (physics, scientific, person, science, university, experiment, journal, project, theory, discovery, issue, institute, beginning, solution, USA)	*наука в США и Россия, наука в США, метафизика и наука, методология и метод, метод и технология (science in the USA and Russia, metaphysics and science, methodology and method, method and technology)*	*наука (science)*	*методология и метод (methodology and method)*	*научные исследования (scientific research)*
опухоль, рак, метастаз, раковый_клетка, клетка, мутация, пациент, раковый_опухоль, терапия, лечение, ткань, ингибитор, опухолевый_клетка, рост, железа (tumor, cancer, metastasis, cancer_cell, cell, mutation, patient, carcinoma, therapy, treatment, tissue, inhibitor, tumor_cell, growth, gland)	*перспектива в лечение, лечение, гормонотерапия при раке, важность, опухолевый рост (promise in treating, treatment, hormone therapy for cancer, importance, tumor growth)*	*раковый_клетка (cancer_cell)*	*лечение (treatment)*	*лечение рака (cancer treatment)*

Table 5 The average ratings for each type of labels

The most important word within the topic	The most important word within the labels	The most important word among general expressions
1.16	0.95	**1.52**

References

1. Daud, A., Li, J., Zhou, L., Muhammad, F.: Knowledge discovery through directed probabilistic topic models: a survey. In: Proceedings of Frontiers of Computer Science in China, pp. 280–301. https://www.researchgate.net/publication/215904200_Latent_Dirichlet_allocation_LDA_and_topic_modeling_models_applications_future_challenges_a_survey (2010)
2. Milkova, M.A.: Topic models as a tool of "distant reading". Digit. Econ. **1**(5), 57–70. http://digital-economy.ru/images/easyblog_articles/520/DE-2019-01-06.pdf?ysclid=lefaetif1z601986150 (2019) [in Russian]
3. Vorontsov, K.V.: Probabilistic topic modeling: ARTM regularization theory and the BigARTM open source library. http://www.machinelearning.ru/wiki/images/d/d5/Voron17survey-artm.pdf (2023) [in Russian]
4. Karpovich, S.N.: Russian-language corpus of texts of SKTM-ru for topic model development. In: Proceedings of the International Conference "Corpus Linguistics-2015", Saint-Petersburg (2015) [in Russian]
5. Mitrofanova, O., Kriukova, A., Shulginov, V., Shulginov, V.: E-hypertext media topic model with automatic label assignment. In: Recent Trends in Analysis of Images, Social Networks and Texts: 9th International Conference, AIST 2020, Revised Supplementary Proceedings. Communications in Computer and Information Science, vol. 1357, pp. 102–114. Springer (2021). https://doi.org/10.1007/978-3-030-71214-3_9
6. Mamaev, I.D., Mitrofanova, O.A.: Automatic detection of hidden communities in the texts of Russian social network corpus. In: Filchenkov, A., Kauttonen, J., Pivovarova, L. (eds.) Artificial Intelligence and Natural Language: 9th Conference, AINL 2020, Helsinki, Finland, October 7–9, 2020, Proceedings. Communications in Computer and Information Science, vol. 1292, pp. 17–33. Springer (2020). https://doi.org/10.1007/978-3-030-59082-6_2
7. Mitrofanova, O., Sampetova, V., Mamaev, I., Moskvina, A., Sukharev, K.: Topic modeling of the Russian corpus of Pikabu posts: author-topic distribution and topic labeling. In: CEUR Workshop Proceedings, 2813, pp. 101–116 (2021)
8. Nikolenko, S.I., Koltcov, S., Koltsova, O.: Topic modeling for qualitative studies. J. Inf. Sci. **43**, 1–15 (2017)
9. Khawaji, K., Almubark, I., Almalki, A., Taylor, B.: Similarity matching for workflows in medical domain using topic modeling. In: 2018 IEEE World Congress on Services (SERVICES), pp. 19–20, San Francisco, CA, USA (2018)
10. Dowling, M., Piepenbrink, A., Saqib, A., Helmi, H.: Machine learning in finance: a topic modeling approach. https://arxiv.org/ftp/arxiv/papers/1911/1911.12637.pdf (2019)
11. Vorontsov, K.V., Voronov, S.O.: Automatic filtering of Russian scientific content using machine learning and topic modeling. In: International Conference on Computational Linguistics and Intellectual Technologies "Dialogue–2015", Moscow. http://www.dialog-21.ru/media/2135/vorontsov.pdf (2015)
12. Mitrofanova, O.A., Sedova, A.G.: Topic modeling in parallel and comparable fiction Texts (the case study of English and Russian prose). In: Information Technology and Computational Linguistics (ITCL 2017). Association for Computing Machinery (2017)
13. Rhody, L.M.: Topic modeling and figurative language. J. Digit. Humanit. 2(1). http://journalofdigitalhumanities.org/2-1/topic-modeling-and-figurative-language-by-lisa-m-rhody/ (2012)

14. Sherstinova, T., Mitrofanova, O., Skrebtsova, T., Zamiraylova, E., Kirina, T.: Topic modeling with NMF vs. expert topic annotation: the case study of Russian fiction. In: Martínez-Villaseñor, L., Ponce, H., Herrera-Alcántara, O., Castro-Espinoza, F.A. (eds.) Advances in Computational Intelligence. 19th Mexican International Conference on Artificial Intelligence, MICAI 2020, Proceedings Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 12469, pp. 134–151. Springer (2020). https://doi.org/10.1007/978-3-030-60887-3_13
15. Nokel, M.A., Lukashevich, N.V.: Topic models: adding bigrams and taking account of the similarity between unigrams and bigrams. Numer. Methods Program. **16**(2), 215–234 (2015)
16. Zamiraylova, E., Mitrofanova, O.: Dynamic topic modeling of Russian fiction prose of the first third of the XXth century by means of non-negative matrix factorization. In: R. Piotrowski's Readings in Language Engineering and Applied Linguistics. PRLEAL-2019: Proceedings of the III International Conference RWTH Aahen University. CEUR Workshop Proceedings, vol. 2552, pp. 321–339 (2019)
17. Greene, D., Cross, J.: Exploring the political agenda of the European Parliament using a dynamic topic modeling approach. Polit. Anal. **25**, 77–94 (2016) https://arxiv.org/pdf/1607.03055.pdf
18. Dieng, A.B., Ruiz, F.J.R., Blei, D.M.: Topic modeling in embedding spaces. https://arxiv.org/abs/1907.04907 (2019)
19. Grootendorst, M.: BERTopic: neural topic modeling with a class-based TF-IDF procedure. https://arxiv.org/pdf/2203.05794.pdf (2022)
20. Lau, J.H., Newman, D., Karimi, S., Baldwin, T.: Best topic word selection for topic labeling. In: COLING'10 Proceedings of the 23rd International Conference on Computational Linguistics, pp. 605–613. Association for Computational Linguistics, Stroudsburg, PA (2010)
21. Aletras, N., Stevenson, M., Court, R.: Labeling topics using unsupervised graph-based methods. In: Proceedings of the 52nd Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers), pp. 631–636. ACL, Baltimore, MD (2014)
22. Mei, Q., Shen, X., Zhai, C.: Automatic labeling of multinomial topic models. In: Proceedings of the 13th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining KDD'07, pp. 490–499. ACM Press, New York, NY, USA (2007)
23. Cano Basave, A.E., He, Y., Xu, R.: Automatic labeling of topic models learned from twitter by summarisation. In: Proceedings of the 52nd Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers), pp. 618–624. Association for Computational Linguistics, Stroudsburg, PA, USA (2014)
24. Kou, W., Li, F., Baldwin, T.: Automatic labeling of topic models using word vectors and letter trigram vectors. In: Proceedings of the Eleventh Asian Information Retrieval Societies Conference (AIRS 2015), № 1, pp. 253–264 (2015)
25. Nolasco, D., Oliveira, J.: Detecting knowledge innovation through automatic topic labeling on scholar data. In: 49th Hawaii International Conference on System Sciences (HICSS), pp. 358–367. IEEE Computer Society, Koloa, HI (2016)
26. Magatti, D., Calegari, S., Ciucci, D., Stella, F.: Automatic labeling of topics. In: ISDA 2009 9th International Conference on Intelligent Systems Design and Applications, pp. 1227–1232. IEEE, Pisa (2009)
27. Lau, J.H., Grieser, K., Newman, D., Baldwin, T.: Automatic labeling of topic models. In: Proceedings of the 49th Annual Meeting of the Association for Computational Linguistics: Human Language Technologies, vol. 1, pp. 1536–1545. Association for Computational Linguistics, Stroudsburg, PA (2011)
28. Hulpus, I., Hayes, C., Karnstedt, M., Greene, D.: Unsupervised graph-based topic labeling using DBpedia. In: Proceedings of the Sixth ACM International Conference on Web Search and Data Mining WSDM'13, pp. 465–474 (2013)
29. Bhatia, S., Lau, J.H., Baldwin, T.: Automatic labeling of topics with neural embeddings. In: 26th COLING International Conference on Computational Linguistics, pp. 953–963 (2016)

30. Allahyari, M., Pouriyeh, S., Kochut, K., Arabnia, H.R.: A knowledge-based topic modeling approach for automatic topic labeling. Int. J. Adv. Comput. Sci. Appl. **8**(9), 335–349 (2017)
31. Mao, X., Hao, Y.-J., Zhou, Q., Yuan, W., Yang, L., Huang, H.: A novel fast framework for topic labeling based on similarity-preserved hashing. In: COLING 2016, pp. 3339–3348 (2016)
32. Kriukova, A., Erofeeva, A., Mitrofanova, O., Sukharev, K.: Explicit semantic analysis as a means for topic labeling. In: Ustalov, D., Filchenkov, A., Pivovarova, L., Žižka, J. (eds.) Artificial Intelligence and Natural Language Processing: 7th International Conference, AINL 2018, St. Petersburg, Russia, October 17–19, 2018, pp. 167–177. Springer, Cham (2018)
33. Erofeeva, A., Mitrofanova, O.: Automatic topic label assignment in topic models for Russian text corpora. In: Structural and Applied Linguistics, vol. 12, pp. 122–147, Saint-Petersburg (2019) [in Russian]
34. https://elementy.ru/
35. https://www.nltk.org/
36. https://pypi.org/project/pymorphy2/
37. https://radimrehurek.com/gensim/
38. Cheng, X., Yan, X., Lan, Y., Guo, J.: BTM: topic modeling over short texts. IEEE Trans. Knowl. Data Eng. **26**(12), 2928–2941 (2014)
39. Martin, F., Johnson, M.: More efficient topic modeling through a noun only approach. In: Proceedings of Australasian Language Technology Association Workshop, pp. 111–115 (2015)
40. Egger, R., Yu, J.: A topic modeling comparison between LDA, NMF, Top2Vec, and BERTopic to demystify Twitter posts. Front. Sociol. **7** (2022)
41. Mimno, D., Wallach, H., Talley, E., Leenders, M., McCallum, A.: Optimizing semantic coherence in topic models. In: Proceedings of the 2011 Conference on Empirical Methods in Natural Language Processing, pp. 262–272 (2011)
42. Röder, M., Both, A., Hinneburg, A.: Exploring the space of topic coherence measures. In: Proceedings of the Eighth ACM International Conference on Web Search and Data Mining (WSDM'15), pp. 399–408 (2015)
43. https://webscraper.io/
44. https://www.selenium.dev/downloads/
45. Zhao, B.: Web scraping. In: Encyclopedia of Big Data. Springer International Publishing (2017)
46. https://nutch.apache.org/
47. https://pypi.org/project/pyquery/
48. https://www.import.io/
49. https://pypi.org/project/beautifulsoup4/
50. Chapagain, A.: Hands-On Web Scraping with Python. Packt Publishing (2019)
51. XML Path Language (XPath) Version 1.0 (renderx.com): https://www.renderx.com/~renderx/portal/Tests/xmlspec/xpath.pdf
52. Olteanu, D., Meuss, H., Furche, T., Bry, F.: XPath: Looking Forward. In: EDBT 2002 Workshops, LNCS 2490, pp. 109–127 (2002)
53. Mikolov, T., Chen, K., Corrado, G.S., Dean J.: Efficient estimation of word representations in vector space. https://arxiv.org/abs/1301.3781 (2013)
54. Xue, L., et al.: mT5: a massively multilingual pre-trained text-to-text transformer. In: Proceedings of the 2021 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies. https://arxiv.org/abs/2010.11934 (2021)
55. Narang, S. et al.: WT5?! Training text-to-text models to explain their predictions. https://arxiv.org/abs/2004.14546 (2020)
56. https://openai.com/blog/chatgpt

Where Is Happily Ever After? A Study of Emotions and Locations in Russian Short Stories of 1900–1930

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Abstract The chapter tackles the problem of the automatic detection of emotions in literary texts using distributional semantics techniques. The experiment was carried out on Russian short stories from the 1900s to 1930s. We investigated the emotional lexis distribution across different locations in narratives. At first, we calculated the semantic association score between each word in a corpus and a certain emotion label. This stage resulted in 12 ordered lists of semantic associates for each emotion label: *fear*, *anger*, *sadness*, *happiness*, *shame*, *pride*, *disgust*, *pleasure*, *surprise*, *relief*, *amusement*, and *content.* Then, we calculated the frequency of these emotional words per story and normalized the values. Anger turned out to be the most prominent emotion expressed in the texts. In the next stage, we compared the obtained distributions with the information on where the action takes place in each story. Those data were received from previous annotations by readers. Based on mean relative frequencies, the places with the highest emotionality appeared to be *apartments*, *theaters*, *Petersburg*, *pubs*, and *halls*. Additionally, the emotional diversity of a few thematically specific locations is considered.

Keywords Sentiment analysis · Distributional semantics · Russian short story · Emotional lexicon

1 Introduction

Emotions are an integral part of human existence. Basic emotions, in one interpretation of the term, deal with cross-cultural and even interspecies similarities in behavior and reactions to stimuli. Emotions have an external manifestation (e.g., facial expressions) associated with a physiological state, such as brain activity and oxygen levels [1]. Of course, emotions find their reflection in language: from individual terms expressing different mental states to connotations, metaphors, and

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_10

higher-level phenomena like the general mood of the text. When designed in a certain way, text can produce the right effect on the addressee. In the field of natural language processing, emotion analysis is primarily associated with the task of sentiment analysis, focusing on problems related to the processing of product reviews, opinion mining of social media posts, forecasting the market, and conducting political campaigns [2]. Recently, however, increasing interest has been shown toward the affective category in fiction, from calculating the correspondence of the text with particular emotions to modeling sentimental interactions between characters [3–5].

One of the tasks within the linguistic study of emotions is the assignment of emotional scores to words and building emotional lexicons for further use. Emotional scores of words can be used to explore human nature through norms and deviations in how people use emotional words, applied in calculating the sentiment of the whole message and predicting the valence of other words [6].

The chapter describes a particular approach for detecting and identifying emotional words in literary texts, namely, Russian short stories from the early twentieth century [7], and their distributions over the narrative. The study is performed on a sample of 505 texts by different authors with a total size of 1,834,500 words. Specifically, we delve into the distribution of emotional lexis across locations where the story action takes place. We used a vector space model for Russian and a list of emotional labels to obtain ordered lists of emotional words with scores without using manual annotations. Subsequently, we conducted an analysis of the distribution of these emotional words across the texts, for which different types of locations were previously manually annotated.

2 Analyzing Emotions

2.1 Emotions, Labels, and Lexicons

There are two major approaches to defining and studying emotions: dimensional and categorical. The dimensional approach defines emotions through values on several bipolar scales that represent components of emotion. The most popular model of this kind is VAD: valence, arousal, and dominance [1, 6]. The combination of values on each scale defines the particular emotion label. Categorical models, on the other hand, are based on the existence of a number of discrete categories or emotional labels. Studies in this approach are more focused on creating such lists (e.g., well-known lists of five or six basic emotions: *happiness*, *anger*, *sadness*, *fear*, *disgust*, *surprise*). Both views have proved useful in empirical studies, including the not-so-unambiguous attempt to combine them [8]. Westbury and colleagues in paper [1] bring together human affective ratings and semantic associations between words and emotional labels based on co-occurrence. As one of the main research tasks, the authors test how well twelve different basic emotion label sets predict the given VAD values.

One of the first and most influential works aimed at the collection of emotional word ratings was performed by Bradley and Lang [9], who created the Affective Norms for English Words (ANEW). The affective score consisted of values on three dimensions: pleasure (*happy* vs. *unhappy*), arousal (*excited* vs. *calm*), and dominance (*controlled* vs. *in control*). Participants used Self-Assessment Manikin (SAM), i.e., picture scales that graphically depict the 9-point scales for evaluating each word among 600 words in three dimensions. Later, the lexicon was extended to include 13,915 words that were human-annotated in the same affective terms [6]. The next step was the NRC VAD Lexicon [10], which includes more than 20,000 English words and uses a different approach to evaluating emotions—Best-Worst Scaling, which authors claim to be more adequate. Finally, there is the NRC Word-Emotion Association Lexicon, based on manually annotated associations of words with basic emotions [11]. The NRC lexicons obtained by auto-translation are available for different languages, including Russian.

2.2 Emotions and Distributional Semantics

In [1], authors addressed the issue of basic emotion label lists and proposed a computational method for evaluating these lists, based on word co-occurrence information, thus combining experimental psychology and distributional semantics. The authors make a strong point that lexical labels we use when referring to emotions might not be exactly representative of the underlying phenomena of basic emotions. They point out that emotions likely constitute an "emotional space," where distinct lexical labels correspond to specific regions. These regions are organized within a particular topology and situated at varying distances, potentially measurable in size. This authorizes us to pose questions such as "How close are *anger* and *fury*?" or "Is the relation between *love* and *hatred* equivalent to that between *hope* and *despair*?" not only on the semantic level but on the physical and psychological representation level as well. From a linguistic point of view, though, such questions are obviously associated with the area of distributional semantics and vector space language models.

We followed the approach presented by A. Jacobs in [4] that uses vector space models to study the emotionality of literary texts. The researchers developed the Python-based sentiment analysis tool SentiArt[1] [ibid.]. It does not support the Russian language, but the idea behind it is generally reproducible with one's own data. This approach allows us to calculate the degree of semantic association between each word in a corpus and a certain emotion. The obtained values can either be summed up to classify data into generally positive or negative or be used for more complex emotional analysis, the latter being our case. The first task is to choose the list of emotional labels that are going to be involved in the analysis. The SentiArt

[1] https://github.com/matinho13/SentiArt

tool uses six basic emotions, usually attributed to Paul Ekman [12]: *happiness*, *anger*, *sadness*, *fear*, *disgust*, and *surprise.* However, in their research, Jacobs and colleagues employ another model, consisting of twice as many labels [4], extended by *contentment*, *pleasure*, *pride*, *relief*, *satisfaction*, and *shame*. For comparison, the NRC Word-Emotion Association Lexicon contains data on eight emotions [11]: *anger*, *anticipation*, *disgust*, *fear*, *joy*, *sadness*, *surprise*, *and trust.*

2.3 Calculating Emotions

Since the initial number of labels does not affect the outcome and the calculations are performed automatically, we have ended up using a combined model with 12 emotions. These emotions are represented by corresponding nouns: *happiness* ("schastye"), *contentment* ("udovolstvie"), *pride* ("gordost'"), *relief* ("oblegcheniye"), *amusement* ("vesel'ye"), *pleasure* ("naslazhdeniye"), *surprise* ("udivleniye"), *anger* ("zlost'"), *sadness* ("grust'"), *fear* ("strakh"), *disgust* ("otvrashcheniye"), *and shame* ("styd").

A language model, using the data on word co-occurrence of words, organizes the data in a vector space in such a way that words with similar meanings (those that occur in similar contexts) are positioned close to each other. This reminds us of the idea of emotional space and its internal structure we have discussed earlier. By using a vector space model, we can answer the question of how similar the meanings of the words are by measuring the distance between their vector representations (or embeddings).

For each emotion, the degree of semantic association to the target words (labels) was calculated as the cosine distance between the vectors obtained using the fastText skipgram model trained on the Russian National Corpus.[2] Based on the scores, we created ordered lists of words, semantically close to emotion labels. If the score exceeded the threshold value of 0.4, the word was considered as somehow referring to the corresponding emotion and was used in further calculations. The highest number of unique lexemes turned out to be associated with the emotion of *anger* (3681); the second and third places are occupied by *amusement* (1326) and *sadness* (1329). The emotions of *relief* (137) and *happiness* (223) have the lowest lexical diversity. If we divide emotions into positive and negative in terms of valency, then the total number of negative lexemes (7631) significantly exceeds the total number of positive ones (3653). Although so far we have not taken into account frequencies, this preliminarily refutes the positivity bias postulated in several studies [6, 13].

For each of the "emotional" words, we also calculated the frequency (number of occurrences in a corpus) to estimate its contribution to the emotional charge of the texts (see Table 1).

[2] http://vectors.nlpl.eu/repository/20/181.zip

Table 1 Top 5 words for *sadness* emotion

Word	Similarity score	Frequency
Sadness (*грусть*)	1.000	103
Sorrow (*печаль*)	0.770	71
Melancholy (*тоска*)	0.728	428
Sad (*грустный*)	0.723	268
Bitterness (*горечь*)	0.718	65

There are interesting nuances when it comes to automatically generated lists of emotional words. When measuring similarity based on vector distances, not only words with synonymous meanings but also words that are semantically related in other ways, such as hypernyms, hyponyms, collocates, and even antonyms, may happen to be closely associated with the target word. For example, in the list of words associated with *sadness*, the word "nejnost'" (*tenderness*, 0.648, 114) ranks 10 while "zadumchivost'" (*thoughtfulness*, *dreaminess*, 0.621, 26) ranks 15. Similarly, in the case of *pleasure*, the derivative antonym "neudovolstvije" (*displeasure*, 0.692, 27) ranks 7 with a significant similarity score.

It is possible for a word to score high for different emotions. When this is the case, the similarity scores still differ, reflecting differences in meanings. This is partly because all emotional words constitute a particular semantic group and thus occupy a specific region in vector space (that, by the hypothesis discussed earlier, topologically corresponds to human emotional space). For example, the word "vlyublennost'" (*being in love*) has a score of 0.404 as a marker of *happiness* and a score of 0.460 as a marker of *sadness*. This may mean that, based on the National Corpus of the Russian Language, falling in love has a slightly higher possibility of making one sad rather than happy.

At the next stage of the study, for each story from the sample, the number of "emotional" words was calculated, as well as their total weight (based on the cosine similarity value) for each emotion (see Tables 2 and 3). This data was further used when analyzing emotional distribution over locations.

3 Emotional Locations Analysis

Prior to this study, as part of the literary annotation of the Russian short story corpus, each story was annotated with the locations where the action takes place (as understood by the reader). It must be noted that typically, geographic location is of predominant interest for such annotations [14]. In our case, the change of scenery was meant to be traced continuously, so habitual locations were included, such as *apartments*, *banks of rivers*, *restaurants*, *trains*, and *stairs*, along with some undefined places (*where the party takes place*, *on* the *way to work*, etc.). Based on this annotation, location labels were assigned for each story following two rules: (1) repetitions were ignored, so each location was either present or not; (2) labels were normalized from story-specific to more generic. For example, *Petrograd*, *Petersburg*, and *Nevsky Avenue* were merged into a single generic tag—*Petersburg*. In total, 380 different types of locations were distributed across all stories.

Table 2 Total score for each emotion and frequency, not normalized by length (fragment)

Story	fear_freq	fear_score	sad_freq	sad_score	anger_freq	anger_score
Resort Husband (*Kurortnyj muzh*) by A. Amfiteatrov	21	9.714	33	14.91	48	21.799
Drops (*Kapli*) by Yu. Baltrushajtis	54	26.639	76	35.819	45	20.623
The Seven Who Were Hanged (*Rasskaz o semi poveshennykh*) by L. Andreev	288	149.135	339	160.693	393	179.353
The Will (*Zaveshchanie*) by B. Bentovin	12	5.599	18	8.369	16	7.292
Own Minute (*Svoya Minuta*) by N. Annenkova-Bernar	96	46.92	122	59.69	204	93.122

Table 3 Mean score for emotions (fragment)

Story	Happiness	Fear	Relief	Sadness
The Sea Deceived (*Obmanulo more*) by V. Gofman	0.199	0.194	0.148	0.195
Too Late (*Pozdno*) by A. Verbitskaya	0.203	0.195	0.151	0.195
The Apple's Law (*Zakon yabloka*) by N. Zarudin	0.193	0.190	0.151	0.193

3.1 Emotiveness of Location

To gain emotional portrayals of locations, the most frequent tags were selected, such as *house* (170),[3] *street* (127), *road* (109), *room* (53), *village* (51), *yard* (49), *hut* (47), *city* (44), *forest* (43), *apartment* (42), *on a visit* (35), *train* (31), *countryside* (31), *hospital* (29), *garden* (28), *study room* (27), *station* (22), *railway station* (21), *bank of a river/sea* (18), *cemetery* (18), *field* (18), *at the front* (17), *Petersburg* (17), *pub* (17), *mountains* (16), *river* (16), *hall* (15), *hallway* (15), *church* (15). It allowed us to avoid emotional peaks that were produced by locations that were unique for the whole corpus. Additionally, it was decided to take into consideration some interesting tags of historical and thematic perspectives—*Moscow* (14), *prison* (12), *prison cell* (8), *train cabin* (13), *theater* (12), and *factory* (8). Regarding thematically specific location, we relied on our previous discussions [15, 16] of the topic modeling results consistently forming topics linked to plots of traveling on trains, visiting or participating in theater performances, and working on a factory, when applied to short stories from the same period.

[3] Hereinafter, the number of occurrences in the corpus is indicated in parentheses.

Next, in order to find places that are strongly associated with emotions, we decided to calculate the mean rank for each location. For each story, the relative number of emotional lexis per emotion normalized by the length of the document was found. After that, the mean percentage of emotional lexis per emotion for subsets of stories grouped by selected locations was computed and, based on that, the ranks of locations per emotion were obtained. To generalize the "emotional fields" of locations, mean ranks were taken into account. As shown in Table 4,

Table 4 List of popular locations (sorted by degree of emotionality)

Rank	Location	Mean rank
1	Apartment (*kvartira*)	4.17
2	Theater (*teatr*)	4.92
3	Petersburg (*Peterburg*)	6.58
4	Pub (*traktir*)	8.08
5	Hall (*zal*)	8.17
6	Room (*komnata*)	9
7	Garden (*sad*)	9.25
8	Hospital (*bol'nica*)	10.08
9	Train (*poezd*)	11.08
10	Prison cell (*kamera*)	11.48
11	Prison (*tur'ma*)	12.50
12	Cemetery (*kladbischshe*)	13.33
13	Cabin (*vagon*)	14.25
14	Street (*ulica*)	14.50
15	On a visit (*v gostyakh*)	15.00
16	Road (*doroga*)	16.08
17	City (*gorod*)	16.33
18	Railway station (*vokzal*)	17.17
19	Yard (*dvor*)	17.58
20	House (*dom*)	18.42
21	Hallway (*coridor*)	19.00
22	Station (*stanciya*)	19.83
23	Church (*cerkov'*)	21.17
24	Study room (*cabinet*)	23.58
25	Field (*pole*)	23.58
26	Forest (*les*)	24.08
27	Bank (*bereg*)	24.08
28	Village (*derevnya*)	26.83
29	River (*reka*)	27.08
30	Factory (*zavod*)	27.50
31	Hut (*izba*)	30.50
32	Countryside (*selo*)	31.00
33	Mountains (*gory*)	31.08
34	At the front (*na fronte*)	31.33
35	Moscow (*Moskva*)	31.42

locations with the highest emotionality are *apartments*, *theaters*, *Petersburg*, *pubs*, and *halls*. It means that these locations generally appear in stories with a large number of emotive lexis.

Though it seems quite expected to see "common," in terms of where people usually tend to gather, locations at the top of the list, the salience of such places as *theater* and *pub* seems to be quite intriguing. The emotionality of the actions associated with being at these places contributes to the interpretation—the vibrance of the scenery suggested by these places, probably, prompts the expression of emotions more explicitly in narrative. Indeed, looking into the stories, the lexis of the corresponding scope of emotionality can be found, and moreover, the common perception of the story prompts an emotional uplift in the reader. For example, the fragment from the story "*Decorator's Love*" by Skitalecz:

> Vidite li, e'to budet vtoroj akt. Dvoe zabludilis' noch'yu v stepi. Mesto dolzhno by't' dikoe, gluxoe. Na nix napadaet **strax**. Tut proisxodyat sverx"estestvenny'e veshhi. Vot vy' i napishite takuyu step', chtoby' vsyo by'lo: i dal', i mgla, i tuchi, i chtoby' publike **zhutko** delalos'. . .
>
> *You see, this will be the second act. Two got lost at night in the steppe. The place should be wild, deaf.* ***Fear*** *attacks them. Supernatural things are happening here. So you will write such a steppe, so that everything is: and the distance, and the haze, and the clouds, and the audience is* ***scared***. . .

As can be seen, while discussing the decoration needed to be prepared for the performance, the director and the decorator address the emotional state that corresponds to a certain act.

Interestingly, at the bottom of the list, one can observe locations related to nature (*field*, *forest*, *bank*, *village*, *river*, *countryside*, *mountains*), everyday life (*hut*, *factory*), and wartime (*at the front*). Stories centered around *Petersburg* (6.58) and *Moscow* (31.42) turned out to occupy opposite positions in the list. Thus, here we also observe the contrast between places where people gather (first part) and peopleless locations, such as natural landscapes or lifestyle (second part), with Moscow being an exception. Probably, it is due to the fact that the stories where Moscow is mentioned are also taking place in other, less emotional locations such as *at the front*, *village*, *house*, which levels the emotional vibrancy expected to be found in the context of life in the city. Therefore, we can postulate the importance of the plot when considering emotions related to a specific location or its placing in a text fragment of a certain emotionality that may also influence the results.

3.2 Associating Locations with Emotions

To calculate the degree of association between particular scenery and emotions, the frequency lists of locations per emotion based on the average relative number of lexis of the corresponding emotion were formed (see Fig. 1). For a number of emotions—fear, sadness, amusement, pride—the most typical locations seem to be quite logical. It is interesting that the theater is rather diverse in terms of

emotionality—this is where either "angriest" stories take place or such emotions as pride, pleasure, amusement, and even disgust are involved. At the same time, there are emotion-specific locations. For instance, a *prison cell* that is only found among fear, shame, surprise, and anger.

When tracking distributions of emotions, locations with presumably similar vectors of emotionality single out. In our case, it was assumed that locations such as *at the front*, *cemetery*, *prison*, and *prison cell*, sharing themes of death, violence, and deprivation, would lean toward the representation of similar emotional fields. As

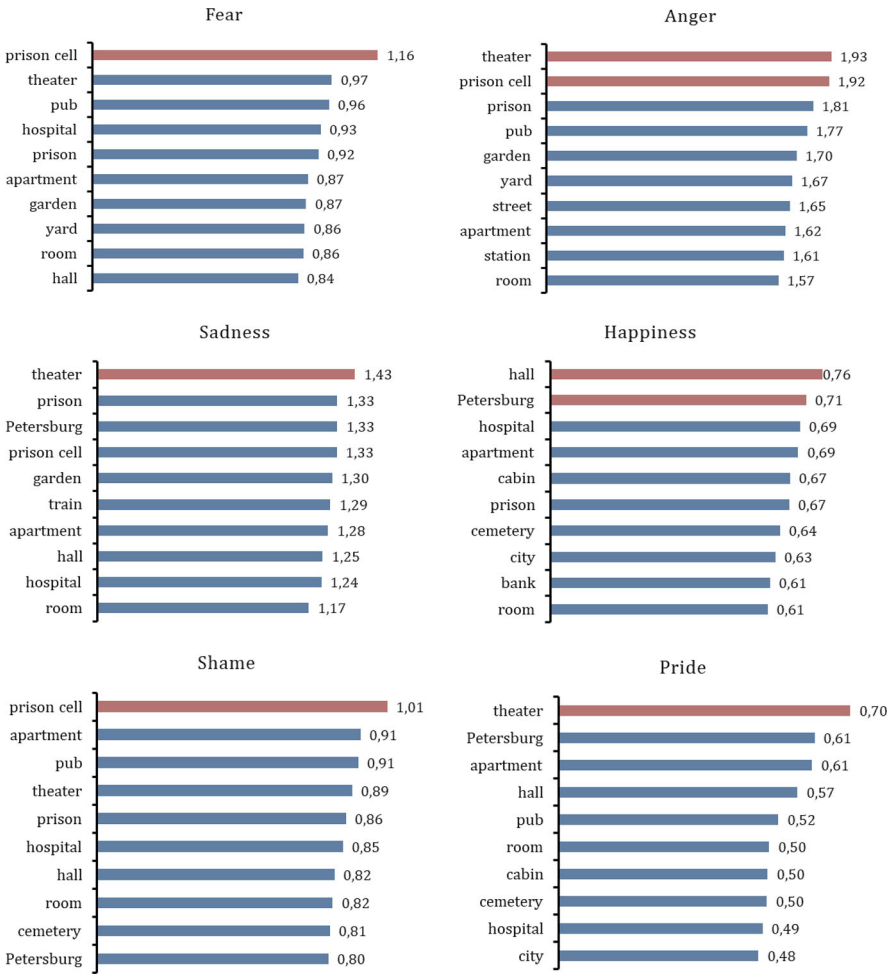

Fig. 1 Frequency lists of locations per emotion (sorted by mean relative percentage of emotional lexis in stories)

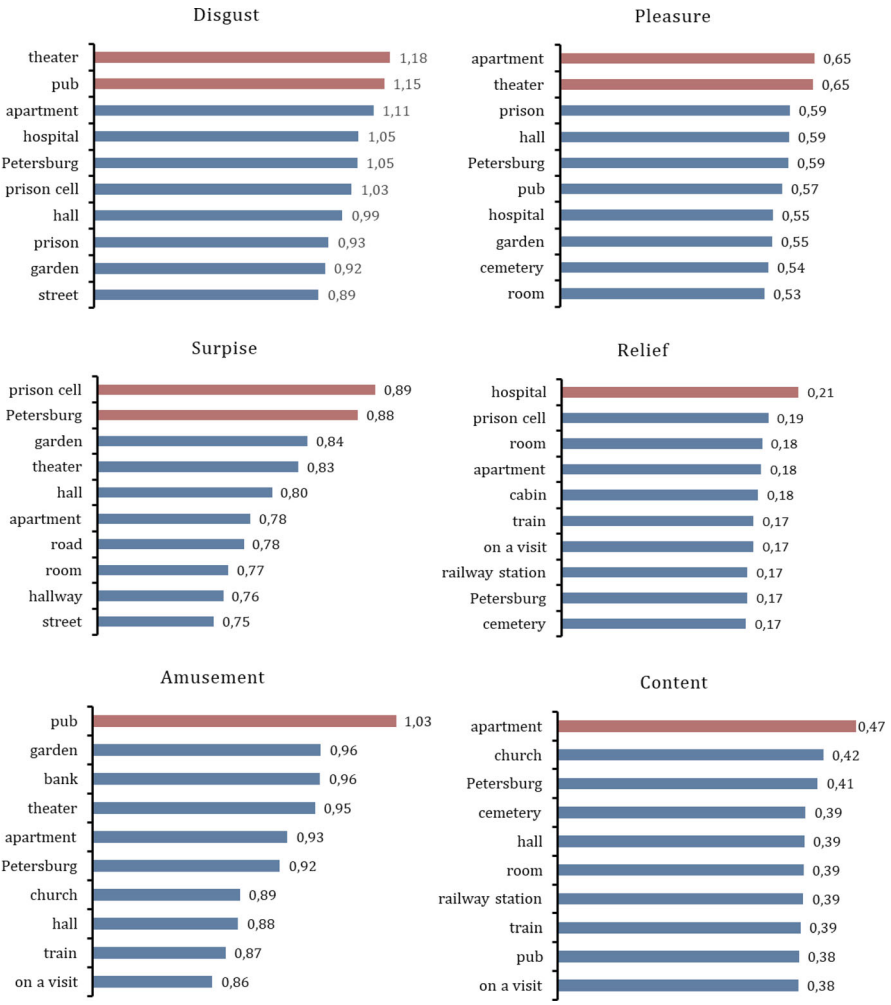

Fig. 1 (continued)

previously mentioned, stories about wartime lack emotion. However, as shown in Fig. 2, they are also characterized by a smaller amount of "angry" lexis.

In the case of Petersburg and Moscow, the emotionality of the latter is significantly smaller, as shown in Fig. 3, especially when it comes to emotional lexis describing states of happiness and sadness.

Interestingly, as Fig. 4 shows, the cities seem to be the places of action in more emotional stories, judging from the amount of emotional lexis. The most compatible categories are *anger* (for all settings, both natural and urban) and sadness (for *forest* and *city*/*street*).

Then, we considered the connection between the diversity of locations within a story and its emotional salience. The short stories with more than 10 different types

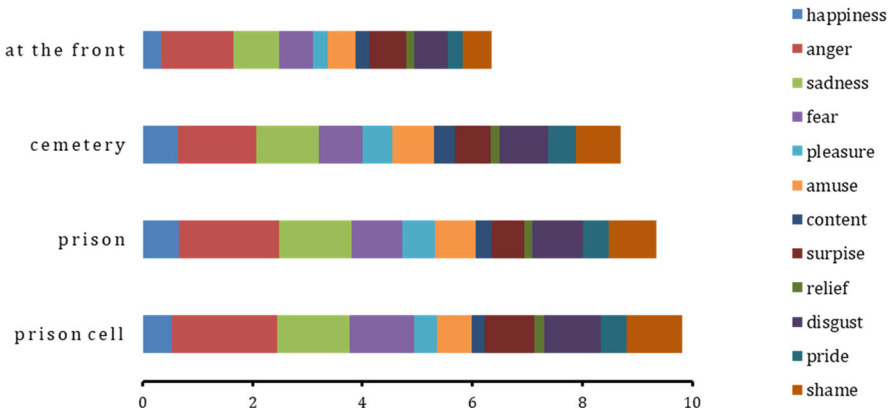

Fig. 2 Proportions of emotive lexis: *at the front*, *cemetery*, *prison*, and *prison cell* (mean, %)

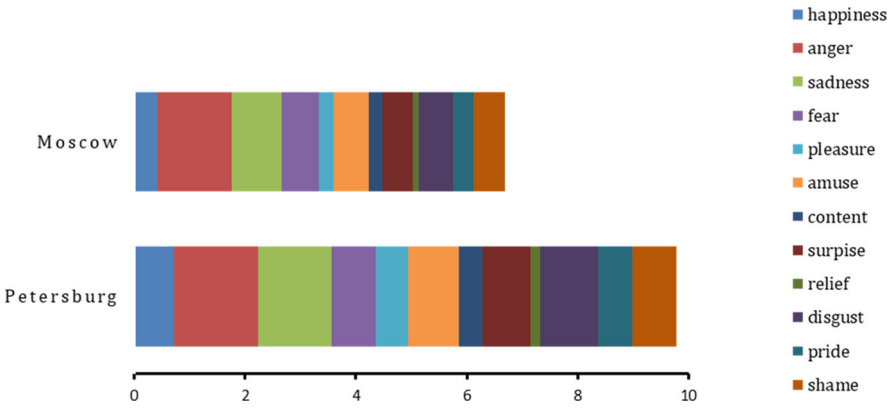

Fig. 3 Proportions of emotive lexis: *Moscow* vs. *Petersburg* (mean, %)

of locations showed no preference for any specific emotion. It seems that regardless of the diversity of scenery, the emotional state is constructed coherently, probably, for the story as a whole. However, it is possible that there are other factors that dictate the plot dynamics.

Another question concerned the stories with the highest emotionality—*is there a location that prevails in those?* Considering the texts with a cumulative number of emotional lexis more than 15%, the following frequency list was obtained: *house* (9), *street* (7), *road* (6), *park* (5), *wasteland* (3), *apartment* (3), *city* (3), *hospital* (3), *room* (3). The top of the list corresponds with the results obtained from analyzing all subcorpus. On the other hand, the inclusion of less conventional locations like *wastelands* and *hospitals* may suggest that these places have a particular emotional resonance that can be leveraged in storytelling.

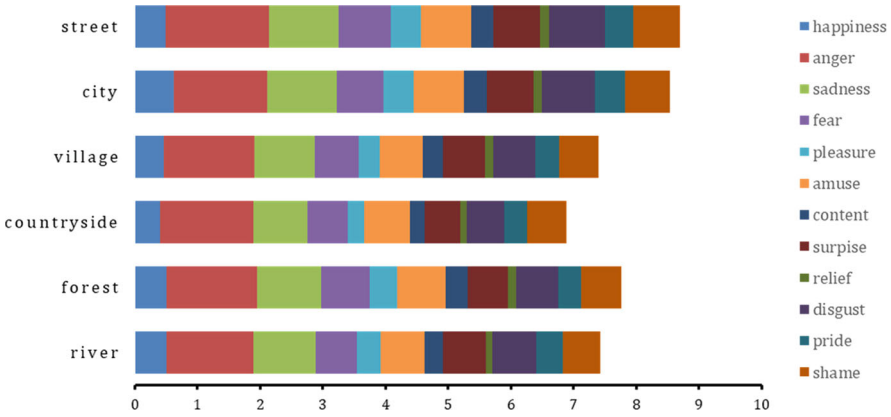

Fig. 4 Proportions of emotive lexis: *street*, *city* vs. *village*, *countryside*, *forest*, and *river* (mean, %)

4 Conclusion

Our study has identified the locations most strongly associated with emotions in Russian short stories from the beginning of the twentieth century. By analyzing the emotional language used in the stories, we found that *apartments*, *theaters*, *Petersburg*, *pubs*, and *halls* are the locations that most frequently appear in stories with a high number of emotive words. Our findings suggest that certain locations have greater emotional significance than others and that the type of emotion experienced can influence the scenery associated with it. These results have important implications for understanding the ways in which our surroundings can impact our emotional experiences.

Besides, the previously registered (at least in English) phenomenon of positivity bias, which predicts the prevalence of positive lexemes in books, social media texts, lyrics, and literary texts, reflecting "the preference of humankind for prosocial and benevolent communication" [6], seemingly did not reveal itself in Russian short stories of the period in question.

For further investigation, it seems promising to perform a more detailed analysis by calculating emotionality for particular segments of the text annotated with location labels, as opposed to the text-as-a-whole emotional score used in the present study.

Acknowledgments The chapter was prepared within the framework of the Basic Research Program at HSE University in 2023 (project "Text as big data: the modeling of convergent processes in language and speech by computational methods").

References

1. Westbury, C., Keith, J., Briesemeister, B.B., Hofmann, M.J., Jacobs, A.M.: Avoid violence, rioting, and outrage; approach celebration, delight, and strength: using large text corpora to compute valence, arousal, and the basic emotions. Q. J. Exp. Psychol. **68**(8), 1599–1622 (2015)
2. Liu, B.: Sentiment Analysis: Mining Sentiments, Opinions, and Emotions. Cambridge University, Cambridge (2015)
3. Kim, E., Klinger, R.: A survey on sentiment and emotion analysis for computational literary studies. *arXiv preprint arXiv*, *1808.03137* (2018)
4. Jacobs, A.M.: Sentiment analysis for words and fiction characters from the perspective of computational (neuro-) poetics. Front. Robot. AI. **6**, 53 (2019)
5. Mohammad, S.M.: From once upon a time to happily ever after: tracking emotions in mail and books. Decis. Support. Syst. **53**(4), 730–741 (2012)
6. Warriner, A.B., Kuperman, V., Brysbaert, M.: Norms of valence, arousal, and dominance for 13,915 English lemmas. Behav. Res. Methods. **45**, 1191–1207 (2013)
7. Martynenko, G.Y., Sherstinova, T.Y., Popova, T.I., Melnik, A.G., Zamirajlova, E.V.: O printsipakh sozdaniya korpusa russkogo rasskaza pervoy treti XX veka. In: Proceedings of the XV International Conference on Computer and Cognitive Linguistics 'TEL 2018', pp. 180–197, Kazan (2018)
8. Stevenson, R.A., Mikels, J.A., James, T.W.: Characterization of the affective norms for English words by discrete emotional categories. Behav. Res. Methods. **39**(4), 1020–1024 (2007)
9. Bradley, M.M., Lang, P.J.: Affective Norms for English Words (ANEW): Instruction Manual and Affective Ratings Technical Report C-1, vol. 30, No. 1, pp. 25–36. The Center for Research in Psychophysiology, University of Florida (1999)
10. Mohammad, S.: Obtaining reliable human ratings of valence, arousal, and dominance for 20,000 English words. In: Proceedings of the 56th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers), pp. 174–184 (2018)
11. Mohammad, S.M., Turney, P.D.: NRC emotion lexicon. National Research Council, Canada. **2**, 234 (2013)
12. Ekman, P.: Basic emotions. Handb. Cognit. Emot. **98**(45–60), 16 (1999)
13. Jacobs, A.M., Herrmann, B., Lauer, G., Lüdtke, J., Schroeder, S.: Sentiment analysis of children and youth literature: is there a pollyanna effect? Front. Psychol. **11**, 574746 (2020)
14. Heuser, R., Moretti, F., Steiner, E.B.: The Emotions of London. Literary Lab (2016)
15. Sherstinova, T., Mitrofanova, O., Skrebtsova, T., Zamiraylova, E., Kirina, M.: Topic modelling with NMF vs. expert topic annotation: The case study of Russian fiction. In: Advances in Computational Intelligence: 19th Mexican International Conference on Artificial Intelligence, MICAI 2020, Mexico City, Mexico, October 12–17, 2020, Proceedings, Part II 19, pp. 134–151. Springer (2020)
16. Kirina, M.A.: A Comparison of topic models based on LDA, STM and NMF for qualitative studies of Russian short prose. NSU Vestnik. Series: Linguist. Intercult. Commun. **20**(2), 93–109. (in Russian) (2022). https://doi.org/10.25205/1818-7935-2022-20-2-93-109

On Readability Evaluation of News Texts from Russian Multimodal University Websites

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Abstract Multimodal university websites have drawn researchers' attention since their appearance at the turn of the century. This chapter reviews the foci of salient studies on university websites, noting that very few of them deal with the readability of materials on university websites. Those few researchers who conducted readability evaluation of university websites used freely available software based on classic readability indices. None of them evaluated the readability of Russian university websites. To bridge this gap, we started a project aimed at evaluating the readability of leading Russian university websites. In the first stage of the project, a corpus of 1000+ texts was built by parsing the selected university websites. The readability of the texts was evaluated both automatically with Python script based on readability indices and by 132 human assessors who evaluated a representative sample of 340 texts of the corpus according to three groups (linguistic, structural and logical, and appealing) of 10 criteria completing the questionnaire. The correlation analysis showed a negative correlation between the automatic and respondents' estimates for easier and more difficult texts. This chapter proposes a possible explanation for this divergence and outlines further research. The most logical explanation capitalizes on the fact that readability is a function of two groups of mega-parameters: objective parameters of text comprising quantitative and qualitative characteristics and individual characteristics of the reader. Probably, readability indices do not take into account the contributions of text's qualitative characteristics and readers' characteristics in full.

Keywords Multimodal Russian university websites · Readability indices · Automatic readability evaluation · Survey · Respondents' readability evaluation

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_11

1 Introduction

The modern university is a multifunctional mechanism with the information space being its integral part. Today, the official university website functions as a means of interaction with the public medium, image making and promotion of the university in national and international university rankings. It is vital for universities to ensure effective communication with a wide audience of their stakeholders via university websites. The higher information value and readability of website multimodal materials, the better the target readers' (including nonnative Russian speakers) understanding, perception, and interaction with the information on the website. The scope and complexity of the task become clear if we take into account the fact that a web portal of modern higher education (HE) institutions includes an ever-increasing number of pages of original texts running to thousands. The variety of genres they cover some researchers describe as discourse colonies, i.e., as discontinuous structures built from series of constituent texts of a variety of subgenres, unified by a common communicative purpose—presenting the institution and promoting it in their multimodal realization [1]. University websites have been studied since their appearance in the 1990s [2]. A brief review of the related research is given in the following section.

2 Literature Review

2.1 Foci of Research on Multimodal University Websites

University websites have been studied by researchers from different countries with different research foci and methods. A majority of studies took into account the website's multimodality by putting nonverbal components into the center of research. Thus, Tomášková [1] examined the role of nonverbal elements in university homepages in *attracting prospective students* to universities. She highlights the regular updating and quality development of the websites of leading universities in the USA and the UK, with Eastern European universities lagging behind. Zollo [3] also points out a higher interactivity of UK university websites in comparison with Italian ones, with the former using new communicative and persuasive strategies and their students being increasingly associated with goods consumers. This trend is much less visible on Italian university websites [3].

International student representation was the focus of research by Zhang and Tu [4], who used critical multimodal discourse analysis. By comparing *how international students are addressed* on Australian and Chinese university web pages (a total of 6 university websites were studied), the researchers noticed that Australian universities use prospective students' home languages, such as Chinese, Vietnamese, and Arabic (alongside English), while providing recruitment

information or describing the university's cooperation with the students' regions, thus demonstrating a trend to converging to their international students [5].

The multimodal discourse approach applied to the analysis of *Why Choose* web pages of one British and two Australian universities allowed the researchers find the reasons why international students should choose one university over another as their destination university. They revealed that traditional education values are presented as part of the marketing discourse. International students are supposed to be agentive doers to achieve individual gain [6].

The analysis of *Mission statements* (from the English version of the university websites) of 35 Russian Federal and National Research Universities and 12 leading Kazakh Universities has revealed (1) the relationship between the scientific profile of a university and its leadership; (2) the practice of mutually beneficial relationships with business structures and marketization practices; and (3) the fact that both Russian and Kazakh universities support their states' political and economic strategies [7].

The text analysis of *History* and *About the University* sections on the websites of 45 leading Russian universities allows researchers to understand how the past is viewed by universities and which communicative and speech techniques are exploited to convey this view. In this section, universities highlight their involvement in the life of the country from a historical perspective. The much shorter length of the English versions of the History sections in comparison with the Russian ones indicates that these sections are aimed primarily at the Russian consumer of information and educational services [8].

The trend toward marketization noticeable on university websites worldwide is referred to as neoliberal thinking in higher education by Western researchers [1, 5, 6, 9] (to name just a few). Neoliberalism treats higher education as a marketplace where universities compete with each other for a larger market share through marketization and corporate models of management. In this thinking, students are constructed as clients. Michelson & Alvarez Valencia [9] illustrated this trend with an example of the *Study Abroad* page of the Arcadia University website covering issues about exchange programs with overseas universities. The authors noticed that texts and photos in the *Study Abroad* section foreground the touristic experience and downplay the educational experience of university exchange programs.

As critical multimodal discourse analysis and its variations are very labor intensive, researchers usually deal with websites of a very limited number of university websites. In light of this, a 90 million word academic Web as a Corpus (WaC) of European and UK university websites collected by Italian researchers with financial support from the EU seems unparallel. The corpus was built with a semi-automatic procedure based on parsing a list of URL addresses of university websites and consists of two subcorpora: WaCEu or English as Lingua franca (ELF), which includes materials from European university websites, and ukWaC (or native, NAT corpus), which contains materials from English and Irish university websites. The analysis of URL addresses revealed that the most frequent domains in the list were "news," "courses," and "research." The AcWaC was used for a number of contrastive studies, namely, frequency and functions of modals and semi-modals

[10], "degree of formulaicity" of native and ELF texts [11], "the journey metaphor"as a communicative strategy used in native English and Italian university websites [12], and the way students are depicted in visual and written components of university websites [13]. In all the studies, the differences between the ELF and NAT subcorpora were demonstrated.

2.2 Text Readability Assessment

The modern research paradigm defines text readability as a function of two types of mega-parameters: individual characteristics of the Reader and objective parameters of the Text. The latter is also subdivided into quantitative and qualitative parameters. The quantitative metrics include text length in words, average sentence length in words, and word length in characters or syllables, which affect the information processing rate. There are a number of such parameters in different languages, with 179 parameters being identified for the Russian language, including 30 considered the most informative/indicative of RFL (Russian as a Foreign Language) text readability [14].

Qualitative features account for the plot, syntactic ease, noun abstractedness and textual coherence. Individual variables affecting a potential Reader include his/her age, word familiarity, cognitive and linguistic abilities, and cultural and topic knowledge [15].

The intuitive concept of reading text ease related to the reading rate and understanding was formalized in a readability formula (indices) that ignores the characteristics of multimodal texts.

Taking into account a variety of situations in which Text and its Reader meet text readability assessment is conducted in different areas, namely:

1. Learning texts, tasks, and tests for students learning L2 as a second/foreign language (for Russian as a foreign language, see publications by Laposhina [16] and Reynolds [14]).
2. An examination of secondary school textbooks, exam tests, and other materials for native speakers of L1 (for the Russian language, see works by researchers from Kazan (Volga region) Federal University [15, 17]).
3. Business documentation, advertising materials, medical documentation, etc. A number of research groups in Russia study the readability of Russian legal texts and acts [18, 19].
4. Websites are evaluated in terms of attractiveness and comprehensibility from the perspective of the target user and others.

We consider studies devoted to website readability assessment in some detail. A literature review shows that researchers usually assess the readability of official websites, including those of state and local governments [20, 21].

Only three papers considered the readability of university websites alongside other characteristics listed in the Web Content Accessibility Guidelines (WCAG).

Karhu and her colleagues analyzed the readability of the web pages, which present the history of each of the seven Finnish universities selected for the research, using free software (http://flesh.sourceforge.net). They revealed that three of them showed a "hard" level of readability while the other four were ascribed "very hard" level [22]. Patra et al. studied compliance with WCAG 2.0 for Indian official web portals, including five university websites. They found that 39.60% of educational websites violated readability rules [21]. Akgül, in his 2021 comparative study of 179 state and private Turkish university websites, evaluated the readability of the websites using 6 classic readability formulas [23]. He concludes that both state and private university websites are difficult to read according to the FRES[1] scores, which is in line with the abovementioned studies. Akgül also considered the impact of some multimodal features on readability, such as the number of continuous lines of all-capitalized text (text capitalization) and underlining the main body text layout [23].

Some researchers have evaluated target users' satisfaction with their university websites via surveys. Thus, Rashida and coauthors [24] conducted a survey in 22 public and private universities in Bangladesh, resulting in a total of 1820 students answering 23 questions in their questionnaire. In answering the last open question about what needs improvement in Bangladeshi university website performance, no one has mentioned high text complexity.

As far as we know, there are no similar studies of Russian university websites. That is why a research project on the readability assessment of multimodal texts from Russian university websites was launched. As the first stage of the project, it was decided to evaluate text readability automatically and compare the results with estimates given by respondents: students and postgraduate students of Peter the Great SPbPU.

3 Data and Methodology

3.1 A Subsection Sample Building Up a Corpus of Russian Multimodal University Websites

To evaluate the readability of multimodal text from Russian university websites, the PolyLing corpus was built up. For the first stage of the research, it was decided to make up a corpus of news section from university websites. The arguments to focus on this section are as follows: (1) frequent and regular updating; (2) a wide range of topics covered (e.g., news about latest R&D, science and education, administrative and student life, cooperation with industrial partners and other universities); (3) often written by professional journalists; (4) presumably most visited after the home page (e.g., Top University news first appears on the home page, and the reader is

[1] FRES—Flesch Reading Ease Score.

Table 1 The PolyLing University website corpus statistics

University	Number of texts	Number of tokens
Peter the Great Saint Petersburg Polytechnic University (SPbPU)	215	158,924
Higher School of Economics (HSE)	84	156,933
Saint Petersburg State University (SPBU)	50	47,561
Tomsk Polytechnic University (TPU)	50	22,831
15 universities from 11 cities of RF	40 from each university website	237,888
Tomsk State University (TSU)	27	12,740
Total	1026	636,877

redirected to the Media section of the website for details.); and (5) ideally, compelling for all categories of university stakeholders, including potential students and their parents. The PolyLing corpus was constructed through the following steps: first, 20 leading Russian universities and participants of the Priority 2030 Program[2] were selected; second, a list of their URLs was compiled; and finally, the news pages were crawled by parsing, resulting in a collection of 1026 downloaded texts for the period from January 01, 2022, to March 31, 2022. Table 1 provides statistics about the PolyLing corpus.

We utilized Python 3 to automatically parse the websites of selected Russian universities. To gather the required data, we developed a custom program[3] that created two types of files: one with plain text and another with metadata, such as the title, the number of visuals, and university. Each text is assigned a unique ID and contains metadata, along with morphological and syntactic markup. The program developed for parsing news texts from Russian university websites does not provide for morphological and syntactic markups. For morphological and syntactic markup, an adapted Pymorphy analyzer [25] was used.

3.2 Automatic Readability Evaluation

The readability of the university website's texts was calculated through a Python script featuring the ruTS library. The ruTS library is a Python package that contains a set of readability formulas, namely, the Flesch–Kincaid Reading Ease (FRE) adapted for the Russian language, the Simple Measure of Gobbledygook (SMOG), the

[2] Priority 2030—the Program of Russian Ministry of HE aimed at providing financial support to leading Russian universities in development of the cutting edge technologies and conducting the first class research in different spheres.

[3] Certificate # 2022669940 about state registration of electronic computer program for automatic parsing news texts from Russian university websites as intellectual property of 26.10.2022 / Rakova V.V., Cherkas A.V., Kozina E.D., Rubtsova A.V., Kogan M.S.

Automatic Readability Index (ARI), the Dale-Chall Readability formula, the Coleman–Liau Index (CLI), and the Gunning FOG, some of which are adapted for the Russian language. For an overview of the readability indices, see [26]. As a result of automatic readability evaluation, all the texts were put into three categories: easier to read, middle difficulty, and more difficult (using the terminology of [27]).

3.3 Survey Organization

The subjective evaluation of news text readability was conducted through online surveying of students, postgraduate students, and faculty members of Peter the Great SPbPU. Totally, 132 respondents aged 17–45 years participated in the survey. Each respondent had to evaluate the readability of a set of three texts by completing the questionnaire. Each set was given to 5 respondents.

The sets were formed from a representative corpus sample. To make the sample representative relative to the whole corpus, texts from each readability category were selected according to the following criteria: proportionality (the number of texts from a website of a certain university was proportional to the number of texts from the university website (further: a subcorpus) in the corpus); randomicity (random selection of texts from subcorpora); and the length of selected texts was about the average value in the corpus.

The questionnaire has two parts: the first part addresses the credentials of the participants (name, educational level, department, age, email) and the second part includes 10 closed questions about different aspects of text readability. The respondents had to express their agreement with each of them via a 5-point scale ranging from 1 (completely disagree) through 3 (so-called) to 5 (completely agree) and evaluate the overall text readability via a 5-point scale from 1 (very difficult to understand) to 5 (very easy to understand). The respondents were asked to evaluate the following three groups of aspects and give the overall score: linguistic, structural and logical, and compelling. The respondents' evaluations were collected and statistically processed using regression analysis.

4 Results and Discussion

Our respondents were not supposed to imitate experts; rather, their contribution was seen as similar to that of respondents in an opinion poll, which cannot produce "wrong" answers. Disagreeing individuals are not filtered out because they may reflect a part of the target readers' perception (Koltsova et al. followed the same logic in their research [28: 281]). Table 2 summarizes the results of the survey's processing and the percentage of unique texts in each readability group for each aspect.

Table 2 Results of survey processing

Aspect	Easier texts (%)	Texts of middle difficulty (%)	More difficult texts (%)
Compelling aspects			
The headline of text is catchy	11.73	48.78	39.49
The text is interesting	12.78	46.96	40.26
The text is clear to me	29.75	35.09	35.16
Linguistic aspects			
The text is easy to read because there are short sentences in it	11.75	47.17	41.08
There are no difficult collocations impeding understanding	21.03	42.51	36.46
I can easily understand all words in the text	23.74	39.59	36.67
There are no unfamiliar words impeding understanding	24.88	39.65	35.47
Structural and logical aspects			
The text is logical	30.68	32.13	37.19
Key idea of the text is easy to comprehend	37.85	30.63	31.52
The text is easy to read	21.36	40.17	38.47

These results indicate different levels of agreement among the respondents on various aspects of readability. The criterion with the highest consensus was "The headline of the text is catchy" (convergence = 0.49), while the lowest was "The key idea of the text is easy to comprehend" (convergence = 0.31).

The correlation between respondents' evaluation and automatic evaluation differed for texts from different categories of readability. For easier texts, the correlation coefficient is −0.2, indicating a weak negative correlation; for texts of middle difficulty, the correlation coefficient is 0.4, which demonstrates good agreement; for more difficult texts, the correlation coefficient is −0.3, showing a medium negative correlation.

Taking into account the representativeness of the sample, we suggest that a similar correlation between the automatic evaluation and the respondents' evaluation of news text readability can be applicable to the whole corpus.

The divergence can be explained as follows. The readability formulas were developed for the needs of two main groups of readers: foreign language learners, young native speakers, and learners of different disciplines at the secondary school level. The formulas might not be applicable to the assessment of news texts from university websites aimed primarily at educated native speakers. As a result, the complexity of news text is sometimes overestimated when it is assessed automatically. It is also possible that different linguistic factors are of different importance for different readers, educated native speakers of a language.

Another explanation may be that for this category of readers, qualitative features as well as appealing aspects of news texts are important. Both groups of parameters accounting for qualitative features and appealing aspects are poorly (if any) taken

into account by readability formulas. To support our hypothesis about the impact of appealing aspects in news text perception, we analyzed texts of equal automatic readability assessment but put in different categories of text readability by respondents. It turned out that news texts from websites of other universities, presumably less interesting for respondents from SPbPU, were perceived as more difficult.

5 Conclusions and Further Research

As a result of the first stage of a project assessing the readability of multimodal texts from leading Russian university websites, a pilot corpus containing 1000+ news texts parsed from 20 university websites was compiled and annotated morphologically and syntactically.

The respondents' evaluations of linguistic, structural and logical, and appealing aspects provided better insight into the target readers' perceptions of the readability of university website texts from the News section. The reasons for the difference between the automatic evaluation and the respondent evaluation need further research.

One of the consequences of the fact that respondents find texts from their alma-mater website easier than estimated automatically might be a recommendation of wider use of the university website multimodal materials in Russian as second/foreign language classes.

It seems reasonable to conduct what is known as partial replication studies with the extended corpus of multimodal texts from Russian university websites, checking if trends revealed in the analyses of overseas university websites are also typical of Russian universities.

The authors understand the limitations of this research in terms of the corpus size, sample size, thematic and genre variety, and number of respondents involved in readability assessment.

Acknowledgments The research has been partially funded by the Ministry of Science and Higher Education of the Russian Federation under the strategic academic leadership program "Priority 2030" (Agreement 075-15-2021-1333 dated 30.09.2021). The authors would like to thank their colleagues T.G. Evtushenko and E.S. Klochkova, associate professors of SPbPU, for their valuable comments during the preparation stage of this chapter.

References

1. Tomášková, R.: A walk through the multimodal landscape of university websites. Brno Stud. English. **41**(1), 7–100 (2015). https://doi.org/10.5817/BSE2015-1-5
2. Middleton, I., McConnell, M., Davidson, G.: Presenting a model for the structure and content of a university World Wide Web site. J. Inf. Sci. **25**(3), 219–227 (1999)

3. Zollo, S.A.: Internationalization and globalization. A multimodal analysis of Italian universities' websites. J. Multimodal Commun. Stud. **3**(1–2), 1–17 (2016) https://hdl.handle.net/11588/702252
4. Zhang, Z.C., Tu, W.: Representation of international students at Australian university websites: a critical multimodal discourse analysis. Iberica. **37**, 221–243 (2019)
5. Zhang, Z., Tan, S., Wignell, P., O'Halloran, K.: Addressing international students on Australian and Chinese university webpages: a comparative study. Discourse Context Media. **36** (2020). https://doi.org/10.1016/j.dcm.2020.100403
6. Zhang, Z., Tan, S., O'Halloran, K.L.: Managing higher education and neoliberal marketing discourses on why choose webpages for international students on Australian and British university websites. Discourse Commun. **16**(4), 462–481 (2022). https://doi.org/10.1177/17504813221074076
7. Chernyavskaya, V.E., Zharkynbekova, S.K.: Linguistic and social construction of national university identity: Kazakh and Russian universities' mission statements. Vestnik of Saint Petersburg University. Lang. Lit. **16**(2), 304–319 (2019)
8. Chernyavskaya, V.E., Safronenkova, E.L.: Towards constructing identity of a National University: "our past" at the websites of Russian universities. J. Sib. Fed. Univ. Humanit. Soc. Sci. **12**(10), 1819–1839 (2019). https://doi.org/10.17516/1997-1370-0491
9. Michelson, K., Alvarez Valencia, J.A.: Study abroad: tourism or education? A multimodal social semiotic analysis of institutional discourses of a promotional website. Discourse Commun. **10**(3), 235–256 (2016). https://doi.org/10.1177/1750481315623893
10. Bernardini, S., Ferraresi, A.: The academic web-as-corpus. In: Evert, S., Stemle, E., Rayson, P. (eds.) Proceedings of the 8th Web as Corpus Workshop, pp. 53–62. Association for Computational Linguistics, Stroudsburg (2013)
11. Bernardini, S., Ferraresi, A.: Chapter 9: Institutional academic English and its phraseology: native and lingua franca perspectives. In: Diani, G., Thompson, P. (eds.) English for Academic Purposes: Approaches and Implications, pp. 225–244. Cambridge Scholars Publishing, Cambridge (2015)
12. Venuti, M., Nasti, C.: Italian and UK university websites: comparing communicative strategies. ESP Across Cult. **12**, 127–137 (2015)
13. Nasti, C., Venuti, M., Zollo, S.A.: UK university websites: a multimodal, corpus-based analysis. Int. J. Lang. Stud. **11**(4), 131–152 (2017)
14. Reynolds, R.J.: Russian Natural Language Processing for Computer-Assisted Language Learning. PhD dissertation, UiT. The Arctic University of Norway, Tromsø, 196p. (unpublished) (2016)
15. Solnyshkina, M.I., Kiselnikov, A.S.: Text complexity: study phases in Russian linguistics. Tomsk State Univ. J. Philol. **6**(38), 86–99 (2015). https://doi.org/10.17223/19986645/38/7
16. Laposhina, A.N.: Insights from an experimental study on the text complexity for Russian as a foreign language. Dinamika jazykovyh i kul'turnyh processov v sovremennoj Rossii. **6**, 1154–1179 (2018)
17. Ivanov, V., Solnyshkina, M., Solovyev, V.: Efficiency of text readability features in Russian academic texts. In: Computational Linguistics and Intellectual Technologies. Proceedings of the International Conference "Dialogue 21" (May 30—June 21, 2018), vol. 17 (24), pp. 284–293, Moscow (2018) http://www.dialog-21.ru/media/4302/ivanovvv.pdf
18. Blinova, O.V., Tarasov, N.A. Complexity of Russian legal texts: assessment methods and language data. In: Proceedings of International Conference "Corpora 2021" (July 1–3, 2021). pp. 175–182. Skifija-Print, Saint Petersburg (2021)
19. Saveliev, D.: A study in complexity of sentences constituting Russian Federation legal acts. Law J. HSE. **1**, 50–74 (2020). https://doi.org/10.17323/2072-8166.2020.1.50.74
20. Akgül, Y.: The accessibility, usability, quality and readability of Turkish state and local government websites: an exploratory study. Int. J. Electron. Gov. Res. **15**(1), 62–81 (2019). https://doi.org/10.4018/IJEGR.2019010105

21. Karhu, M., Hilera, J.R., Fernández, L., Ríos, R.: Accessibility and readability of university websites in Finland. J. Access. Des. **2**(2), 178–189 (2012) http://www.jacces.org/index.php/jacces/article/view/70/136
22. Patra, M.R., Dash, A.R., Mishra, P.K.: A quantitative analysis of WCAG 2.0 compliance for some Indian web portals. Int. J. Comput. Sci. Eng. Appl. (IJCSEA). **4**(1), 9–23 (2017)
23. Akgül, Y.: Accessibility, usability, quality performance, and readability evaluation of university websites of Turkey: a comparative study of state and private universities. Univ. Access Inf. Soc. **20**, 157–170 (2021). https://doi.org/10.1007/s10209-020-00715-w
24. Rashida, M., Islam, K., Kayes, A.S.M., Hammoudeh, M., Arefin, M.S., Habib, M.A.: Towards developing a framework to analyze the qualities of the university websites. Computers. **10**(57), 1–16 (2021). https://doi.org/10.3390/computers10050057
25. Korobov, M.: Morphological analyzer and generator for Russian and Ukrainian languages. In: Khachay, M., Konstantinova, N., Panchenko, A., Ignatov, D., Labunets, V. (eds.) Analysis of Images, Social Networks and Texts. AIST 2015. Communications in Computer and Information Science, vol. 542, pp. 320–332. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-26123-2_31
26. Gómez, P.C., Sánchez-Lafuente, Á.A.: Readability indices for the assessment of textbooks: a feasibility study in the context of EFL. Vigo Int. J. Appl. Linguist. (VIAL). **16**, 31–52 (2019)
27. Blinova, O., Tarasov, N.: Complexity metrics of Russian legal texts: selection, use, initial efficiency evaluation. In: Computational Linguistics and Intellectual Technologies: Proceedings of the International Conference "Dialogue 2022" (June 15–18, 2022), pp. 1017–1028, Moscow (2022). (in Russian)). https://doi.org/10.28995/2075-7182-2022-21-1017-1028
28. Koltsova O. Yu, Alexeeva S. V., Kolcov S. N. An Opinion word lexicon and a training data set for Russian sentiment analysis of social media computational linguistics and intellectual technologies: Proceedings of the International Conference "Dialogue 2016" (June 1–4, 2016) Moscow (2016), pp. 277–287. https://www.dialog-21.ru/digest/2016/articles/

Russian Feminitives on Social Media: A Corpus-Aided Approach for Their Analysis

Yulia S. Shishebarova, Lyubov A. Sokolova, and Ivan D. Mamaev

Abstract This chapter presents ongoing research on the frequency of use of Russian feminine nouns. In the recent past, feminine nouns have been widely used in the Russian media. However, contemporary feminine noun models are difficult to find in Russian dictionaries. The first stage of the experiment is to identify productive word-formation models of feminine nouns. We use Sketch Engine and NoSketch Engine corpus systems, the General Internet Corpus of Russian, as well as the method of distributional and statistical analysis. Furthermore, Student's *t*-test is used to check if the models are interchangeable. The final stage of the research is the automatic creation of semantic fields for lemmata with different feminine suffixes. Our chapter provides insight into discussions regarding the use of Russian feminine nouns, in terms of both the language rules and the prescribed usage.

Keywords Suffix · Feminine noun · Masculine noun · Distributive and statistical analysis · Student's *t* test · Semantic field · Corpus

1 Introduction

In modern linguistics, researchers pay attention to social media texts since web text collections have unique linguistic features. For example, Russian speakers unconsciously use different word-formation models of feminine forms (feminitives) for a

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_12

single masculine word. This diversity leads to difficulties in choosing the appropriate feminine form.

At the beginning of the twentieth century, Russian speakers frequently used feminine forms. However, in official speeches, it became common to use masculine-gendered words (e.g., masculine-gendered professions) when referring to women. The post-revolutionary desire of the Bolsheviks to equalize men and women unintentionally reinforced the tendency to use masculine words in a "generalized" sense. The idea was only widely accepted in the second half of the twentieth century [1].

Recently, Russian feminitives have been studied quite actively. The theory of functional semantics posits that nouns with a feminine meaning (e.g. *bloggerka*, *avtorka*, *doktorka*, and *photographka*) are words with a modified derivational meaning that expresses a certain feature [2]. Such meanings might improve communication by providing a nuanced representation of the person's gender. It is also worth noting that the use of feminitives is considered politically correct and can help avoid offending or excluding women in various contexts.

In this study, we focus on identifying productive and unproductive word-formation models of feminitives. We also aim to determine whether words with the same stem but different feminine suffixes are interchangeable.

2 Related Works

The development of both national and web-based corpora has led to the growth of specialized research [3]. The study of feminine nouns is not an exception. For instance, [4] explores the use of feminitives in the Araneum Russicum Maximum corpus and the Russian National Corpus. It is found that the choice of a feminitive to some extent depends on the morphological properties of the masculine stem. It has also been discovered that feminine suffixes are more common than composites (e.g., *zhenshchina-advokat*), and their distribution changes over time.

Another paper [5] discusses the results of a study conducted on feminitives with the *−ikh* suffix in the texts written between the eighteenth and twentieth centuries. The authors examine the most frequently used words in the Russian National Corpus and compare their usage with their presence in explanatory dictionaries of the eighteenth and twenty-first centuries. The authors note that these feminitives are often not given their own dictionary entries. They are described as the feminine form of the corresponding masculine noun. The article investigates the differences between the grammatical and lexical meanings of feminitives ending with *−ikh(a)* and highlights that these differences are not always clearly defined in dictionaries.

Structural semantics and corpus methods are also used in [6]. The focus is particularly on new words that are feminine ones, and the research proposes a classification system to categorize these words based on their semantic properties. The study also examines how these words are formed in terms of phonetics and morphology. The research suggests that neologisms related to gender are formed

using certain suffixes (e.g., *−shits(a)/−chits(a)*) and through the use of various parts of speech, such as verbs, deverbatives, nouns, and adjectives.

Some studies are dedicated to the problem of translating feminitives in certain language pairs. The paper [7] examines Russian feminine nouns with *−ikh(a)* and *−sh(a)* and their translations into Czech. The study proposes that these types of Russian nouns have an expressive meaning that may be lost in Czech translation. The research is conducted with the InterCorp v13 parallel corpus, which includes Russian and Czech data. The analysis focuses on both word-formation processes and semantic parameters.

These papers confirm the importance of corpus resources in the study of feminine nouns. Our article complements many of these works, and we hope that the findings will be useful for further discussions on trends in the formation of language norms.

3 Experimental Design: Corpus Resources and a Traditional Derivational Model

To conduct this research, it is necessary to collect a corpus of feminitives. We collected 43 sets of masculine nouns and their derivative feminitives with *−sh(a)*, *−k(a)*, *−ess(a)*, *−in(ya)*, and *−its(a)* suffixes. We used segments of the Russian Internet (blogs, posts on social networks, etc.). The first stage of the study was carried out with the help of web-based corpora, such as ruTenTen11 (Sketch Engine), Araneum Russicum Maximum (NoSketch Engine), and the General Internet Corpus of Russian (GICR). Relative ipm frequencies, which indicated the use of feminitives, were obtained. Tables 1, 2, and 3 present parts of the quantitative data.

Table 1 Distribution of ipm frequencies based on Araneum Russicum Maximum

	ipm				
Masculative	*−sh(a)*	*−k(a)*	*−ess(a)*	*−in(a)*	*−its(a)*
Aviator	≈ 0.01	0	0	0	0
Avtor	0.05	0.02	0.01	≈ 0.01	≈ 0.01
Bibliotekar’	0.1	≈ 0.01	0	≈ 0.01	0
Bukhgalter	0.04	≈ 0.01	≈ 0.01	0	≈ 0.01
Geroj	≈ 0.01	0.01	0	19.4	0
Doktor	0.1	≈ 0.01	≈ 0.01	≈ 0.01	0.01
Operator	0.01	≈ 0.01	0	0	0
Ofitsiant	≈ 0.01	2.03	0	0	0
Partner	3.33	0.59	0	0	0
Patsan	0	0.04	0	0	0
Sanitar	≈ 0.01	0.57	0	0	0
Spetsialist	0	0.05	0	0	0
Tovarishch	0	0.04	0	0	0
Shef	≈ 0.01	≈ 0.01	≈ 0.01	≈ 0.01	≈ 0.01

Table 2 Distribution of ipm frequencies based on ruTenTen

	ipm				
Masculative	*−sh(a)*	−k(a)	*−sh(a)*	*−in(ya)*	*−sh(a)*
Aviator	0.01	0	0	0	0
Avtor	0.03	≈0.01	0.01	0	0
Bibliotekar’	0.18	≈0.01	0	0	0
Bukhgalter	0.09	0	0	0	≈0.01
Geroj	0	≈0.01	0	14.17	0
Doktor	0.15	≈0.01	≈0.01	≈0.01	0.01
Operator	0.01	≈0.01	0	0	0
Ofitsiant	0	2.42	0	0	0
Partner	3.09	0.29	0	0	0
Patsan	0	0.04	0	0	0
Sanitar	–	1.05	0	0	0
Spetsialist	0	0.09	0	0	0
Tovarishch	–	0.25	0	0	0
Shef	≈0.01	≈0.01	≈0.01	0.02	≈0.01

Table 3 Distribution of ipm frequencies based on GICR

	ipm				
Masculative	*−sh(a)*	*−k(a)*	*−sh(a)*	*−in(ya)*	*−sh(a)*
Aviator	≈0.01	≈0.01	0	0	0
Avtor	0.02	0.06	≈0.01	≈0.01	≈0.01
Bibliotekar’	0.06	≈0.01	0	≈0.01	0
Bukhgalter	0.06	≈0.01	≈0.01	0	≈0.01
Geroj	≈0.01	≈0.01	≈0.01	2.6	≈0.01
Doktor	0.09	≈0.01	≈0.01	≈0.01	0.01
Operator	0.01	≈0.01	≈0.01	0	0
Ofitsiant	≈0.01	0.004	≈0.01	0	0
Partner	0.2	0.06	0	0	0
Patsan	0	0.2	0	0	0
Sanitar	≈0.01	0.3	0	0	0
Spetsialist	0	0.05	0	0	0
Tovarishch	–	0.02	0	0	≈0.01
Shef	≈0.01	≈0.01	≈0.01	0.02	≈0.01

To test the assumption about the change in the meanings of suffixes, it is necessary to choose a word-formation model. We focus on the model of Natalia Yu. Shvedova, described in the *Russian Grammar* [8]. It is presented in Table 4.

The final stage of the experiment is visualizing semantic fields in the Sketch Engine corpus system to check whether stylistic differences among feminitives with the same masculine stem exist.

Table 4 Shvedova's derivational model

Suffix	Example
−k(a)	Komsomolka, inostranka, vnuchka...
−its(a)	Dyakonitsa, protopopitsa, ponomaritsa...
−nits(a)	Svidetelnitsa, predsedatelnitsa, izobretatelnitsa...
−ikh(a)	Dvornichikha, gorodnichikha, plovchikha...
−sh(a)	Redaktorsha, organizatorsha, gastrolersha...
−n(a)	Tsarevna, popovna, panna...
−in(ya)	Gertsoginya, inokinya, monakhinya...
−|j|- (before |j|, fleeting vowel |α1|, orthograph. u)	Boltunjya, shalunjya, drachunjya, lgunjya...
−ess(a)	Poetessa, printsessa, patronessa...
−is(a)	Aktrisa, abbatisa, diakonisa...
−in(a)	Kusina, siniorina, kurfyurstina...

4 Results and Discussions

Based on the preliminary results of ipm frequencies from Sketch Engine and NoSketch Engine, we can conclude that feminitives with the *−sh(a)* and *−k(a)* suffixes are the most frequent ones in Russian texts. The most relevant corpus is the GICR, as it contains texts from different social networks (VK, LiveJournal, etc.) up to 2021. For example, ruTenTen11 (Sketch Engine) contains texts only up to 2011. It should also be noted that the GICR allows for a parallel search for several lexical units at once (in the current study, five), which significantly speeds up the data collection process. According to the results given in Tables 1, 2, 3, and 4 in Sect. 3, words such as *geroessa*, *operatressa*, and *ofitsiantessa* have begun to be used in Russian social media. This suggests that feminitives with various suffixes are being incorporated into modern Russian, but *−sh(a)* and *−k(a)* still remain the most productive suffixes.

The next step of the study is to identify the interchangeability of the suffixes mentioned above (see Tables 1, 2, and 3). First of all, using the Kolmogorov-Smirnov test, we identify that the obtained samples match the characteristics of a normal distribution. As a result, we are able to use Student's *t*-criterion for independent samples. This method allows us to test the hypothesis that the average values of ipm frequencies for feminitives with two different suffixes do not differ significantly from each other.

In Excel, we have calculated the *p*-value. The initial hypothesis is as follows: there are no statistical differences, i.e., suffixes can be interchangeable. If it is rejected, an alternative hypothesis is accepted. The results of the calculations are presented in Table 5.

Table 5 Final *p*-values for ipm frequencies

	p-value				
	Sketch engine				
Suffixes	*−sh(a)*	*−k(a)*	*−ess(a)*	*−in(ya)*	*−its(a)*
–sh(a)	–	0.674	0.203	0.483	0.723
–k(a)	0.674	–	0.043	0.563	0.402
–ess(a)	0.203	0.043	–	0.325	0.322
–in(ya)	0.483	0.563	0.325	–	0.426
–its(a)	0.723	0.402	0.322	0.426	–
p-value					
NoSketch engine					
	–sh(a)	*–k(a)*	*–ess(a)*	*–in(ya)*	*–its(a)*
–sh(a)	–	0.736	0.237	0.438	0.628
–k(a)	0.736	–	0.035	0.474	0.317
–ess(a)	0.237	0.035	–	0.324	0.310
–in(ya)	0.438	0.474	0.324	–	0.380
–its(a)	0.628	0.317	0.310	0.380	–
p-value					
GICR					
	–sh(a)	*–k(a)*	*–ess(a)*	*–in(ya)*	*–its(a)*
–sh(a)	–	0.137	0.004	0.531	0.795
–k(a)	0.137	–	0.007	0.859	0.544
–ess(a)	0.004	0.007	–	0.339	0.329
–in(ya)	0.531	0.859	0.339	–	0.643
–its (a)	0.795	0.544	0.329	0.643	–

The results suggest that almost all suffix pairs are interchangeable except for *–k(a)* and *–ess(a)*. Calculations based on the data of the GICR show that word-formation models with the *–sh(a)* and *–ess(a)* suffixes, and those with the *–k(a)* and *–ess(a)* suffixes, have statistical discrepancies. Nevertheless, we assume that word-formation models with the *–sh(a)* and *–ess(a)* suffixes can be interchangeable, and over time, a feminitive with one of the suffixes may develop a specific stylistic meaning that was not previously noted in lexicographic sources. Thus, despite the prominence of two leading word-formation models with *–sh(a)* and *–k(a)* suffixes, we can state that there is a possibility that the *–ess(a)* suffix will also come into use.

However, despite the interchangeability of the suffixes, we need to address the following question: is it possible to interchange suffixes without causing semantic or stylistic shifts in the meaning of a statement? To explore this, we can use automatic methods of generating semantic fields, which are described in [9].

Semantic fields are hierarchical structures of words united by a common (invariant) meaning; they reflect a certain conceptual sphere in the language [10]. The idea of a semantic field refers to a system of interrelated networks that form the basis of the vocabulary. Each core word is surrounded by a network of associations

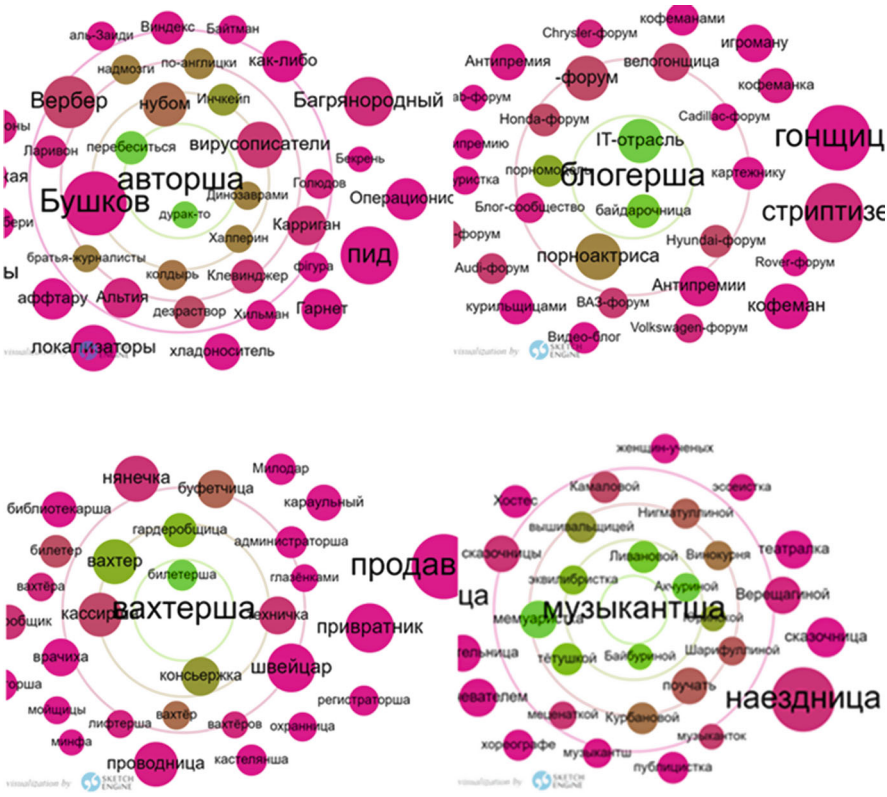

Fig. 1 Semantic field of lexemes with the *–sh(a)* suffix

connected to other terms. To determine if there are any stylistic differences, we decided to visualize the semantic fields of the feminitives (see Figs. 1, 2, 3, 4, and 5) with five suffixes presented in this chapter. The visualization was created with one of the Sketch Engine tools.

According to Shvedova's classification, the *–sh(a)* suffix denotes the wife of a masculine worker (*professor—professorsha*, *doctor—doctorsha*) or forms the names of female people by profession or occupation (*sekretarsha* and *pedikyursha*). It can be assumed that the semantic fields of words with the *–sh(a)* suffix will contain words with a neutral connotation, but Fig. 1 shows that words with reduced stylistics and/or negative connotation prevail in the semantic fields of the *avtorsha* and *bloggersha* words (e.g., *durak-to*, *nubom*, *afftaru*, *striptizyor*, *antipremiya*, etc.). In contrast, the semantic fields of *vakhtersha* and *muzykantsha* words contain more neutral vocabulary, primarily related to workers, both female and male.

The *–k(a)* suffix is a unit that forms nouns, such as names of women from the corresponding male names. This suffix does not contain additional lexical meaning;

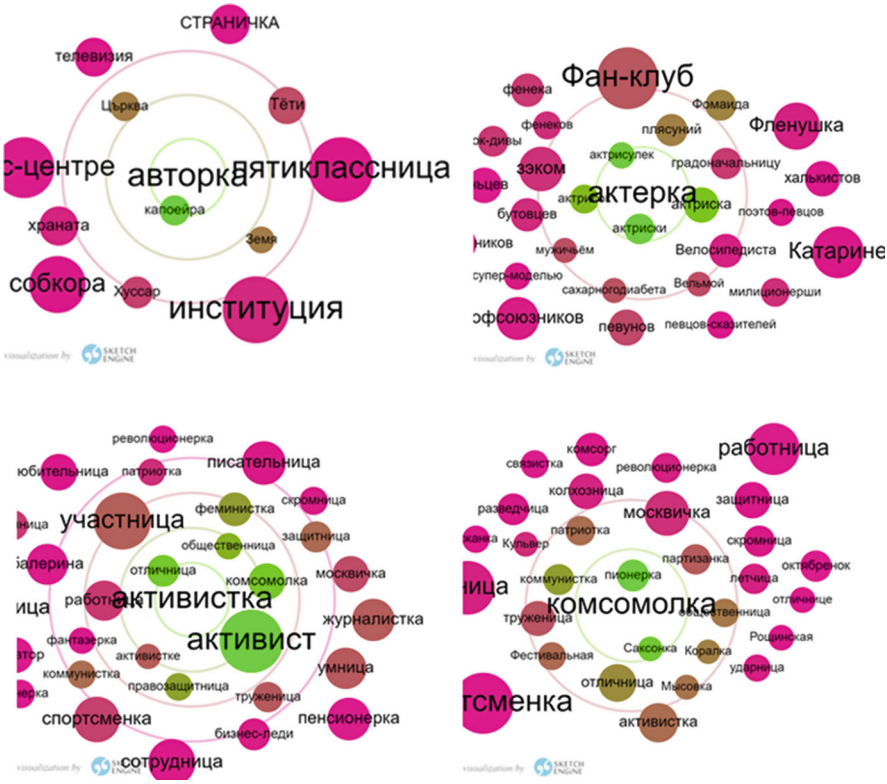

Fig. 2 Semantic field of lexemes with suffix *–sh(a)*

therefore, the semantic fields of feminitives with the *–k(a)* suffix should also contain neutral words. The results confirm this assumption; only the semantic field of the *aktyorka* word includes stylistically marked units: *aktrisulek*, *plyasunii*, and *zekom.*

Initially, the *–ess(a)* suffix was used mainly in titles or to denote artists or athletes (*printsessa* and *baronessa*). This trend continues today. We suggest that a feminitive with this suffix is most often used to denote a woman's professional status (the exception is *klounessa*).

The *–its(a)* suffix forms feminine nouns with a diminutive meaning. It is also used to form feminine nouns from masculine stems that do not have any suffixes (with some exceptions): *masteritsa*, *feldsheritsa*, *prorochitsa*, etc. In modern Russian social media, the *–its(a)* suffix has retained its meaning in the formation of feminitives from masculine nouns, as words with neutral (*geroinya*, *tennisistka*, and *iskusstvoved*) or positive connotations (*mama*, *babushka*, and *podruga*) tend to appear more often (cf. Fig. 4).

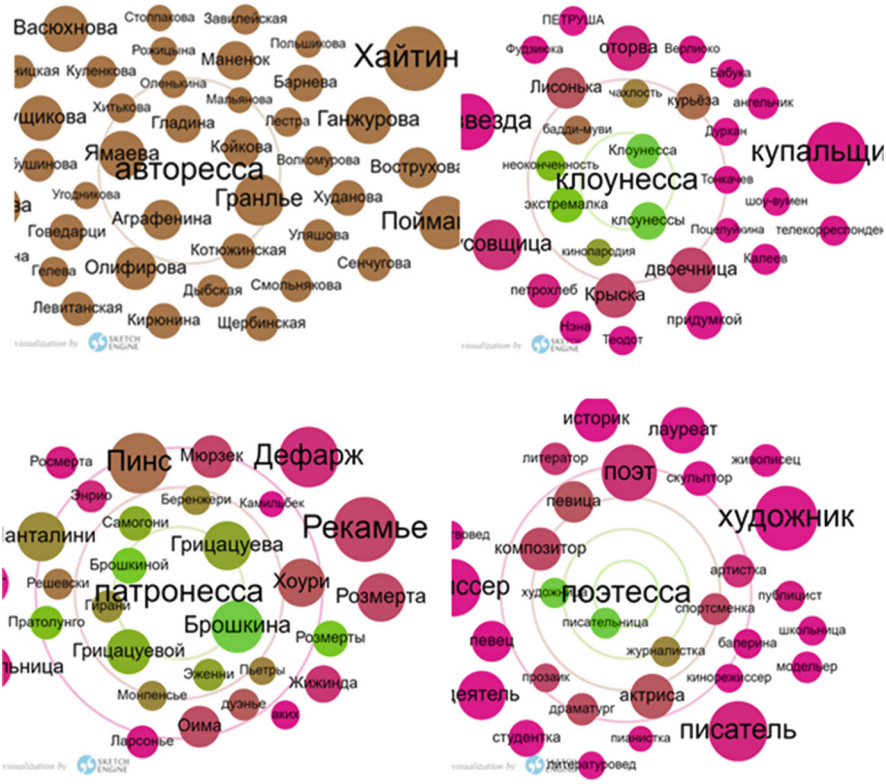

Fig. 3 Semantic field of lexemes with *–ess(a)* suffix

Finally, the *–in(ya)* suffix is more common in words that are currently historicisms (*boyarynya*, *gosudarynya*, and *monakhinya*). At the same time, the semantic fields of feminitives denoting professions demonstrate that the suffix has ironic connotations (e.g., *chef—chefinya*, *filolog—filologinya*, and *petrograf—petrografinya*), as there are neglecting words (*podachka*, *vosh*, and *teterya*) and obscene lexical units.

5 Conclusion

The creation of feminine nouns is an important topic for both linguists and native speakers. Traditional methods of analysis do not focus on computational tools that provide researchers with up-to-date automatic procedures. By studying feminine nouns in Russian corpora, we were able to identify productive models for word formation and their semantic and stylistic shifts according to semantic fields.

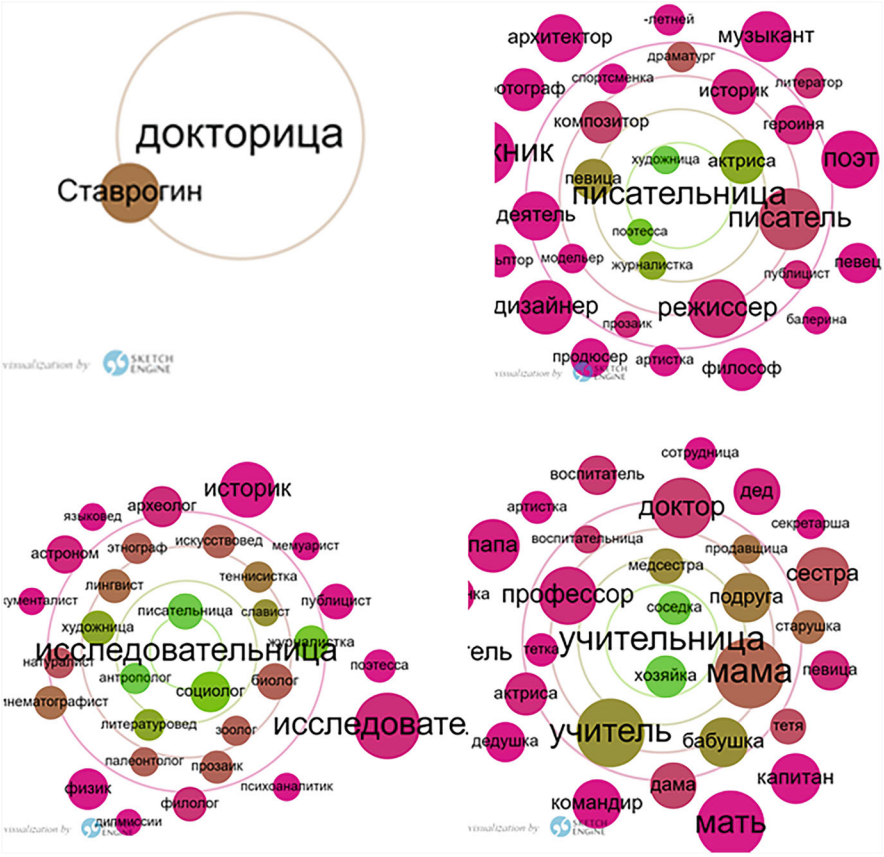

Fig. 4 Semantic field of lexemes with *–its(a)* suffix

Although the data from the corpora demonstrate distinct patterns, we want to emphasize that the overall observations are based on statistical information. This means that the assumptions are not rigid rules but tendencies that might become a language norm someday. Future research could expand the range of feminine nouns analyzed and investigate a broader selection of social networks and corpora.

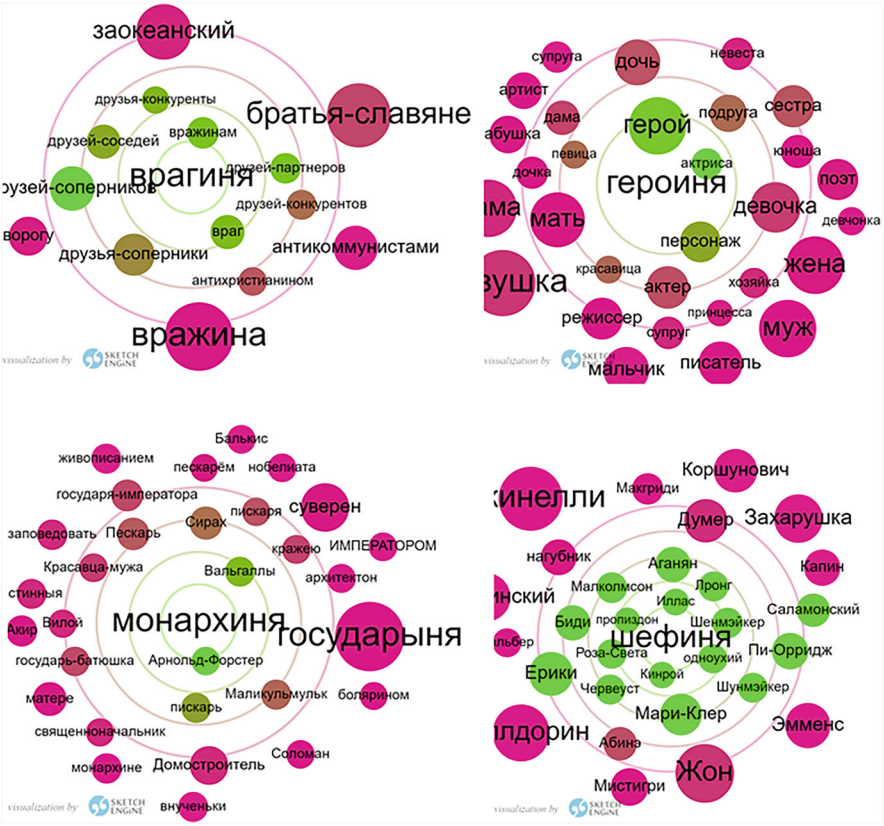

Fig. 5 Semantic field of lexemes with *–in(ya)* suffix

References

1. Vinokur, G.O.: O zadachakh istorii iazyka [Towards the tasks of the history of the language]. In: Izbrannye raboty po russkomu yazyku [Selected works on the Russian language] (in Russian), pp. 207–226, Uchpedgiz Publ, Moscow (1959)
2. Lopatin, V.V., Ulukhanov, I.S.: Slovar' Slovoobrazovatelnykh Affiksov Sovremennogo Russkogo Yazyka [The Dictionary of Word-Formation Affixes of Contemporary Russian] (in Russian), 812 p. Azbukovnik Publ, Moscow (2016)
3. Zakharov, V.P., Bogdanova, S.Y.: Korpusnaya Lingvistika [Corpus Linguistics] (in Russian). Saint Petersburg State University Publ, 234 p (2020)
4. Nesset, T., Piperski, A., Sokolova, S.: Russian feminitives: what can corpus data tell us? Russian Linguistics. **46**, 95–113 (2022). https://doi.org/10.1007/s11185-022-09253-w
5. Kilina, L.F., Sokolova, A.: Feminitives with the suffix -ix(a) in Russian texts of the 18th–20th centuries: a corpus study. Voprosy Jazykoznanija (in Russian). **1**, 85–105 (2022). https://doi.org/10.31857/0373-658X.2022.1.85-105
6. Mineeva, Z.I.: Feminitives with Suffix '-shits(a) /-chits(a)'. Nauchnyi Dialog [Academic Dialogue] (in Russian). **7**, 142–157 (2020). https://doi.org/10.24224/2227-1295-2020-7-142-157

7. Sokolova, A., Koryčánková, S.: Russian feminitives with expressive suffixes −ixa, −ša and their Czech translation equivalents: a corpus study. Russian Linguistics. **47**, 41–59 (2023). https://doi.org/10.1007/s11185-023-09270-3
8. Shvedova, N.Y.: Russkaya grammatika: Fonetika. Fonologiya. Udareniye. Intonatsiya. Slovoobrazovaniye. Morfologiya [The Russian Grammar: Phonetics, Phonology, Stress, Intonation, Word-Formation, Morphology] (in Russian), vol. 1, 660 p. Nauka Publ, Moscow (1982)
9. Zakharov, V., Pivovarova, S., Gvozdyova, E., Semenova, N.: Corpus methods and semantic fields: the concept of empire in english, russian and czech. In: Proceedings of the III International Conference on Language Engineering and Applied Linguistics, Saint Petersburg, pp. 233–244 (2020)
10. Karaulov, Y.N.: Struktura leksiko-semanticheskogo polya [The structure of the lexical and semantic field]. Filologicheskiye nauki [The Philological Studies] (in Russian). **1**, 57–68 (1972)

Generation of Space Descriptions Based on Distributional Semantic Models

S. P. Gorovaia

Abstract The report describes a method for generating descriptions of space in virtual reality based on corpora modeling. We performed an analysis of mathematical methods and machine learning algorithms for processing large arrays of text data and creating text descriptions of objects and scenes in virtual space. A large corpora of descriptions was collected and processed. The report includes keyword extraction and named entity approach. We used pretrained static Word2Vec models to predict lexical substitutions for nouns and adjectives with a locality function in description and compared their predictions with a Word2Vec model trained on our corpora. Textual data preparation was performed by means of Latent Dirichlet Allocation. Nouns and adjectives expressing a locality function were substituted with three models learned on different datasets. The results of the experiments prove that our approach allows us to create texts that meet the requirements of well-formedness, meaningfulness, and coherence.

Keywords Text generation · Corpus modeling · Spatial structures · Machine learning

1 Introduction

The idea of this research goes back to school literature lessons, where students often take tests on the content of home reading. In these tests, it was required to indicate what color the wallpaper was in the hero's room, or what paintings hung on the walls, or describe the hero's dwelling. In virtual reality games, users can create interiors, and there are examples of space design where names of artifacts are grouped by type and specified in lists. Our focus is on the development of such a linguistic processor so that it would be possible to input a literary text containing a description of the space and at the output to get a compressed description of all the

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_13

spaces that are mentioned in the text or a list of objects that would be convenient to visualize.

Thus, the purpose of this research is to explore methods of extracting words and structures that are used to describe space using corpus modeling methods and to identify the most appropriate model for predicting words in this thematic group.

To achieve this goal, it is necessary to solve the following tasks:

1. Analyze the concept of literary space.
2. Investigate corpus modeling methods.
3. Collect a corpus of texts rich in descriptions of literary space.
4. Preprocess the corpus.
5. Study the features of Word2Vec Static Models.
6. Train the model on our own text corpus.
7. Compile gap-filling texts to evaluate the models.
8. Generate locative substitutions using models.
9. Evaluate the results obtained in the course of experiments.

The relevance of the study lies in the need to expand the potential of distributional semantics and the lack of systematic empirical data for predicting vocabulary related to specific topics such as space descriptions. Our solution is based on the task of lexical substitution, which consists in selecting a suitable replacement for a target word in context and has been actively studied over the past few decades in relation to English and some other European languages, but not Russian. The results obtained may be of interest to specialists in the field of computational linguistics and artificial intelligence and can be applied in tasks such as natural language processing and paraphrasing, machine translation, text simplification, and generation of lexical-grammatical tests [1].

2 Location Constructions Detection

2.1 Literary Space

Literary space is the totality of all details in which the hero of a text exists. A specific literary space not only binds the world to some topographic realities but also influences the characters portrayed by the author. In literature, descriptions of spaces such as cities or the hero's house are most often found. The reader perceives the literary hero as an inseparable part of the space in which they live.

In literary texts, the following spatial models can be distinguished:

1. Psychological.
2. Real.
3. Space.
4. Mythological.
5. Fantastic.

6. Virtual.
7. The space of reminiscences.

In our work, we consider real geographical space. It can be a specific place: a city, village, nature, or a room setting.

The characteristics of real space can be divided into the following:

1. Horizontal—the length of the four cardinal points or four spatial landmarks.
2. Open—do not have specific boundaries.
3. Closed—have strictly defined and permanent boundaries.
4. Dynamic—in motion and changeable.
5. Static—unchanging and motionless.

All these will be called locatives.

2.2 Locativity

The conceptual category of space is realized in language as a functional-semantic category of locativity.

Locatives typically appear in sentences as spatial circumstances. Their functions are implemented in the following versions [2]:

1. Locative proper—a place relative to which an object, action, or event is determined: *we live in a house, a summer shift*, and *in a camp*.
2. Ablative and finitive—the starting and ending points of an action: *left the apartment* and *go to the finish line*.
3. Transitive—the space between the beginning and end of an action: *walk along the building* and *run through the yard*.

Locatives can be situational in nature; they are not considered in this chapter.

Named entities have a locative meaning; in this work, parts of phrases like "adjective + noun" will be considered.

Paraphrasing is the process by which a given text is modified so that it is different in spelling but similar in meaning. Also, the new text must meet the criteria of integrity and coherence. The result of the task of generating a space description can be a text.

One of the methods of paraphrasing is lexical substitutions. To predict lexical substitutions, the RusVectores [3] service can be used, which contains trained static models that perform the function of finding the "most similar word." Research has been conducted on the capabilities of the RusVectores service to identify semantic associates of Russian verbs [4], as well as a study of the typology of semantic relations identified by the RusVectores service [5]. These studies allow us to make an input that the RusVectores service can be used to identify lexical substitutions for nouns and adjectives.

2.3 How Word2Vec Models Work

The principle of operation of static models Word2Vec [6] is as follows: the input is a dictionary of words, each of which is assigned a one-hot vector. It is fed into the hidden layer, where it is multiplied by the weight matrix. Then, using the softmax algorithm, it receives a set of numbers equal to the probability of meeting the word of the given output neuron next to the initially given word. It is the rows of the weight matrix, in the selection of which the training of the model consists, that are semantic vectors. The proximity of words is calculated by the proximity of vectors in the vector space; in this case, the dimension is 400. The difference between the words is measured by the difference in the cosines of the vectors.

2.4 Topic Modeling Task

The LDA (Latent Dirichlet Allocation) [7] algorithm is most often used for topic modeling. By such tasks, we mean the tasks of fuzzy clustering where each class or cluster contains texts with similar topics.

In order to apply LDA to a corpus of texts, it is necessary to convert the corpus into a term-document matrix.

The term-document matrix is a matrix that has the size of the number of documents in the corpus by the size of the vocabulary of the corpus, i.e., the number of unique words that occur in our corpus. The *i*th row, *j*th column of the matrix contains a number—how many times the *j*th word occurs in the *i*th text.

For a given term-document matrix and a predetermined number of topics T, LDA builds two distributions:

1. Distribution of topics in texts.
2. Distribution of words by topic.

The values of the cells of these matrices are, respectively, the probability that a given topic is contained in this document for the "Distribution of topics by texts" matrix.

For the "Distribution of words by topics" matrix, the values are, respectively, the probability of meeting word *j* in the text with topic *i*. Qualitatively, these numbers can be considered as coefficients characterizing how a given word is typical for a given topic.

In this case, it is more appropriate to speak of a topic as some kind of abstract entity, which is given by a line in the matrix of distribution of words by topics and with some probability corresponds to the given text. One can think of it as a family of characteristic sets of words occurring together, with corresponding probabilities, in some particular set of texts.

3 An Experiment on Generating Descriptions of Spaces Based on Corpus Modeling

3.1 Research Corpora

To generate descriptions of spaces, a text model created by corpus modeling is required. The primary task of this method is to create a suitable corpus.

Not every text contains a description of a real geographic space. To carry out the necessary experiments, a corpus of texts saturated with locatives was required. The final corpus consisted of 878 texts/727080 word usages, including texts from the Moshkov library: all texts from the travel genre, lives of the saints, complete works of F. M. Dostoevsky, N. V. Gogol, I. A. Goncharov. After the exclusion of texts with prerevolutionary orthography, 614 texts remained. Parsing was used to collect the corpora using the beautifulsoup Python language library. The corpora manager AntConc was used to process the case. Examples of texts: A. N. Oleinikov's "Geological Clock," E. L. Markov's "Russian Armenia," I. P. Minaev's "Lion Island," N. V. Gogol's "Dead Souls," K. D. Ushinsky's "Trip for the Volkhov," and A. Dumas' "Caucasus".

3.2 Keyword Extraction and Named Entity Recognition

At the first stage of the study, corpus processing technique was applied that combines automatic extraction of keywords and phrases with the procedure for name entity recognition using libraries containing semantic markup, selecting *n*-grams with locative value from keywords. Keywords were extracted from preprocessed texts of the corpus using the RAKE [8] algorithm. Then, using the Spacy library, the named entities were marked up (special attention was paid to locations). However, the result turned out to be unsatisfactory, namely, the markup of entities turned out to be inaccurate, and there were fewer locatives than they actually were. Therefore, a different strategy was adopted.

3.3 Word2Vec Models

At the second stage of the study, it was decided to use Word2Vec static predictive models. For the experiment, ready-made trained models were taken from the RusVectores platform: trained on the 2021 Russian National Corpus (RNC) [9] and Wikipedia corpus and a CBOW model trained on the 2019 RNC. The third Word2Vec model was also trained on the assembled corpus of texts with a high content of locatives. The resulting model contains 447,235 vectors, and the learning parameters were selected empirically (see Table 1).

Table 1 Parameters of models

Identifier	Corpora	Corpora size	Vocabulary	Vector dimension	Window	Date
ruwikiruscorpora_upos_cbow_300_10_2021	RNC and Wikipedia November 2021	1.2 billion words	249,333	300	10	December 2021
ruscorpora_upos_cbow_300_20_2019	RNC	270 million words	189,193	300	20	January 2019
Trained model	Corpus of space descriptions	727,080 occurrences	447,235	400	3	April 2023

The essence of the experiment was to compare the accuracy of predicting the replacement of words of a certain topic using models trained on general language corpora and a model trained on corpora of specific texts with selected learning parameters.

It was noted that the result of the "most similar words" function in general language models contained a variety of paradigmatic correlates—hyperonyms, hyponyms, synonyms, as well as antonyms, derivatives of other parts of speech, and words with errors in morphological markup. In training our own model, the parameters (the size of the context window and the dimension of the vectors) were selected so that the output would mainly contain synonyms, hyponyms, and hyperonyms. Before training, the corpus was cleaned with a stop dictionary, lemmatized, and marked up using UDPipe [10]. In the morphological markup that was carried out, there are many fewer errors than in general language models.

Static models were chosen to generate predictions of lexical substitutions because they allow to set more restrictions related to the linguistic properties of the structures under study and also allow researchers to control the learning process and have more influence on the result.

3.4 Collecting the Dataset

To compare the accuracy of substitution prediction, 29 texts were selected. For the convenience of working with a large collection, the TopicModelingTool was chosen, which implements a user-configurable LDA topic modeling algorithm. From the corpora, 10 texts with a total volume of 926,211 word usages were selected, in which it was assumed that there were descriptions of dwellings. These texts were lemmatized using the pymorphy2 library [11] and divided into segments of 10 lines. Then, using TopicModelingTool [12], 20 topics were selected in each of the 10 texts. Of these, topics that included locatives were selected. According to the results of topic modeling, the texts within the topics were ranked by representativeness; as a result, 29 segments were selected.

3.5 Predicting Substitutions

At the next stage, nouns with the meaning of the locative and adjectives that describe them were selected from the texts of the generated dataset. The resulting text model was taken as the basis for generating a paraphrased text, namely, it was proposed to generate lexical substitutions for the selected words so that the new text was coherent and did not distort the meaning of the original text. For the selected nouns and adjectives, 5 closest words were predicted using the given models. Example results for a noun *стол*: ***модель Вики и НКРЯ****: 'столик_NOUN', 'стул_NOUN', 'диван_NOUN', 'табурет_NOUN', 'табуретка_NOUN'; **модель НКРЯ**:*

‘столик_NOUN’, ‘стул_NOUN’, ‘стол_PROPN’, ‘табурет_NOUN’, ‘диван_NOUN’; ***обученная модель:*** *‘столик_NOUN’, ‘стул_NOUN’, ‘скамья_NOUN’, ‘скамейка_NOUN’, ‘диван_NOUN’.* Пример результатов для прилагательного *ситцевый:* ***модель Вики и НКРЯ:*** *‘стеганый_ADJ’, ‘сарафан_NOUN’, пестрядинный_ADJ’, ‘цветастый_ADJ’, ‘кружевный_ADJ’,* ***модель НКРЯ:*** *‘кумачный_ADJ’, ‘холстинковый_ADJ’, ‘сарафан_NOUN’, ‘холстинный_ADJ’, ‘кисейный_ADJ’,* ***обученная модель:*** *‘ватный_ADJ’, ‘суконный_ADJ’, ‘шитый_ADJ’, ‘вышитый_ADJ’, ‘парчовый_ADJ’.*

The results can be assessed as follows: for locative nouns, the trained model performs better because general language models, antonyms, derivatives of other parts of speech, and erroneous words (repetition of the word to be replaced or words with an erroneous label of the part of speech, e.g., *солнце_VERB*) are often found. With common words, the results of all models are worse; the trained model coped a little worse because the corpus for training was not large and balanced enough. For adjectives describing locatives (*ситцевое одеяло*), the trained model offers more options, of which almost all are suitable. Despite a relatively small corpus and a small number of vectors, the predicted words have rather high cosines (0.6–0.75), the same as in general language models. In rare words, all three models had problems. It is also noticeable that, since the training building was unbalanced, specific words occur in the predicted replacements (e.g., *юрта* instead of *комната* because there were many notes from travels to northern Russia).

3.6 Estimation of the Accuracy of the Results

To estimate the accuracy of the results, a survey was conducted among native Russian speakers. Respondents were offered three gap-filling texts, each with 5 missing words. For each gap, the original word and all the words that three models predicted were proposed (each model predicted 5 words, but words with incorrect part-of-speech tags were excluded, and some words overlapped, so there was an individual number of suggested words for each gap). A total of 22 people were interviewed. Absolute and relative metrics were chosen to evaluate the results. To calculate the absolute score, all the votes left by the respondents for each of the five predicted words were added up and divided by the maximum number of votes that the model could receive in total for all the predicted words. The relative score was obtained by adding up all the words for which at least one person voted and dividing this sum by the number of all words predicted by the model. The absolute accuracy was 28.42% for the Wiki model and RNC, 24.78% for the RNC model, and 25.27% for the model we trained. The relative accuracy was 74.67% for the Wiki model and RNC 2021, 62.67% for the RNC 2019 model, and 82.67% for the trained model.

4 Conclusion

The results of the experiment show that the static model is effective in solving the problem of paraphrasing and, in many cases, copes even better than general language model (fewer markup errors, more word choices, and fewer antonyms and derivative words). The model copes well with specific vocabulary [*ситцевое одеяло* (*chintz blanket*), *коридор* (*corridor*), *шкаф* (*closet*)]; for common words, there is not enough data for training.

The planned development of this work is to retrain the model on an extended corpus so that it copes well with high-frequency words and compare the results with transformer models. Further use of this model is to extract locatives from solid literary texts in order to visualize the literary space.

The results of this study may be useful for specialists in the field of computational linguistics and artificial intelligence working on paraphrase generation and lexical substitution. The study presented in this chapter may serve as an impetus for further research on applications of distributional semantic models in language acquisition. The models developed and tested in the course of these experiments can be used to compose gap-filling texts for learning the Russian language.

References

1. Leont'ev, A.V., Mitrofanova, O.A.: Razrabotka i ocenka algoritma leksicheskoj sub-stitucii dlya russkogo yazyka na osnove predskazyvayushchih nejrosetevyh modelej//Terra Linguistica. 2023. [Leontev, A.V., Mitrofanova, O.A.: Development and evaluation of the lexical substitution algorithm for Russian based on predictive neural network models. Terra Linguistica. **14**(2), 31–44 (2023)]
2. Fedoseeva, L.N.: Denotativnye funkcii slov v russkom predlozhenii (na primere funkcionirovaniya lokativov), Vestnik Ryazanskogo gosudarstvennogo universiteta im. S. A. Esenina, (2016). [Fedoseeva, L.N.: Denotative functions of words in the Russian sentence (according to the perception of locatives), Bulletin of the Ryazan State University. S. A. Yesenina, (2016)]
3. RusVectores, Homepage, https://rusvectores.org/ru/. Last accessed 2023/05/26
4. Timofeeva, M.K.: Vozmozhnosti ispol'zovaniya servisa RusVectores dlya vyyavleniya semanticheskih associatov glagolov russkogo yazyka, Nauchnyj dialog, №9, 117–131 (2018). [Timofeeva M. K.: Possibilities of using the RusVectores service to determine the semantic associates of Russian verbs, Scientific Dialogue, №9, 117–131 (2018)]
5. Timofeeva, M.K.: Tipologiya semanticheskih otnoshenij, vyyavlyaemyh posredstvom instrumenta RusVectores, Nauchnyj dialog, №8, 74–87 (2018). [Timofeeva, M.K.: Typology of semantic relations revealed by the RusVectores tools used, Scientific Dialogue, №8, 74–87 (2018)]
6. Seleverstov, V.: Word2Vec: pokazhi mne svoj kontekst, i ya skazhu, kto ty., Sistemnyj Blok (2019), https://sysblok.ru/knowhow/word2vec-pokazhi-mne-svoj-kontekst-i-ja-skazhu-kto-ty/, last accessed 2023/05/26. [Seleverstov, V.: Word2Vec: show me your context and I'll tell you who you are, System Block (2019), https://sysblok.ru/knowhow/word2vec-pokazhi-mne-svoj-kontekst-i-ja-skazhu-kto-ty/. Last accessed 2023/05/26]
7. Blei, D.M., Ng, A.Y., Jordan, M.I.: Latent Dirichlet Allocation. J. Mach. Learn. Res. **3** (2003)

8. Moskvina, A.D., Erofeeva, A.R., Mitrofanova, O.A., Harabet, Y.A.K.: Avtomaticheskoe vydelenie klyuchevyh slov i slovosochetanij iz russkoyazychnogo korpusa tekstov s pomoshch'yu algoritma RAKE, Trudy Mezhdunarodnoj konferencii «Korpusnaya lingvistika – 2017. SPb.», (2017). [Moskvina, A.D., Erofeeva, A.R., Mitrofanova, O.A., Kharabet, Y.A. K.: Automatic selection of words and phrases from the Russian corpus using the RAKE algorithm. Proceedings of the International Conference "Corpus Linguistics, 2017. SPb." (2017)]
9. Russian National Corpus, https://ruscorpora.ru/. Last accessed 2023/05/26
10. UDPipe, https://lindat.mff.cuni.cz/services/udpipe/. Last accessed 2023/05/26
11. pymorphy2, https://pymorphy2.readthedocs.io/en/stable/user/index.html. Last accessed 2023/05/26
12. TopicModelingTool, https://github.com/senderle/topic-modeling-tool. Last accessed 2023/05/26

Part III
Interactive Systems & Information Society Technologies

"UnnCyberpsy": A Web Application for Psychophysiological Research of Subjective Sleepiness Dynamics

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Abstract Data collection is a crucial stage in conducting scientific research, and data-driven approaches are now common in psychological research. In this paper, we present our experience of conducting a large-scale psychophysiological (i.e., studying the relationship between physiological and psychological processes) study using our web application, "UnnCyberpsy," for data collection and processing. UnnCyberpsy was developed using the PHP programming environment and "CodeIgniter" microframework (version 4.0) and provides several key features, such as the ability to schedule appointments for equipment collection, complete testing steps based on a branched algorithm, and store and preprocess data. Each testing step is pre-programmed into the system, and participants can complete the testing process independently using their personal devices. The data is collected, pre-processed, and stored automatically, and after the experiment is complete, all participant data is checked and saved. By utilizing UnnCyberpsy, we have significantly reduced data loss, increased participant turnout by 30%, and significantly increased the speed of data collection, which is now limited only by the number of potential participants and equipment kits. Our experience highlights the potential benefits of online applications as a convenient and efficient tool for data collection and research facilitation for both researchers and participants.

Keywords Web application · Psychophysiological research · Subjective sleepiness

1 Introduction

Data collection is a crucial stage in scientific research, and the growing presence of information technologies has encouraged researchers to explore avenues for automating this process. This is particularly important as data quality becomes a concern with the rise of big data analysis, and manual data collection is prone to human error

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_14

and slower than automated methods. Consequently, data-driven approaches are gaining traction in psychological research [1]. This need for automation is especially pronounced when developing automatic systems for detecting human conditions.

The development of intelligent systems for detecting drowsiness in human operators has become crucial in recent years for preventing human-caused accidents. Therefore, new research is necessary to develop reliable methods for identifying drowsiness episodes during human interaction with complex technical systems. While studies have successfully developed intelligent warning methods for smart vehicles, achieving up to 97% accuracy in preventing driver drowsiness accidents [2–5], no current research analyzes large, representative samples. Our project distinguishes itself by targeting a specific territory's specialized population involved in a critical process—drivers—and by collecting, for the first time, a complexly marked large dataset with multi-hour heart rhythm recordings marked for sleepiness using three measures: subjective sleepiness based on self-assessment scales, daily hour, and time of the last questionnaire filling.

In this paper, we share our experience conducting large-scale psychophysiological research using our web application, "UnnCyberpsy," for data collection and processing. This two-year project (2022–2023) aimed to develop a sleepiness detector through analysis of heart rate data. There are several necessary steps we had to take to collect data suitable for identifying markers of different sleepiness levels in heart rate patterns: (a) invite participants to a laboratory for instructions and equipment.; (b) gather information about their sleepiness levels at different points to capture individual variations; (c) collect data on sleep patterns, including the time participants went to sleep, to understand the pre-sleep period; (d) collect sociodemographic information to identify factors influencing sleepiness and improve the detector's accuracy.

Previous studies have highlighted the advantages of automated data collection systems, including faster collection, improved data quality and completeness, and reduced workload for data receivers [6–10]. Given the project's requirements (a)–(d) and the need for a sizable participant group, these advantages motivated our decision to develop an automated system using a web application format.

2 Related Works

Data gathering methods can present challenges for researchers, prompting the development of various software options. In a comprehensive review conducted by Alavi and Massman, these options were compared based on the features they provide and their associated costs [11]. Electronic data management systems span from simple services to full-scale solutions with administrative support. The researchers categorized the available sources into five distinct groups, ranging from stand-alone spreadsheets in Microsoft Excel and basic databases in Microsoft Access to high-cost, large-scale database systems and cloud-based solutions.

However, not all of these categories ensure the secure containment of participants' personal information despite their accessibility and user-friendly interfaces.

Conversely, some options lack flexibility in customizing survey forms, while others demand extensive tailoring for each study, accompanied by high maintenance costs, ultimately yielding optimally pre-processed data. Additionally, the authors underscore that certain studies may have unique requirements that are not met by existing commercial solutions. This assertion finds support in numerous papers detailing researchers' experiences in crafting their own digital solutions.

Bizzego and colleagues describe the development of a custom web resource called Physiolyze, designed to process heart rate variability (HRV) data—one of the most frequently used types of data [6]. However, processing this type of data requires high computational capacity, particularly in different life contexts where fast calculations are crucial. The system presented by the researchers is based on two main components: pyHRV, an open-source Python toolbox with a range of functions for HRV analysis, and the Galaxy platform—a back-end software tool commonly used for bioinformatics research. The system was successfully tested with different heart rate sensors and demonstrated support for various HRV indexes. The undoubted advantage of the system is that it provides the collection of physiological data (heart rate) in the context of real life. However, Physiolyze does not provide for the construction of research scenarios, which is often very important in experimental works.

Another team presented a case study on the development of an educational management information system and provided a detailed analysis of web-service data collection in general [7]. The authors emphasize the positive impact that online data collection methods have brought to the quality of datasets in terms of speed, accuracy, reliability, and completeness. Additionally, the use of web services has helped overcome issues related to data transfer in heterogeneous computer environments, time spent on data collection, and data presentation formats. This system is a good example of the automation of manual data collection and processing. At the same time, the system assumes data collection only by predetermined blocks and does not assume a branched algorithm. We argue that the information system for assessing sleepiness dynamics should (a) be cyclic (sleepiness should be recorded at equal intervals) and (b) be branched (cyclicity should be interrupted when a person reports going to bed).

Hanbury and colleagues describe how the implementation of a web-based management application improved the data management process for longitudinal studies [8]. The researchers encountered various challenges, such as geographical remoteness of research sites, variable work hours of the participants, a large number of variables involved in testing, different types of research teams, and a multilingual community of participants. The use of an integrated web application significantly reduced the amount of time spent on data collection, leaving more time available for the field researchers to communicate with the participants and produce more accurate and detailed reports. The application also facilitated communication between different research teams, enabling them to split up responsibilities and providing real-time updates on gathered information, allowing researchers to adjust the course of the

study if necessary. However, access to the internet was a limitation in some remote parts of the country, and occasional IT support was required from the developers to add users to the system or resolve other programming-related issues. Thus, this case also confirmed that web applications can increase the efficiency of data collection. Key benefits include increasing the speed and quality of data collection, having the possibility of automatic report preparation, and receiving real-time updates on gathered information.

Zhang and colleagues discuss their experience of using digital services in a medical environment [9]. Their goal was to assess the advantages of data collection, project management, and telemonitoring in a hospital setting, and they developed a mobile application called mEDC for electronic data capture. The mEDC consisted of a mobile application and a server-based clinical database that allowed for a range of functions such as creating appointments, signing informed consent, inputting patient data, delivering medicine, and scheduling appointments for biological sample collection. The system was tested with different users, from patients to research associates and managers across 14 hospitals, and the researchers received positive feedback, particularly on real-time data collection and management. The mobile application was particularly effective, as it allowed doctors to input data directly into the system and reduce the time spent on patient records. However, the stability of the Internet connection was a limitation of the system, and the authors suggest further development to include features such as medical record change tracking and electronic signature implementation. Consequently, the use of an automated system has saved time while maintaining the information required in this context.

Finally, Canino et al. present an innovative approach to improving wellness through the integration of geographical data into medical records [10]. The authors introduce GeoBlood, a web-based system that collects patients' blood analysis results and their geolocation to investigate the potential correlation between environmental factors and health issues. The system stores clinical information, hospital information, and geographic information, enabling users to access and analyze the collected data. It provides features such as descriptive statistics, data navigation, and data export, allowing users to monitor changes in biological data over time for individual patients, as well as statistical data by age or gender. The system was tested with clinical data and showed promising results, though the authors suggest further improvements are necessary to enhance its functionality. Thus, GeoBlood provides effective access and analysis of the collected data. An important advantage is the possibility both to export data and to obtain descriptive statistics. Also, users have the ability to track the dynamics of the input data, which is important if we consider experimental studies involving large samples.

Thus, the reviewed experience of creating and using automated systems, reflected in scientific publications, shows that such systems are created: (a) either for continuous data recording without regard to the context and the possibility of setting stages; (b) or to automate manual data entry in surveys for different tasks and to automate reporting. The undoubted advantage of using automated systems is the ability to aggregate data and obtain descriptive statistics and reports. At the same time, the considered systems: (a) do not assume the branched algorithm of the data

collection scenario; (b) do not give the possibility of interaction with the system before the stage of authorization. Experimental research in natural conditions with the use of laboratory equipment involves the participant coming to the laboratory to receive instructions and equipment. This stage can also be automated to eliminate the need to contact the participant directly. Authorization is not necessary at this stage, as the potential participant may not "reach" the stage of the experiment itself. Therefore, we believe that this stage should also be automated and included as part of a comprehensive system for conducting mass psychophysiological research. A branching algorithm is necessary, for example, when studying the dynamics of sleepiness from evening to nighttime because in this case the system needs to disable the cyclic questioning of sleepiness levels when a person reports that he/she is going to bed. Therefore, none of the existing automated systems provide all the required options for our project, and we created our own web application that allows (a) both interacting with and without authentication and (b) a branched algorithm for the data collection scenario.

3 Web Application Description

Starting in 2022, the Laboratory of Cyberpsychology conducted a large-scale psychophysiological research study on subjective sleepiness dynamics in adults, involving, by the date of this paper's preparation, 230 participants. The study design required each participant to record their electrocardiogram, pulse, and interbeat intervals using a Polar H10 sensor from 07:50 PM until 06:00 AM, as well as provide their sociodemographic characteristics, including the presence of chronic conditions, caffeine consumption, the presence of sleep problems, driving experience, sleep and wakefulness habits, and subjective sleep characteristics. Additionally, participants were required to fill in three different questionnaires (Karolinska Sleepiness Scale (KSS), Stanford Sleepiness Scale (SSS), and Epworth Sleepiness Scale) at home.

An automated system called "UnnCyberpsy" was developed to overcome the challenges of collecting and processing large amounts of data in a recent psychophysiological study on subjective sleepiness dynamics in adults. This web application was designed using the PHP programming environment and the "CodeIgniter" microframework (version 4.0), based on the model-view-controller (MVC) pattern. To ensure user-friendliness and compatibility with different devices, the Bootstrap CSS framework (version 5.2) was utilized. The system employs MariaDB for data storage.

UnnCyberpsy provides several key features to facilitate the study.

1. First, participants can schedule an appointment to collect the necessary equipment and receive instructions. The system allows them (without authentication) to select a convenient date and time and sends reminders to their email. The

equipment pickup records are based on the availability of Polar H10 sensors, ensuring that participants can only sign up for dates when equipment is available for pickup.

Before implementing key feature (1), the experimenters telephoned potential study participants to set a date and time for them to come to the lab. Of the 38 calls, only in 23 cases could the date and time be immediately agreed upon. Seven potential participants did not pick up the phone (probably ignoring calls from unfamiliar numbers), and eight had already reconsidered participating in the experiment. Thus, the delay that occurs between the application to participate in the experiment and the experimenter's call leads to a loss of motivation to participate in the experiment.

The implementation of key feature (1) made it possible to exclude the participation of the experimenter at the stage of determining the date and time of the respondent's arrival at the laboratory to receive instructions and equipment. After the implementation of key feature (1), 90% registration and arrival of potential participants at the laboratory were ensured. Consequently, using UnnCyberpsy in its full version increased the turnout of potential study participants from 60% to 90%.

2. Second, the system requires users to create an account that is approved by the administrator, who, in this case, is the experimenter, before accessing it. Participants provide their email addresses as their login IDs, and the system generates a secure, randomly generated password that is sent to their email addresses. The system is pre-programmed for every stage of the testing process. Participants can complete pre-programmed tests with a branched algorithm using their devices, and the system automatically collects, pre-processes, and stores the data. Since the experiment design involves participants filling out tests at specific times, the system automatically opens the tests at predetermined intervals. The stages of pre-programmed testing with timing are presented in Table 1.

To ensure data accuracy and consistency, the system validates all input fields before saving them to the database. Most questions have limited answer options, while open-ended questions are checked for correct symbols. If errors are detected, the field is highlighted and accompanied by an error message. This approach eliminates human errors and standardizes participant responses, improving data

Table 1 The stages of pre-programmed testing

Information to fill out	Time
Personal information	07:50 p.m.
ESS	07:55 p.m.
SSS and KSS	08:00 p.m. and each 30 min after
	Until going to bed
Time of going to bed	Exact time when going to bed
SSS and KSS	06:00
Sleep quality	06:00
Dreams	06:00

quality. Detailed instructions are provided for all fields to assist participants in completing the survey accurately. Upon completion of the experiment, all participant data is checked and stored in the system.

Fifteen participants (6% of the current dataset volume) had episodes of completing cyclic tests with a delay of up to 10 min. However, this data is also suitable for analysis. These incidents occurred during the early stages of data collection, and later, the instructions in the web application were revised, leading to the disappearance of cases of late completion of cyclic tests. We can say that the data loss after updating the instructions became 0%. Given that the system automatically checks the accuracy of the forms, all the stored data is suitable for analysis. This means that UnnCyberpsy collects high-quality and accurate data.

The fact that the system is based on a branched algorithm allowed for taking into account the individual characteristics of each respondent's sleep-wake mode, evaluating the dynamics of their sleepiness up to the moment they went to sleep.

3. Third, the experimenter can view and download the results, as they have access to the database with all the stored data. Participants can be identified by their email address and the date of their first entry, allowing researchers to match the data recorded by the system with the data collected by the sensor during the experiment. Additionally, the system enables the export of a CSV file containing all user data for further analysis. Built on these principles, the database provides real-time access to updated results for the research group. The system's general pipeline is illustrated in Fig. 1.

In addition, it should be noted that the number of participants who can undergo the study in one day is limited only by the number of cardiac sensors and smartphone kits available in the laboratory (currently, there are ten of them). The use of the system allows the experimenter to be removed from the experiment itself, which has also increased the speed of data collection. In other studies of sleepiness (e.g., [12]), there was a need for specially trained experimenters to monitor compliance with the experiment protocol. Thus, UnnCyberpsy makes it possible to collect data on the respondents, on the dynamics of sleepiness, and on the heart rate as quickly as possible.

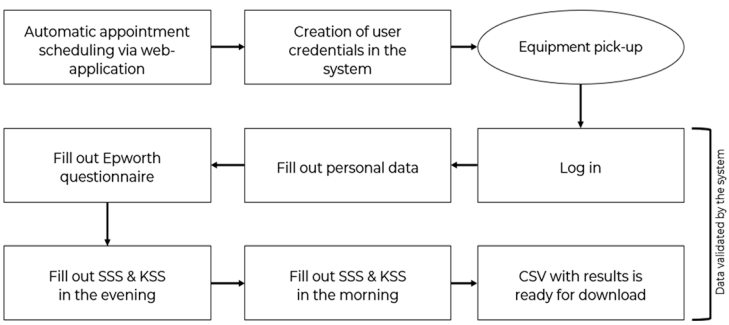

Fig. 1 General pipeline of UnnCyberpsy. Square blocks represent automatic interactions, and an oval block represents person-to-person interaction

4 Conclusions

The manual process of collecting and processing data for a psychophysiological study of subjective sleepiness dynamics can be overwhelming, especially with a large number of participants and a complex experiment design. To address this challenge, we developed a custom web application "UnnCyberpsy," which automates data collection, storage, and pre-processing. By adopting this solution, our research team was able to reduce the probability of data loss to 0%, increase the turnout of potential participants by 30%, and accelerate the speed of data collection, which is now limited only by the number of potential participants and equipment kits. Our case demonstrates that web applications can significantly simplify data collection and streamline research procedures for both researchers and participants. As a next step, we plan to expand the capabilities of UnnCyberpsy by incorporating the automatic downloading of heart rate data from Polar H10 sensors via our Android application "CyPsy."

Acknowledgments This work was supported by the Russian Science Foundation under Grant No. 22-28-20509.

References

1. Moustafa, A.A., Diallo, T.M.O., Amoroso, N., Zaki, N., Hassan, M., Alashwal, H.: Applying Big Data methods to understanding human behavior and health. Front. Comput. Neurosci. **12**, 84 (2018)
2. Phan, A.-C., Trieu, T.-N., Phan, T.-C.: Driver drowsiness detection and smart alerting using deep learning and IoT. Internet of Things. **22**, 100705 (2023)
3. Jabbar, R., Al-Khalifa, K., Kharbeche, M., Alhajyaseen, W., Jafari, M., Jiang, S.: Real-time driver drowsiness detection for android application using deep neural networks techniques. Proc. Comput. Sci. **130**, 400–407 (2018)
4. Mohana, B., Sheela Rani, C.M.: Drowsiness detection based on eye closure and yawning detection. Int. J. Recent Technol. Eng. (IJRTE). **8**(4), 8941–8944 (2019)
5. Wong, J.Y., Lau, P.Y.: Real-time driver alert system using raspberry Pi. ECTI Trans. Electr. Eng. Electron. Commun. **17**(2), 193–203 (2019)
6. Bizzego, A., Mina, M., Zarbo, C., Esposito, G., Furlanello, C.: Physiolyze: A Galaxy-based web service for Heart Rate Variability analysis with online processing. In: Proceedings of the 8th Conference of the European Study Group on Cardiovascular Oscillations (ESGCO), pp. 97–98. IEEE (2014)
7. Thukral, R., Goel, A.: Web service interface for data collection. Int. J. Comput. Sci. **9**(3), 525–530 (2012)
8. Hanbury, M.M., Sadeghi, B., Tseregounis, I.E., Gomez-Camacho, R., Manzo, R.D., Rangel, M. I., Alexandrescu, B., de la Torre, A.: A web-based application to improve data collection in an interventional study targeting childhood obesity: pre-post analysis. J. Med. Internet Res. **21**(1), e10861 (2019)
9. Zhang, J., Sun, L., Liu, Y., Wang, H., Sun, N., Zhang, P.: Mobile device–based electronic data capture system used in a clinical randomized controlled trial: advantages and challenges. J. Med. Internet Res. **19**(3), e66 (2017)

10. Canino, G., Scarpino, M., Cristiano, F., Mirarchi, D., Tradigo, G., Guzzi, P.H., Cuda, G., Veltri, P.: Geoblood: a web based tool for geo-analysis of biological data. Proc. Comput. Sci. **58**, 473–478 (2016)
11. Alavi, C.B., Massman, J.D.: Selecting an electronic data capture system. Urol. Pract. **3**(3), 236–241 (2016)
12. Casale, E.C., Yamazaki, E.M., Brieva, T.E., Antler, C.A., Goel, N.: Raw scores on subjective sleepiness, fatigue, and vigor metrics consistently define resilience and vulnerability to sleep loss. Sleep. **45**, zsab228 (2022)

Smart Video Number Plate Character Recognition Using Hybrid Optimization-Based YoloV3

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Abstract The number plate recognition (NPR) system plays a vital role in solving multi-level problems of security. NPR utilizes hybrid model techniques comprising image processing and optical character recognition (OCR). Accuracy measures how well the ANPR system correctly identifies license plate characters. Precision-recall balance is crucial in ensuring that the system does not miss any important details (recall) while minimizing false positives (precision). By combining precision and recall in a single metric, the F1-score provides a complete evaluation of the system's performance. Efficient management and monitoring in areas like toll roads and parking lots rely heavily on the reliability of ANPR systems. They enable streamlined operations, enhance security, and facilitate effective enforcement of regulations. NPR enables efficient management and monitoring in various applications like parking facilities for both public and private sectors, restricted areas such as gated communities, secure facilities, and sensitive government installations. Primary phase of NPR system is to capture image of number plate by using camera or imaging devices. By utilizing image processing techniques quality of image is enhanced and once the image is enhanced next step is locating the number plate within the image. The next step is to apply OCR algorithm to image to accurately identify and recognize number plate character. ANPR system accuracy depends on two important parameters, namely, quality of captured image and efficiency of OCR algorithm. Survey of research papers shows that the accuracy of recognizing Indian number using NPR system is 75–85% because of font size, regional language, and environmental conditions. Use of Optimized YOLOv3 for detecting number plate on

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_15

high-speed vehicle is logical choice. YOLOv3 is a popular algorithm for its speed and accuracy. By Improved Convolutional Neural Network (ICNN), character recognition of number plate is done after identifying the number plate. Overall, better performance has shown by Convolutional Neural Network (CNNs) in the identifying process. Convolutional Neural Networks (CNNs) have demonstrated strong performance in image recognition tasks. The role of NPR systems is vital in enhancing efficiency, safety, and compliance in transportation law enforcement and parking management system. Also, it is helpful for automatic toll collection. Overall, the NPR system has the ability to improve efficiency, enhance security, ensure compliance, enhance customer experience, and, by integrating with other technologies, make it a vital assets for transportation-related operations.

Keywords OCR · NPR · YOLOV3

1 Introduction

The integration of vehicle into information systems has become important with advancements in technologies. This integration opens up a wide range of possibilities for collecting valuable data from vehicles and using it for various purposes. This can be achieved by gathering important data obtained from vehicle for accurate and informational purposes, which is collected by automatic system or human that detect vehicles smartly, recognize number plate of that vehicle in real-time application, and forward data to theoretical process. Increasing numbers of vehicles on road has indeed create a demand for more efficient management and monitoring of parking. Automated system uses sensors, cameras, and advanced algorithm for better performance. Such systems are helpful in tracking the number of vehicles. For further development, the incorporation of vehicles into information system is helpful for obtaining truthful data for traffic management, such as accident location detection, real-time traffic updates, and traffic congestion information. Overall, the integration of vehicles into information systems holds immense potential to transform various fields and areas of work, driving innovation, efficiency, and sustainability.

By splitting the detected number plate image into separate characters and focusing on the relevant data required for character identification, the overall accuracy and efficiency of the number plate recognition can be tremendously improved. This approach reduces computational complexity and improves the system accuracy of character recognition of number plates.

Automatic number plate recognition systems have experienced significant growth and acceptance in recent year. This system consists of cameras and specialized software to capture images of number plate extract characters and convert them into machine-readable text. ANPR provides a number of benefits in terms of accuracy, efficiency, and automation in various domains. The gathered data from NPR system can be leveraged to automate variety of processes ranging from vehicle tracking and identification to enforcement of traffic regulations and monitoring parking.

Number plate recognition can be challenged due to a variety of factors, each of which presents unique obstacles for automated system [1]. In the number plate detection and acknowledgment system, the deprivation and disappearance of the number plate play an important role. Sometimes, environmental factors like dirt, mud, or fading can significantly impact the legibility of number plates, thereby affecting the performance of number plate recognition systems [2].

Convolutional neural networks have generated significant attention in recent years due to their remarkable effectiveness in handling image and video processing. From input data, CNN algorithms outclass feature extraction, creating powerful tools such as image classification, object detection, and semantic segmentation [3]. CNN has proved highly efficient in solving a wide range of problem. CNN has indeed revolutionized machine learning, particularly in computer vision tasks like image identification and classification. CNN can effectively extract relevant features from number plate, enabling accurate identification and recognition of number plate. One popular advantage of CNN in the NPR system is its strength in different lighting conditions [4].

The papers mentioned above provide different CNN-based algorithms for the identification and recognition of number plates. Each algorithm has its own approach to achieving high accuracy in tasks. These algorithms vary in their architecture and approach but show the common goal of accurately detecting and recognizing number plates from images or videos. Their accuracy is always dependent on the diversity of training data as well as the application area.

2 Literature Survey

Literature survey serves to provide essential insights and guidance for formulating a well-defined research problem and designing an effective study.

2.1 Related Work

In Ref. [5], discuss various advanced techniques for improving CNN-based image classification algorithm. The approach involves combining different CNN architecture to create a more powerful and robust model. The paper introduces a newer model including convolution layer to improve the performance of architecture. Overall, the paper approaches building more powerful and robust CNN-based image classification models by integrating state-of-the-art architecture and employing advanced techniques for data augmentation.

The utilization of YOLO-based networks for object detection [6] highlights the importance of speed and accuracy in real-time applications. YOLO is renowned for its ability to achieve high-speed object detection while maintaining accuracy. YOLO takes the entire image as input and processes it in a single pass through a neural

network. This reduces computational overhead and speeds up the process. The grid-based approach of YOLO simplifies the detection process and provides accuracy. YOLO enables real-time object detection, making it suitable for application. Despite speed, YOLO maintains competitive accuracy in object detection. It is a versatile algorithm can be used for different application with accuracy. The use of YOLO-based network for object detection provides a guarantee of achieving speed and accuracy.

Capsule network indeed introduces newer perspectives in neural network deviating from traditional CNN [7]. The concept of capsule is to overcome some limitations of CNN particular spatial relationship within data. CNN spatial information is often lost as the network process through the pooling layer leading to a reduction in the resolution of feature maps. The architecture typically involves a combination of the convolution layer, capsule layer and fully connected layer. Capsule networks offer a promising approach for tasks where preserving spatial relationships and hierarchical structure is important.

In Ref. [8], the method proposed for detecting and recognizing license plates in unrestricted states employs a multi-step process. The first step involves generating potential regions that contain license plates after identifying the license plate segment's individual character within the plate. Once characters are segmented, character recognition and decoding license plate are carried out. By combining these techniques and algorithm, the proposed method achieved robust and accurate number plate identification in and detection in diverse and challenging situations such as varying light condition.

2.2 Proposed Work

The recommended method consists of three major steps. The first step involve identifying the presence of vehicles within the image or video, which is input. The purpose of this stage is to sense the region of motor vehicle in image or in video where the vehicle is present. Once the vehicle is detected, locate the number plate of vehicle. After number plate location, the character recognition is performed on number plate. OCR optical character recognition is crucial stage in license plate recognition. OCR algorithm analyze the segmented characters on the license plate and attempts to recognize each character and convert them into machine-readable text. Traffic management is at the forefront of computer vision applications and transportation systems. Traffic management system is increasingly integrating with emerging technology and connected vehicle system. While bounding box representation is commonly used in standard object detection models to localize the object within the images or video frames, they may fail to provide precise location of vehicles in complex conditions. A number of methods presently used for such tasks are discussed here. YOLOv3 performs better in terms of accuracy in object detection on sunny days, and it has a lower minimum rate in the police investigation of multiple vehicle detection. YOLOv3's performance decreases when dealing with

rainy conditions [8]. RSE-NET and YOLO offer efficient solutions with minimum parameters while maintaining strong cryptography and enhancing object detection quality through some additional procedure [9]. An improved version of YOLOv3 delivers faster detection speed and higher accuracy; there is problems such as slower convergence and training speed as well as increased delay during inference [10]. YOLOv3 employs modified techniques like error correction to enhance performance. Challenges such as similar objects and high vehicle space ratio can still pose difficulties for object detection [11]. DNN mentioned offers such as high accuracy and faster processing camera frames. It requires advanced learning techniques and computational integration to achieve the desired output [12]. While Deep CNN provides accurate accident detection in live video with powerful representation and fewer parameters, it may suffer from instability in extracting the targeted region, which will degrade the performance of the system. Because of the above challenges, it is required to innovate advanced transportation systems using deep learning methods.

3 Research Methodology

With promulgation of police investigation cameras there is need for efficient video encoding techniques. Efficient coding is important for managing large volume of video data generated by these cameras. However, present video encoding standards are primarily designed for general purposes such as entertainment. While the bounding box is widely used for object detection tasks, it often falls short when it provides precise vehicle location. For more comprehensive applications like intelligent transport systems or laptop vision applications, accurately determining the precise location of vehicle is a crucial task. For different purposes, location of running vehicles on road plays an important part such as speed detection and accident prediction of vehicles. Advancements in intelligent transportation systems have really been monumental in the field of traffic analysis and law enforcement. The important task of this proposal is designing and developing advance video transportation checking system using advanced deep learning techniques. The proposed video traffic management system offers powerful combination of deep learning and real-time analysis to improve traffic safety, efficiency, and traffic law enforcement. The proposed process steps for the projected model are (a) gathering information, (b) vehicle identification, (c) number plate recognition, and (d) number plate character identification. Primary phase of model is data collection, in which video information on traffic is gathered. YOLOv3 and deep learning classifier are used for vehicle detection after collecting data [13]. Spider Monkey Optimization (SMO) and Coyote Optimization Algorithm (COA) are utilized to combine parameters [14, 15]. For speedy vehicle optimization YOLOv3 is used for number plate detection. Further character detection is carried out using an improved convolution neural network (ICNN). The information about vehicles that are violating traffic rules is conveyed to the vehicle owner and RTO for further action to avoid future

mishaps. Experimental results obtained from the proposed model show improvement in performance parameters compared to conventional models in different light conditions and weather conditions. This guarantees the safety of the transport system.

3.1 Pre-processing

Algorithm that uses a neural network for object detection from image is YOLOv3 (You Only Look Once version 3) [18]. Integrating YOLOv3 with Coyote Spider Monkey Optimization (MCSMO) can show an improvement in the performance of the YOLOv3 algorithm and decrease the computational difficulties. YOLOv3, a popular object detection algorithm based on convolutional neural networks (CNNs), is known for its real-time performance and accuracy. The incorporation of YOLOv3 with MSMCO optimization shows an improvement in the accuracy of speed detection as well as vehicle and license plate detection.

3.2 Proposed Yolov3-Based Number Plate Recognition

In this step, applying YOLOv3 to the data collected from vehicles efficiently detects vehicles and potentially extracts information such as license plate and speeds of the vehicles that have crossed the speed limit. Optimized YOLOv3 algorithm is used to identify a vehicle that has crossed the speed limit. The next step involves extracting information from number plate for further processing. This process ensures highway security and traffic violations. Tailoring the vehicle with the detected high speed and its corresponding license plate for an intelligent traffic management system using a video surveillance system for further action is a prudent step in ensuring the safety and enforcement of traffic regulations. The hybrid algorithm is proposed with combination of Coyote Optimization Algorithm (COA) and Spider Monkey Optimization (SMO) for character detection on number plate. MCSMO algorithm is designed to efficiently optimize performance while minimizing fuel cost. Spider Monkey Optimization algorithm is known for its effectiveness and independent functioning in solving optimization problem. The reliability and robustness of the Spider Monkey Optimization (SMO) algorithm play crucial role in overall performance. Hybridized MCSMO algorithm holds promise in addressing global optimum issue and resolving finite set of problem. The combining algorithm proves that it can solve optimization problem easily with good convergence speed. The functional block diagram to implement MCSMO is shown in Fig. 1. Hybridized algorithm offers many advantages, but they are not without limitations. COA is not designed to update the position of an object; it can be used to optimize the position of an object or vehicle based on a specific objective function. SMO is a powerful optimization algorithm that can be used to optimize the position of an object or vehicle based on a specific objective function.

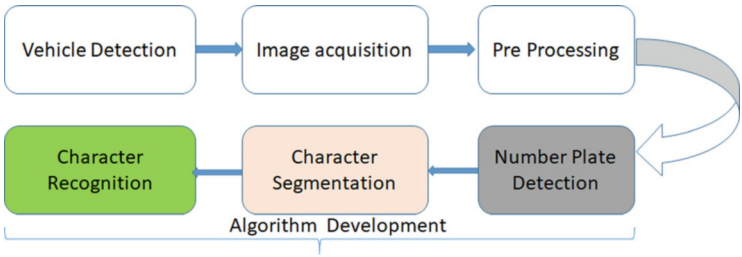

Fig. 1 Proposed functional block diagram

Fig. 2 Input real-time dataset

4 Results and Discussion

The discussed automatic transportation surveillance system was implemented using Python as simulation software, and video captured by the camera is a real-time input. The said algorithm together recognized multiple vehicles and number plates of vehicles and identified the number plate of the targeted vehicle. The method conducts experimental analysis, evaluating its performance using positive and negative measures. In this context, positive measures indicate successful detection and recognition of number plates, while negative measures assess any shortcomings or inaccuracies in the system's performance. The system utilizes a genetic algorithm approach, where chromosome length refers to the number of parameters or variables encoded in each chromosome and is fixed to 3. For the performance evaluations, the number of iterations was 20. The performance of the proposed MCSMO is compared with the particle Swarm optimization algorithm (PSO) [16]. JAYA optimization algorithm [17], Region-Based CNNs (RCNN) [19], Faster R-CNN [20], and Improved Faster R-CNN [21].

Dataset: input real-time data is gathered by camera. It consists of video of duration of 1.2 min; the video is in MP4 format. Each frame in the video has a resolution of 352 pixels in height and 640 pixels in width. The video contains six to seven vehicles, as shown in Fig. 2.

The proposed algorithm simultaneously detects multiple number plates and recognizes the charters in the number plate of the targeted vehicle. The performance of multiple algorithms for number plate detection, with MCSMO-ICNN showing

Table 1 Overall performance for number plate detection

TERMS	%PSO	%JAYA	%COA	%SMO	%MCSMO-ICNN
Accuracy	82.12	72.85	78.10	84.51	94.38
Precision	82.12	72.15	79.40	85.81	93.68
Recall	71.24	64.00	70.67	77.33	85.33
F1-score	76.29	68.27	74.33	81.62	88.57

higher values across different learning percentages. This suggests that MCSMO-ICNN outperforms the other algorithms in terms of its effectiveness in detecting number plates. When comparing F1-score values across different algorithms and datasets, MCSMO-ICNN consistently outperforms PSO-ICNN, JAYA-ICNN, COA-ICNN, and SMO-ICNN by a significant margin. At a learning percentage of 35% in dataset 1, MCSMO-ICNN achieves an F1-score that is 56% higher compared to the other algorithms, which have F1 scores of 40%, 38%, 36%, and 38%, respectively. The proposed traffic video surveillance system model uses MCSMO-ICNN and other reference algorithms in terms of accuracy, recall, F1-score, and precision. The results likely demonstrate that the proposed model outperforms the reference algorithms in both accuracy and precision metrics. This suggests that the MCSMO-ICNN model is more effective and reliable for the task of traffic video surveillance compared to the other algorithms; the combination of MCSMO and ICNN holds promise for improving the effectiveness of traffic video surveillance systems, particularly in terms of accuracy and precision in identifying and tracking vehicles, including the recognition of number plates. Table 1 summarizes the comparison of proposed and reference algorithms.

The performance of the proposed algorithm offers a promising approach for number plate character recognition in traffic video surveillance systems, potentially outperforming other algorithms, specifically focusing on accuracy in Fig. 3. It shows that the projected algorithm offers improvements of 13% in PSO, 21% in JAYA, 16% in COA, and 9% in SMO.

The performance of the proposed algorithm offers a promising approach for number plate character recognition in traffic video surveillance systems, potentially outperforming other algorithms, specifically focusing on precision in Fig. 4. It shows that the projected algorithm offers improvements of 13% in PSO, 21% in JAYA, 14% in COA, and 8% in SMO.

The performance of the proposed algorithm offers a promising approach for number plate character recognition in traffic video surveillance systems, potentially outperforming other algorithms, specifically focusing on the F1-score in Fig. 5. It shows that the projected algorithm offers improvements of 14% in PSO, 21% in JAYA, 17% in COA, and 9% in SMO.

The performance of the proposed algorithm offers a promising approach for number plate character recognition in traffic video surveillance systems, potentially outperforming other algorithms, specifically focusing on recall in Fig. 6. It shows that the projected algorithm offers improvements of 12% in PSO, 21% in JAYA, 14% in COA, and 7% in SMO.

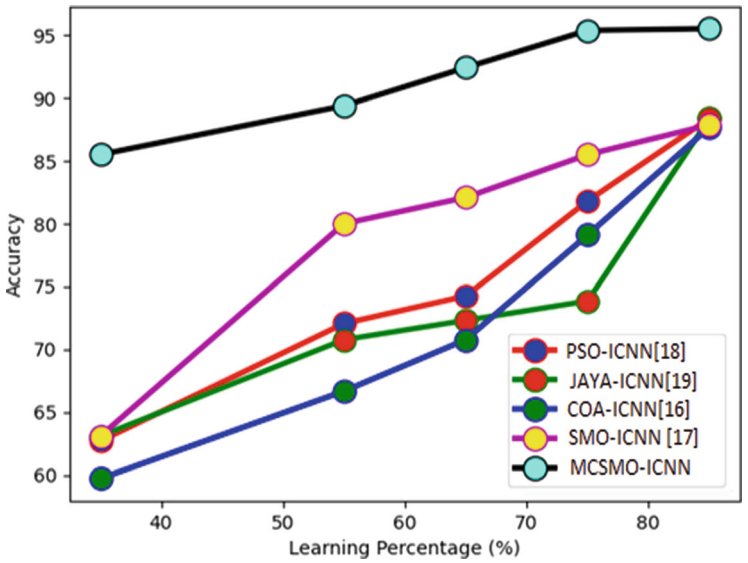

Fig. 3 Accuracy

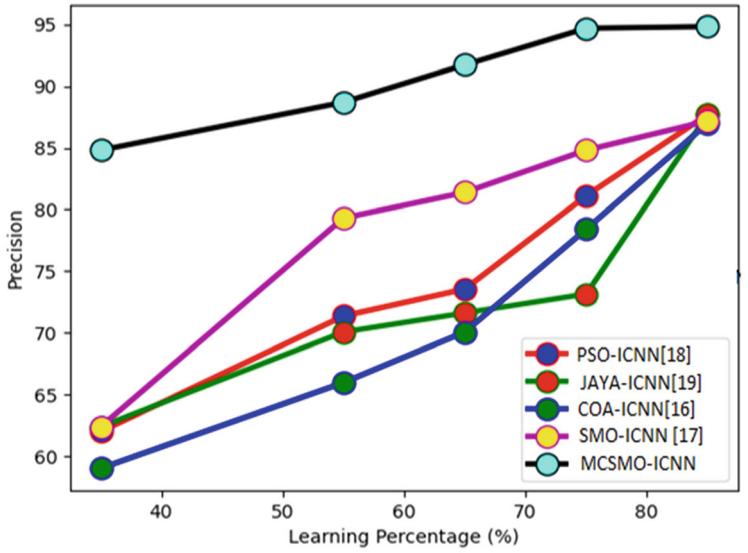

Fig. 4 Precision

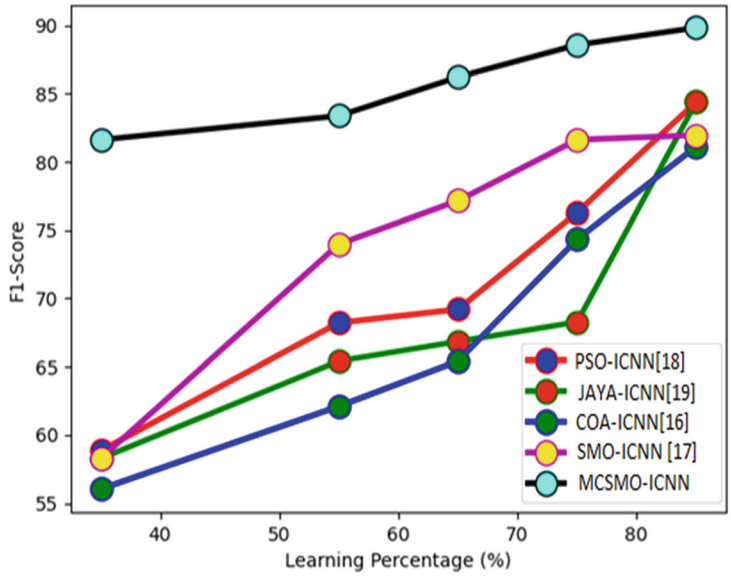

Fig. 5 F1-score

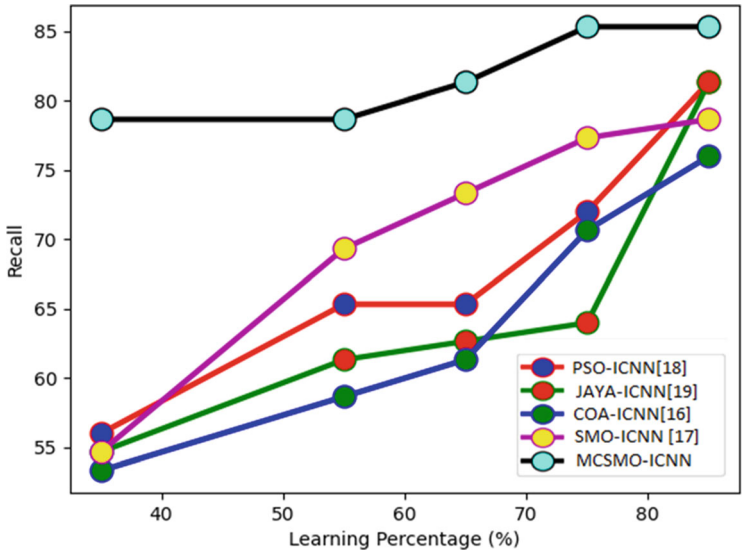

Fig. 6 Recall

5 Conclusion

The proposed algorithm was implemented to identify the vehicle, number plate, and speed. Primary step is identifying the number plate within the image or video frame. Once region of number plate is recognized it is isolated for further processing. Secondary step is identifying the characters on the number plate. For the character recognition phase, an Improved Convolutional Neural Network (ICNN) is used. To optimize the performance of ICNN, the Modified Coyote Spider Monkey Optimization (MCSMO) algorithm is employed. MCSMO is used to optimize parameters such as the number of epochs and the count of hidden neurons in the ICNN model. By using MCSMO to optimize the parameters of the ICNN model, we can achieve near-maximum accuracy and precision in number plate recognition. Recommended MCSMO shows a 10% and 10% increase in accuracy and precision while a 12% and 8% increase in F1-score and recall, respectively, over other classifiers. The mentioned algorithm shows the maximum accuracy and precision values attained for the traffic video surveillance system. Detecting number plates accurately in night vision and abnormal weather conditions presents additional challenges due to reduced visibility and potential image distortion.

References

1. Sathya, K.B., Vasuhi, S., Vaidehi, V.: Perspective Vehicle License Plate Transformation using Deep Neural Network on Genesis of CPNet. Elsevier (2020)
2. Yonten, J., Panomkhawn, R., Rattapoom, W.: Real-Time Bhutanese License Plate Localization Using YOLO. Elsevier (2020)
3. Francisco, D.K., Rodrigo, M.: Convolutional Neural Networks for License Plate Detection in Images. IEEE (2017)
4. Ibtissam, S., Abdelmoghit, Z., Wahban, A.O., Issam, A., Abdellatif, H.: An Automated License Plate Detection and Recognition System Based on Wavelet Decomposition and CNN. Elsevier (2020)
5. Jungkyu, L., Taeryun, W., Tae, K.L., Hyemin, L., Geonmo, G., Kiho, H.: Compounding the Performance Improvements of Assembled Techniques in a Convolutional Neural Network. IEEE (2020)
6. Sergio, M.S., Claudio, R.J.: Real-Time License Plate Detection and Recognition Using Deep Convolutional Neural Networks. Elsevier (2020)
7. Silva, S.M., Jung, C.R.: License Plate Detection and Recognition in Unconstrained Scenarios. ECCV (2018)
8. Priyadarshini, J., Sudha, D.: An intelligent multiple vehicle detection and tracking using modified vibe algorithm and deep learning algorithm. Soft Comput. **24**, 17417–17429 (2020)
9. Tong, J., Ding, D., Kong, L.: A deep learning approach for quality enhancement of surveillance video. J. Intell. Transp. Syst. **24**(3), 304–314 (2020)
10. Ding, S., Wan, S., Chen, C.: Edge computing enabled video segmentation for real-time traffic monitoring in internet of vehicles. Pattern Recogn. **121**(108146) (2022)
11. Chilukuri, B.R., Dhatbale, R.: Deep learning techniques for vehicle trajectory extraction in mixed traffic. J. Big Data Anal. Transp. **3**, 141–157 (2021)

12. Amosov, O.S., Pashchenko, F.F., Amosova, S.G., Ivanov, Y.S., Zhiganov, S.V.: Deep neural network method of recognizing the critical situations for transport systems by video images. Proc. Comput. Sci. **151**, 675–682 (2019)
13. Nejad, A.E., Romoozi, M.: Presenting a traffic management and control system in driver assistance form based on vehicular networks. Autom. Control Comput. Sci. **51**, 1–12 (2017)
14. Yuan, Z., Wang, W., Wang, H., Yildizbasi, A.: Developed coyote optimization algorithm and its application to optimal parameters estimation of PEMFC model. Energy Rep. **6**, 1106–1117 (2020)
15. Agrawal, V., Rastogi, R., Tiwari, D.C.: Spider monkey optimization: a survey. Int. J. Syst. Assur. Eng. Manag. **9**(4), 929–941 (2018)
16. Gad, A.G.: Particle swarm optimization algorithm and its applications: a systematic review. Arch. Comput. Methods Eng. **29**, 2531–2561 (2022)
17. Venkata Rao, R.: Jaya: a simple and new optimization algorithm for solving constrained and unconstrained optimization problems. Int. J. Ind. Eng. Comput. **19–34** (2016)
18. Ge, L., Dan, D., Li, H.: An accurate and robust monitoring method of full-bridge traffic load distribution based on YOLO-v3 machine vision. Struct. Control. Health Monit. **12** (2020)
19. Lenc, K., Vedaldi, A.: R-cnn minus r. arXiv preprint arXiv, 1506.06981 (2015)
20. Girshick, R.: Fast R-CNN. arXiv preprint arXiv, 1504.08083V2[cs.CV] (2015)
21. Cao, C., Wang, B., Zhang, W., Zeng, X., Yan, X., Feng, Z., Wu, Z.: An improved faster R-CNN for small object detection. IEEE Access, 1–1 (2019)

Vehicular CO_2 Emission Prediction Using LSTM Network

Shreejeet Sahay, Pranav Pawar, and Yogita Wagh

Abstract Climate change has become one of the most pressing challenges confronting the global community today. Governments worldwide are now implementing measures to address this issue, recognizing that if left unchecked, it could become irreversible and result in catastrophic consequences, potentially including the extinction of humanity. Greenhouse gas concentration, particularly CO_2, serves as a significant contributor to climate change. Vehicular emissions, a major source of CO_2 emissions, play a substantial role in this regard. While specialized sensors can be utilized to monitor such emissions, their scalability and effectiveness are limited. To tackle this problem, the proposed solution offers an efficient, feasible, and scalable system for monitoring vehicular CO_2 emissions. This solution employs a Long Short-Term Memory (LSTM) network and has been trained and evaluated using openly accessible data based upon On-Board Diagnostics II (OBD-II). A comparison between the model introduced in this study and an avant-garde solution has also been presented in this chapter. The suggested solution is cloud-deployable, with dongles based on IoT installed on vehicular end. These dongles gather sensor readings from vehicles and channel them to cloud, where the model runs and provides real-time predictions of the vehicle's CO_2 emissions.

Keywords OBD-II · RNN · CO_2 estimation · Deep learning · Climate change · CO_2 emission · LSTM · CO_2 prediction

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_16

1 Introduction

Today, climate change has become a concern of pivotal importance, posing the risk of profound ramifications for the future. While natural factors play a significant role, it is primarily human activities, driven by the extensive industrialization of the past century and the resulting demand for natural resources, that have led to this alarming phenomenon. If left unaddressed, the consequences could be dire, potentially endangering humanity and even leading to the obliteration of the human race. The readily perceivable consequences of climate change include increased atmospheric CO_2 levels, deforestation, declining wildlife populations, and water scarcity, among many. It is estimated that approximately 3,300,000,000 to almost 3,600,000,000 people reside in a state of heightened risk [1], underscoring the detrimental potential of this phenomenon.

The increasing concentration of greenhouse gases, particularly CO_2, is a major driver of climate change [2], as indicated in Fig. 1 [3]. This is further substantiated by the data in Fig. 2, which highlights the emissions from greenhouse gases across the globe as per the sector of the economy in the year 2018 [3, 4], clearly illustrating the significant contribution of the transportation sector.

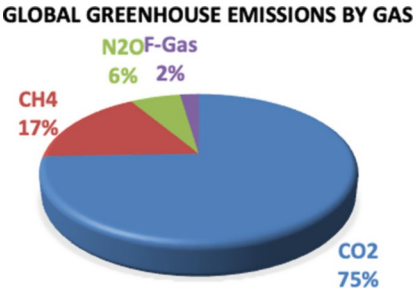

Fig. 1 Emissions from global greenhouse gases (2018)

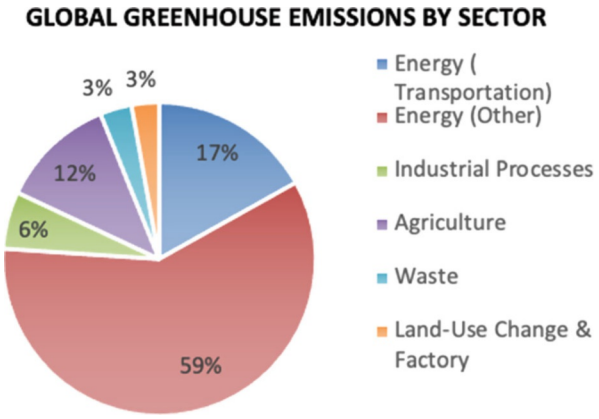

Fig. 2 Emissions from global greenhouse gases by economic sector (2018)

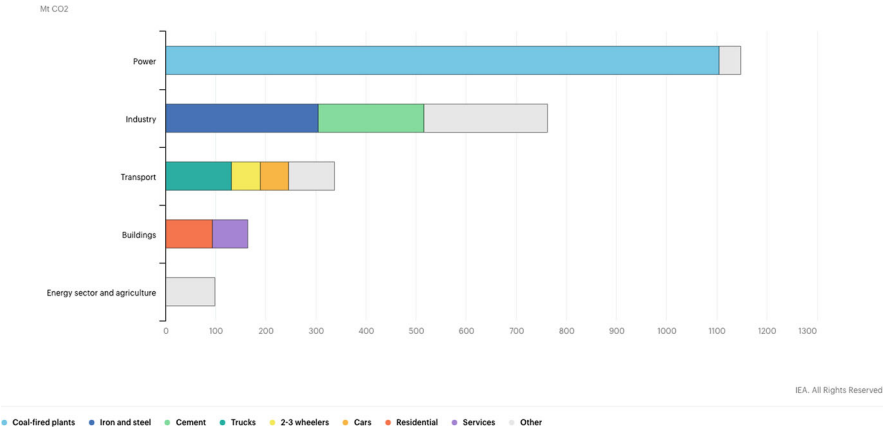

Fig. 3 Share of different sectors in India's CO_2 emission as of 2019

In India, the transport sector's impact on climate change is notable, with approximately 337 metric tons of carbon dioxide emitted in 2019 [5], as depicted in Fig. 3 based on data from the International Energy Agency. This reinforces the sector's substantial role in contributing to climate change.

From the above, it is evident that an effective and macroscale system is required to monitor vehicular CO_2 emissions, which is not easy as there are numerous vehicles available across the globe with varying types or makes. Using special types of CO_2 emission monitoring sensors in vehicles can be done, but it is neither cost-effective nor scalable. This is the problem, which is the motivation behind the proposed study.

As can be seen in the related work of this chapter, various data-driven models using machine learning techniques are found to work well for CO_2 estimation. Such methods of CO_2 emission estimation are feasible economically and are easily scalable. In order to monitor automobile emissions in an efficient manner, a two-layer LSTM model using OBD-II dataset has been proposed in this chapter. This study proposes a system where dongles using IoT technology can be utilized for transmission of vehicular data from OBD chip to the proposed solution running on cloud, which then forecasts CO_2 emissions in real-time. With modern advancements in cellular communication technologies, this application of vehicle telematics is easily deployable [6] and is cost-effective.

The suggested model underwent training and evaluation using the openly accessible dataset based upon OBD-II, which was collated by P. Rettore et al. [7, 8]. OBD-II offers information on sensor readings inside a vehicle, including Engine Load, Engine Revolutions Per Minute (RPM), and others, in addition to vehicle fault codes. It has been determined that the emissions of internal combustion engines are directly connected to sensor readings such as RPM, indicating the potential usefulness of OBD-II data in inferring a vehicle's emission characteristics [9]. Conventional machine learning techniques fall short while dealing with data of vehicle

telematics in time series form, as they only train on current examples [10] without considering past outcomes. Consequently, these techniques are unable to establish sequential relationships among the data. In order to come to grips with this limitation, this study suggests using an LSTM-based system, which has been found to be highly effective for time series prediction. Moreover, the suggested model is compared to an avant-garde implementation, and it demonstrates superior performance.

This chapter has been arranged into five sections. Section 2 provides the related work studied for literature review of this study. Section 3 discusses in detail the methodological approach of this study. Section 4 highlights the obtained results along with summarizing the experimentation. Section 5 highlights the contributions of this study, and also its limitations along with future scope.

2 Related Work

Due to advancements in cellular communication technologies [6] and the field of machine learning and artificial intelligence, data-driven models [4] utilizing data from vehicle telematics have now become readily deployable and accessible, contributing to their widespread popularity. As highlighted in the previous section, this section deals with the relevant literature that has been studied as part of this research, which will be presented in the following paragraphs.

The authors of the study in [11] highlighted the insufficient calculation of CO_2 emissions when relying solely on two features. The researchers utilized VT-Micro solutions and Artificial Neural Network (ANN) along with Support Vector Machine (SVM) to forecast CO_2 emissions. They incorporated OBD-related data, including speed, acceleration as well as throttle, gathered at intervals that were of 30 s. This data was used to find the most ecologically friendly routes for vehicles. In addition, the authors have put out the idea of creating a large-scale emissions estimating system as a future project, which we want to propose in this study.

The authors in [12] discovered a linear correlation between CO_2 emissions and vehicle speed and acceleration using regression analysis. The researchers discovered that there was a stronger association between speed and CO_2 emissions than between acceleration and CO_2 emissions. This observation is also evident in our proposed study, as demonstrated in the ensuing procedure of selecting features.

In [13], a proposal is made for a hybrid of models based on OBD along with inductive loop detectors (ILDs). The framework based on OBD uses data from sensors in a car, including acceleration, fuel flow, speed, and mileage. This data is collected at 30-s intervals using OBD ports to obtain ILD model parameters. The ILD model employs data supplied by the Urban Transport Corporation (UTC) to estimate emissions of CO_2. The authors suggest that the practical estimation of CO_2 emissions from traffic on roadways can be achieved by integrating real-time traffic flow data with vehicle categorization using the OBD model.

The authors of [14] collected data from the OBD system of a particular car model, the Maruti Dzire from 2019, using a programmed ELM327 microcontroller and an

app named "Torque" while driving in the city. Feature selection was conducted via additional tree regression, resulting in the selection of seven features. These features were then used to train five typical machine learning models. Out of the models that were evaluated, Support Vector Machine, Linear Regression, and K-Nearest Neighbor had unsatisfactory performance. As a result, the authors suggest using random forest estimators and decision trees because they performed well. Nevertheless, a notable limitation of this study is its reliance on data obtained exclusively from a solitary vehicle, hence constraining its potential for scalability.

The authors in [15] conducted tests on roads in rural, motorway, and urban settings [4] using a Portable Emissions Measurement System (PEMS) based on the Global Positioning System (GPS) [4] for a vehicle that was fully hybrid. They generated 4000 records at a frequency of 1 Hz, using speed, acceleration, and road gradient given in the form of input to a Gaussian Process Regression (GPR) solution [4] for predicting CO_2 emissions in vehicles that are hybrid in nature [4]. This study collected data from one vehicle of a specific category (full hybrid) using a sophisticated PEMS system, which restricts its generalizability to various vehicle types and conditions.

In [16], the authors obtained data by utilizing the port of OBD-II to gather instantaneous information of engine from a vehicle, including metrics like intake air temperature, Revolutions Per Minute (RPM), and factors that are environmental like ambient temperature. In addition, a PEMS system was employed to quantify the emissions of carbon monoxide (CO), nitrogen oxides (NO), hydrocarbon (HC), and carbon dioxide (CO_2) during the idle state of a light-duty vehicle. The data collection involved real-world tests conducted over a distance of greater than 1600 km on highways in the USA's southern state of Texas. To forecast emissions while idling a vehicle, the authors propose a framework based on Boosted and Bagged Decision Trees (BBDT) [4]. Nevertheless, it is important to acknowledge that a constraint of the study conducted in [16] is that the training and evaluation of the model were exclusively carried out using data from a single vehicle. This limitation hinders its capacity to be applied to many vehicles operating in mobile situations.

Authors in [17] obtained data from laboratory tests conducted on two passenger cars [4] using the New European Driving Cycle (NEDC) standard [4] for fuel consumption and tailpipe emissions. An exponential correlation was discovered between the speed and CO_2 emissions of an automobile [4]. This correlation was then used to develop and assess a solution using the Gradient Boosting Regression (GBR) algorithm for predicting CO_2 levels. However, this study suffered from the limitation of collecting data in a controlled laboratory environment and relying on a single-speed feature for model training and evaluation.

The literature research reveals that the existing approaches for modeling and estimating CO_2 are not suitable for widespread and scalable implementation [4]. While sophisticated systems may provide accuracy, they lack scalability. The review also highlights the relevance of OBD-II data, which has shown promising results in the efficient prediction of CO_2 emissions. Conventional techniques such as ANN and SVM are not convenient with time series data, as they only consider the example that is current without considering results of the past and fail to analyze

sequential relationships. Approaches built upon Recurrent Neural Network (RNN)-related frameworks such as LSTM have exhibited superior results. Additionally, deep learning models generate features automatically, eliminating the need for extensive feature engineering and extraction.

In [18], the authors have presented a solution that is robust, scalable, efficient, and effective. They have proposed the utilization of a three-layer LSTM model, with 120, 240, and 500 neurons, respectively, along with dropout layers of 20% rate in between. To train and validate the model, the authors have employed vehicle telematics OBD-II data from [7], using data from one vehicle. Evaluation of the performance of their framework is conducted using data from another vehicle, which demonstrates satisfactory results. The authors have recommended the use of six features, namely acceleration, engine RPM, speed, fuel flow, mileage, and throttle, as the input set. Additionally, the authors have followed an RNN-based LSTM approach, which outperforms ANN and SVM when predicting time series data.

The work done by authors in [18] has been used as a basis for this research. Through this research, we have proposed a solution, a two-layer LSTM neural network, that is more optimal, scalable, and robust at the same time. It uses OBD-II data to predict real-time CO_2 emissions for vehicles, using three features determined after a detailed feature selection process. As mentioned earlier, the OBD-II dataset collated by P. Rettore et al. [7, 8] has been employed for proposed solution's training and evaluation. To ensure that the proposed model encompasses the wide range of vehicle types and quantities found in real-world scenarios, the training and evaluation stages incorporate data from different vehicles. We would also like to note that during the course of our research, we successfully implemented an LSTM network with two layers utilizing 120 and 360 neurons, respectively. This network utilized six features, namely Mileage, Engine RPM, Throttle, Acceleration, Fuel Flow, and Speed, for accurately forecasting the emissions of CO_2 in vehicles. The details of this deployment can be found in [4].

3 Research Methodology

This section outlines the methodology used for this research work in detail, along with discussing the terminology used for this research in a lucid manner. Here, Sect. 3.1 gives an overview of the suggested solution, Sect. 3.2 provides detailed terminology of different technical terms used throughout the system, Sect. 3.3 throws light on the dataset used, Sect. 3.4 provides detailed information about how the training and evaluation data were prepared, and Sect. 3.5 focuses on the suggested LSTM-based framework.

3.1 Overview of the Suggested Solution

Figure 4 demonstrates the system architecture of the solution presented in this chapter. First, the ports of OBD positioned in the vehicle provide data in the form of time series, which is raw in nature. This data then undergoes data preparation, which involves a series of steps that converts it into a supervised learning format appropriate for the LSTM. Now, this prepared data is given as input to the suggested LSTM solution, which then forecasts instantaneous emissions of CO_2. The solution suggested here can be employed over the cloud, where the vehicle can send data at regular intervals utilizing dongles based on IoT, thus allowing real-time forecasting and output of the vehicle's CO_2 emissions.

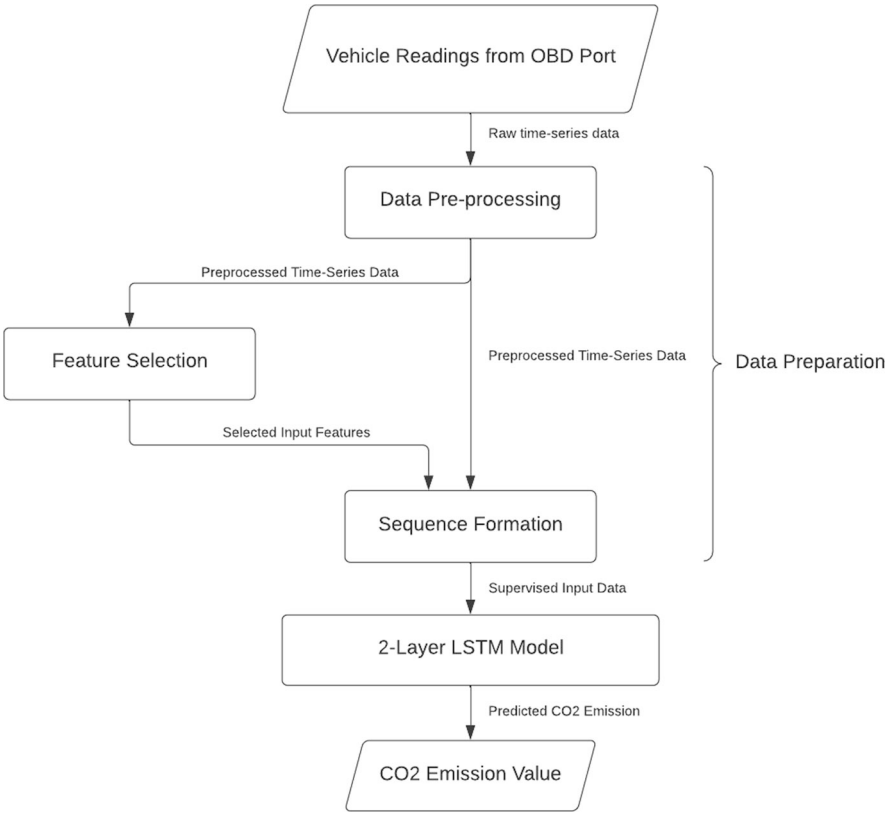

Fig. 4 Proposed system architecture

3.2 Terminology

Before beginning the discussion of the steps of the proposed system in detail, the technical terms used in this research work need to be discussed, namely RNN, LSTM, and OBD-II. Therefore, all these terms are elaborated in a lucid manner in the paragraphs inside this subsection.

Recurrent Neural Network (RNN) The Deep Neural Networks (DNNs) find it difficult to accommodate sequential relationships among data, as they learn from a single training example at a time [19]. In contrast, the RNN loops the regular back propagation neural network many times, and productively utilizes the previous output, describing the dynamic time behavior, thus making it a better option to process any sequential input as compared to other neural networks by utilizing its internal memory [20]. Unlike the backpropagation network, RNN performs multiple input processing during single forward calculation, where input is organized into two parts- the element in the training sample that is prepared and the result of calculation, where a single calculation is finished after many recurrences, thus making RNN an ideal choice to process continuous data, especially sequential data. RNNs, basically have a "memory" that remembers all information regarding what has been computed. It uses the parameters that are the same for each input as it does the task that is the same on all the hidden layers or inputs to yield the output. This leads to a decline in the parameters' complexity, unlike other neural networks.

In mathematical terms, the current state at a given time t, that is, h_t depends on both current value at instant t, x_t as well as the previous state h_{t-1}:

$$h_t = f(h_{t-1}, x_t) \tag{1}$$

Figure 5 shows the unrolled or unfolded RNN on the forward pass. A significant shortcoming of RNN is the disappearance or vanishing of gradients. The gradients are responsible for carrying the information utilized in RNN, and as they become too small, they cause the parameter updates to become insignificant. This leads to the decline of weights as the training continues, thus making learning long data sequences difficult. This shortcoming was later addressed in the LSTM networks.

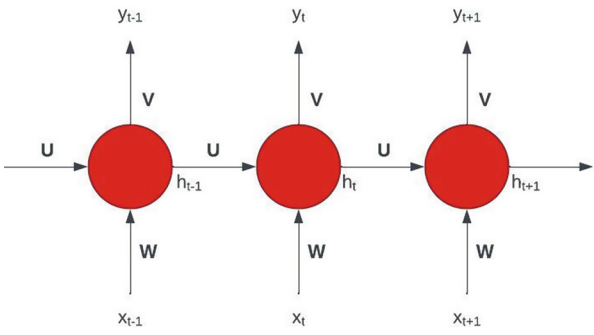

Fig. 5 Unfolded RNN on forward pass

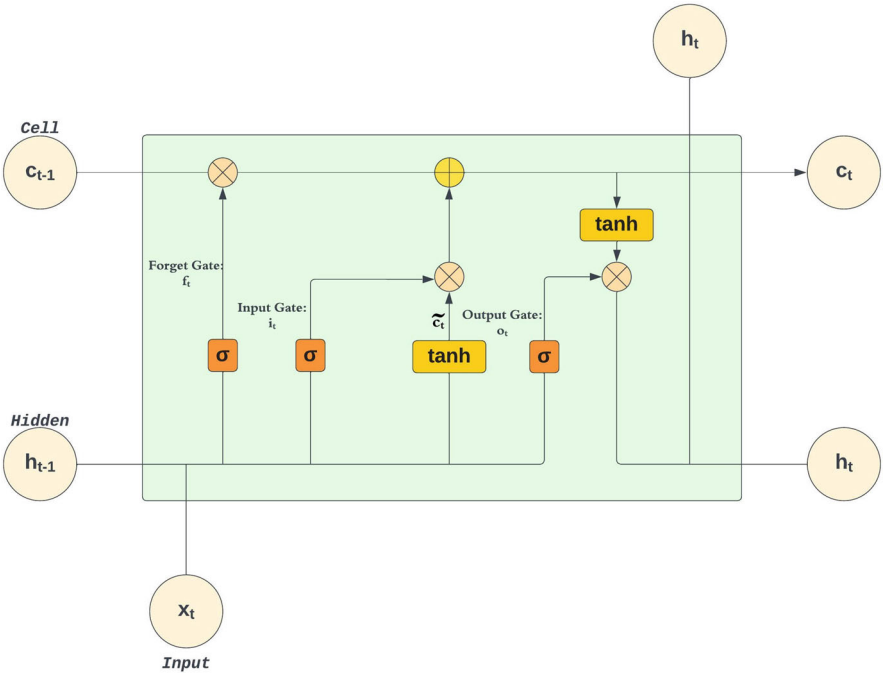

Fig. 6 Structure of LSTM

Long Short-Term Memory (LSTM) As mentioned in the previous paragraph, a major shortcoming of RNN is the vanishing of gradients due to repeated activation by the sigmoid function as it sequentially passes information of all nodes. This was addressed later in LSTM [21], which is now preferred for forecasting based on data of time series, as it is found to work well for forecasting of both short-term and long-term natures.

Figure 6 [22] clearly shows that LSTM, along with the memory like in RNNs, comprises of input gate i_t, forget gate f_t and output gate o_t, which are used for tracking the sequence information [23]. The primary function of the input gate is to determine and choose the specific data that will be saved for the subsequent stage. The forget gate determines which information will be excluded from the state data and not stored. For example, when a computation yields a value of 0, it indicates that the information will be fully preserved, whereas a value of 1 signifies the entire elimination of the information. The output gate determines which information from the state should be directed to the output. The sign c represents the unit state, and $\tilde{c}$ represents the next state.

On-Board Diagnostics-II (OBD-II) To put it simply, OBD-II is OBD's second generation. On-board diagnostics, or OBD, is an automotive electronic system that gives repair workers the ability to self-diagnose vehicles and get reports. It is the common protocol used by the majority of light-duty automobiles to receive

diagnostic data produced by the engine control modules in those vehicles. The on-board computer can detect malfunctions or deterioration that may impact emissions and activate the malfunction indicator LEDs [24] by monitoring and evaluating different components and systems. The OBD system is comprised of a collection of emission control and engine components/systems, together with the malfunction indicator lamp and diagnostic computer software. The OBD standards are documented in reference [25].

OBD-II acts as an interface for accessing the internal sensor [4] reading and vehicle's fault codes. The vehicles considered here have provision of sensors that have measured Fuel Flow, Coolant Temperature, RPM, Throttle, Speed, Manifold Pressure, Engine Load, Acceleration, and CO_2 Emission. The device gathering the data also attaches GPS Co-ordinates, Ambient Pressure, distance traveled, Ambient Air Temperature, along with timestamps [24, 25]. More features of virtual nature such as fuel consumption and mileage are calculated and added from fuel flow and distance [24, 25].

3.3 Dataset

The proposed approach was trained and evaluated using a publicly accessible dataset put together by Rettore et al. [4] [7]. The data-gathering procedure is outlined in Table 1 [7]. The data were collected from a total of 14 drivers and 2 automobiles, and the specific details may be found in references [8, 26]. The first automobile was operated by ten drivers, and the second automobile was operated by the remaining four. The travels taken by the two automobiles were notably different. The four drivers of the second automobile were given specific instructions to follow two separate itineraries, whereas the ten drivers of the first automobile used the automobile for different purposes in their everyday routines. The beginning and ending

Table 1 Set up of data collection process

	Vehicle 1	Vehicle 2
Engine	1.0 16v	1.6 16v
Max RPM	7000	7000
Transmissions	5	5
Power	76cv	122cv
Weight	1025 kg	1000 kg
Manufacturer	Renault	Hyundai
Model	Sandero	HB20
Trips	36	8
Trip time	28 h	3 h
Trip type	Naturalistic	Controlled
Drivers	10	4
Gender	6 M–4 F	2 M—2 F
Age	25–61	20–53

locations of each voyage were removed, and all accessible data was anonymized to safeguard drivers' privacy. This led to a smaller dataset. The CO_2 emission measurements from the dataset are utilized as the real values for training and evaluating the suggested solution.

In the training step, we made things simpler by training the model just using data from the first automobile and drivers 1 through 8. Next, using information from the first automobile and drivers 9 and 10, we validated the model. We used data from driver 11 and the second automobile, which were not included in the model's training phase, to evaluate the model during testing. This methodology ensures that the research article's suggested solution accounts for a broad variety of car types and volumes in its projections.

3.4 Preparation of Data

This step is crucial for handling and transforming raw time series data into a format suitable for the LSTM network's training and evaluation, as shown in Fig. 4. This format was created especially for learning data that has been supervised. This stage involves a number of processes, including feature selection, sequence creation, and data pre-processing [4]. The output of these procedures is supervised learning data, which guarantees that the input data is appropriately prepared and arranged for the LSTM network. The next paragraphs provide a detailed explanation of each of these procedures.

Data Pre-processing This is an essential and vital stage in preparing data for training and evaluating models. We searched for any NaN values after importing the dataset, but none were found. The device time column served as a timestamp, and this was the particular column that the data cleaning technique targeted. For instance, when the abbreviation "set" was mistakenly used instead of "Sep" in multiple cases for the month of September, the Python str object's replace function was employed to standardize it as "Sep." Furthermore, the datatype of the timestamp column was changed to datetime64[s] [4].

The dataset contains column titles that may be challenging for someone without expertise to understand, such as "OBD_CO_2_gkm_Instant," which depicts the instantaneous CO_2 emission in simplified words. As a result, the titles of the column were changed to make them easier to understand.

The dataset was then divided into two separate sets [4], each for input and output respectively. After that, the input set was normalized to make sure all of the features adhered to the same scale. Normalization is a crucial process because when characteristics are assessed on different scales, they may have differential impacts on fitting the model, which can potentially introduce biases. Hence, it is imperative to normalize the data. Min-Max normalization has been employed to normalize the data, using the following mathematical equation,

$$x_{\text{scaled}} = \frac{x - \min(x)}{\max(x) - \min(x)} \tag{2}$$

where x_{scaled} is the feature value that is normalized or scaled [4], having value x at a given instance of data.

As a result, data pre-processing, as previously shown in Fig. 4, entails taking raw time series data and producing a normalized and cleaned pre-processed time series data. Sequence building and feature selection then make use of this pre-processed data.

Feature Selection This is an important step, especially in high-dimensional data analysis, which is quite challenging due to the existence of data that is not relevant or redundant in nature. It assists in getting rid of such data, which enhances the functionality of the solution. In this study, it has been performed using Principal Components Analysis (PCA) loading scores and correlation values.

PCA is a dimensionality reduction technique which acts as a variance maximizer for high-dimensional data by projecting it onto a new lower or equal dimensional subspace. It is basically computing the principal components and using them for a change of basis on a set of data, which can sometimes use only the first few principal components and ignore the rest. A route that maximizes the variance of the projected data may be used as an equivalent term for the first principal component. In order to maximize the variance of the projected data, the *i*-th principal component might be interpreted as a direction orthogonal to the first *i*-1 principal components. The characteristics utilizing the first two Principal Components (PC) are biplotted in Fig. 7, accounting for a total variance score of 91.21%. The weights of the different characteristics for each component are indicated by the coefficients in each row of the loading matrix produced by PCA. PC-1 and PC-2 are shown on the x- and y-axes, respectively, in the biplot. The proportionality between the contributions of each different feature in the PC and its vector lengths is evident. Thus, the foundation for ranking feature selection is these vector lengths: Table 2 feature IDs and the vector labels 1 through 6 in Fig. 6 match. The biplot in Fig. 7 makes it abundantly evident that the main component (PC) is significantly influenced by mileage, engine RPM, and speed. Thus, in this work, the CO_2 emission has been estimated using these three characteristics.

The feature set, which comprises relational data that may be utilized to anticipate missing values, is shown in Fig. 8 as the correlation matrix. The chosen qualities or features provide additional information to the dataset, as shown by the low correlation scores seen in the correlation matrix in Fig. 8.

In order to choose the best subset of features for the model, this step of data preparation uses pre-processed time series data for feature selection.

Sequence Generation This step converts the time series data into a format suitable for deep learning using the pre-processed data and the best feature subset selected during the feature selection procedure, as shown in Fig. 4. In particular, it transforms the data into an input-output sequence-based format of supervised learning.

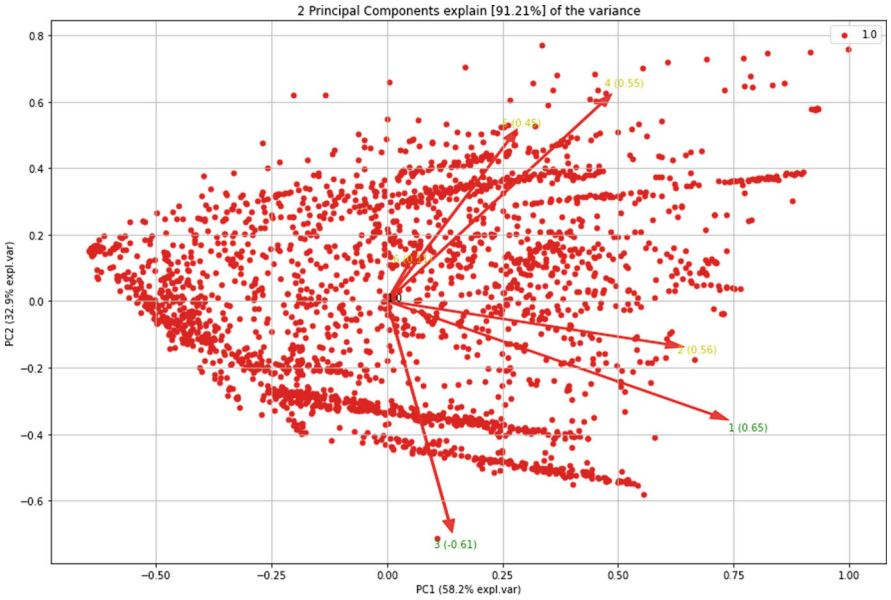

Fig. 7 Principal components analysis (PCA) biplot (first two components)

Table 2 Characteristic/feature set description

Characteristic	Unit(s)	Value range	Feature ID
Speed	km/h	0–121	1
Engine RPM	Revolutions/min	0–5500	2
Mileage	km/l	0–45	3
Fuel flow	cc/min	0–350	4
Throttle	%	0–100	5
Acceleration	km/s^2	−25–45	6

	Speed	Engine_RPM	Mileage	Fuel_Flow	Throttle	Acceleration
Speed	1.000000	0.887075	0.520566	0.431011	0.235326	0.047234
Engine_RPM	0.887075	1.000000	0.334794	0.548642	0.345876	0.202360
Mileage	0.520566	0.334794	1.000000	-0.443444	-0.437644	-0.304038
Fuel_Flow	0.431011	0.548642	-0.443444	1.000000	0.851709	0.393862
Throttle	0.235326	0.345876	-0.437644	0.851709	1.000000	0.376566
Acceleration	0.047234	0.202360	-0.304038	0.393862	0.376566	1.000000

Fig. 8 Feature set's correlation matrix

Before applying deep learning techniques to forecast time series data, it is essential to convert the time series information into a supervised learning-based dataset. This format is appropriate for training and assessing deep learning models.

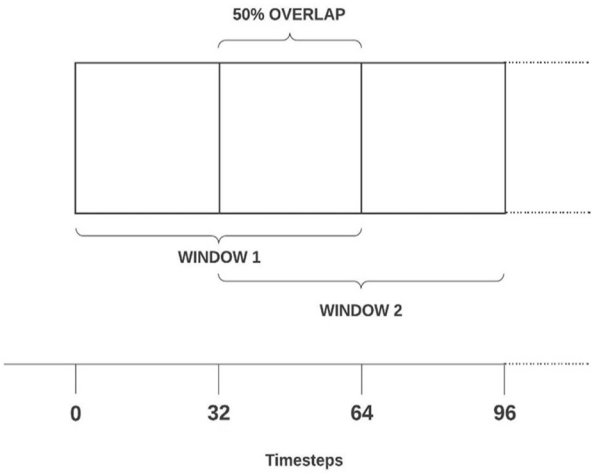

Fig. 9 Windowing used in the suggested solution

The time series nature of the dataset under analysis necessitates its transformation into a supervised learning format with input and output sequences.

The dataset has been split into two separate sets for input and output, respectively, as was previously indicated during the pre-processing phase. Three carefully chosen input aspects make up the input set: mileage, engine RPM, and speed. One output feature, the instantaneous CO_2 emission, or CO_2, is included in the output set. Next, the input set undergoes min-max normalization to achieve standardization. Following this, the input and output sets, which are both time series, are transformed into a supervised learning format. This is accomplished by using the sliding window methodology, which uses a 64-s window with a 50% overlap. Stated otherwise, the data in the first window spans within the 0–64 s range, whereas the data in the second window spans within the 32–96 s range, and so on. The windowing approach used in this instance is shown in Fig. 9. Using a similar methodology as in [18], where several window lengths were tried on the validation set, a window width of 64 s was used. The window width of 64 s produced the lowest Mean Squared Error (MSE) out of all of them. Furthermore, each window's mean value is computed and applied to the output dataset.

The input set will contain 64*3 number of columns when this phase is finished, whereas the output set will only have one column devoted to CO_2 emission output. As previously said, we have carried out this process for every training, validation, and test set.

3.5 LSTM-Based Framework

Within the proposed technique or framework, this specific step employs the data that was collected during the data preparation phase to train and evaluate the suggested

solution. Due to the sequential pattern of the input samples, forecasting on them is not served well by traditional machine learning algorithms. The use of LSTM networks, which have particular connections that enable feedback and efficient processing of consecutive inputs, is shown in this chapter. As was already established in this study's terminology section, LSTMs outperform RNNs because they address the problem of gradient disappearance. They have a particular benefit when it comes to time series data since they can handle gaps in the data that have unknown durations. They differ from RNNs and conventional machine learning methods because of this [18].

Instead of receiving input data in a two-dimensional manner, the LSTM model needs three-dimensional data. The 2D shape format uses the number of rows (r) and columns (c) to indicate how the data is configured. Three dimensions are used by the 3D shape format to define the data structure: the row count (r), the window's timestep (t), and the amount of features (f). Evidently,

$$c = t \times f \tag{3}$$

The set of data produced during the data preparation phase initially takes the shape of a two-dimensional structure. However, due to the sequential structure of this data, it is necessary to convert it into a three-dimensional format in order to involve crucial information about the quantity of features and time steps involved. This three-dimensional geometric form is essential for carrying out computational activities on data of sequential nature. In order to accomplish this, the values of the input are transformed from their two-dimensional format to a three-dimensional one using reshape functionality available in Python. All of the input sets used for training, validation, and testing go through this reshaping process.

The number of layers, nodes, and other hyperparameters have a direct impact on the model's performance and complexity. The optimal configuration of the hyperparameters for the suggested LSTM model was discovered by doing a random search. A sequential two-layer LSTM model is the suggested optimal architecture for the neural network in this investigation. Ninety number of neurons make up the LSTM's first layer, while 180 number of neurons make up the second; 120 training epochs are used to train the model using the MSE loss function, which can be understood from the following equation,

$$\text{MSE} = \frac{1}{N}\sum_{i=1}^{N}(y_i - \widehat{y}_i)^2 \tag{4}$$

where N is the count of values, y_i is the true or observed value, and $\widehat{y}_i$ is the estimated value of a variable [4]. MSE essentially calculates the mean of the squared differences between a variable's actual and forecasted values.

The RMSProp Optimizer is used by the model during training. RMSProp and the gradient descent technique with momentum are comparable. By making bigger horizontal steps, it lessens vertical oscillations, allowing for a quicker convergence

Table 3 Algorithm of the presented solution

Algorithm suggested LSTM algorithm
Require: Size of the Batch = 32, Epoch Count = 120, Input Feature Count = 3, Timestep Count = 64, Output Feature Count = 1
1. Define Sequential Model
2. model.add(LSTM(90,return_sequences=True,input_shape=(64,3)))
3. model.add(LSTM(180))
4. model.add(Dense(1))
5. model.compile(loss='mse',optimizer='rmsprop')
6. history=model.fit()
7. model.predict()
8. rmse=sqrt(mean_squared_error(y_predicted,y))
Output: Training loss, Validation loss, Evaluation RMSE

and a better learning rate. The running average of the squared gradients is computed, and the gradient is then divided by the square root of this average, which is the basic idea of RMSProp. The variance is estimated by this optimizer using the moving average of gradients.

The algorithm for the LSTM model that is suggested is presented in Table 3. The document displays the necessary conditions for this method, followed by its sequential instructions and the resulting output.

4 Results

In this part, we look at the findings from the observations made for this research. Our developed technique was employed in a Google Colab Pro environment using Python 3, leveraging Graphics Processing Unit's (GPU) hardware acceleration.

The results were evaluated using two metrics: MSE, as explained in the previous section, and Root Mean Squared Error (RMSE), which, unlike MSE, is expressed mathematically as the square root of the mean of the squared deviations between the observed and estimated values of a variable. Hence,

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\widehat{y}_i - y_i)^2} \tag{5}$$

where N is the count of values, y_i is the true or observed value and $\widehat{y}_i$ is the estimated value of a variable [4].

Figure 10 shows the MSE loss curve while the suggested solution was being trained. As mentioned in Sect. 3.3, vehicle 2's data, which was not included in the training set, is used to evaluate the model. This method increases the model's

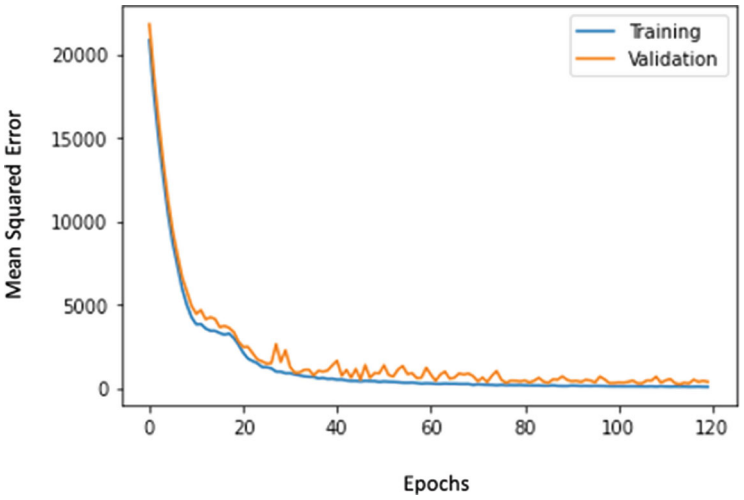

Fig. 10 Loss (mean squared error) during training

Table 4 Comparison between different deep learning frameworks

Framework	RMSE
DNN with four layers	64.87
Deep CNN with three layers	17.82
LSTM with three layers (avant-Garde)	9.30
Suggested solution	7.97

autonomy by guaranteeing its strength and efficacy regardless of the particular brand and class of vehicle.

The recommended model performed well when tested with the test dataset, giving an RMSE of 7.97 and an MSE of 63.52. Notably, these evaluations were carried out using data from an automobile that the model had never used before. This outcome suggests that the suggested solution may be scaled up or down, which means it can be used for a wide range of automobiles regardless of the particular make or model. This suggests that a single model can accurately and efficiently predict CO_2 emissions using common automobile characteristics like Mileage, Speed, and Engine RPM.

The suggested two-layer LSTM solution's effectiveness is evaluated against an avant-garde solution [18], four-layer DNN, and a three-layer Deep Convolutional Neural Network (CNN) models [18] [4]. A thorough analysis of each of the four models' performances is shown in Table 4, amply illustrating how effectively the study's suggested approach works.

Table 5 presents the main distinctions between the two-layer LSTM method suggested in this study and the avant-garde solution [18].

Table 5 Contrast between avant-garde solution and the suggested solution

	Avant-garde solution	Suggested solution
i.	Employs input features: Mileage, speed, engine RPM, fuel flow, acceleration, and throttle	Employs three input features: Mileage, speed and engine RPM
ii.	There are three layers, each containing 120, 240, and 500 neurons, respectively	There are two layers, one with 90 neurons and the other with 120 neurons
iii.	RMSE achieved: 9.30	RMSE achieved: 7.97

5 Conclusion and Future Scope

This research work presents a study that introduces a two-layer LSTM network-based solution, utilizing three features, Speed, Engine RPM, and instantaneous mileage, to forecast CO_2 emissions from vehicles. By utilizing OBD-II data, this proposed system enables the monitoring of vehicular CO_2 emissions. By deploying this system on a cloud platform, it can be enabled to receive input from in-sensor readings of vehicles through dongles based on IoT positioned at the source and forecast real-time emissions of CO_2. The high metrics of performance for the designed solution are proof of its high robustness, efficiency, and effectiveness and also show that systems based on OBD-II can be utilized for the estimation of emissions from vehicles. Additionally, a comparative analysis with the avant-garde solution has been conducted, which ensures that the proposed solution is optimal in nature. The suggested solution is not only scalable but is also acquiescent to changes in the vehicle's surroundings, like road conditions, traffic, etc., as such changes have an influence on the readings of the OBD-II, thereby affecting CO_2 emission prediction.

A major limitation of the current study is the limited scope of the OBD-II dataset used, which consists of data from only two vehicles [7]. Although efforts were made to address this limitation by training and testing the proposed model on data from these two different vehicles, it is imperative to expand the range of vehicles included in the study. By incorporating a wider variety of vehicles, we can enhance the accuracy and reliability of the model in predicting CO_2 emissions, regardless of the specific make or model of the vehicle.

To ensure the applicability of the model across a broader range of scenarios, future research should focus on the validation of the proposed model using data collected from various vehicles of different sizes and types. This expansion would provide valuable insights into how well the model performs across different vehicle categories, accounting for variations in engine types, fuel efficiency, and other factors that influence CO_2 emissions.

By incorporating diverse vehicles into the study, we can establish the generalizability of the model and determine its efficacy in predicting emissions for a wider range of vehicles. This expanded scope would not only strengthen the validity of the findings but also enable the model to be more useful in practical applications. For instance, it could support policymakers in developing effective regulations to reduce

carbon emissions from a diverse fleet of vehicles or aid individuals in making informed decisions about their vehicle choices based on environmental impact.

Furthermore, the inclusion of a larger and more diverse dataset would help identify any potential biases or limitations that may be specific to certain vehicle types or manufacturers. By understanding these nuances, researchers can refine the model to account for such variations and improve its overall performance and reliability.

In summary, this work's future scope must prioritize a broader range of vehicles' inclusion to ensure the accuracy, reliability, and generalizability of the proposed model in predicting CO_2 emissions. Expanding the dataset to include vehicles of different sizes and types will enable the model to be more applicable across various scenarios and enhance its usefulness in real-world applications.

References

1. IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., Rama, B. (eds.)]. Cambridge University Press (in press)
2. Solomon, S., Plattner, G.-K., Knutti, R., Friedlingstein, P.: Irreversible climate change due to carbon dioxide emissions. Proc. Natl. Acad. Sci. **106**(6), 1704–1709 (2009). https://doi.org/10.1073/pnas.0812721106
3. Climate Watch Historical GHG Emissions, World Resources Institute, Washington, DC. (2021). Available online at: https://www.climatewatchdata.org/ghg-emissions
4. Sahay, S., Pawar, P.: An optimal approach to vehicular CO2 emissions prediction using deep learning. In: 2023 International Conference on Emerging Smart Computing and Informatics (ESCI), pp. 1–5, Pune (2023). https://doi.org/10.1109/ESCI56872.2023.10099940
5. IEA: CO2 Emissions from the Indian Energy Sector. IEA, Paris (2019) https://www.iea.org/data-and-statistics/charts/co2-emissions-from-the-indian-energy-sector-2019
6. Bandara, D., Amarasinghe, M., Kottegoda, S., Arachchi, A.L., Muramudalige, S., Azeez, A.: Cloudbased driver monitoring and vehicle diagnostic with OBD2 telematics. **6**(8) (2015)
7. Vehicular data trace of the city of Belo Horizonte and surroundings, Brazil (2018), http://www.rettore.com.br/prof/vehicular-trace/
8. Rettore, P.H.L., Campolina, A.B., Villas, L.A., Loureiro, A.A.F.: Identifying relationships in vehicular sensor data: a case study and characterization. In: DIVANet '16, pp. 33–40. Association for Computing Machinery, New York (2016)
9. Ortenzi, F., Costagliola, M.: A new method to calculate instantaneous vehicle emissions using OBD data. SAE Tech. Pap. **4** (2010)
10. Khandekar, V.S., Shrinath, P.: Hybrid dynamic chunk ensemble model for multi-class data streams. Indonesian J. Electr. Eng. Comput. Sci. **25**(2), 1115–1122 (2022). https://doi.org/10.11591/ijeecs.v25.i2.pp1115-1122
11. Zeng, W., Miwa, T., Morikawa, T.: Prediction of vehicle co2 emission and its application to eco-routing navigation. Transp. Res. Part C Emerg. Technol. **68**, 194–214 (2016)
12. Oduro, S., Metia, S., Duc, H., Ha, Q.: CO2 Vehicular Emission Statistical Analysis with Instantaneous Speed and Acceleration as Predictor Variables, pp. 158–163 (2013)

13. Grote, M., Williams, I., Preston, J., Kemp, S.: A practical model for predicting road traffic carbon dioxide emissions using inductive loop detector data. Transp. Res. Part D: Transp. Environ. **63**, 809–825 (2018)
14. Kangralkar, S., Khanai, R.: Machine learning application for automotive emission prediction. In: 2021 6th International Conference for Convergence in Technology (I2CT), pp. 1–5 (2021). https://doi.org/10.1109/I2CT51068.2021.9418152
15. Mądziel, M., Jaworski, A., Kuszewski, H., Woś, P., Campisi, T., Lew, K.: The development of CO2 instantaneous emission model of full hybrid vehicle with the use of machine learning techniques. Energies. **15**(1), 142 (2021). https://doi.org/10.3390/en15010142
16. Li, Q., Qiao, F., Yu, L.: A machine learning approach for light-duty vehicle idling emission estimation based on real driving and environmental information. Environ. Pollut. Clim. Change. **1**, 106 (2016)
17. Subramaniam, N., Yusof, N.: Modelling of CO2 emission prediction for dynamic vehicle travel behavior using ensemble machine learning technique. In: 2021 IEEE 19th Student Conference on Research and Development (SCOReD), pp. 383–387 (2021). https://doi.org/10.1109/SCOReD53546.2021.9652757
18. Singh, M., Dubey, R.: Deep learning model based CO2 emissions prediction using vehicle telematics sensors data. In: IEEE Transactions on Intelligent Vehicles. https://doi.org/10.1109/TIV.2021.3102400
19. Dietterich, T.G.: Machine learning for sequential data: a review. In: Caelli, T., Amin, A., Duin, R.P.W., de Ridder, D., Kamel, M. (eds.) Structural, syntactic, and statistical pattern recognition, pp. 15–30. Springer, Berlin/Heidelberg (2002)
20. Wang, Y., Liu, Y., Wang, M., Liu, R.: LSTM model optimization on stock price forecasting. In: 2018 17th international symposium on distributed computing and applications for business engineering and science (DCABES), pp. 173–177 (2018). https://doi.org/10.1109/DCABES.2018.00052
21. Hochreiter, S., Schmidhuber, J.: Long short-term memory. Neural Comput. **9**(8), 1735–1780 (1997). https://doi.org/10.1162/neco.1997.9.8.1735
22. Xiang, J., Qiu, Z., Hao, Q., Cao, H.: Multi-time scale wind speed prediction based on wt-bi-lstm. In: MATEC Web of Conferences, vol. 309, p. 05011. EDP Sciences (2020)
23. Moharm, K., Eltahan, M., Elsaadany, E.: Wind speed forecast using LSTM and bi-LSTM algorithms over Gabal El-Zayt wind farm. In: International Conference on Smart Grids and Energy Systems (SGES), pp. 922–927 (2020). https://doi.org/10.1109/SGES51519.2020.00169
24. United States Environment Protection Agency (EPA). Vehicle emissions on-board diagnostics (OBD) (2020), https://www.epa.gov/state-and-local-transportation/vehicle-emissions-board-diagnostics-obd
25. ISO: Open diagnostic data exchange (ODX). OBD-II Exchange
26. Rettore, P.H.L., Campolina, A.B., Villas, L.A., Loureiro, A.A.F.: A method of eco-driving based on intra-vehicular sensor data. In: 2017 IEEE Symposium on Computers and Communications (ISCC), pp. 1122–1127 (2017)

ResNet and ResNeSt-Based Deep-Learning Models for Accurate COVID-19 Detection from Chest X-ray Radiographs

C. P. Indumathi, V. Santhoshsivan, and R. Selvakumar

Abstract The emergence of the COVID-19 pandemic has had a notable influence on the health of populations worldwide and has also affected numerous socioeconomic factors globally. Early identification and timely management of COVID-19 are essential to prevent the proliferation of the disease and protect people's lives. Recent studies indicate that utilizing deep-learning models gives a feasible solution for the diagnosis of COVID-19 by employing chest X-ray imaging. Combining advanced deep-learning models with radiological imaging can enhance the accuracy of COVID-19 detection and address the shortage of specialized physicians in remote areas. In this study, four distinct deep-learning models are used to detect COVID-19 from chest X-ray images: ResNet50, ResNet101, ResNeSt50, and ResNeSt101 using transfer learning techniques. Specifically, the ResNeSt models are the new variant of ResNet that utilizes a split-attention network. The main objective is to compare the potential of ResNet and ResNeSt models for detecting COVID-19 from chest X-ray images. The models used in this study underwent training and validation using the most extensive publicly accessible repository of COVID-19 chest X-ray (CXR) images. We evaluated the models' ability to generalize to new data by testing their performance on independent data not utilized during training or validation. Evaluated the performance of all models in which ResNet models showed higher precision, recall, and accuracy scores than ResNeSt models. Our result indicates that deep-learning models show significant potential for COVID-19 medical research, providing a promising avenue for a deeper understanding of COVID-19 disease.

Keywords Deep learning · COVID-19 · Chest X-rays · ResNet · ResNeSt · Transfer learning · Split-attention network

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_17

1 Introduction

On December 31, 2019, a cluster of pneumonia cases emerged in Wuhan, Hubei province of China, which led to the rapid global spread of the COVID-19 pandemic [1]. The virus responsible for the disease is called SARS-CoV-2, and it took only 30 days to over all the other parts of China [2] and later spread to all other countries through the affected people [3] indicates that the first seven cases of COVID-19 were confirmed in America on January 20, 2020, but in just a few months, by April 5, 2020, the number of cases had surged to over 300,000, indicating a significant and alarming increase in the rate of infections. The profound global impact of this virus with nearly 684 million confirmed cases and 6.8 million deaths reported to date [4]. The common symptoms of COVID-19 are primarily present with fever, cough, fatigue, headache, dizziness, sputum production, and shortness of breath. Some patients may develop severe respiratory complications, including lower lobe lesions in both lungs or acute respiratory distress syndrome (ARDS) [5].

RT-PCR is the primary diagnostic method for COVID-19 and is currently the most frequently employed technique [6]. In addition to RT-PCR, chest radiological imaging techniques such as computed tomography scan (CT) and chest X-ray (CXR) play a crucial role in the early diagnosis of the disease [7]. However, the sensitivity of the RT-PCR kit can be low, ranging from 60% to 70%, which means that a negative test result does not necessarily rule out an infection. Therefore, examining radiological images and CT scans of patients can be an essential tool for detecting symptoms. CT scans are a sensitive method for detecting COVID-19 pneumonia used in conjunction with RT-PCR tests as a screening tool [8]. However, CT findings may not be observable in the first 0–2 days after symptom onset, and patients may have normal CT scans during this time [9]. According to a study conducted on lung CT scans of individuals who had recuperated from COVID-19 pneumonia, the most severe pulmonary damage was observed approximately 10 days after the onset of symptoms [10].

At the onset of the pandemic, due to the high number of cases and insufficient test kits, doctors in many countries, including China, had to rely on clinical and chest CT results for diagnosis [9]. According to research, combining clinical image characteristics and laboratory findings could assist in the timely detection of COVID-19 [11]. Radiology images from COVID-19 cases are considered valuable for diagnosis, and several studies have reported significant findings in imaging studies of COVID-19. For instance, Kong et al. [12] described the presence of Right infra hilar airspace opacities issue in a COVID-19 patient, while Yoon et al. [13] noted the occurrence of a nodular opacity in the left lower lung region in approximately 33.33% of the patients examined.

Figure 1a shows a posteroanterior chest radiograph of a 29-year-old woman who presented with fever, cough, chest pain, diarrhea, and myalgias. The image demonstrates faint peripheral rounded opacities in the lower lungs [14]. Figure 1b displays a chest radiograph of a 40-year-old man with a history of diabetes who had a fever, cough, and shortness of breath for 1 week. The image demonstrates diffuse bilateral

Fig. 1 Affected chest X-ray images of different people

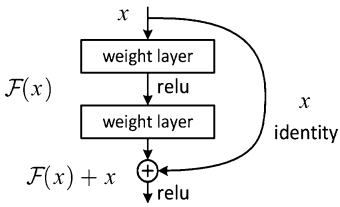

Fig. 2 ResNet—Residual Block

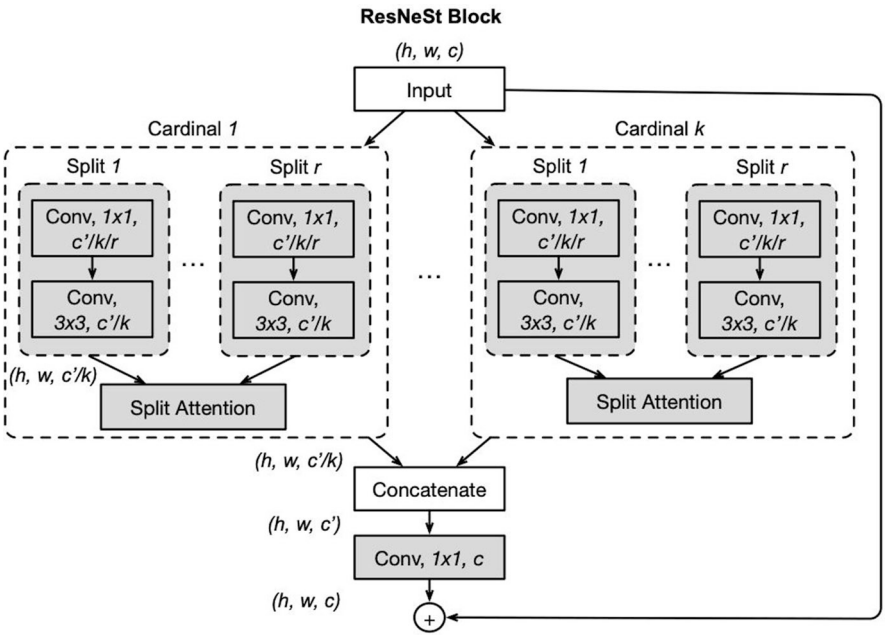

Fig. 3 ResNeSt—Cardinal architecture

opacities with dense consolidation in the mid- to lower lungs [14]. Figure 1c illustrates a portable chest radiograph of a 50-year-old man with hypertension admitted with fever, cough, and myalgias and subsequently intubated. On the 7th day of admission, the image showed multiple bilateral diffuse and hazy pulmonary

opacities. The patient's inflammatory markers were evaluated, and he died 2 days later. The figures show all three patients tested positive for COVID-19 [14]. In recent years, there has been immense growth in the field of machine learning, particularly in medicine. It is being utilized for a wide range of tasks, such as classifying cardiovascular diseases, detecting diabetic retinopathy, and more [15–17]. Deep learning is a widely recognized and commonly used field within the broader domain of artificial intelligence (AI). One of the significant contributions of deep learning to the medical field is the development of convolutional neural networks (CNNs), which has revolutionized the medical field by allowing medical experts to diagnose skin lesions, detect brain tumors, and detect breast cancer with higher accuracy [18, 19]. It enables the creation of end-to-end models to achieve accurate results without manual feature extraction [20, 21]. The rapid rise of COVID-19 has increased interest in developing automated detection systems using AI techniques. AI models can be simple, accurate, and fast, making them helpful in providing timely assistance to patients, particularly in the face of the limited availability of radiologists. AI technologies in radiology can assist in obtaining accurate diagnoses while also addressing issues such as insufficient testing resources, costs, and waiting times for test results.

Several researchers have demonstrated that deep-learning models applied to chest X-ray (CXR) images are showing promising solutions for diagnosing pulmonary diseases such as COVID-19 and pneumonia. CheXNet architecture, like DenseNet121, was developed by Rajpurkar et al. [22], which trained under 100,000 chest X-ray images and classified 14 variants of pulmonary diseases. Hemdan et al. [23] introduced the COVIDX-Net model, including seven CNN models. Ioannis et al. [24] achieved high success rates with the model that used 224 positive COVID-19 images, while Wang and Wong developed the COVID-Net model, which achieved an accuracy of 92.4% in finding three different categories: COVID, non-COVID, and normal. Sethy and Behera [25] extracted features from different CNN models using X-ray images, with the ResNet50 model and SVM classifier provide a good result. Another method [26] used pre-trained CNNs to achieve 99% accuracy in automatically detecting COVID-19 pneumonia from CXR images. Keidar et al. [27] developed a model for COVID-19 detection from X-ray images and used image clustering to improve results. Otherstudies [28, 29] used various deep-learning models with CT images for COVID-19 detection. AI techniques in COVID-19 diagnosis can provide timely assistance to patients and overcome the limited availability of radiologists in hospitals. The study aims to compare various deep learning methods for accurately detecting COVID-19 from chest X-ray images and assess their potential as decision-making tools for COVID-19 diagnosis. Different ResNet and ResNeSt-based models were used, and the largest available dataset at the time of writing [20] was used for testing. Some patients have tested positive for COVID-19 even 5–13 days after recovery, indicating the need for more accurate diagnostic methods. Chest radiography analysis has limitations in detecting early-stage COVID-19 due to its insufficient sensitivity in the early periods. However, deep learning models can identify features that are not easily noticeable to humans, which can potentially overcome this limitation.

2 Materials and Methods

2.1 Chest X-ray Image Dataset

This study utilized the COVID-Q U dataset [20], which is composed of 33,920 COVID-X-ray images classified into three categories: COVID-19, non-COVID-19, and normal. The COVID-19 category comprises 11,956 X-ray images of patients who have been confirmed to have contracted coronavirus, while the non-COVID-19 category includes 11,263 images of patients with viral or bacterial pneumonia, and the normal category comprises 10,701 healthy images. The COVID-QU dataset only contains X-ray images in posterior-to-anterior (PA) and anterior-to-posterior (AP) views, and each image and the dataset include lung masks that correspond to each X-ray image. However, masks were not used in this research. The dataset was created and employed in a previous study [21], where the research team conducted infection localization and severity grading using COVID-X-ray images. They then made their data publicly available for other researchers to use. The sources utilized to create the COVID-QU dataset are thoroughly outlined as follows:

The dataset consists of 11,956 X-ray images that depict positive cases of COVID-19. The images were obtained from several sources, which include 10,814 images from the BIMCV-COVID19+ database [30], 183 images from a medical school in Germany [31], 559 images from SIRM [32], GitHub [33], Kaggle [34], and Eurorad [35], and 400 images from a separate COVID-19 database.

The RSNA COVID-X-ray [36] repository contains a total of 14,863 chest X-ray images, out of which 8851 are healthy images and 6012 are lung opacity images. The lung opacity images are part of the non-COVID-19 images in the COVID-QU.

The chest X-ray pneumonia dataset [37] offers 1300 viral pneumonia images, 1700 bacterial pneumonia images, and 1000 healthy X-ray images. The X-ray images of viral and bacterial pneumonia were included in the non-COVID-19 category of the COVID-QU dataset. The PadChest [38] dataset was utilized to obtain 4000 healthy and 4000 pneumonia X-ray images. The 4000 pneumonia images from the PadChest dataset were included in the COVID-QU dataset as part of the non-COVID-19 class.

The Montgomery dataset [39] includes a total of 138 X-ray images, 80 of which are healthy and 58 of which showcase tuberculosis. The dataset also includes the corresponding lung masks for each image. The Shenzhen dataset [40], on the other hand, contains a larger number of X-ray images, with 326 normal and 336 tuberculosis cases. 566 of the 662 images in the Shenzhen dataset are accompanied by their corresponding lung masks. The QaTa-Cov19 dataset contains approximately 120,000 CXR images and accompanying ground-truth infection masks. The COVID-QU dataset producers created supplementary segmentation masks for their research by utilizing their segmentation models, which were trained and evaluated using the masks.

Table 1 presents the distribution of the dataset into three subsets: train, validation, and test. The training subset contains 21,715 CXR images divided into three

Table 1 Data distribution overview for the study conducted

#	Subset	Non-COVID-19	COVID-19	Normal	Total
1	Train	7208	7658	6849	21,715
2	Validation	1802	1903	1712	5417
3	Test	2253	2395	2140	6788

divisions: COVID-19 with 7658, non-COVID-19 with 7208, and normal with 6849 pictures. The validation set contains 5417 CXR images, with COVID-19, non-COVID-19, and normal classes containing 1903, 1802, and 1712 images, respectively. Lastly, the test set comprises 6788 CXR images, with COVID-19, non-COVID-19, and normal categories containing 2395, 2253, and 2140 pictures, respectively.

2.2 Proposed Method

The field of artificial intelligence has been revolutionized by the progress of deep learning techniques, particularly in the area of image classification. Deep-learning networks tend to grow by adding more layers to their architecture. The layer depth increase allows for greater representational capacity, enabling the model to learn more complex and abstract features from the input data. In deep learning, a convolutional neural network includes convolutions, a mathematical operator, to extract feature properties from input data. A typical CNN architecture contains a convolution layer, which applies filters to the input, a pooling layer that reduces computational requirements, and a fully connected layer that acts as a neural network. By stacking and linking these layers in a specific way, a CNN can learn the features and patterns of inputs used for various tasks such as classification, object recognition, or segmentation.

Instead of creating a deep neural network from scratch, a more promising approach is to construct a model using already-trained models using the fine-tuning method. Fine-tuning involves taking a pre-trained model and adjusting its parameters on a new and smaller dataset to learn the specific patterns and features relevant to the new task.

In this study, the proposed approach involves conducting a comparative study of ResNet 50, 101, and ResNeSt 50, 101 models. The objective is to evaluate and compare the performance of these models and trains the models using the Python programming language and popular deep-learning frameworks like TensorFlow and Keras, utilizing publicly available large datasets to classify COVID-19 based on chest X-ray images.

2.3 Setup and Tools

For this study, we used Python 3.10.2 with Visual Studio Code version 1.69.2 as our code editor. To create and train our models, we utilized TensorFlow version 2.10 and Keras version 2.10.0. We conducted the training on Google Colab, which uses similar versions of TensorFlow and Keras frameworks similar to our local environment.

3 Methods and Architectures for COVID-19 Classification

The study evaluated four state-of-the-art convolutional neural networks (CNNs) for COVID-19 classification using chest X-ray (CXR) images. Two variants based on the ResNet architecture (ResNet50 and ResNet101) and two based on the ResNeSt architecture (ResNeSt50 and ResNeSt101) was pre-trained on the ImageNet dataset, then fine-tuned on a large dataset of CXR images of patients with COVID-19, pneumonia, and normal lungs. To evaluate the performance of CNNs, standard metrics such as accuracy, precision, recall, and $f1$ score are used. Results showed that all four CNNs achieved high accuracy in COVID-19 classification. ResNet50 and ResNeSt101 had the highest recall scores.

3.1 ResNet: Residual Network

The Residual Network (ResNet) architecture [41] has gained popularity in computer vision tasks due to the ability to train deeper neural networks without the vanishing or exploding gradient problem. In a traditional neural network, there was a degradation problem due to the accuracy of the network saturating and then starting to degrade rapidly as the network got deeper. The ResNet architecture addresses this problem by using skip connections, also known as residual connections, between layers. Each residual block contains convolution layers and shortcut connections. The ResNet function expresses the relationship between $F(x)$ and $G(x)$ as $F(x) = x + G(x)$, where $G(x)$ represents an additional mapping applied to x, as illustrated in Fig. 2.

3.2 ResNeSt: Residual Network with Split Network Mechanism

ResNeSt [42] is a new and improved version of the Residual Network Architecture that incorporates a split network mechanism, combining the cardinality of ResNeSt

[43] with the attention mechanism of Squeeze-and-Excitation Net [44]. ResNeSt introduced cardinality to break channel information into smaller groups using bottleneck blocks, achieving state-f-the-art results in image classification in 2016. SE-Net includes a module for channel-wise feature recalibration involving squeezing, global average pooling, and excitation, two linear transformations gated with a sigmoid function.

ResNeSt models improve representation learning in convolutional neural networks using channel-wise attention and multi-path representation. The Split-attention module in ResNeSt provides a simple and modular computation block that can replace the popular residual block. Figure 3 displays the architecture of the ResNeSt model, consisting of Cardinal groups.

3.3 Image Processing

During the pre-processing of images, the following augmentation techniques were employed randomly on each image to address overfitting: random rotation within a range of 20°, random horizontal flip, shear range of 0.1, and no vertical flip (as shown in Fig. 4). These techniques are applied during the model training process on the training set. For the image size requirements of the ResNet and ResNeSt models, all images underwent bilinear interpolation and were adjusted to dimensions of 224 × 244 for both architectures.

3.4 Model Definition

In this study, four different models were developed and tested using CXR images. The process began by customizing a pre-trained ImageNet model to create a template for each model. The base model's pre-trained weights were then used, excluding the classifier added at a later stage. The base model layers are frozen, and input is defined for each model. Additionally, data augmentation was applied to each model to

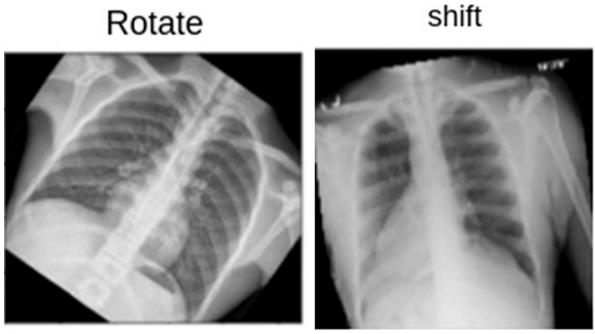

Fig. 4 Image augmentation: rotate and shift

improve its performance. It is essential to note that the weights of the base model were not updated during the fine-tuning stage. The input image was pre-processed and normalized between 0 and 1 based on the architecture of each model. Overall, the process involved creating a template for each model, customizing the base model with a custom classifier, setting the layers to a frozen state, defining the input, applying data augmentation, and normalizing the input image.

The final stage of the model development process involved creating a new classifier. This classifier consisted of three layers. The first layer was a global average pooling layer, which helped reduce the spatial dimensions of the feature maps obtained from the previous convolutional layers. Following this layer, a RELU activation function introduced non-linearity into the model. A dropout layer with a dropout rate of 0.2 was added to prevent overfitting. The last layer was a dense layer with three units. This layer utilized the SoftMax activation function, as shown in Eq. (1), to compute the probability distribution of the model's output across the three possible classes. The normal kernel initializer was used to set the initial values of the weights in this layer:

$$\text{SoftMax}(Z) = \frac{e^{z}}{\sum_{i=1}^{k} e^{z_i}} \tag{1}$$

In Eq. (1), Z represents the output layer's values, and K is the number of classes or possible outcomes.

3.5 Evaluation Metrics

Assessing the performance of ResNet or ResNeSt models using evaluation metrics is crucial for effectively monitoring their effectiveness in image classification. The evaluation metrics used in these classification tasks include categorical accuracy, recall, precision, and $F1$-score, as shown in Eqs. (2–5) with true positives, true negatives, false positives, and false negatives. The training process involved the implementation of the Adam optimization algorithm with an initial learning rate of 3×10^{-3}. Lastly, categorical cross entropy was used as a loss function, as shown in Eq. (6):

$$\text{Category Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}} \tag{2}$$

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}} \tag{3}$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}} \tag{4}$$

$$F1 = 2\frac{\text{Precision} \times \text{Recall}}{\text{Precision} \times \text{Recall}} \tag{5}$$

$$\text{Loss} = -\sum_{i=1}^{N} y_{i\times \log \widehat{y_i}} \tag{6}$$

Evaluating machine learning models is critical to creating dependable and efficient models. In multi-class classification, different evaluation metrics gauge the model's performance. Categorical accuracy is a frequently used metric that computes the percentage of instances classified correctly in a dataset, which is useful for balanced datasets. Precision measures the ratio of true positive predictions to all positive predictions by the model, and recall calculates the ratio of true positive predictions to actual positive instances in the dataset. The $F1$ score combines precision and recall to provide a more reliable and comprehensive measure of the model's performance. Evaluating models using these metrics can help improve their performance.

In addition to evaluating the performance of the model, preventing overfitting, and reducing training time are critical factors in building efficient and robust models. Defining appropriate callbacks is crucial to achieving these goals. In our research, we have identified two essential callback methods that are commonly used for ResNet and ResNeSt models. The Model Checkpoint callback saves model weights at regular intervals during the training process, allowing the model to be restored to the last saved state in the event of a crash or other interruption. Early stopping terminates the training process early if the validation loss fails to improve, preventing overfitting and reducing the training time. These callback methods are crucial in building efficient and accurate models for various applications.

3.6 Model Training and Fine-Tuning

After setting up all the necessary functions, parameters, and callbacks, the initial training can begin. In this stage, all layers of the models are unchanged except for the classifier. Each model trains for 50 epochs, and an early stopping callback is used to halt the training if there is no improvement in performance.

The fine-tuning phase follows, where some of the layers of each model are unfrozen and the models have trained again for approximately 10–15 epochs, using the same callbacks, loss function, and metrics as before. The only difference is in the optimizer function, which Adam set with a learning rate of 4×10^{-4}. By utilizing the early stopping callback, the issue of overfitting was addressed, and as a

Table 2 Summary of model parameters: trainable and non-trainable parameters after unfreezing selected layers

Parameters	ResNet50	ResNet101	ResNeSt50	ResNeSt101
Total	2,463,833	43,708,803	27,483,240	46,232,163
Trainable	4,466,179	23,859,715	16,158,979	16,158,979
Non trainable	201,721,605	19,849,088	9,281,408	30,073,184

Table 3 Overall performance of all models

Model	Accuracy	Precision	Recall	*F*1 score
ResNet50	97	97	97	97
ResNet101	98	98	98	98
ResNeSt50	95	95	95	95
ResNeSt101	96	96	96	96

result, none of the models had to train for 100 epochs. For each model, a detailed breakdown of the number of parameters is provided in Table 2 after unfreezing the layers.

4 Result

This section compares the training and evaluation efficiency of all the models used in this study. For this comparison, relevant metrics were discussed earlier. The table includes all the model's crucial metrics, including accuracy, precision, recall, and *F*1 score. Table 3 demonstrates the classification performance of various models, including ResNet50, ResNet101, ResNeSt50, and ResNeSt101, on different categories, such as COVID-19, non-COVID-19, and normal. ResNet50 exhibited an overall 97% accuracy, precision, recall, and *F*1-score. ResNet101 achieved impressive results with an overall precision of 98% and an *F*1-score of 98%. Similarly, ResNeSt50 and ResNeSt101 showed comparable performance to ResNet, with overall recall rates of 96%. Figures 5, 6, 7, and 8 displays the training and validation loss curves for ResNet50 and ResNet101 models during classification across three variants: COVID-19, non-COVID-19, and normal. The results indicate that the accuracy of ResNet50 and ResNet101 remained relatively stable, as reflected in the loss curve. On the other hand, ResNeSt50 and ResNeSt101 also maintained a consistent level of accuracy and demonstrated a better loss curve, performing equivalently to ResNet. Therefore, in real-world applications, both ResNet and ResNeSt models can be effective choices.

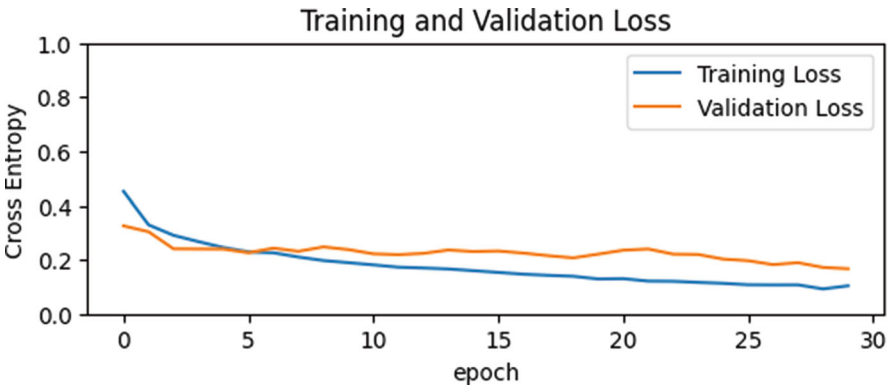

Fig. 5 ResNet50 loss curve

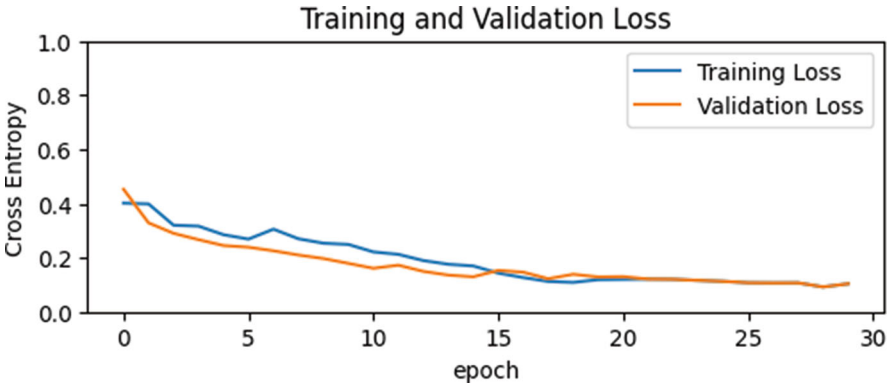

Fig. 6 ResNet101 loss curve

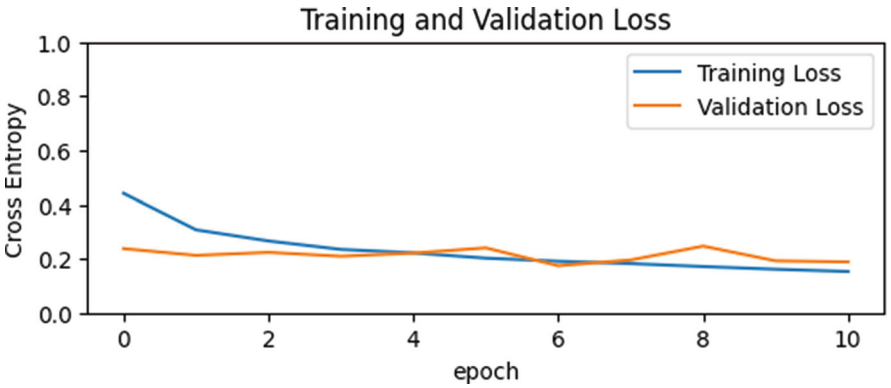

Fig. 7 ResNeSt50 loss curve

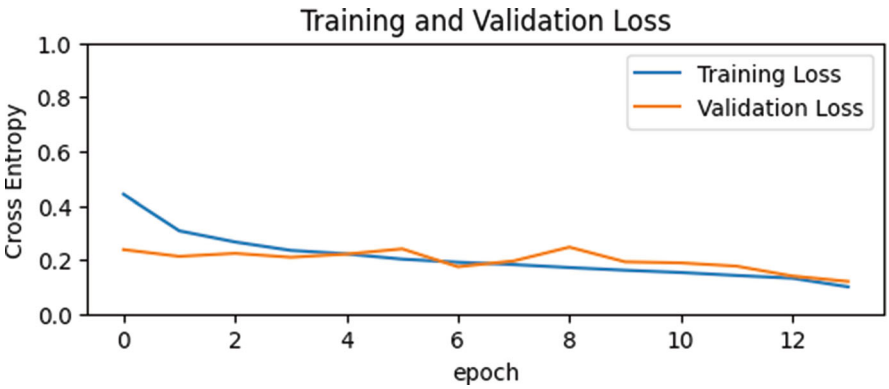

Fig. 8 ResNeSt101 loss curve

5 Discussion

The COVID-19 pandemic severely impacts global health, and rapid and accurate detection of positive cases is crucial to preventing the further spread of the virus. CXR imaging is a cost-effective and efficient method for COVID-19 identification. Although various deep-learning models have shown promising results, some studies have used limited data, which may affect their generalization to new, unseen data. The study utilized the largest COVID-19 CXR dataset for training and evaluating four deep-learning models for COVID-19 identification, achieving high precision and recall scores, with ResNet models (ResNet50 and ResNet101) emerging as the top performers. Note that despite the impressive performance of deep-learning models, evaluating and validating their practical use in a clinical setting will be necessary, which includes testing against radiologists and exploring ensemble models.

6 Conclusion

In this study, four distinct models based on deep learning were utilized and trained on an enormous dataset of CXR images consisting of COVID-19, viral or bacterial pneumonia diseases, or no disease. Our objective is to explore the capability of those models in COVID-19 identification. The results obtained from those four models showed encouraging outcomes, with all models achieving a recall score of 95% or higher, and the best performers being ResNet models (ResNet50 and ResNet101) with a 97% and 98% recall score. To increase the accuracy by implementing lung segmentation images and conducting tests on a collaborative model to enhance its effectiveness and capacity to generalize to novel X-rays. Furthermore, it would be beneficial to work with experienced radiologists and obtain their input on the practicality of the system as a decision-making aid in a clinical environment.

References

1. A new coronavirus associated with human respiratory disease in China. Nature. https://www.nature.com/articles/s41586-020-2008-3%7D
2. Automated detection of COVID-19 cases using deep neural networks with X-ray images. https://www.sciencedirect.com/science/art cle/pii/S0010482520301621#bib21
3. First case of 2019 novel coronavirus in the United States. NEJM. https://doi.org/10.1056/NEJMoa2001191
4. Coronavirus graphs: worldwide cases and deaths – Worldometer. https://www.worldometers.info/coronavirus/worldwide-graphs/#total-cases
5. Alimohamadi, Y., Sepandi, M., Taghdir, M., Hosamirudsari, H.: Determine the most common clinical symptoms in COVID-19 patients: a systematic review and meta-analysis. J. Prev. Med. Hyg. **61**(3), E304 (2020). https://doi.org/10.15167/2421-4248/jpmh2020.61.3.1530
6. Artik, Y., et al.: Comparison of COVID-19 laboratory diagnosis by commercial kits: effectivity of RT-PCR to the RT-LAMP. J. Med. Virol. **94**(5), 1998–2007 (2022). https://doi.org/10.1002/jmv.27559
7. Coronavirus disease 2019 (COVID-19): a perspective from China. Radiology. https://doi.org/10.1148/radiol.2020200490
8. Lee, E.Y.P., Ng, M.-Y., Khong, P.-L.: COVID-19 pneumonia: what has CT taught us? Lancet Infect. Dis. **20**(4), 384–385 (2020). https://doi.org/10.1016/S1473-3099(20)30134-1
9. Chest CT findings in coronavirus disease-19 (COVID-19): relationship to duration of infection. Radiology. https://doi.org/10.1148/radiol.2020200463
10. Time course of lung changes at chest CT during recovery from coronavirus disease 2019 (COVID-19). Radiology. https://doi.org/10.1148/radiol.2020200370
11. Shi, H., et al.: Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study. Lancet Infect. Dis. **20**(4), 425–434 (2020). https://doi.org/10.1016/S1473-3099(20)30086-4
12. Kong, W., Agarwal, P.P.: Chest imaging appearance of COVID-19 infection. Radiol. Cardiothorac. Imaging. **2**. https://doi.org/10.1148/ryct.2020200028
13. Yoon, S.H., Lee, K.H., Kim, J.Y., Lee, Y.K., Ko, H., Kim, K.H., Park, C.M., Kim, Y.H.: Chest radiographic and CT findings of the 2019 novel coronavirus disease (COVID-19): analysis of nine patients treated in Korea. Korean J Radiol. **21**(4), 494–500. https://doi.org/10.3348/kjr.2020.0132
14. Manna, S., et al.: COVID-19: a multimodality review of radiologic techniques, clinical utility, and imaging features. Radial. Cardiothoracic. Imaging. **2**(3), e200210 (2020). https://doi.org/10.1148/ryct.2020200210
15. Alghamdi, A.S., Polat, K., Alghoson, A., Alshdadi, A.A., Abd El-Latif, A.A.: A novel blood pressure estimation method based on the classification of oscillometric waveforms using machine-learning methods. Appl. Acoust. **164**, 107279 (2020). https://doi.org/10.1016/j.apacoust.2020.107279
16. Hammad, M., Maher, A., Wang, K., Jiang, F., Amrani, M.: Detection of abnormal heart conditions based on characteristics of ECG signals. Measurement. **125**, 634–644 (2018). https://doi.org/10.1016/j.measurement.2018.05.033
17. Khalil, H., et al.: Classification of diabetic retinopathy types based on Convolution Neural Network (CNN). Menoufia J. Electron. Eng. Res. **28**(1), 126–153 (2019)
18. Automatic brain tumor detection and segmentation using U-net based fully convolutional networks. SpringerLink. https://doi.org/10.1007/978-3-319-60964-5_44
19. Shen, L., Margolies, L.R., Rothstein, J.H., Fluder, E., McBride, R., Sieh, W.: Deep learning to improve breast cancer detection on screening mammography. Sci. Rep. **9**, 12495 (2019) https://www.nature.com/articles/s41598-019-48995-4.
20. COVID-QU-Ex dataset. https://www.kaggle.com/datasets/cf77495622971312010dd5934ee91f07ccbcfdea8e2f7778977ea8485c1914df

21. Tahir, A.M., et al.: COVID-19 infection localization and severity grading from chest X-ray images. Comput. Biol. Med. **139**, 105002 (2021). https://doi.org/10.1016/j.compbiomed.2021.105002
22. Rajpurkar, P., et al.: CheXNet: radiologist-level pneumonia detection on chest X-rays with deep learning. arXiv. (2017). https://doi.org/10.48550/arXiv.1711.05225
23. Hemdan, E.E.-D., Shouman, M.A., Karar, M.E.: COVIDX-Net: a framework of deep learning classifiers to diagnose COVID-19 in X-ray images. arXiv. (2020). https://doi.org/10.48550/arXiv.2003.11055
24. Covid-19: automatic detection from X-ray images utilizing transfer learning with convolutional neural networks SpringerLink. https://doi.org/10.1007/s13246-020-00865-4
25. https://pdfs.sematicscholar.org/9da0/35f1d7372cfe52167ff301bc12d5f415caf1.pdf
26. Chowdhury, M.E.H., et al.: Can AI help in screening viral and COVID-19 pneumonia? IEEE Access. **8**, 132665–132676 (2020). https://doi.org/10.1109/ACCESS.2020.3010287
27. COVID-19 classification of X-ray images using deep neural networks. SpringerLink. https://doi.org/10.1007/s00330-021-08050-1
28. Song, Y., et al.: Deep learning enables accurate diagnosis of novel coronavirus (COVID-19) with CT images. IEEE/ACM Trans. Comput. Biol. Bioinform. **18**(6), 2775–2780 (2021). https://doi.org/10.1109/TCBB.2021.3065361
29. A deep learning algorithm using CT images to screen for Corona virus disease (COVID-19). SpringerLink. https://doi.org/10.1007/s00330-021-07715-1
30. Vayá, M.D.L.I., et al.: BIMCV COVID-19+: a large annotated dataset of RX and CT images from COVID-19 patients. arXiv. (2020). https://doi.org/10.48550/arXiv.2006.01174
31. COVID-19 Image Repository. ml-workgroup, 6 Feb 2023. Accessed 14 Apr 2023 [Online]. Available: https://github.com/ml-workgroup/covid-19-image-repository
32. COVID-19 Database – SIRM, 31 May 2020. https://sirm.org/category/covid-19/
33. Cohen, J.P., Morrison, P., Dao, L.: COVID-19 image data collection. arXiv. (2020). https://doi.org/10.48550/arXiv.2003.11597
34. COVID-19 radiography database. https://www.kaggle.com/datasets/tawsifurrahman/covid19-radiography-database
35. Homepage. Eurorad. https://www.eurorad.org/
36. RSNA Pneumonia detection challenge. https://kaggle.com/competitions/rsna-pneumonia-detection-challenge
37. Chest X-ray images (Pneumonia). https://www.kaggle.com/datasets/paultimothymooney/chest-xray-pneumonia
38. Bustos, A., Pertusa, A., Salinas, J.-M., de la Iglesia-Vayá, M.: PadChest: a large chest x-ray image dataset with multi-label annotated reports. Med. Image Anal. **66**, 101797 (2020). https://doi.org/10.1016/j.media.2020.101797
39. Jaeger, S., et al.: Automatic tuberculosis screening using chest radiographs. IEEE Trans. Med. Imaging. **33**(2), 233–245 (2014). https://doi.org/10.1109/TMI.2013.2284099
40. Candemir, S., et al.: Lung segmentation in chest radiographs using anatomical atlases with nonrigid registration. IEEE Trans. Med. Imaging. **33**(2), 577–590 (2014). https://doi.org/10.1109/TMI.2013.2290491
41. He, K., Zhang, X., Ren, S., Sun, J.: Deep residual learning for image recognition. In: 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 770–778 (2016). https://doi.org/10.1109/CVPR.2016.90
42. Zhang, H., et al.: ResNeSt: split-attention networks. arXiv. (2020). https://doi.org/10.48550/arXiv.2004.08955
43. Xie, S., Girshick, R., Dollár, P., Tu, Z., He, K.: Aggregated residual transformations for deep neural networks. arXiv. (2017). https://doi.org/10.48550/arXiv.1611.05431
44. Hu, J., Shen, L., Sun, G.: Squeeze-and-excitation networks. In: 2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition, pp. 7132–7141 (2018). https://doi.org/10.1109/CVPR.2018.00745

Applying Norm Analysis Method on Value-Oriented Requirements for a Solution Against Violence

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Abstract Human values are an important aspect to consider when developing interactive systems, as these values influence technology operation and adoption by different people. The literature on human values in interactive systems already provides artifacts, methods, and techniques to conduct a value-oriented development of technology. However, artifacts and methods to consider and to represent values in formal phases of development are lacking. This chapter presents a study on the organizational semiotics concept of norms to formalize understanding of human values in technical phases of technology design, such as modeling, implementation, and testing. As a proof of concept, this norm approach is illustrated in the scenario of violence against children: a social and complex problem affecting different people and their values of protection and safety. As the main results, we present our approach with examples of technical norms derived from value-oriented requirements for a technology to promote awareness against child violence. This approach to representing value-related requirements and knowledge through norms can indicate ways human values can be characterized and tracked to enable a transversal value-oriented way of developing interactive systems.

Keywords Values · Norms · Organizational semiotics · Violence · Children

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_18

1 Introduction

Human values comprise a generalized framework or plan in which we collectively try to determine, on a case-by-case basis, what is good or valuable, what is preferable and not, what we endorse or oppose, and what we believe or not [1]. Human values, culture, and ethics are intertwined [2, 3] and seem critical for a sociotechnical and socially aware understanding of technologies.

"The challenges and problems of a technology-mediated society can neither be solved from a technically-centered perspective—ignoring the social world in which solutions are used and people live—nor be addressed with specific approaches in an isolated and fragmented way" ([3], p. 5). The lack of attention to values and the complex cultural context of people have led to products that are not suitable to their needs and expectations, do not make sense to them, and often generate undesirable side effects [4].

The literature indicates that research on values, culture, and ethics in technology has a fragmented view of the phenomenon [5]. Human values are addressed in specific project stages or activities by specific individuals (usually designers and clients), and often without any theoretical foundation [3]. Although the literature on human values has been published for almost three decades, the human values field still demands solutions that support the value consideration in designing interactive systems.

Dealing with values, culture, and ethics in computational systems without a specific theoretical foundation and in isolated stages of a design process indicates that providing a value-oriented approach to the design and evaluation of computational systems is still challenging. Thus, the success of value-oriented design depends on the skill and knowledge of those involved in the design process [3, 6]. Hence, designers, planners, developers, and other professionals without experience in human values interventions may be unprepared to conduct a value-oriented design.

Pereira et al. [4] indicate the need to investigate how to deal with values and cultural aspects in formal and technical activities of a design process and point out norms as a promising method of formalizing information about human values. Norms are defined by Stamper [7] as "socially agreed rules affecting and directing the actions within an organizational system." Norms enable the representation of abstract information in the social world into formal, technical, and shared modes of representation. For Liu [8], for example, once norms of an organizational system are understood, captured, and represented, they can serve as a basis for programming intelligent agents to perform many regular activities.

In this research, we are inspired by the work of Pereira et al. [4], who investigated the potential of norms for supporting the understanding, involvement, and formalization of values and culture in the design of interactive systems. Similarly, we aim to investigate how to characterize value-related knowledge and high-level requirements into more formal ways of representation in a design process utilizing norms. Our approach to representing value-related requirements is based on the Norm

Analysis Method (NAM) from the organizational semiotics [7, 8]. As context for investigation, we used the set of 43 value-oriented requirements for a technological solution to raise awareness and educate about violence against children identified in Silva Junior et al. [9] work. The requirements were identified using the Socially Aware Design [10] and the Value and Culturally Informed Approach (VCIA) recommendations, phases, and artifacts [5]. The authors identified a set of requirements inspired by stakeholders' values in the context of solutions against violence, and the set has a high-level abstraction, far from technical ways of representation.

Our main contribution is the presentation of 12 value-oriented norms that represented a solution to help raise awareness about protecting children and adolescents against violence. We present these value-oriented norms as one promising way to transform a shared understanding of values into something that helps develop a solution aligned with the stakeholders' values, which is even more relevant when developing solutions to complex social problems. With value-oriented norms, human values could be tracked and disseminated by a design team to more formal phases of technology development, such as prototyping, coding, and testing.

Section 2 presents our background, constituted by value and culture in interactive systems, organizational semiotics, and norms. In Sect. 3, we present our methodology. In Sect. 4, we present our main results from the norm analysis and discussion about the results. Finally, in Sect. 5, we present our conclusion.

2 Background and Related Work

This section characterizes value and culture in interactive systems, our methodological background of organizational semiotics, the concept of norms, and the Norm Analysis Method.

2.1 Human Values in Interactive Systems

Human values have various definitions in literature (c.f., [6, 11]). In this work, as we use the Norm Analysis Method from the organizational semiotics, we adopt the definition of Pereira et al. [3] because their definition of values is interactional and grounded on the definition of signs from Peirce semiotics [12]. For the authors, "*a value is something that denotes importance to somebody for something in some respect or capacity*" ([3], p. 6).

Among the existing methodologies for working with values [13, 14], Value Sensitive Design (VSD) is a theoretically grounded approach to technology design that takes into account human values in a comprehensive and principled manner throughout the design process [11]. VSD seeks to be proactive, influencing technology design early on and throughout the design process by integrating conceptual, empirical, and technical investigations [15].

Pereira and Baranauskas [5] present the value-oriented and culturally informed approach (VCIA), which comprises artifacts and methods to support the explicit consideration of values and culture in designing interactive systems. VCIA is a theoretically informed approach, based on Edward T. Hall theory of culture [16], organizational semiotics [8, 17], and the semio-participatory design model [18]. VCIA indicates artifacts to support designers at different stages of a design process, such as understanding the problem, identifying requirements, and evaluating systems. Pereira et al. [3] indicate a need for further investigations on supporting designers in elaborating the information elucidated by the VCIA to map the information into design decisions and solutions.

2.2 Organizational Semiotics and Norm Analysis Method

Organizational semiotics deals with interactive systems to balance technological and social aspects in a socially constructed reality based on the behavior governed by signs of the agents that participate in it [19]. Based on Hall's [16] informal, formal, and technical levels, Stamper [7] and Stamper et al. [7] proposed the Organizational Onion (also known as Semiotic Onion) to explain how these levels coexist in the context of organizations and information systems: any technical system is embedded in a formal system which, in turn, is embedded in an informal one.

Pereira and Baranauskas [5] describe that the informal system represents the organizational culture, customs, and values reflected as the members' beliefs, habits, and individual behavior patterns. The formal represents conventions, norms, or social laws. Finally, the technical system, located at the core of the Semiotic Onion, represents aspects so formalized that they can be addressed and supported technically. Figure 1 illustrates the Organizational Onion with the iterative design process transversal to the informal, formal, and technical layers. Society is the broader environment upon which people's perceptions, actions, and artifacts exist and where the effects of the (co)design are felt [10].

Supported by the Semiotic Onion framework, the Universal Design, and the participatory design, Baranauskas proposed the semio-participatory model of design,

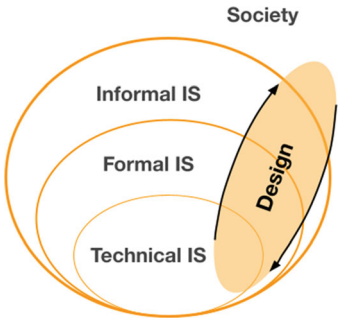

Fig. 1 Organizational onion. (Adapted from Stamper et al. [7])

which sees an organization (or organized social group) as an information system composed of a technical level (technology design), formal (laws, rules, and procedures) and informal (beliefs, behavior, values) of the domain [18, 19]. The design movement that crosses informal, formal, and technical levels characterizes a sociotechnical vision that can be adopted to understand different stages of a design process that engage activities at different levels of formality. Through this vision, we consider that culture, human, moral, and ethical values are aspects of the informal level that can be progressively represented in interactive systems' formal and technical design.

Pereira et al. ([4], p. 38) point out that norms may act as the bridge between the informal and the technical levels of an interactive system: "*We consider norms as a concept able to support designers to move from informal understandings about values and culture of different stakeholders to their effective involvement and consideration in the resulting technical artifact*". In this way, norms can be used to support the design of interactive systems. For example, norms associated with a pattern of actions can be programmed and incorporated into computer operations and functions to ensure the system behaves 'reasonably' and 'correctly' [8]. Norms can shape a system's design, delivery, and use and be implemented as a system functionality or interface feature [3].

Pereira et al. [4] postulate that we can understand human values as norms in the sense that values can be standards to guide action, judgment, argument, evaluation, and choice. For example, Von Wright [20] understands norms as laws, regulations, patterns, and standards [20]. Relating norms with culture and everyday life, Liu [8] indicates that shared norms define a culture or subculture, as norms exist and will govern the community members' behavior, thinking, judgments, and perceiving the world. In this way, norms are developed through the practical experiences of people in a culture and, in turn, have functions of directing, coordinating, and controlling actions within the culture [8].

The Norms Analysis is useful for studying an organization from the perspective of agents' behavior [8]. According to Liu [8] and Stamper et al. [7], the Norm Analysis Method (NAM) specifies the agents' general behavior patterns in an organizational system through the social, cultural, and organizational norms that govern the agents' actions. Then, NAM can capture norms that act as conditions, constraints, and rules that govern agents' behavior, generally in a prescriptive manner, to decide when specific actions are performed. The NAM also supports the study of a design context, making it possible to specify norms to characterize aspects of values and culture related to the problem and its solution [3]. Thus, because it supports norm specification and is grounded in the theoretical basis of organizational semiotics, the NAM is used in this study to represent the knowledge and understanding of stakeholders' values in a design process into norms.

Pereira et al. [4] point out that understanding evaluative norms, how they interact with other kinds of norms, and representing them are still issues that demand further investigation. Thus, this work aims to advance the ability to deal with, understand and represent values-related norms.

3 Methodology

Our methodology is based on the NAM's phases and way of structuring norms. According to Liu [8], a complete norm analysis through NAM can be performed in four steps.

1. *Responsibility Analysis.* Enables identifying and assigning responsible agents to each action. Answer the question of which agent is responsible for what type of actions [8].
2. *Proto-norm Analysis*. Identify relevant types of information for making decisions concerning a certain behavior and facilitate human decisions without overlooking any necessary factors or types of information [8]. The proto-norm structure is <condition> → <D > <agent> <action>. A norm in this form specifies the circumstances in which the action may, must, or must not (as indicated by the 'D'—deontic operator) be performed by the agent [8].
3. *Trigger Analysis*. Consider the actions concerning absolute time, such as calendar, and relative time, that reference other events [8]. All the actions can be organized in dynamic sequences. The automated system can prompt human agents to respond in time by setting up and managing triggers for the actions. The triggers can be first stated in a natural language and later translated into a computable form [8].
4. *Detailed Norm Specification*. The contents of norms can be fully specified in two versions: a natural language to capture the norms as references for human decisions and a formal language to perform actions in the automated system by executing the norms in the formal language [8].

We applied NAM in a set of technological requirements derived from value-oriented problem analysis in the context of technologies to support raising awareness against child violence [9]. Violence is a serious problem for children and families, negatively impacting the development of children and their relationships in physical and psychological ways [21]. In complex social problems, an "understanding of values and norms may enable a broader view of the problem that includes what people believe, value as important, and what guides their actions, reinforcing the communication of positive values and mitigating values that may cause more harm" ([9], p. 1).

Silva Junior et al. [9] conducted a socially aware and value-oriented design process, which included a problem understanding of violence against children, its main stakeholders and challenges, the identification of values of main stakeholders in the violence context, and the identification of 43 value-oriented requirements for potential technological solutions to raise awareness against child violence. The 43 requirements are represented as textual requirements but at a high abstraction level, far from technical requirements that specify detailed features, characteristics, and restrictions. Through the NAM, we aim to transform the requirements into technical and formalized norms that could be implemented as restrictions for a

<function> <condition>
if <state>
then <agent>
is/are <deontic operator>
to <action>.

Frame 1 Norm structure used in this study. (Adapted from Stamper et al. [7])

computer agent or to define rules for the technological implementation of solutions to raise awareness against violence.

In Chap. 5 of his book "Norm and Action," von Wright [20] characterizes norms through six components: (1) *character*: the effect of the norm, typically, "ought" for mandatory, "may" for permissive, and "must not" for prohibitive norm; (2) *content*: the action or activity prescribed in norms; (3) *condition*: the conditions for performing the corresponding elementary acts; (4) *authority*: the agent who gives or issues the norm; (5) *subject(s)*: the agent(s) who can apply the norm; (6) *occasion*: location (space) or span (time) in which the norm is given. Using von Wright's components of norms, Stamper et al. [7] point out that the specification of a behavioral norm can follow the format of *whenever <condition> if <state> then <agent> is <deontic operator> to <action>*; and new functions could cover the construction of norms, such as *orwhile, whilenot, before, after, whenever*. Adapting the structure of Stamper et al. [7], we will use the following format in our analysis, presented in Frame 1:

A function specifies a condition (whenever, while, whilenot, orwhile, before, and after). An agent is the "subject" in von Wright's terms. The deontic operator is related to the "character" of von Wright and can be one of the following: obligatory, permitted, and prohibited, or "may, must, must not" perform some action [7, 8]. A norm expressed in this structure with the deontic operator has an intended reading: *if .... then it is obligatory/permitted/prohibited for some agent to do some action* [7, 8]. Considering the NAM [7, 8] and the identified requirements [9], our methodology is presented in Fig. 2 in three main steps.

1. *Responsibility and requirements analysis.* The requirements identified in Silva Junior et al. [9] were analyzed, identifying stakeholders, associated values, area of culture, and system requirements from the Culturally Aware Requirements Framework (CARF) artifact [5]. This identification is related to the first step of NAM and helped us to understand the stakeholders in the role of agents in a norm and what related actions were represented.
2. *Norm specification.* After identifying the main agents and their possible actions, we specified a norm related to at least one system requirement related to the ten areas of Culture [16]. The structure utilized for the specification was previously presented in Frame 1. The two first authors iteratively identified norms, consulting the values and requirements and specifying one or more norms.
3. *Discussion and Consolidation.* The first two authors analyzed and commented on their norm specifications. They consolidated if the norm was adequate and if the

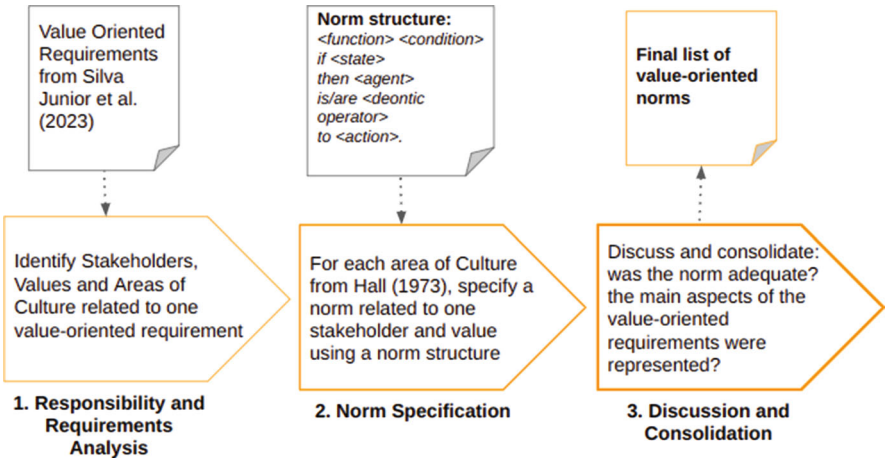

Fig. 2 Methodology steps for our norm analysis

main aspects of the value-oriented requirements were represented. They also discussed shortcomings and opportunities of specifying norms considering values.

4 Results and Discussion

Using the norm structure Frame 1 presented in Sect. 3, we selected at least one requirement from Silva Junior et al. [9] for each area of culture and wrote a norm that structures and represents that requirement. Table 1 presents our analysis of norms derived from high-level requirements.

The specified norms from Table 1 are related to the ten areas, which are the building blocks of culture [16]. People develop norms within these areas that also communicate values. These norms, derived from value-oriented requirements, are a formal representation specifying different aspects of a value: ideal characteristics and behavior, what is desirable, and what is accepted.

The specified norms are related to a value from one or more stakeholders. A design team can track and follow how the values are transformed in a design process, from stakeholder identification to norm specification. Figure 3 presents the tracking from stakeholder to norm.

This tracking enables the management of values throughout the design process. From norms, a design team could specify rules and technical behavior for the system and simultaneously understand the value and stakeholder rationale. In this way, the design team can develop a more intertwined awareness of values as something that influences the design decisions and not something that appeared at the beginning of the project but was abandoned or forgotten.

Table 1 Norm analysis from value-oriented requirements

Value and stakeholder	Value-oriented requirement	Norms
"Identity" for Children [Interaction]	"A solution must presuppose understanding and respect for the identity of children and adolescents as beings with their desires, experiences, opinions, and needs, leaving aside the idea that the child is just someone to be controlled or dominated by an adult." ([9], p. 12–13).	*whenever* designing a technology for children, *if* possible to involve children, *then* designers *should* adopt participatory practices *to* allow children active participation.
"Norms" for Health professionals [Interaction]	"A solution must reinforce organizational norms and procedures that prevent a problem from being underreported, as in cases where health professionals do not perform a notification in a system because they think they can solve the problem independently." ([9], p. 12–13).	*whenever* dealing with a situation of violence, *if* a professional identifies a violent situation in Brazil *then* this professional *must* follow the legal procedures of notification of the Ordinance No. 1968, of October 25, 2001.
"Norms" for Health Ministry [Interaction]	"A solution must align with the norms and values associated with an equitable vision of gender and justice, communicating this to users and not condoning practices that promote violence through the solution." ([9], p. 12–13).	*whenever* an act of violence is happening through the solution *if* the solution can control the act then the solution *is* obliged *to do not* permit the sharing and replication of violence.
"Conversation" for Child/Adolescent [Association]	"A solution must not tolerate violent conversations, dialogues, and information-sharing practices." ([9], p. 12–13).	*whenever* a technology operating has communication features *if* a violent dialogue is detected *then* the technology *is* obliged *to* interrupt the conversation/use and open the report violence function.
"Metacommunication" for Child/Adolescent [Learning]	"A solution must encourage users with violent behavior to learn or raise awareness about these behaviors as soon as they occur and are detected by the solution." ([9], p. 12–13).	*whenever* people use a technology to interact with others *if* a violent behavior is detected *then* the technology *is* obligated *to* inform the user about the detected behavior and inform the consequences it may cause to others.
"Emotion and Affection" for Children/ Adolescent [Play]	"A solution must prevent users from feeling pleasure and fun from harmful, violent practices." ([9], p. 12–13).	*whenever* a person communicates and interacts with others through a technology *if* harmful or violent practices are detected *then* the solution *is* obliged not *to* play fun sounds, animations, or any interaction

(continued)

Table 1 (continued)

Value and stakeholder	Value-oriented requirement	Norms
		that could stimulate the behavior to continue.
"Security" for Health Professionals [Defense]	"The solution must communicate confidence and security for a health professional who uses the solution to assist or receive reports or complaints from the victim, clearly and explicitly guiding procedures, rules, and steps and helping to recover from errors." ([9], p. 12–13).	*whenever* a person starts reporting violence through technology *then* the solution *is* obligated *to* visually inform the steps of the process (the completed ones, the current ones, and the following ones).
"Object" for Health Ministry [Exploitation]	"The solution can collect the location information of the report and send notification information to guardianship councils and police to notify possible emergency care." ([9], p. 12–13).	*whenever* a violence reporting technology is being developed *if* it is necessary to enable an emergency report mode *then* developers *are* obliged to implement a function *to* collect the location where the violence was reported and insert the option to notify guardianship councils, health care, and police requesting emergency care.
"Presence" for Children and Health Ministry [Temporality]	"The solution must show that professionals, institutions, organizations, and government sectors are responsible for and concerned with ending violence and that users can count on them." ([9], p. 12–13).	*whenever* a person accesses a technology against child violence *then* the solution *is* obliged *to* show on the front page and visible spots the online helplines, telephone numbers, and other locations where help can be found.
"Visibility" for Children and Health Professionals [Territoriality]	"The solution must make visible the necessary actions, the necessary fields, the form of interaction and the flow of actions, what the information is being collected for, and what the impacts of the action are on the system so that it does not cause doubts or confusion for whoever uses the solution." ([9], p. 12–13).	*whenever* a violence report is being made through technology *then* the solution *is* obliged *to* show the full necessary steps of the report, what data is obligatory, who will receive this report, and how much time will be waiting for a reply.
"Classification" for Children [Classification]	"The solution can help children, teenagers, and people of the surroundings identify and classify violent actions." ([9], p. 12–13).	*whenever* a person interacts with an operating technology against violence *if* privacy can be respected and the interaction is individually based *then* the solution *should* show a QA assistant

(continued)

Table 1 (continued)

Value and stakeholder	Value-oriented requirement	Norms
		to help users identify verbal, physical, and psychological violence.
"Object" for Children [Subsistence]	"The solution must ensure that the necessary infrastructure resources, such as server and storage, are available with reserve resources and load balancing if necessary." ([9], p. 12–13).	*while* a solution is operating *if* a person wants to access and interact with it *then* a solution server or physical infrastructure *is* obliged *to* respond.

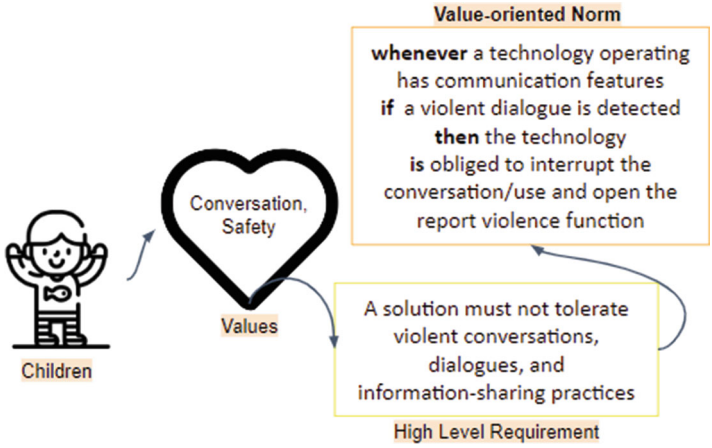

Fig. 3 Tracking information from stakeholders to the norm specification

The value specification is related to different areas of culture that people apprehend and communicate values, such as values in interaction with other people (Interaction) and manipulation of the environment (Exploitation), about how to group and associate with each other (Association), about their safety (Defense) and ways of living (Subsistence), about space (Territoriality) and time that people live (Temporality), their education (Learning), and ways of enjoyment (Play). Formalizing norms from the values of these areas of culture can specify essential aspects of the design problem, the solution development, and its operation that must be respected.

Our norm analysis also revealed different things (technology, infrastructure) and stakeholders (users, designers, developers) that must respect the norms, showing concrete examples of how values can influence people, the design process and its elements, and technology. Each norm is related to a space-time situation specified in the norm's function and condition elements, indicating the influence of values in time and specific or broad situations.

Through this work, we have demonstrated using norms to represent high-level value-oriented requirements. The norm analysis and structure are grounded in the theoretical basis of organizational semiotics, where the value definition, identification, and characterization of norms are guided through the understanding of signs and sociotechnical (informal, formal, and technical) view of the design process. This theoretical grounding of norms favors designers to understand and consider values systematically and not by ad-hoc approaches. Beyond representing value understandings, a norm specification opens up new possibilities for investigation, such as helping designers and students from technical backgrounds to understand different aspects of human values in more technical terms that could be otherwise challenging to understand. Future work also includes investigating how norms are communicated and tracked in a design process and the acceptance of using the norm specification by people involved in a design situation.

5 Conclusion

In this study, we investigated the utilization of norms as a formal representation of abstract and informal human values. Grounded in the organizational semiotics theory, the Norm Analysis Method was used to derive norms from value-oriented requirements for a technology to raise awareness against child violence. We derived a set of norms representing values for different stakeholders and in different moments of a design process and technology use. We conclude that norms are a viable option to structure requirements derived from human values. Thus, norms enable human values to be considered in formal and technical phases of software development.

As people utilize a set of norms to guide their actions, we can specify norms to control and predict what technology must do and what is acceptable behavior and operation in a different time and social space. This set of norms can be directly derived from different values that people communicate from their situated culture.

Technology operates in the lives of people and influences society. A technology operating in the world should consider society's social, moral, and ethical values and the collective values of people who will interact or be influenced by this technology. The norm identification, specification, and analysis have the potential to help designers understand and represent this diversity of human values.

References

1. Leong, T.W., Iversen, O.S.: Values-led participatory design as a pursuit of meaningful alternatives. In: Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction, pp. 314–323 (2015)
2. Friedman, B., Hendry, D.G.: Value sensitive design: shaping technology with moral imagination. Mit Press (2019)

3. Pereira, R., Baranauskas, M.C.C., Liu, K.: An essay on human values in hci. J. Interact. Syst. **9**(1), 20180601 (2018)
4. Pereira, R., Baranauskas, M.C.C., Liu, K.: On the relationships between norms, values and culture: preliminary thoughts in hci. In: Information and Knowledge Management in Complex Systems: 16th IFIP WG 8.1 International Conference on Informatics and Semiotics in Organisations, ICISO 2015, Toulouse, 19–20 March 2015. Proceedings 16, pp. 30–40. Springer (2015)
5. Pereira, R., Baranauskas, M.C.C.: A value-oriented and culturally informed approach to the design of interactive systems. Int. J. Hum.-Comput. Stud. **80**, 66–82 (2015)
6. Kheirandish, S., Funk, M., Wensveen, S., Verkerk, M., Rauterberg, M.: A comprehensive value framework for design. Technol. Soc. **62**, 101302 (2020)
7. Stamper, R., Liu, K., Hafkamp, M., Ades, Y.: Understanding the roles of signs and norms in organizations-a semiotic approach to information systems design. Behav. Inform. Technol. **19**(1), 15–27 (2000)
8. Liu, K.: Semiotics in Information Systems Engineering. Cambridge University Press (2000)
9. da Silva Junior, D.P., Baranauskas, M.C.C., Pereira, R.: Conducting socially aware and value oriented investigations: a case study on the violence against children and adolescents. J. Interact. Syst. **14**(1), 72–91 (2023)
10. Baranauskas, M.C.C., Pereira, R., Bonacin, R.: Socially aware systems design: a perspective towards technology-society coupling. ACM Trans. Comput. Hum. Interact. **15**(1), 29 (2024)
11. Friedman, B., Kahn, P.H., Borning, A., Huldtgren, A.: Value sensitive design and information systems. In: Early Engagement and New Technologies: Opening up the Laboratory, pp. 55–95. Springer, Dordrecht (2013)
12. Peirce, C.S.: Philosophical Writings of Peirce, vol. 217. Courier Corporation (1955)
13. Shahin, M., Hussain, W., Nurwidyantoro, A., Perera, H., Shams, R., Grundy, J., Whittle, J.: Operationalizing human values in software engineering: a survey. IEEE Access. **10**, 75269–75295 (2022)
14. Winter, E., Forshaw, S., Hunt, L., Ferrario, M.A.: Towards a systematic study of values in se: tools for industry and education. In: 2019 IEEE/ACM 41st International Conference on Software Engineering: New Ideas and Emerging Results (ICSE-NIER), pp. 61–64. IEEE (2019)
15. Friedman, B.: Value-sensitive design. Interactions. **3**(6), 16–23 (1996)
16. Hall, E.T.: The Silent Language. Anchor (1973)
17. Stamper, R.K.: Information systems as a social science: an alternative to the frisco formalism. In: Information System Concepts: An Integrated Discipline Emerging: IFIP TC8/WG8. 1 International Conference on Information System Concepts: An Integrated Discipline Emerging (ISCO-4), 20–22 September 1999, University of Leiden, pp. 1–51. Springer (2000)
18. Baranauskas, M.C.C., Bonacin, R.: Design: indicating through signs. Des. Issues. **24**(3), 30–45 (2008)
19. Baranauskas, M.C.C., Martins, M.C., Valente, J.A.: Codesign de Redes Digitais: tecnologia e educação a serviço da inclusão social. Penso Editora (2013)
20. von Wright, G.H.: Norm and Action: A Logical Enquiry. Routledge and Kegan Paul, New York (1963)
21. WHO. (2020). *Global status report on preventing violence against children 2020: executive summary*. Retrieved from https://www.who.int/teams/social-determinants-of-health/violenceprevention/global-status-report-on-violence-against-children-2020. Accessed August 28, 2024.

Bi-Staged Attendance Automation System with Face and Voice Detection Using Viola-Jones Recognition Algorithm

R. Devi Priya, P. Kirupa, T. Rajasekaran, and S. Manoj Kumar

Abstract In recent times, there have been numerous attempts to create technology that enables manual interactions between humans and machines. Such an interface has the potential to yield significant benefits. Facial detection refers to identifying the location and dimensions of faces, particularly those of humans, in digital images and videos, frequently as part of a larger facial recognition system. The organization will be able to automate the tracking of student attendance using a system that employs face detection and recognition algorithms and also recognizes the voice of the student for marking the attendance of that particular student. Whenever a student appears in front of the camera (webcam or CCTV), the system will automatically recognize them with their voice and mark their attendance in the cloud web server database through Bi-Staged Attendance Automation System (BSAA). In BSAA, Viola-Jones algorithm is used for face detection. This chapter aims to enhance the performance of face detection with a second stage for voice detection. The system takes voice input through Audacity, a recording tool and the system ensures that the recorded voice retains its original quality to a significant degree. The proposed system BSAA is found to be better than the existing systems by incorporating additional features such as extensive data storage and efficient computing while minimizing hardware costs and increasing accuracy with high level of privacy.

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Keywords Attendance automation · Face recognition · Voice detection · Cloud web server · Region-based CNN · Voice bio-metrics · Viola-Jones algorithm

1 Introduction

In the 1960s, the initial effort to make use of face recognition involved a semi-automated system. This system utilized photographs with markers that identified key features of the face, such as the nose, eyes, and mouth. However, a challenge lay in

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_19

selecting a small set of records from the database in which one of the image records matched the photograph. The rapid advancements in pattern recognition and its application in various areas, such as facial recognition and signature recognition, highlights the significance of incorporating this technology in large organizations.

1.1 Biometric System

A biometric system is essentially a pattern recognition system that authenticates an individual's identity based on their physiological and behavioral characteristics. Despite the application of biometric technologies in various fields, they have yet to fulfill their promise of providing automatic human recognition. These biometric systems rely on the distinctive features of each individual to accurately identify them, making them ideal for security and access control applications in a wide range of settings. Some of them are:

1.2 Face Recognition

Face recognition is a biometric identification technique that involves analyzing and processing images of a person's face. It is considered one of the most successful applications of image analysis and processing and has received significant attention in recent years. The facial recognition process in face-based biometric systems involves several stages that are similar to the general biometric recognition process. These stages include detection, alignment, feature extraction, and matching. Then, during alignment, the system corrects for any pose or lighting variations to normalize the face image. Next, feature extraction is performed to identify unique characteristics of the face, such as the distance between the eyes or the shape of the jawline. Figure 1 explains the workflow of the Image Processing steps to detect and recognize the face of the student.

Voice Recognition Voice recognition is a form of biometric identification that involves analyzing various physiological and behavioral characteristics of an individual's voice. Physiological features include the shape and size of vocal tracts, mouth structure, and nasal and lip cavities. Human speech features are also sensitive to various factors such as background noise, and the quality of the voice signal is often degraded during communication. The computers will have the ability to produce speech as output based on textual input (speech synthesizer) and recognize speech as input (speech recognizer). First, the teachers or instructors who are responsible for taking attendance in the classroom have certain requirements. These systems should be able to automatically mark attendance for students, provide real-time updates of student attendance, and allow them to quickly identify absentees. Second, the students who are attending the classes have their own set of

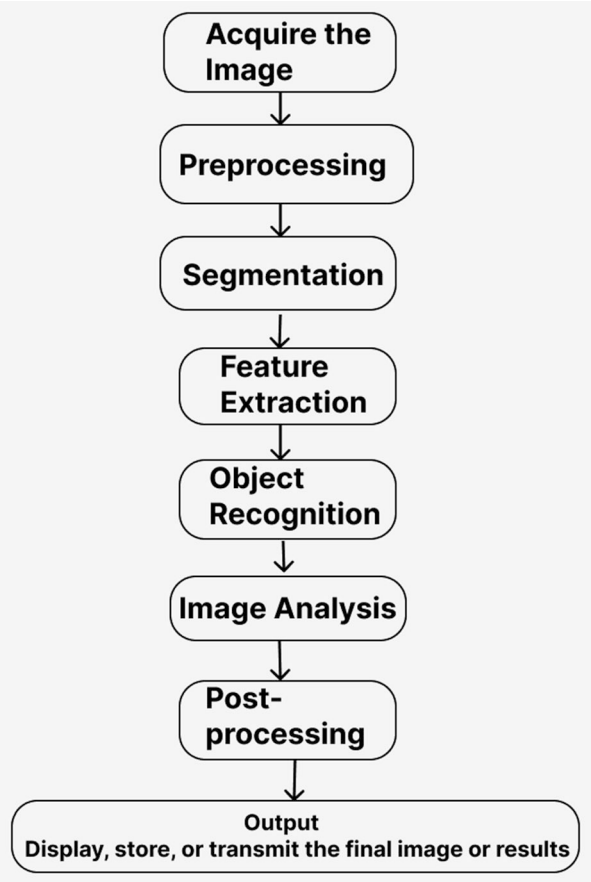

Fig. 1 The flow diagram of image processing

requirements. These systems provide a high level of privacy that does not intrude on their privacy, is non-intrusive, and does not disrupt the classroom environment. Third, the system administrator, who is responsible for maintaining the system has certain requirements. These systems are secure, reliable and scalable. It is easy to install and maintain. Finally, the school management or authorities have certain requirements. These systems are cost-effective, scalable and can be easily integrated into the existing infrastructure. These systems must also be compliant with data protection regulations and policies.

The proposed system addresses the above common attendance monitoring problem by using BSAA, which has two stages for a strong monitoring system. It uses Viola-Jones algorithm for face detection and the Mel-Frequency Cepstral Coefficients method for voice detection.

2 Literature Survey

A research [1] has shown that certain faces manage to survive multiple stages of the rejection cascade, yet they are ultimately rejected in the final decision stages, resulting in missed detection. To address this issue and increase the ability to detect these faces, they are motivated to develop a hybrid framework that incorporates multiple methodologies. Their aim is to improve our ability to identify and retain these missed faces using Viola–Jones algorithm based on hybrid network [2].

Dev and Patnaik [3] developed a device to efficiently and robustly take attendance in a classroom without any manual work or time consumption. Three algorithms were used in the development of this device, namely K-Nearest Neighbour, CNN (convolutional neural networks), and Support Vector Machines (SVM). After testing the algorithms, the SVM algorithm was found to be less efficient than the others. On the other hand, CNN demonstrated low computational complexity, making it the most suitable algorithm for the device.

In Ranei et al. [4], the proposed methods have four different methodologies, namely, generating the database, detection of face, recognition of face, and updating the attendance. The detection and recognition of faces can be done by the Haar Cascade (HC) classifier and the LBP. Paul Viola and Michael Jones defined the Haar Cascade Classifier for object detection. By using these classifiers in the approach of Machine Learning, the negative and positive images are looked over by these classifier approaches.

Kasiselvanathan et al. [5] proposed the framework for identifying the faces accurately and uses the Eigen Face (EF) algorithm and which can detect images with different color variation conditions (grayscale or color) and also the distance of the facial feature in the detected images. The face detection is processed by the Viola-Jones algorithm, which can work efficiently in different lighting. They also combine these real-time efficient techniques with Haar classifiers for good results. They also use the GSM module for sending messages in the text format if the particular student is absent if that particular face of the student is not detected and verified in the detection process. This system shows good results, such as for face recognition, and the accuracy rate is up to 93–95%. For face identification, the result is around 99%.

This system proposed by [6] is built by using haar cascade features, a face recognition library, and OpenCV. The CCTV camera in the classroom captured the images of the college students by roll call, and the attendance can be marked automatically. Later, they concluded that the haar cascade feature works more efficiently than the face recognition library. The minute facial features of the image are detected by using the Machine Learning algorithm for cleaning data like SURF and SVM. The main disadvantage of these systems is that they do not work accurately if the face angle is on the z-axis because they work only on the vertical and horizontal axes.

Muhammad et al. [7] have tried to implement the system using PCA (Principal Component Analysis), which is used for feature detection, along with the OpenCV

framework, which is used for recording automatic attendance electronically with high accuracy quality. There is an attendance system facility that identifies student faces by collecting the dataset and training the image using various algorithms. However, the algorithms used have low accuracy in training the student dataset, and the generated attendance report is not maintained for future use.

Shah et al. [8], Soewito et al. [9], and Sandhya et al. [10] have reported using voice-based recognition for attendance monitoring. In order to provide more authentic monitoring, [11–14] have implemented face recognition. [15, 16] have implemented machine learning-based smart methods for making attendance. Yet, there is a large scope for improvement in methods that are used for monitoring attendance.

Hence, efficient strategies are needed to overcome the issues in the existing system. Here, the attendance also needs to be monitored and the information needs to be stored on the cloud web server. The proposed system aims to improve the efficiency and success of an attendance system by delivering an effective solution.

3 Proposed System

In this proposed system, effective face recognition and detection can be achieved by integrating the benefits of both Viola-Jones face detection algorithm and Mel-Frequency Cepstral Coefficients for detecting voice. When both face and voice are checked, it serves as a strong authentication mechanism. The proposed system captures the students'faces when they enter the classroom and takes individual images of each student that have been stored in the database for comparison. A cloud web server is used for storage purposes to store large amounts of data without file compression. After installation, the admin has to enter student details and grant access privileges to staff who want to know the details of a particular individual student.

In addition, the student's voice has been recorded using speakers and recognized for attendance purposes. It is stored in the database for the staff/admin reference. Figure 2 defines the block diagram of the proposed system.

To access their attendance record, a student must log in to the system using his ID and password. The system verifies the credentials and saves their real-time face from different angles, along with their voice, that have been pre-saved in the database, and grants access to the student if they are correct. The teaching staff needs to keep track of students' attendance. They can easily calculate and process the performance of students based on their attendance rates. To access these systems, the staff must provide their ID and password.

The system will verify the credentials against the database and grant access to the appropriate page based on their privileges. In the case of incorrect credentials, an error message will be displayed, and they will be prompted to re-enter their ID and

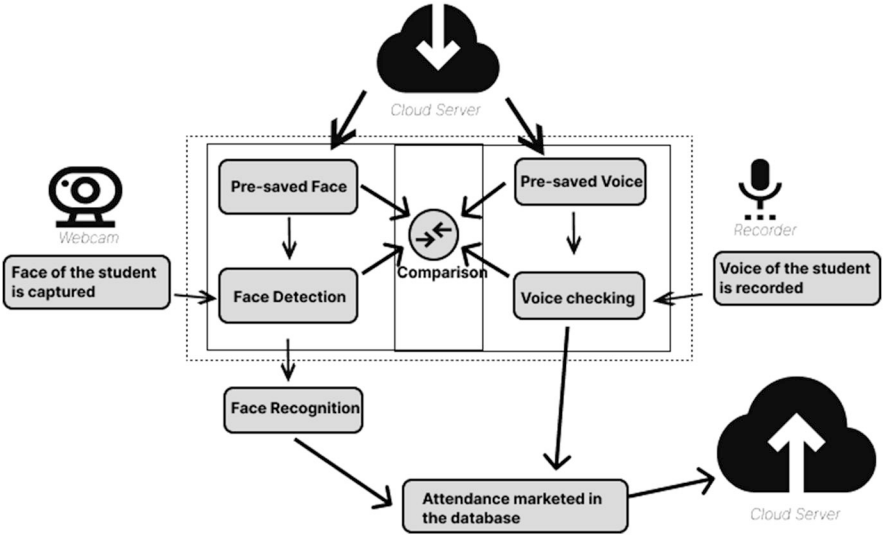

Fig. 2 Overall block diagram of BSAA

password. If the staff forgets their password, the system will display a message asking them to obtain a new password from the administration department or receive it on their personal email.

3.1 Steps in BSAA

(i) *Dataset Creation*

The dataset can be created with the student's images with some similar angle changes (up to 5 or 6 images) along with their name, unique registration number, student details, and voice model. Then, these datasets can be trained several times. Here, the unique features of the student's face can be processed and specified. The unique data of each individual student can be stored in the database. Preparation of the dataset is the main and initial step of the admin. The admin has to store the dataset for each and every student image, including their name, registration number, and mobile number. They also have to store both student and staff details in the system and provide an ID and password for each member, and even for a single student, there is a need to store at least five to six images with different facial angles in the system to maintain face recognition in a better way. They have to add new student details for every academic year and need to delete the details of the students who are all leaving the institution.

(ii) *Capturing Images of the Student*

The webcam can capture the student's face at a regular interval when the student faces the camera, and the student has to register their voice for further authentication. The webcam or camera at the entrance of the classroom or institution gate can record the student's face and then create snapshots. Then, the speaker can detect the voice of the student. Likewise, whenever the student enters, the system can record their face and their voice to recognize and store in the dataset. The Viola-Jones algorithm was employed in this technique to detect the faces of students. This implementation has significantly increased the efficiency and accuracy of the detection process.

(iii) *Face Detection*

Viola-Jones face detection algorithm, which is specifically designed for live facial recognition in digital cameras, is used to detect and recognize faces. Compared to other techniques, this algorithm provides faster and more accurate face detection capabilities. The system will compare the captured image (test image) from the camera with the stored image database (trained image) of faces. To improve the accuracy of face recognition, the captured face image is normalized to account for differences in tone. Grayscale images are used to enhance the image quality, and histogram normalization is applied to improve image contrast, reduce noise, and smooth the image. Other techniques like median filtering can also be used for this purpose.

The system completes various processes, including feature detection, matching, and extraction, in sequential order. During the face-matching process, the system compares the face with one or more known faces in a cloud database to identify the individual. In order to accurately identify faces, the system utilizes two distinct feature detection methods: the Histogram of Oriented Gradients (HOG) and the Binary Pattern Histogram (LBPH). These methods extract features from the face image, which are then classified for comparison against known faces in the database. By combining the results of both methods, the system can accurately recognize faces in both trained and untrained images based on specified facial features.

3.2 Steps in the Viola-Jones Algorithm (Fig. 3)

1. The first step in the Viola-Jones algorithm is to calculate the integral image or summed area table, which is essential for performing fast calculations during face detection.
2. Haar-like features are used as the basic building blocks of the algorithm; these are simple, rectangular features that have been shown to perform slightly better than random ones.
3. The AdaBoost learning algorithm is then used to select only the best features and create a small set of efficient classifiers. This process involves interactively training weak classifiers on different subsets of the data and selecting the ones

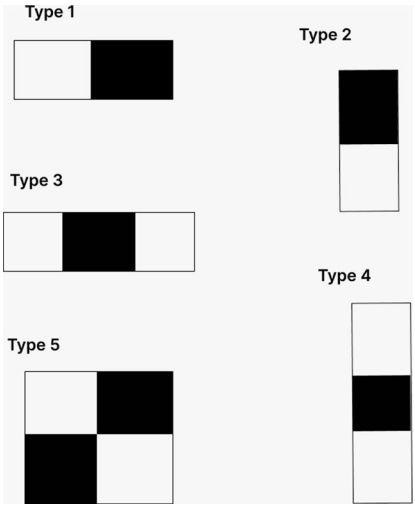

Fig. 3 Different features in Viola-Jones algorithm

that perform best. By combining these classifiers, the algorithm is able to accurately and efficiently detect faces in real-time.

(i) *Voice Recognition*

The student has to register the voice, which can be detected by the speaker, and recognized with the pre-stored voices. If the system detects a match, it can mark the attendance of the individual student. Once the comparison is finished, the Excel sheet is automatically opened to generate the attendance report. The generated student report is updated on the cloud server for future use. It improves the accuracy rate, takes less time to train the dataset, and uses the Viola-Jones face detection algorithm to detect the student's image. By using the Viola-Jones algorithm, it brings the advantages of feature selection that is sophisticated and an invariant detector that locates scales. The features alone can be scaled instead of scaling the image itself.

Advantage of the proposed method lies in achieving real-time talker identification through the use of GMM modeling. By employing this method, the log-likelihood value can be calculated and accurately determine which speaker is currently speaking. The process is partitioned into two distinct parts: the training phase and the testing phase. During the training phase, data is gathered and the necessary models are developed to perform speaker identification. In the testing phase, the trained models are used to make real-time speaker identification decisions based on the log-likelihood function.

Once the training process is complete, the computer can test the speaker who is currently speaking. To achieve this, Mel-Frequency Cepstral Coefficients are used, which play a crucial role in the utilize-speech input. The most important aspect of speech input is that the sounds generated by an individual are filtered by the shape of the vocal movement, including the movement of the tongue, lips, and other parts

of the vocal tract. This shape determines the resulting sound that is produced (Shah et al. [8]).

The packages that capture the spectrum of short-term power are used, and then the MFCC algorithm is used to precisely represent these packages. The goal is to extract features from the human voice and create models for each individual.

3.3 Mel-Frequency Cepstral Coefficients

MFCC is a commonly used feature extraction technique in voice recognition systems. The MFCC method involves breaking down the speech signal into short segments and calculating the Mel-frequency filter bank energies of each segment. The Mel-frequency filter bank energies are then converted to cepstral coefficients using the discrete cosine transform (DCT). The resulting MFCCs provide a compact representation of the spectral characteristics of the speech signal that are typically used as input features for machine learning models, such as hidden Markov models (HMM) and neural networks.

MFCCs have been widely used in speech recognition tasks due to their ability to capture the important acoustic characteristics of the speech signal while reducing the dimensionality of the feature space. The MFCCs, along with the Gaussian Mixture Model (GMM) are the key components used to build these models. Once the models are trained, the system is ready for testing. The efficiency of the testing process mainly depends on the hardware being used.

The pseudocode given in Fig. 4 utilizes the python_speech_features library to calculate MFCCs from an audio signal. Subsequently, the code conducts feature scaling, dimensionality reduction, and clustering in order to identify whether there is a voice present in the signal. It is designed to perform binary classification

```
# Compute MFCCs
    mfccs = mfcc(signal, fs)
  # Feature scaling
      scaler = StandardScaler() mfccs_scaled = scaler.fit_transform(mfccs)
   # Dimensionality reduction
       pca.value = PCA(n_components=2)
       mfccs_reduced = pca.value.fit_transform(mfccs_scaled)
  # Clustering
        kmeans = KMeans(n_clusters=2)
       labels = kmeans.fit_predict(mfccs_reduced)
 # Voice detection
     if labels[0] == labels[-1]:
        print("Voice detected")
     else:
        print("No voice detected")
```

Fig. 4 Voice detection using MFCC

(voice vs. non-voice), but it can be modified for multi-class classification. It is important to note that the efficacy of this approach depends on the particular application and the quality of the audio signal.

(i) *Attendance Marking*

After the detection of face and voice, the database can collect information about the student who is in front of the camera. Then, the attendance of that particular student is marked as present.

(ii) *Update on Cloud Server*

Once the testing phase is complete, the admin or class advisor can upload the attendance report in an Excel sheet to a secure cloud server for future use. This cloud server is highly confidential and can only be accessed with the required login ID and password.

By using this approach, a secure attendance report can be provided, and the data of the students will never be lost. The attendance data can be stored on the cloud server for later retrieval and generation of the report. This ensures the security and confidentiality of the data and makes it easily accessible to authorized personnel.

The expected output of this system is a secure attendance marking system that utilizes speech recognition technology to detect and verify the attendance of students. Once the system detects the speech of users, it will automatically mark their attendance for record-keeping purposes. By using this technology, the attendance process can be streamlined by reducing the potential errors and inaccuracies associated with manual attendance taking. The system also offers added security measures to ensure that the attendance data is kept confidential and only accessible to authorized users by storing it in the cloud.

4 Experimental Results and Discussion

The evaluation of the proposed BSAA has been performed on various face image databases that consist of diverse collections of student images. The performance of proposed BSAA is compared with that of existing algorithms, namely, HC classifier [4], EF algorithm [5], SURF & SVM [6], PCA [7], and other standard methods. The worst-case and best-case accuracies are compared in Table 1.

The proposed system BSAA shows a better accuracy rate of around 94–98%. When Viola-Jones Algorithm is implemented individually for attendance monitoring, detection accuracy is around 90–97%, which when combined with MFCC as in the proposed method, accuracy is improved and stands in the range of 94–98%. SIFT is also close in performance, whereas other methods like EF algorithm SVM show the least performance. The better performance of the proposed BSAA is due to the fact that both face and voice detection mechanisms, when introduced combinedly, increase the overall detection performance (Table 2).

Table 1 Comparison of accuracy for BSAA and other algorithms

Algorithm/classifier	Feature extraction methods	Accuracy rate	
		Worst case	Best case
SVM	PCA	57.34	88.63
	LDA	55.12	86.25
SURF	–	90.38	96.74
CNN	HOG	89.47	92.04
SIFT	PNN	92.08	95.38
LBPH	–	70.52	74.13
EF algorithm	Euclidean	69.31	87.36
Viola-Jones	LBP	93.84	97.21
	–	90.63	95.81
PCA	–	90.97	96.30
BSAA	–	94.69	98.34

Table 2 Precision, recall, and *F*1 measure of different voice recognition algorithms

Algorithm/classifier	Feature extraction methods	Precision	Recall	*F*1 score
SVM	PCA	0.84	0.87	0.83
	LDA	0.81	0.82	0.86
SURF	–	0.78	0.79	0.83
CNN	HOG	0.80	0.82	0.84
SIFT	PNN	0.82	0.85	0.82
LBPH	–	0.71	0.73	0.75
EF algorithm	Euclidean	0.69	0.72	0.70
Viola-Jones	LBP	0.84	0.86	0.88
	–	0.85	0.90	0.92
PCA	–	0.75	0.77	0.78
BSAA	Voila Jones + MFCC (voice recognition)	0.92	0.94	0.97

5 Conclusion and Future Scope

There are various methodologies for face recognition. Every technique has its own merits and demerits. The proposed method, by combining Viola-Jones and MFCC methods to perform two-staged authentications using face and voice detection mechanisms, performs better in monitoring attendance. By comparing all other existing techniques, BSAA shows superior results in terms of all evaluated metrics. The proposed system is anticipated to deliver an efficient, convenient, and time-saving solution for students and teachers in educational institutions such as schools and colleges. By refining the system's features and conducting further research, its functionality and performance can be improved in the future.

References

1. Murphy, T.M., Broussard, R., Schultz, R., Rakvic, R., Ngo, H.: Face detection with a Viola–Jones based hybrid network. IET Biom. **6**, 200 (2016)
2. Bhavania, P., Saraswathib, C., Sobab, K., Preethikab, R.: Automated attendance system and voice assistance using face recognition. Turk. J. Comput. Math. Educ. **12**(10), 3207–3217 (2021)
3. Dev, S., Patnaik, T.: Student attendance system using face recognition. In: Proceedings of International Conference on Smart Electronics and Communication, Trichy, pp. 90–96 (2020)
4. Ranei, M., Elton, D., Saeesh, M., Divya Naik, G.: Face recognition-based attendance management system using machine learning. Int. Res. J. Eng. Technol. **8**(11), 1–9 (2021)
5. Kasiselvanathan, M., Kalaiselvi, A., Vimal, S.P., Sangeetha, V.: Smart attendance management system based on face recognition algorithm. Int. J. Pure Appl. Math. **120**(5), 32–39 (2018)
6. Malhotra, S., Aggarwal, V., Mangal, H., Nagrath, P., Jain, R.: Comparison between attendance system implemented through haar cascade classifier and face recognition library. IOP Conf. Ser. Mater. Sci. Eng. **1022**, 012045 (2021)
7. Muhammad, A., Usman, M., Wamapana, A.P.: A generic face detection algorithm in electronic attendance system for educational institute. World J. Adv. Res. Rev. **2**, 1–11 (2022)
8. Shah, J., Salunkhe, V., Saturwar, J., Parab, O.: Voice input based attendance system. Int. J. Recent Technol. Eng. **9**(1), 1085–1087 (2020)
9. Soewito, B., Lumban, F., Fergyanto, G., Gunawan, E.: Smart mobile attendance system using voice recognition and fingerprint on smartphone. In: International Seminar on Intelligent Technology and Its Applications, pp. 175–180 (2016)
10. Sandhya, N., Saraswathi, V.R., Preethi, P., Chowdary, A., Rishitha, M., Sai Vaishnavi, V.: Smart attendance system using speech recognition. In: Proceedings of 4th International Conference on Smart Systems and Inventive Technology, Tirunelveli, pp. 144–149 (2022)
11. Rama Krishnan, R., Renuka, R., Swetha, C., Ramakrishnan, R.: Effective automatic attendance marking system using face recognition with RFID. Int. J. Sci. Res. Sci. Technol. **4**(3), 807–811 (2016)
12. Madhu, S., Adapa, A., Vatsavaya, V., Pothula, P.: Face recognition based attendance system using machine learning. In: Proceedings of 2nd International Conference on Intelligent Computing and Control Systems, Madurai, pp. 414–419 (2019)
13. Jenif, D., Souza, W.S., Jothi, S., Chandraseker, A.: Automation attendance marking and management system by facial recognition using histogram. In: Proceedings of 5th International Conference on Advanced Computing & Communication Systems (ICACCS), Coimbatore, pp. 66–69 (2019)
14. Chintalapati, S., Raghunadh, M.V.: Automated attendance management system based on face recognition algorithms. In: Proceedings of International Conference on Computational Intelligence and Computing Research, IEEE, Enathi, pp. 1–5 (2013)
15. Gopika, M., Prasad, D.: Machine learning classifier model for attendance management system. In: Proceedings of 4th International Conference on IoT in Social, Mobile, Analytics and Cloud I-SMAC, Palladam, pp. 1034–1039 (2020)
16. Mohana, H.S., Mahanthesha, U.: Smart digital monitoring for attendance system. In: Proceedings of International Conference on Recent Innovations in Electrical, Electronics & Communication Engineering (ICRIEECE), Bhubaneswar, pp. 612–616 (2020)

Ethnographic Analysis of a Gamified Course

Gustavo Yuji Sato, Roberto Pereira, and Isabela Gasparini

Abstract The Federal University of Paraná, in Brazil, offers an introductory course as part of the Computer Science bachelor degree. To engage students, these classes use gamification. Although the lectures use gamified resources, a better understanding of how gamification elements contribute to engagement in this context was needed. With this goal, ethnography was used to understand whether and how students interact with game elements and to raise ideas to improve the design of gamification elements. Results suggest that narrative and cognitive challenges are gamification elements that provoke student engagement.

Keywords Gamification · Education · Ethnography · Computing education

1 Introduction

Computer science is expected to contribute to the world's sustainable growth, assisting a variety of areas: healthcare, industry productivity, agriculture, manufacturing, and energy [1]. However, dropouts and retention occur at an alarming rate [2], mainly in the first periods [3], caused by difficulties related to the learning process [4].

For this reason, the Federal University of Paraná, in Brazil, has an introduction to Computer Science course that aims to exercise and promote several skills that are considered essential to Computer Science students [5]: abstraction, decomposition, pattern recognition, formulating clear instructions to solve problems (algorithms), debugging problems, solving problems efficiently, reading, writing, synthesis, autonomy, collaboration during work, rigor, ethics, professional responsibility,

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_20

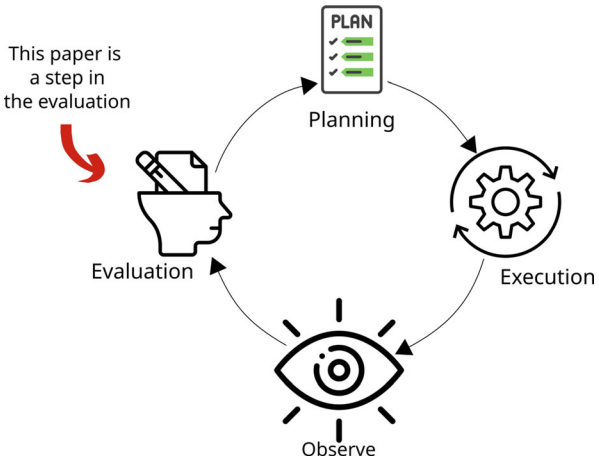

Fig. 1 This research in an action research perspective

experience in projects, and systemic thinking. The course applies gamification, the adoption of gaming design principles in contexts outside digital games [6] to promote user engagement. Gamification can increase student motivation and engage students in the learning process [7].

Although the course uses gamified resources, understanding how students interact with those game elements can provide information to better design gamification and increase student engagement. This research uses ethnography as part of this effort to investigate how students use the gamified resources.

Contextualizing in the Lewin action research model (Fig. 1), the work discussed in this paper is part of the evaluation step. Results from this evaluation activity will inform the plan of changes for gamified resources in the course. After that, new techniques for monitoring the effect of gamified elements may be employed.

This paper is organized as follows: Section 2 presents the concept of gamification; Section 3 explains how gamification was used in the analyzed course; Section 4 introduces the method of ethnography used to study the gamified course; Section 5 presents the studied group; Section 6 presents results and discussions, and Sect. 7 presents the main conclusions and directions for future research.

2 Gamification

According to Deterding [6], gamification addresses two main ideas: the first considers the influence of digital games on society and how game elements influence it; the second contemplates how digital games produce intense and lasting engagement, and for this reason, it is possible to take inspiration from their design principles and apply to other activities. Given these ideas, the following definition of gamification is formulated: 'The use of game design elements in non-game contexts' [6, 8]. Among those design elements, it can be mentioned [6]: ranking, levels,

badges, time constraints, resource constraints, clear goals, durable games, and the variety of game styles such as challenge, fantasy, and curiosity.

Gamification can be applied to different contexts and can be used in health and well-being to promote healthier behavior, such as the increase in physical activities and better use of medication [9]. Also, gamification can be applied to marketing to increase positive responses to a service, such as visits to tourism locations, by engaging people to learn about it [10]. Game design elements can also be used in e-commerce to increase consumer loyalty and engage consumers [11].

When applied to education, gamification can engage students by using badges and leaderboards to promote competition between students [7]. However, unthoughtful design and lousy implementation of game mechanics can lead to negative results [12], such as loss of performance and the students' intrinsic motivation. So, it is important to take into account gamification theory and the context in which it is applied when designing a gamified educational solution.

Toda et al. [13] organize a taxonomy classifying game elements according to experts' opinions into the following dimensions (Fig. 2):

- *Performance game elements* are used as a response from the system to provide feedback to the learner when a task is completed successfully or to promote a desired behavior, such as communication between students [14]. This group contains game elements, such as acknowledgment, which represents a reward for an expected action from the system (badges, medals, trophies, or achievements); level, or skill tree, which represents learner knowledge; progression, visual feedback of how much is needed to complete a course; points, used as feedback to the student when he accomplishes learning activities.
- *Ecological game elements* are related to the environment (system or software) where gamification is implemented. The chance of random events creates surprises. The Imposed Choice is the game element that forces students to go through different contents' path. Using a virtual economy in the gamified system is possible, allowing students to trade virtual goods, some of which are not available to everyone (rarity game element). Time pressure can make tedious tasks more challenging.
- *Social* game elements create interactions between learners. Competition and Cooperation can be used between students to achieve a common goal. Highlighting students' reputations for well-performed activities and social pressure motivates students to take desired actions.
- *Personal game elements* assist in designing how each learner interacts with the environment. Novelty adds new behavior and content to the system, surprising students. Objectives can be used to guide students in developing tasks. Puzzle tasks provide a cognitive challenge to students; renovation (or extra life) allows students to re-do a previously failed task.
- *Fictional elements* provide meaning to the task using storytelling. A Narrative can be used so the students can be affected by their choices.

Creating a feedback loop is one of the main strategies for designing a gamified system [15]. In the feedback loop, actions are rewarded with feedback. Using

Fig. 2 Gamification taxonomy by [13]

badges, experience points, or another personal gamification element [13] as feedback is possible. Users' feedback will motivate them to take further actions in the system, creating a feedback loop (Fig. 3).

3 Gamification in the Introduction to Computer Science Course

Narrative is a game element that can be used in gamified systems to contextualize other elements better [13]. The studied course is organized around a narrative, articulating six main elements [16]:

Fig. 3 A feedback loop [15]

1. *Context*: the narrative assists students in social integration at the university. For example, the Computer Science department, university, professors, and laboratories are part of the narrative.
2. *Computing*: the narrative includes computing concepts such as methods, techniques, and historical facts about computer science.
3. *Profession*: elements that refer to aspects of working in Computer Science. Project roles, activities, dynamics, and problems in Computer Science, including working conditions.
4. *Human issues:* ethical aspects of computer science, responsible professional practice, issues of a political, social, and cultural nature.
5. *Skills*: skills to be developed throughout the course [5].
6. *Gamification*: the narrative articulates other game elements to instigate.

The narrative used in the course explores a distant future where digital society collapsed due to a series of catastrophic events triggered by a high-tech wearable computing artifact. The story takes place in the computing department that students are starting to know, opening up the possibility for students to find in the story laboratories where they will study and read reports in which their professors comment on sociotechnical aspects that could have led to the catastrophe. So, students get familiar with the places and people they will study with. Because the chronicle takes place in a dystopian future, the use of computers and access to information is compromised. The problems are given in the format of unplugged computing [17], requiring no programming skills and no use of digital technology but a Moodle Learning Management System to register tasks and assignments.

The discipline is organized in 13 phases, generally occurring once a week. At each phase, the narrative's story progresses and contextualizes problems involving aspects of computational thinking [18]. Outside the narrative, students must present their opinion about ethical dilemmas or a design problem in a computer system using electronic polls. In addition, students read papers whose content can be related to the problems of narrative and polls. At the end of each phase, the student must write a self-assessment of delivered work and receive feedback from the teacher via an electronic forum. Aside from the teacher feedback in text, badges and experience points are awarded at the end of each phase.

Fig. 4 An easter egg is hidden in a book, available in a book pile in the computing department

The course employed a hybrid gamification strategy. While unplugged gamification is a gamification applied in a non-virtual environment [13], hybrid gamification has parts of the process supported by digital technologies and other parts without using them [19]. The course is supported electronically, partially by Moodle, and partially by non-virtual environments where the gamification occurs, such as the classroom and the Computer Science department at the university.

The department hides Easter eggs and objects in the story (Fig. 4). For example, a classic algorithm book is placed where any student can access it. The same book appears during the narrative with a hidden message that can be found in the story and the real world.

4 Ethnographic Research

Ethnographic research studies a group of people as they go about their lives. The ethnographer enters a new social environment, observes, and produces written records (field notes). Such transcripts go through a filter process, as the ethnographer writes about events he considers relevant and leaves other events aside [20]. Therefore, such records are not 'neutral', as observations depend on the perception of the actor who observes them [20].

In Computer Science, ethnography is important for research that aims contextual analysis to understand the relationship between people and technology in fields such as Human-Computer Interaction, Games, Computers in Education [21], and Software Engineering [22], where transcripts and recordings of meetings and interviews may be applied to conduct such analysis.

One characteristic that may confuse strangers to ethnography is the consequence of presence. The ethnographer must immerse in that culture to understand how social interactions occur in another cultural context [20]. In order to remember events

observed by the ethnographer, it is common to use jottings. Jottings are quick notes later transcribed to field notes.

'Jottings' should be done at suitable times. A person may feel suspicious when noticing another person is constantly taking notes of their actions. Therefore, the ethnographer waits until a reserved moment to carry out the jotting; yet, in certain scenarios, it is possible for the ethnographer to constantly take notes. Subsequently, jotting is transcribed into field notes. This should be done as quickly as possible so that the events that occurred are still fresh in the ethnographer's mind.

It is necessary to raise the issue of how the students use the gamification elements and how they affect the students in the classroom to redesign the gamification elements. These facts are not always reported in a study using questionnaires. In addition, the low enrollment rate made a survey by questionnaires impracticable. Therefore, ethnography was adopted for this analysis.

5 The Studied Group

The analyzed class had a small number of people, starting with ten students enrolled in the course and ending with seven. Two of which were females, and five were male.

Due to the delay in the university's semester provoked by preventive measures being taken to stop the spread of the coronavirus, classes took place in the second half of 2022, starting in October and ending in March 2023.

In this atypical scenario, and because qualitative research had been carried out with 45 students using questionnaires [16] in the previous semester, the Ethnography Method was chosen to explore blind spots that the answers to the questionnaires may not obtain.

The class was formed by Computer Science students and also by students of Biomedical Informatics, which had an equivalent credit course. Enrollment in Computer Science and Biomedical Informatics occurs once a year, and their courses are semiannual. Since the course was in the first period, students who, for various reasons, did not complete the course upon entering the university participated in the class. Among them was a student opting to change her course to Biomedical Informatics and a student who had to cancel his previous enrollment due to work and studies schedule conflicts.

Lectures were watched in a classroom to conduct the ethnographic study. Although the classroom had 10 students enrolled, it had 42 seats. Classes started at 15:30 and ended at 17:30.

In the first class, the teacher introduced the students to the ethnographer who would make the observations. Field notes were written from these observations. To better understand the social context of the group, the ethnographer followed interactions carried out in the online discussion forums (Moodle), and access to other contents of the virtual learning environment was also obtained.

During classes, jottings were produced using abbreviations and encodings. In general, observations could be taken in jottings immediately, without conflict. The nature of the classroom, in which students remain seated with a chair in front of them, does not result in the ethnographer gaining the spotlight when taking notes. After the end of the class, in less than 3 h, the process of transcribing the jottings into field notes was started.

6 Results and Discussion

During the course, some students were observed moving their legs restlessly. In one case, it was noticed that a student did not stop the movement for more than half of the class. As written in the field notes, it was observed the focus capacity in the students: 'It was noticed that student L was swinging her leg all the time, since the beginning of the class, then stopped it when it was required to work on a practical exercise and remained several minutes (approximately 20) after its end without doing so'. Before that moment, the professor was solving and discussing the activities previously developed by students and talking about the narrative plot already published in the virtual learning environment. The movement only ceased when concentration was needed to solve a problem. The exercise explored an encryption problem that required cognitive effort to solve it.

One of the gamification concerns is promoting the flow state during the development of activities [23]. The flow state can be defined as a 'mental state in which a person performing some activity is fully immersed in a feeling of energized focus, full involvement, and enjoyment in the process of the activity' [24]. The systematic review [23] studies how levels, points, badges, and leaderboards relate to the flow state, with mixed results.

On the other hand, the ethnographic observation reveals that challenge design is the gamification element with more relevance to the flow state. Converging with Csikszentmihalyi's statement, one of the conditions for the flow state to occur is the balance between the challenge presented by a given task and the skills of those who perform it [24].

Another observed topic was that the teacher's role in the narrative in unplugged and hybrid gamification. The ethnographic observations noted that the teacher constantly returned to narrative plots already mentioned, linking different concepts of the narrative and of different activities. This fact converges with [25], which discusses how differences in storytelling performance can influence students' perceptions.

Using narrative in an educational scenario generates triggers, stimulating the exchange of information in a safe space since a choice is given to those who want to share the information [25]. In addition, storytelling can socialize young people into socially accepted forms of behavioral and emotional expressions [25].

In discussion with the course's professors, it was revealed that the narrative involved ethical issues aiming to provoke students to discuss the theme. In the

course, students find eight fictitious news stories throughout the course. In these fictional papers, it was speculated that a programming error caused a tragedy, but it is then revealed that its causes had origins in problems in the development process, tests, user experience, working conditions, etc.

In addition to the narrative, polls are also used for students to express themselves about ethical dilemmas, such as the trolley's problem and issues related to computational projects. In this case, using polls is important because it makes students commit to an opinion and avoids the herd effect in discussions.

7 Conclusion and Future Work

The class that was the focus of the research was atypical, with a low number of enrollments. As one research study with questionnaires had already been carried out [16], with a more significant number of participants, it was decided to conduct ethnographic research.

According to the literature, the most used elements related to gamification are levels, points, badges, and leaderboards [23]. One of the main observations was that gamification elements less explored in the literature, such as the challenge design and the integration of the discipline around the narrative, significantly impact student engagement.

Those findings will be aggregated with other results, such as the questionnaire where narrative impacted engaging students [16]. Furthermore, more experiments can be made to evaluate better the applied gamification elements, such as ethnographic studies with bigger classes and Moodle data analysis.

References

1. Kolmos, A.: Engineering education for the future. In: Engineering for Sustainable Development: Delivering on the Sustainable Development Goals, pp. 121–128. UNESCO (2021)
2. Takács, R., Kárász, J.T., Takács, S., Horváth, Z., Oláh, A.: Successful steps in higher education to stop computer science students from attrition. Interchange. **53**, 637–652 (2022)
3. Cook, A., Leckey, J.: Do expectations meet reality? A survey of changes in first-year student opinion. J. Furth. High. Educ. **23**(2), 157–171 (1999)
4. Felisbino, E., dos Santos, M.R., Lima, S.M.A.: Percepção dos estudantes que abandonaram a educação superior: Olhares diversos para o impacto dos fatores da evasão. Jornal de Políticas Educacionais. **16**(1), e87079 (2022)
5. Pereira, R., Peres, L., Silva, F.: Hello world: 17 habilidades para exercitar desde o início da graduação em computação. In: Anais do Simpósio Brasileiro de Educação em Computação, pp. 193–203. SBC (2021)
6. Deterding, S., Dixon, D., Khaled, R., Nacke, L.: From game design elements to gamefulness: defining "gamification". In: Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, pp. 9–15 (2011)

7. Looyestyn, J., Kernot, J., Boshoff, K., Ryan, J., Edney, S., Maher, C.: Does gamification increase engagement with online programs? A systematic review. PLoS One. **12**(3), e0173403 (2017)
8. Deterding, S., Khaled, R., Nacke, L., Dixon, D.: Gamification: toward a definition. CHI 2011 gamification workshop proceedings. In: 2011 Annual Conference on Human Factors in Computing Systems (CHI'11) (2011)
9. Johnson, D., Deterding, S., Kuhn, K.A., Staneva, A., Stoyanov, S., Hides, L.: Gamification for health and wellbeing: a systematic review of the literature. Internet Interv. **6**, 89–106 (2016)
10. Noorbehbahani, F., Salehi, F., Jafar Zadeh, R.: A systematic mapping study on gamification applied to e-marketing. J. Res. Interact. Mark. **13**(3), 392–410 (2019)
11. Rahmadhan, M.A.W.P., Sensuse, D.I., Suryono, R.R., Kautsarina, K.: Trends and applications of gamification in e-commerce: a systematic literature review. J. Inf. Syst. Eng. Buss. Intell. **9**(1), 28–37 (2023). https://doi.org/10.20473/jisebi.9.1.28-37. https://e-journal.unair.ac.id/JISEBI/article/view/39025
12. Toda, A.M., Valle, P.H., Isotani, S.: The dark side of gamification: an overview of negative effects of gamification in education. In: Higher Education for All. From Challenges to Novel Technology-Enhanced Solutions: First International Workshop on Social, Semantic, Adaptive and Gamification Techniques and Technologies for Distance Learning, HEFA 2017, Maceió, 20–24 March 2017, Revised Selected Papers 1, pp. 143–156. Springer (2018)
13. Toda, A.M., Palomino, P.T., Oliveira, W., Rodrigues, L., Klock, A.C., Gasparini, I., Cristea, A. I., Isotani, S.: How to gamify learning systems? An experience report using the design sprint method and a taxonomy for gamification elements in education. J. Educ. Technol. Soc. **22**(3), 47–60 (2019)
14. Klock, A.C.T., Gasparini, I., Pimenta, M.S.: 5w2h framework: a guide to design, develop and evaluate the user-centered gamification. In: Proceedings of the 15th Brazilian Symposium on Human Factors in Computing Systems, pp. 1–10 (2016)
15. Werbach, K., Hunter, D.: The Gamification Toolkit: Dynamics, Mechanics, and Components for the Win. University of Pennsylvania Press (2015)
16. Pereira, R., Reis, R., Oliveira, L., Derenievicz, G., Peres, L., Silva, F.: A liga do pensamento computacional: uma narrativa distópica para gamificar uma disciplina introdutória de computação. In: Anais do III Simpósio Brasileiro de Educação em Computação, pp. 205–215. SBC (2023)
17. Bell, T., Alexander, J., Freeman, I., Grimley, M.: Computer science unplugged: school students doing real computing without computers. N. Z. J. Appl. Comput. Inform. Technol. **13**(1), 20–29 (2009)
18. Wing, J.M.: Computational thinking and thinking about computing. Philos. Trans. R. Soc. A Math. Phys. Eng. Sci. **366**(1881), 3717–3725 (2008)
19. González-González, C.S.: Unplugged gamification: towards a definition. In: International Conference on Technological Ecosystems for Enhancing Multiculturality, pp. 642–649. Springer (2023)
20. Emerson, R.M., Fretz, R.I., Shaw, L.L.: Writing Ethnographic Fieldnotes. University of Chicago press (2011)
21. Duque, E.M., Ishitani, L., Mol, A.M., Machado, M.C., Neves, D.E., Martins, S.W., de Oliveira Santos, L.G.N.: The use of ethnography in computer science research: a systematic literature review. Revista Tecnologia e Sociedade. **15**(35) (2019). https://doi.org/10.3895/rts.v15n35.7801
22. Passos, C., Cruzes, D.S., Dybå, T., Mendonça, M.: Challenges of applying ethnog-raphy to study software practices. In: Proceedings of the ACM-IEEE International Symposium on Empirical Software Engineering and Measurement, pp. 9–18 (2012)

23. Oliveira, W., Pastushenko, O., Rodrigues, L., Toda, A.M., Palomino, P.T., Hamari, J., Isotani, S.: Does gamification affect flow experience? A systematic literature review. arXiv preprint arXiv:2106.09942 (2021)
24. Csikszentmihalyi, M.: Beyond Boredom and Anxiety. Jossey-bass (2000)
25. Parfitt, E.L.: Storytelling as a trigger for sharing conversations. Exch. Interdiscip. Res. J. **1**(2), 206–219 (2014)

A Prototype Catalog of Adaptation Resources to Support Game Designers in Developing Accessible Digital Games

Caio Carvalho, Luciano Teran, Marcelle Mota, and Roberto Pereira

Abstract Accessibility involves removing barriers to allow a product or service to be used by as many people as possible. In the context of digital games, one way to address the diversity of an audience is through adaptability, allowing game characteristics to be customized to the needs of its different users. The current state of the art in the literature on game adaptation for accessibility reveals various adaptation features targeting specific user groups, such as patients, regular gamers, students, and health professionals. However, designing adaptable games for a diverse audience can be challenging, and designers with little experience may struggle to understand which features are helpful for different audiences and needs. To mitigate this challenge, we present a prototype for a catalog of adaptation resources to support game designers in developing accessible digital games. This catalog will serve as a starting point to help designers choose which adaptation resources to implement to make their games more accessible to their audiences.

Keywords Adaptation · Accessibility · Digital games · Personalization

1 Introduction

Digital games have become an increasingly important part of modern society, with billions of gamers distributed across the globe [1]. These games are not just a source of entertainment; they also serve as a means of socialization [2], education [3], and even therapy [4]. Games can bring people together and foster a sense of community, allowing players to connect with others who share their interests and passions. They

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_21

can also teach valuable skills and knowledge, such as problem-solving, critical thinking, and teamwork. In addition, games have been shown to have therapeutic benefits, providing stress relief and helping to improve cognitive skills [5].

Besides the benefits mentioned above, digital games can also promote inclusivity and diversity. However, to achieve that, game developers must prioritize accessibility in their games. Ensuring accessibility means providing opportunities for individuals with diverse backgrounds and abilities to enjoy and engage with digital games. One way to achieve that is through adaptability, allowing the games to be customized according to the needs and preferences of its users. Some examples of games that were praised for containing many adaptation resources are the Last of Us Part II and God of War: Ragnarök games [6, 7].

To understand how the scientific literature is approaching adaptation for accessibility in digital games, we performed a Systematic Mapping Study [8]. The mapping provided an overview of the area, indicating much research conducted with adaptation features targeting specific user groups, such as patients, regular gamers, students, educational experts, and health professionals. However, designing adaptable games for a diverse audience can be challenging, and designers with little experience may struggle to understand which features are helpful for different audiences and needs.

For example, a developer designing an educational game may have difficulty choosing which elements of a quiz game should be customized to attend to a diversity of students' profiles. The difficulty level is vital to be adapted since beginners may struggle with hard questions, and more advanced students may feel bored with easy questions. The designer may also need help understanding when the adaptation should happen. The option to customize the difficulty level may be provided in a settings menu, in which the student or other stakeholder (e.g., an educational expert) can choose the difficulty from a list of options. Alternatively, the adaptation can also happen automatically during the gameplay, in which case it is up to the system (i.e., the game itself) to choose the appropriate difficulty.

To mitigate this issue, we utilized the data extracted from the mapping as input to develop a prototype catalog of adaptation resources. This prototype is the first version of a catalog intended to support game designers in creating accessible digital games by providing a comprehensive description of the adaptation resources available, including:

(1) What each resource is, (2) the possible audiences for each resource, (3) the adaptation moments to use each resource, (4) the benefits of using each resource, (5) detailed instructions on how to use each resource, and (6) the appropriate contexts in which to use each resource. We expect this catalog will serve as a useful starting point for designers seeking to promote accessibility for their audiences through adaptability features.

The next sections of this chapter are organized as follows: Section 2 presents the Systematic Mapping Study that grounded this research; Section 3 presents the Research Method of this study; Section 4 presents the prototype catalog of adaptation resources; and Sect. 5 presents the conclusions and future work.

2 Systematic Mapping Study

The performed Systematic Mapping Study aimed to provide a rigorous and repeatable process for identifying and documenting scientific studies investigating the adaptation of digital games for the users' needs. The mapping was mainly based on the guidelines defined by [9–11]. Four researchers participated in the Planning, Conducting, and Reporting of the study. The search string defined for the protocol was the following:

```
(Game) AND (Adaptable OR Adaptive OR Personalizable OR Configurable OR
Customizable OR Tailorable OR Adapted OR Personalized OR Configured OR
Customized OR Tailored)
```

The search bases used were The ACM Digital Library and IEEE Xplore Digital Library, both known for their tradition in the academic community and for being the main bases for computing papers. After running the protocol, a total of 4385 unique papers were found (1897 from ACM and 2488 from IEEE). This process occurred on August 25 (2021) and included all papers available until that day.

The following research questions were addressed in the study: (1) What is being adapted in games? (2) Why is it being adapted? (3) For whom is it being adapted? (4) When does the adaptation occur? (5) Who is carrying out the adaptation?

From the initial 4385 unique studies, 111 were selected as relevant papers because they focused on technologies to support the adaptation of digital games and provided enough data to answer our research questions. Figure 1 illustrates an overview of the main results of the study. A detailed report of the findings was published in [8].

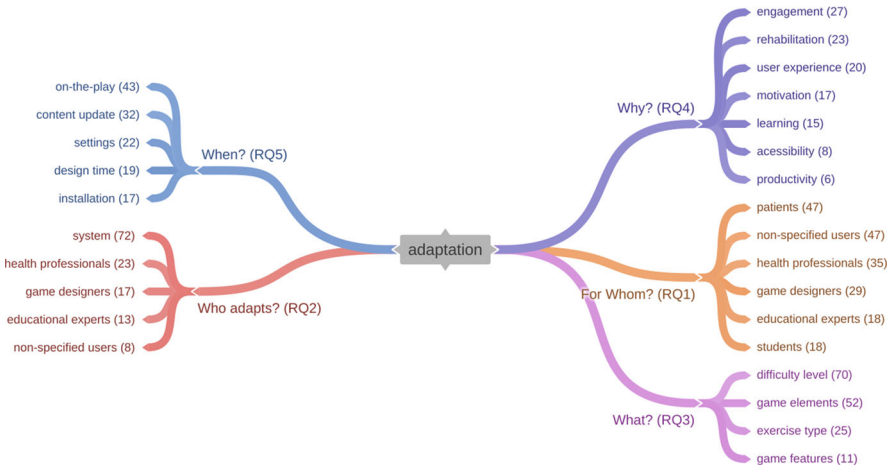


Fig. 1 Overview of research questions [8]

The mapping revealed that the main audiences of the studies were patients, non-specified users, health professionals, and game designers. The adaptation was mainly carried out by the system (i.e., the game itself), but it was also performed by other stakeholders such as health professionals, game designers, and educational experts. The primary advantages identified in performing adaptation were enhancing engagement, improving user experience, and boosting motivation among the target audiences. The adaptation characteristics were categorized into game elements, game features, difficulty level, and exercise type. These findings, as elaborated in the subsequent section, were crucial in developing our catalog.

3 Research Method

To build our catalog, the first step was identifying the adaptation resources that should be included in the catalog. To accomplish this, we collected a detailed list of adaptation characteristics that were identified in the Systematic Mapping Study [8]. Each one of these characteristics was present in at least one of the 111 selected papers from the mapping, with information about its use application. For example, the "Game Feature – Vision Accessibility" was an element that we identified in several papers as the settings such as shadow, brightness, font size, and colors that can be adjusted to benefit a range of users, such as people with low vision or color blindness. Thus, we included it as an adaptation resource.

The second step was determining which fields should be part of the catalog. For this step, we grounded our decision on the dimensions investigated in the mapping study research questions and in the 5W2H Framework [12]. Initially proposed to support the design of gamification scenarios, the 5W2H Framework presents seven dimensions (Who? What? Why? When? Where? How? and How Much?) generic enough to be used as fields for the catalog. Then, we chose the following fields to characterize each adaptation resource:

- *What is*—a brief description of the resource;
- *For Whom*—the list of audiences that can benefit from that resource;
- *When to use*—the list of adaptation moments in which each resource can be implemented;
- *Why to use*—the possible benefits of using each resource;
- *How to use*—detailed instruction on how to use each resource, with sources from the literature;
- *Where to use*—the list of use contexts of the resource.

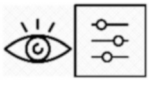
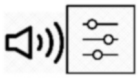
Finally, in the third step, we described each adaptation resource in detail, providing information on each relevant dimension based on the information extracted from the literature mapping.

4 The Prototype Catalog of Adaptation Resources

Table 1 presents the complete list of resources in the catalog prototype, with the name of each resource and a corresponding icon. The icons were selected from websites that offer free resources[1]. In Table 1, we described each resource.

The difficulty level resource may be a physical or a cognitive effort required by a challenge in a game. Regarding physical effort, it can be implemented in a therapeutic game as an exercise necessary for a patient's physical rehabilitation. In this scenario, the patients are the end users of the resource, but health professionals can also be the audience since they usually accompany the patients in rehabilitation

Table 1 Catalog of adaptation resources

Adaptation resources catalog			
Difficulty level—Physical effort		Difficulty level—Cognitive effort	
Game element—Textual dialogue		Game element—NPC	
Game element—Theme		Game element—Image	
Game element—Quest		Game element—Timer	
Game element—Sound		Game element—Avatar	
Game feature—Vision accessibility		Game feature—Hearing accessibility	
Game feature—Input accessibility		Exercise type—Movement/muscle/posture	

[1] Icons from freeicons.io, iconscout.com, flaticon.com, iconfinder.com.

Table 2 Example of the adaptation resource "Game Element – Textual Dialogue" present in the catalog

 Game element—Textual dialogue	
What is:	An element that refers to the written communication between characters in a game. In many games, dialogue is presented by text boxes that appear on the screen.
For whom:	Patients, health professionals, educational experts, students, generic users.
When to use:	During game installation, during gameplay.
Why to use:	It can enhance the player experience by providing context and depth to the game's characters and story.
How to use:	It can be used in creating and editing textual dialog boxes in a therapeutic game to support adolescent mental health [ID16]. It can be used to create textual questions for healthcare professionals to use in monitoring symptoms in victims of child abuse [ID18].
Where to use:	Therapeutic context, educational, entertainment.
Applications in literature:	[ID16] PlayWrite: End-user adaptable games to support adolescent mental health. [ID18] Knowledge assessment: Game for assessment of symptoms of child physical abuse.

sessions. An example of this resource implemented in the literature can be seen in [13].

A detailed example of how the information of an Adaptation Resource is present in the Adaptation Catalog can be seen in Table 2. The resource named "Game Element – Textual Dialogue" was identified in two papers selected in the mapping [14, 15], which provided information to fill the catalog fields. Thus, we described the resource as "*An element that refers to the written communication between characters in a game. In many games, dialogue is presented by text boxes that appear on the screen.*" In the research of [14], the resource was implemented as a Dialogue Builder, allowing mental health care professionals to create interactive dialogues with therapeutic game content.

The Adaptation Catalog also includes "Images," "Sounds," "Theme," and "Timer" as Game Elements. Diverse use scenarios for these features can be seen in [16]. In the paper [16], the researchers designed three adaptable games: (1) the memory game, (2) the puzzle game, and (3) the auditory memory game. All games were developed with an occupational therapist who attended children with diverse physical and cognitive disabilities. Personalizing game elements was crucial to attend to the different children's needs. The memory game and the puzzle game had the option for the therapist to upload custom images to the game to engage the children in the activity. There was also the option to choose predefined themes in the game, such as cartoons, animals, and Christmas. The timer was the option to

Puzzle Game Auditory Memory Game

Fig. 2 Examples of the adaptation resources "images," "sounds," and "theme" implemented. (Source: Ref. [16]). (**a**) Puzzle game (**b**) Auditory memory game

customize how much time the memory cards would be faced up when the game started. In the auditory memory game, a sequence of sounds could be customized to match a sequence of colors, like the classic Simon/Genius games. Figure 2 illustrates some of these resources implemented in the games.

Another resource in the catalog is the "Game Element – NPC," which stands for "Non-Player Character." NPCs are controlled by the computer and play various roles in the game world, such as providing information, offering quests, and serving as allies or enemies to the player. NPCs can also be used in educational games to engage and interact with the player, providing information compellingly and interactively. Research [17] has shown that NPCs can be used to personalize the learning experience according to the player's personality type. For instance, extroverted learners may benefit from having more NPCs to communicate with, while introverted learners may benefit from fewer arousal elements [17].

The catalog also includes a resource named "Game Element – Avatar," which refers to the visual representation of a player's or character's identity in a game. In the literature, this resource was identified in the research of [18], in which authors developed a Customizable Virtual Human to support adolescents with autism spectrum disorder interacting with 3D tasks. The authors performed tests that indicate that avatars could improve the performance of users with autism spectrum disorder by motivating them to play the games and providing a better user experience.

There are three adaptation resources classified as "game features," which are settings related to accessibility options in games. The "vision accessibility" resource refers to settings such as shadow, brightness, font size, and colors that can be customized to allow users with different visual needs to enjoy a game. The "Hearing Accessibility" resource refers to options such as mute, volume, audio description, and subtitles in a game to be personalized to attend to diverse hearing needs. Finally, the "Input Accessibility" resource refers to using alternative input devices, such as keyboards, remapping controllers, and the use of assistive technologies such as eye tracking. Figure 3 illustrates some of these resources implemented in the Last of Us Part II game.

Finally, the "exercise type" refers to personalizing a player's movements, muscles, and posture that can be exercised in a game. In the literature, this resource is widely used to target specific user groups, such as stroke patients, people with

Fig. 3 Example of the adaptation resources "vision accessibility" and "hearing accessibility" in the Last of Us Part II game. (Source: Ref. [19]). (**a**) Visual Accessibility—High Contrast (**b**) Hearing Accessibility—Subtitles

disabilities (motor impairments), people with cerebral palsy, and older adults. However, physical activity benefits all types of users, and much research is done in the field of "exergames," which are games with intrinsic physical exercises. A usage example can be seen in Ref. [20], in which researchers developed user models to understand players' preferences and recommend appropriate exercises.

5 Conclusions and Future Work

This paper presents a prototype catalog intended to assist game designers in creating accessible digital games. Although not all resources could be detailed in this paper, we presented some main features with usage scenarios. The complete catalog[2] provides a comprehensive list of adaptation resources, including a description of each resource, the audiences for which it is intended, when it should be implemented, the potential benefits, step-by-step instructions on how to utilize each resource, and the appropriate contexts in which to use it. By providing such a catalog, we hope to offer a helpful starting point to game designers who want to make their games accessible to a broader audience.

As future work, we plan to improve the catalog through case studies with different audiences. At first, we plan to conduct a pilot study to test the feasibility of the catalog with games and human-computer interaction experts. The participants will be members of the research group of which some of this study authors are part. These participants have experience analyzing artifacts and may provide insight on improving the solution grounded in theories and methodologies from human-computer interaction.

[2] Available at the following link: Adaptation Resources Catalog.

Following the pilot study, we will use our gathered feedback to refine and enhance the catalog. The target audience for this updated version will be game designers for whom this solution is intended. Through a series of case studies, we will examine the catalog's perceived ease of use and usefulness to analyze the overall acceptance of the artifact. Based on the feedback we receive from these case studies, we will continue to refine and test the solution in an iterative process until a reasonable and satisfactory version has been achieved.

Acknowledgments This study was partially supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) via scholarship and the Programa de Excelência Acadêmica (PROEX). Roberto Pereira is a CNPq Research Productivity scholarship holder (306423/2023-5).

References

1. Clement, J.: Number of video gamers worldwide from 2014 to 2025. https://www.statista.com/statistics/293304/number-video-gamers/ (2021). Accessed 11 Apr 2023
2. 25 best online video games to play with friends while coronavirus lockdown continues. https://www.theguardian.com/games/2020/mar/17/25-best-online-video-games-coronavirus-self-isolating (2020). Accessed 11 Apr 2023
3. Manesis, D.: Digital games in primary education. In: Deliyannis, I. (ed.) Game Design and Intelligent Interaction. In-techOpen, Rijeka (2020). https://doi.org/10.5772/intechopen.91134
4. Rodrigues, K.R.D.H., Neris, V.P.D.A., Souza, P.M., Zavarizz, R.G., da Silva, J.W., Silva, T. M., Verhalen, A.E.C.: Rufus – uma plataforma de autoria para jogos digitais terapêuticos. In: X Latin American Conference on Human Computer Interaction. CLIHC 2021, Association for Computing Machinery, New York (2021). https://doi.org/10.1145/3488392.3488407
5. Reynaldo, C., Christian, R., Hosea, H., Gunawan, A.A.S.: Using video games to improve capabilities in decision making and cognitive skill: a literature review. Procedia Comput. Sci. **179**, 211–221 (2021). https://doi.org/10.1016/j.procs.2020.12.027. https://www.sciencedirect.com/science/article/pii/S1877050920324698, 5th International Conference on Computer Science and Computational Intelligence 2020
6. Bayliss, B.: The last of us part ii accessibility consultants — advancing the industry. https://caniplaythat.com/2020/06/23/the-last-of-us-2-accessibility-consultants-advancing-the-industry/ (2020). Accessed 11 Apr 2023
7. Kratiuk, A.: An unbelievable level of accessibility: a blind gamer nicknamed sightlesskombat passed god of war ragnarok almost without assistance. https://gagadget.com/en/games/203245-an-unbelievable-level-of-accessibility-a-blind-gamer-nicknamed-sightlesskombat-passed-god-of-war-ragnarok-almost-wi/ (2022). Accessed 11 Apr 2023
8. Carvalho, C., Teran, L., Mota, M., Pereira, R.: A systematic mapping study on digital game adaptation dimensions. In: Proceedings of the 21st Brazilian Symposium on Human Factors in Computing Systems. IHC '22, Association for Computing Machinery, New York (2022). https://doi.org/10.1145/3554364.3559122
9. Kitchenham, B., Charters, S.: Guidelines for performing systematic literature reviews in software engineering. Tech. Rep., EBSE-2007-01 (2007)
10. Petersen, K., Feldt, R., Mujtaba, S., Mattsson, M.: Systematic mapping studies in software engineering. In: Proceedings of the 12th International Conference on Evaluation and Assessment in Software Engineering, pp. 68–77. EASE'08, BCS Learning & Development Ltd., Swindon, GBR (2008)

11. Petersen, K., Vakkalanka, S., Kuzniarz, L.: Guidelines for conducting systematic mapping studies in software engineering: an update. Inf. Softw. Technol. **64**, 1–18 (2015). https://doi.org/10.1016/j.infsof.2015.03.007. https://www.sciencedirect.com/science/article/pii/S0950584915000646
12. Klock, A.C.T., Gasparini, I., Pimenta, M.S.: 5w2h framework: a guide to design, develop and evaluate the user-centered gamification. In: Proceedings of the 15th Brazilian Symposium on Human Factors in Computing Systems. IHC '16, Association for Computing Machinery, New York (2016). https://doi.org/10.1145/3033701.3033715
13. Afyouni, I., Einea, A., Murad, A.: Rehabot: gamified virtual assistants towards adaptive telerehabilitation. In: Adjunct Publication of the 27th Conference on User Modeling, Adaptation and Personalization, pp. 21–26. UMAP'19 Adjunct, Association for Computing Machinery, New York (2019). https://doi.org/10.1145/3314183.3324988
14. Coyle, D., Doherty, G., Sharry, J.: Playwrite: end-user adaptable games to support adolescent mental health. In: CHI '10 Extended Abstracts on Human Factors in Computing Systems, pp. 3889–3894. CHI EA '10, Association for Computing Machinery, New York (2010). https://doi.org/10.1145/1753846.1754074
15. Zhao, R., Shelton, C.R., Hetzel-Riggin, M.D., LaRiccia, J., Louchart, G., Meanor, A., Risser, H. J.: Knowledge assessment: game for assessment of symptoms of child physical abuse. In: Proceedings of the 14th International Conference on the Foundations of Digital Games. FDG '19, Association for Computing Machinery, New York (2019). https://doi.org/10.1145/3337722.3337747
16. Carvalho, C., Teran, L., Mota, M.: A set of customizable features for adaptable games. J. Interact. Syst. **13**, 139–153 (2022). https://doi.org/10.5753/jis.2022.2428
17. Tlili, A., Denden, M., Essalmi, F., Jemni, M., Kinshuk, C., N.S., Huang, R.: Does providing a personalized educational game based on personality matter? A case study. IEEE Access. **7**, 119566–119575 (2019). https://doi.org/10.1109/ACCESS.2019.2936384
18. Mei, C., Mason, L., Quarles, J.: "I built it!" — exploring the effects of customizable virtual humans on adolescents with asd. In: 2015 IEEE Virtual Reality (VR), pp. 235–236 (2015). https://doi.org/10.1109/VR.2015.7223382
19. The last of us part ii – accessibility (us). https://www.playstation.com/en-us/games/the-last-of-us-part-ii/accessibility/ (2021). Accessed 14 Apr 2023
20. Yoo, S., Heywood, T., Tang, L.M., Kummerfeld, B., Kay, J.: Towards a long term model of virtual reality exergame exertion. In: Proceedings of the 25th Conference on User Modeling, Adaptation and Personalization, pp. 247–255. UMAP '17, Association for Computing Machinery, New York (2017). https://doi.org/10.1145/3079628.3079679

A Toolkit for Ensuring Accessibility of Operating Systems: The Cyrillic Readers Case

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Abstract The concept of accessibility is quite broad. It can affect areas from art to transportation to computer systems and technology. It can be defined as the extent to which any product, device, service or environment is accessible to as many people as possible. Accessibility can be thought of as the 'ability to access' and benefit from some system or object. The term is often associated with disabled people and their rights to access facilities, often through the use of assistive technology. Groups of disabled users who need to use aids for digital inclusion through the provision of equipment to access computer resources may have visual, auditory, speech, cognitive, and motor disabilities. In this chapter, we focus our attention on visually impaired users' issues. Part of their necessary equipment for digital accessibility of computer resources are so-called speech synthesizers and screen readers. Through them, they access the information architecture and content of the computer systems. The purpose of this chapter is to propose an integrated accessibility audit approach for desktop applications in Windows operating system. The objectives of the study are researching the basic equipment through which visually impaired people access Windows operating systems as the most widely used one worldwide; examining the features of those tools targeted to the Cyrillic alphabet users; testing the accessibility of desktop software for finding accessibility issues.

Keywords Digital inclusion · Accessibility · Speech synthesizers · Screen readers · Visually impaired users

1 Introduction

With an estimated 1.3 billion people experience significant disability or 16% of the world's population [1], it is crucial to ensure that operating systems are designed with accessibility in mind. The capacity of people with impairments to utilize and

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_22

navigate the computer interface is referred to as operating system accessibility. This comprises, among other things, adaptations for cognitive, learning, and neurological, visual, auditory, and motor limitations [2].

The visually impaired users face several challenges when accessing computer systems. On the first place, since most computer user interfaces are accessed in graphical mode, visually impaired people face the inability to access visual content such as visual cues, icons, and images. This makes it necessary to ensure a sound correspondence of the graphic content. That is why when working with modern computer technology, this user group mainly works with two types of software applications—a screen reader and a speech synthesizer. They may be part of an operating system or third-party software that is commercial or distributed free of charge by associations of blind users in a given country.

However, not all computer applications and websites are designed to be compatible with the equipment that this group of users uses. If the system is not properly encoded or lacks appropriate alternative texts for the multimedia elements, then visually impaired users are challenged to access and understand the content.

On the other hand, the problems of the blind users are also expressed in the problem-free access to the webspace. More and more websites are being designed to meet international accessibility standards and guidelines, and to be compatible with software programs and hardware devices that blind computer users use. There are some strategies or guidelines for creating an inclusive design. They are aimed comprehensively at the layout of visual content so that it is accessible to people with various visual problems. For example, articles by Gordon [3] and the Bureau of Internet Accessibility [4] combine accessibility recommendations for people who are colorblind and blind. They are related to providing color contrast and visual cues in addition to color to make interactive elements easy to identify. It is also recommended to use robust alternative text for images or graphics, which should be tested with real users to verify the usability of the software. More detailed guidelines are included in the Web Content Accessibility Guidelines (WCAG) of W3C, on which the cited articles are based. According to WCAG content should be perceivable, operable, understandable, and robust. Users must be able to access the content with different technologies [5].

Visually impaired users also often have difficulty accessing documents, especially when working with scanned PDF files, image files, or complex layouts that use graphic elements in content styling. These formats may not be compatible with screen readers or Braille displays, preventing them from accessing the information.

Therefore, when providing accessibility to visually impaired people to computing resources at the first level, an accessible design model of operating systems must also be provided. They are the link between computer hardware and software and regulate user access. Operating systems propose their own set of accessibility options, with specific terms, organization and implementation [6]. Their accessibility has gone a long way, with several built-in tools and features designed to meet the requirements of people with impairments. These accessibility tools allow users to personalize their experience and engage more successfully with their computers, ultimately improving their quality of life. In this chapter, we will look at the

significance of operating system accessibility as well as the many accessibility tools available in prominent operating systems including Windows, macOS, and Linux.

Windows is one of the most widely used operating systems in the world—it holds around 74% worldwide market in January, 2023 [7]. It includes a variety of accessibility features. The Ease of Access Center is a built-in accessibility feature that includes capabilities such as magnification, color filters, high contrast themes, and the option to change text sizes. Windows also has speech recognition and text-to-speech capabilities, allowing users to manage their computers with voice commands or listen to material read aloud.

macOS is another popular operating system that many people use throughout the world. It includes accessibility features to make it easier to turn various accessibility features on or off, and to type users' Siri requests [8]. macOS has accessibility capabilities such as VoiceOver, which reads text aloud and describes visuals, and a built-in screen reader, which offers thorough explanations of what is on the screen [9]. Zoom, a tool that magnifies the screen and includes choices for high contrast and color filters, is also available in macOS [9].

Linux is a popular open-source operating systems family that includes features like screen magnification, high-contrast themes, and text-to-speech capabilities. Orca, a screen reader included with Linux, reads aloud text and descriptions of graphics and icons. Also, Linux community developed distributions that are designed for people with special needs and specially designed for visually impaired users. These are Vinux and b-Linux—operating systems are based on Ubuntu with GNOME desktop environment, which work with the Orca screen reader and the built-in speech synthesizer [10].

Accessibility features in mobile operating systems such as iOS and Android allow individuals with impairments to utilize smartphones and tablets. VoiceOver, for example, is included in iOS and reads aloud the text on the screen as well as explaining graphics and symbols [11]. TalkBack, a screen reader for Android, reads text and descriptions loudly [12]. High contrast themes, text size modifications, and magnification are all available on both iOS and Android.

In this sense, we will focus our attention to accessibility tools for users with disabilities, including how they can improve the user experience and increase digital inclusiveness. Furthermore, we will discuss the challenges faced by individuals with disabilities when using computers and how operating system accessibility can respond them. In that connection, we examined the tools used by blind users to access the desktop operating systems. The purpose of this chapter is to propose an integrated accessibility audit approach for desktop applications in Windows operating system.

The objectives of the study are:

- Researching the basic software equipment through which visually impaired people access Windows operating systems as the mostly used one worldwide.
- Examining the features of that tools targeted to access by Cyrillic alphabet users.
- Testing the accessibility of desktop software for finding issues that can be barriers for visually impaired people.

The limitations of this chapter are related to the testing tools used and the applications tested. Our aim is to demonstrate the applicability of the approach rather than to claim the exhaustiveness of the software used.

2 Literature Review

Screen readers and speech synthesizers are crucial tools for users who are blind or visually impaired. Screen readers transform text on a computer screen into aural output, allowing users to engage with digital material. Speech synthesizers, on the other hand, produce synthetic speech from text, resulting in a more natural-sounding audio output. In this literature review, we will concentrate on Windows operating system third-party screen readers and speech synthesizers that are mainly used.

2.1 Desktop Screen Readers

A screen reader is used to identify and interpret what is displayed on the screen. Feedback to the user is provided via speech or Braille output. Screen readers are a form of assistive technology used by people who are blind, visually impaired, or have learning disabilities. It is often used in combination with other assistive technologies such as screen magnifiers or speech synthesizers.

Choosing a screen reader depends on many factors, such as platform, cost (screen reader renewals can often cost hundreds of dollars), and the role of organizations such as charitable foundations, schools, and employers.

Since the blind cannot use a mouse, they operate computer programs using keyboard shortcuts. The same applies when working with a screen reader. The program queries the operating system or application about what is currently displayed on the screen and receives updates if anything changes. This approach is remarkably easy for screen readers but fails when applications conflict with accessibility APIs: for example, if the application does not work with the Microsoft Active Accessibility (MSAA) API, so the screen reader is required to build an off-screen model for that application or to find another approach to access its content [13].

Screen readers work easily with programs which content is not hidden. Examples of such applications are web browsers, icons, Windows, e-mail clients, etc. They use different approaches to access the textual content of graphical program and operating system elements.

Due to the variety of operating systems, this type of software is tied to the distribution of the operating system type. Microsoft Windows includes Narrator, Apple Mac OS X includes VoiceOver, and Linux uses the console-based Oralux, which accesses the operating system through three purpose-built environments: EmacsSpeak, SpeakUp, and Yasr [14].

Windows Narrator is a screen reader and voice synthesizer that comes standard with Windows operating systems. It has text-to-speech features, allowing visually impaired people to hear the material on the screen [15]. The narrator reads text loudly and discusses visuals to provide a thorough overview of the screen information. It has options for changing the voice, pitch, and speed of the text-to-speech output. Windows Narrator also supports Braille displays, allowing users to access information by touch.

More famous open-source screen readers are for example Linux Screen Reader for GNOME, Fire Vox and NonVisual Desktop Access (NVDA) for Windows, etc. Among the worldwide users NVDA is the most used [16].

The most used screen readers worldwide are the commercial products JAWS owned by Freedom Scientific, Window-Eyes by GW Micro, and Hal by Dolphin Computer Access [16].

The screen readers common among the worldwide blind users are JAWS and NVDA [16]. For this reason, the current chapter (Table 1) examines accessibility software.

JAWS has some additional features like support for chat clients, for example, Skype; MS Access support, various browsers; JAWS Tandem remote access feature—an alternative to Remote Desktop in Windows; keyboard shortcuts when working with individual applications; PEARL Camera; DAISY Player; Scanning

Table 1 Desktop screen reader comparison

Feature	JAWS	NVDA
Operating system(s)	Windows Desktop and Server	Windows Desktop and Server
License	Commercial	Free open source (GPL2)
64-bit operating systems support	Yes	Yes
Accessibility API	MSAA, Iaccessible2, UI Automation, Java Access Bridge	MSAA, IAccessible2, Java Access Bridge, UI Automation
Office applications	MS Office	MS Office
File types support	Documents (e.g., pdf and doc), html	Documents (e.g., pdf and doc), html
E-mail clients support	Yes	Yes
Multiple speech synthesizers support	Yes	Yes
Multiple braille displays support	Yes	Yes
Cyrillic languages supported	Russian UI	Bulgarian, Kyrgyz, Macedonian, Russian, Serbian, Ukrainian
Mobile version	iOS	Android
SAPI support[a]	4 and 5	4 and 5
Voice installation	Yes	Yes

Source: Own Elaboration

[a]Speech Application Programming Interface—Microsoft's API for speech synthesis and recognition

and Reading Software [17]. NVDA's main additional features are cross-browser support, access to Java applications, automatic indication of the current position of the mouse, and sending updates to the speech synthesizer, portable version, and Windows Command Prompt [18].

Based on the listed characteristics, it can be noticed that both screen readers have very good capabilities for working with various basic applications under Windows. This is precisely why they are so preferred.

The main advantage of JAWS is that its latest versions offer the function of remote access to a given computer—JAWS Tandem. It provides an opportunity to train users, provide/receive technical assistance, etc.

JAWS is a commercial product that is often out of reach for people with low incomes. Therefore, as its alternative, NVDA is used.

The good thing about NVDA is the portable version of the reader—it can be run from a portable media without any installation required. This allows users to use it on a computer that is not designed for them.

Both products provide access to different types of applications, thanks to which users can work fully with a computer. They were not afforded such capabilities by other lower-end screen readers or those running in an MS-DOS environment.

Unfortunately, no screen reader has been created to support all Cyrillic languages. Only a Russian language interface is offered in JAWS [17]. NVDA support more but not all Cyrillic languages: Bulgarian, Kyrgyz, Macedonian, Russian, Serbian, and Ukrainian [18]. They support a built-in speech synthesizer for these languages, but the intelligibility of the sound output is not good. So that does not make them a good alternative for Cyrillic languages users.

Currently, blind users have good alternatives for using specialized software that enables them to work with many different applications. The main disadvantage of both screen readers is that they do not support an interface for all Cyrillic languages, which makes it difficult for those who do not speak English or another language supported by the reader.

2.2 Desktop Speech Synthesizers

Speech synthesis is the process of artificially producing speech for a variety of applications, such as telephone service systems of mobile operators, banks, hotel reservation systems, applications for reading public announcements, for reading electronic text, etc. [19]. The computer system that is used for this purpose is called a speech synthesizer.

It can be a software application or a hardware device. It is mainly used by people with disabilities, such as the blind, those with learning difficulties (e.g., those suffering from dyslexia), etc. [20]. It also serves as an aid to people who are learning a language. In the context of assistive technologies for the blind, we have looked at the software that this group of people uses when working with a computer, and in particular the software used by Cyrillic language users.

Synthesizers transform converting the text to the synthetic speech that is as close to real speech as possible incompliance with the pronunciation norms of special language [21]. Depending on the level of refinement, the speech may sound unnatural or closely resemble the voice of a real person.

This type of software can be used as an application to any screen reader or as a stand-alone application to type text or load text from an external file, save the read text as a sound file, etc. In the first case, the synthesizer helps people with disabilities listen to each symbol on the screen. The text displayed on the screen is forwarded by the screen reader. In the second case, the synthesizer can be used, for example, as an assistant in learning a language—by listening, the correct pronunciation of words and expressions is memorized.

Speech synthesizers have databases that store pieces of recorded human speech. By combining them, synthetic speech is created. The size of the database of each system is different and hence the size of the stored speech units is different [22]. Those that have the largest output base are storage sounds or adjacent pairs of sounds (diphones) [23], but they may lack clarity. High quality synthetic speech is achieved by storing whole words or phrases, as well as the synthesizer combines the vocal system model and other human voice characteristics to create a perfect synthetic voice output [24]. Another important feature of this software is that the user has the ability to add abbreviations, new words, and special symbols, that is, to expand the program database. In this way, he can adapt the speech synthesizer to his daily work.

The most important qualities of a speech synthesis system are naturalness and intelligibility. Naturalness means that the output sounds of the system come as close as possible to human speech. Intelligibility is related to how easy these sounds are to understand [23]. The ideal speech synthesizer is both natural and understandable. Various types of speech synthesis can be used to achieve this goal. For example, diphone synthesis uses a minimal speech database containing all the diphones (sound-to-sound transitions) found in the language [25]. The number of diphones depends on the language's phonotheque. Another type of speech synthesis is the formant synthesis, where the reproduction of synthesized speech is done by using an acoustic model [26]. Parameters such as fundamental frequency or noise level are variable during creation of the artificial speech waveform. Statistical parametric speech synthesis is a technique that aims to generate natural-sounding synthetic speech, where acoustic models represent the relationship between input features and acoustic features [27].

Since there are various free and paid versions of speech synthesizers on the software market, for the purposes of our chapter, we have chosen those that are suitable for Cyrillic language users. The only modern synthesizer developed for Bulgarian users is SpeechLab. There are other synthesizers, such as Betsy, RealSpeak, eSpeak, Svox, which are used by the Bulgarian users [28], but not developed with naturalness and intelligibility in mind. The reason they are oriented precisely toward SpeechLab is that the program was created specifically for Bulgarian users. It is developed by the Bulgarian Association for Computational Linguistics and the voice of the actress Gergana Stoyanova was used, as well as it is

Table 2 Desktop speech synthesis systems comparison

Feature	Speech Lab 2.0	eSpeak	RHVoice
Operating system	Windows, Android	Windows, Linux, Mac OSX, RISC OS	Windows, Android, Linux
License	Commercial	Free open source	Free open source
Synthesis method	Diphone synthesis	Formant method	Statistical parametric synthesis
Synthesis rate	Over 150 words/min [29]	Between 80 and 390 words/min [39]	Over 150 words/min [31]
Naturalness and comprehensibility	Yes	Yes	Yes
Multiple voices support	Yes	Yes	Yes
Cyrillic languages support	Bulgarian	Belarusian, Bulgarian, Kazakh, Kyrgyz, Macedonian, Russian, Ukrainian, Uzbek	Russian, Ukrainian, Macedonian, Kyrgyz
User Interface	Bulgarian	English	NVDA compatible
SAPI support	4 and 5	4 and 5	4 and 5
Voice installation	No	No	No
User dictionary support	Yes	Yes	Yes
Ability to adjust the pitch of the voice	Yes	Yes	Yes
Adjusting the reading intensity	Yes	Yes	Yes
Audio files export	*.wav	*.wav	NVDA compatible

Source: Own Elaboration

available for Android users too [29]. People with visual impairments can obtain a free individual license for non-commercial use of SpeechLab 2.0 from the Horizons Foundation or the Union of the Blind in Bulgaria.

The situation with Russian-speaking users is significantly different. A non-exhaustive list of applications of this type that are used by Russian users are: Amazon Polly, Murf, Synthesia, Speechify [30], RHVoice [31], as well as those integrated into the above-mentioned screen readers and operating systems. There are also developments for Belarusian NLP and speech processing [32], as well as for Ukrainian [33], Tajik [34], Kazakh [35], Macedonian [36], Kyrgyz [37], and Uzbek [38] languages.

In Table 2 we have compare some speech synthesis systems suitable for Cyrillic languages users. The aim is to show the differences between these systems and to justify the choice of a preferred synthesizer.

The additional features of SpeachLab 2.0 are related to supporting an accent dictionary for over one million word forms and hundreds of contextual grammar rules; achieving a grammar accuracy of over 98.4%, a dictionary of 60,000 English words, rules for reductions, voice change. Ability to switch between English speaking dictionary and German-like phoneticization rules, ability to turn off accents, intonation, abbreviations, options to insert pauses between words, to read numbers by numbers, etc.

On the other hand, eSpeak supports about 40 languages, some of which are still under development. It can convert typed text into a phoneme code. Possibility to expand the database of the program through provided development tools (additional application eSpeak Edit is installed). Track the current processing that the system is performing, like incomplete SSML support, etc.

RHVoice is compatible with standard text-to-speech interfaces on these platforms: SAPI5 on Windows, Speech Dispatcher on GNU/Linux, and Android's text-to-speech APIs. It can also be used by the NVDA screen reader directly (the driver is provided by RHVoice itself).

As can be seen from Table 2, the synthesizers have very similar characteristics. The differences are that they do not support all Cyrillic languages user interfaces and cannot reproduce texts or figuratively "speak" in all Cyrillic languages. Both systems support Microsoft's Speech Recognition and Synthesis Application Programming Interface (SAPI). It follows that when they are installed simultaneously on the same computer, each of them can use the voices of the other. In this way, the variety of synthetic speech in different languages is increased. From Table 2, it can also be noticed that the applications themselves do not support voice installation, that is, they are like any other program. In order for a blind user to install a speech synthesizer himself, it is necessary to have a screen reader pre-installed on his computer to use with the speech synthesizer built into the respective operating system. If one is not installed, it can use the reader built into the operating system (for Windows it is Narrator with its built-in voices). However, for this purpose, the relevant user must know English at a basic level. Unlike SpeechLab, eSpeak supports multiple voices, as well as greater possibilities to expand its database. The main advantage of SpeechLab remains working with Bulgarian texts, or more precisely, reproduction of understandable Bulgarian speech.

In summary, the screen reader, together with its integrated speech synthesizer, allows blind computer users to fully work with a computer and be competitive in the labor market. The most common combination of screen reader and speech synthesizer depends on the native language of the users. However, as statistics said, the most used screen readers for Windows users are JAWS and NVDA [14].

3 Method

Accessibility testing of the operating system and its applications depends on its architecture. For example, Microsoft developed the accessibility evolution model (AEM), which is implemented in the Windows operating system. It includes a set of structured levels that describe how well the behaviors, practices, and processes of an organization can reliably and sustainably integrate digital accessibility with disabled people in mind [40]. Microsoft's evolutionary model is shown in Fig. 1. It includes eight overarching dimensions of accessibility: People & Culture, Vision, Strategy and Engagement, Investments, Standards, Training, Support & Tools, Procurement, Product Development Lifecycle, and Sales, Marketing & Communications [40]. They are used as a basis for developing accessible applications and creating an inclusive environment.

To verify the accessibility of applications under Windows operating system, we use the model of Fig. 1, integrating with accessibility testing proposed by [41]. Thus, in this chapter, we form an integrated accessibility audit approach for desktop applications in Windows operating system (Fig. 2).

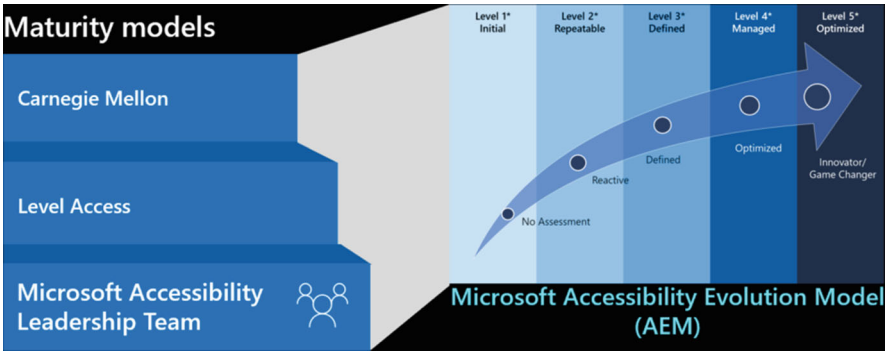

Fig. 1 Microsoft accessibility evolution model by [40]

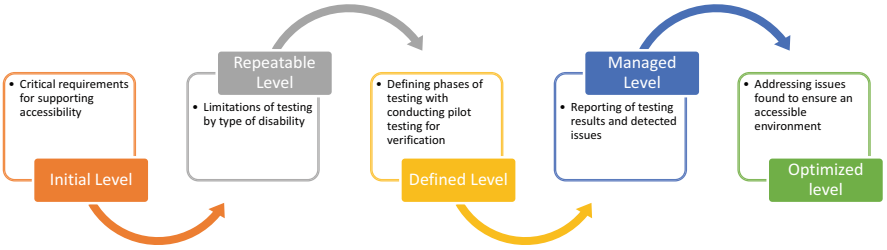

Fig. 2 Integrated accessibility audit approach for desktop applications in Windows operating system. (Source: Own Elaboration)

In this chapter, we propose accessibility testing and provision of an accessible digital environment based on the model and strategies above. It should take place at the following basic levels:

- *Initial Level*: It is related to defining critical requirements for supporting accessibility. Testing the accessibility of the operating system and applications is crucial to ensure a successful user experience for people with various disabilities 38.
- *Repeatable Level*: According to the type of disability, the restrictive conditions of the accessibility testing must be determined. There is no single approach to accessibility testing and evaluation, as the characteristics that software must meet vary by disease. For example, availability of text descriptions (for people with visual disabilities), availability of sound alternatives to texts (for people with visual disabilities), joystick operation (for people with motor disabilities), etc. This is also the framework imposed on testing, which can be conducted in multiple passes depending on the type of disability for which an accessible environment is provided.
- *Defined Level*: Defining phases of testing with conducting pilot testing for verification of defined requirements and limitations. If they do not find inaccuracies in the requirements, they are removed through the pilot testing and only then the actual testing is conducted.
- *Managed Level*: Specialized accessibility testing software is used, for example Accessibility Insights, AccScope, UI Accessibility Checker (AccChecker), support of Microsoft's testing framework for manual and automated testing UI Automation Verify (UIA Verify), etc. [41]. It reports accessibility issues by outputting the number of errors in the tested application and suggestions for fixing them. In combination with these, screen readers with a speech synthesizer in the relevant Cyrillic language can be used to verify that the reported problems are not actually read and reproduced adequately by the assistive tools.
- *Optimized Level*: The issues found to ensure a digitally accessible environment are removed under the defined restrictions.

In the next section, we test the proposed integrated accessibility audit approach for desktop applications in Windows operating system.

4 Results and Discussion

To test the proposed integrated approach, we implement the Accessibility Insights for Windows tool. The tool supports three primary scenarios [42]:

- Live Inspect allows inspection of elements in an app that has the right properties through which their accessibility is ensured.

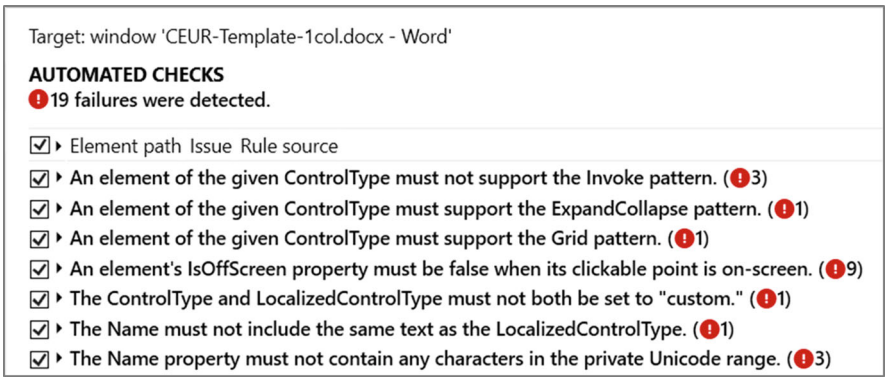

Fig. 3 Results of testing docx file of a chapter template with accessibility insights for Windows

- FastPass: Two-step process that helps identifying common, high-impact accessibility issues in accordance with predefined 60 accessibility requirements. Instructions and a visual helper are also provided to fix critical accessibility issues.
- Troubleshooting allows diagnosing and fixing specific accessibility issues.

To conduct the test, we chose doc and pdf files to demonstrate the results of applying the approach. We used the template for this chapter before and after adding its text. After that we saved it as pdf file. We runed the test under Windows 10 Pro 22H2 19045.2846.

The result of the plain template is shown on Fig. 3. The test is a combination of document and application accessibility. The "Entire App" test type is selected to cover all possible errors.

19 Section 508 Compliant errors were found. For example, some required properties of controls in the application were not provided to comply with Section 508. The tool's recommendation is to provide a UI Automation Name property for the element that concisely identifies the element, and does not include the same text as the element's type property. Most errors are related to irrelevant control properties. Regarding the content, problems were found with the format of the tables and links.

A further 17 were added to these errors when adding the full text of this chapter to the template (Fig. 4). The new bugs are also related to a lack of alt text on the images. Also contains special characters that are not in the scope of Unicode. There are problems reading the format of tables with final content added.

Figure 5 shows the number and type of errors on the pdf file of the full text of the chapter. The default reader is FoxitReader. Eighteen errors were found.

The errors are similar to those mentioned above, including lack of image alt texts and problems with properties of application controls, especially their description.

In addition to the test with Accessibility Insights for Windows, we conducted a test with the NVDA screen reader and Alexander voice on the RHVoice speech synthesizer. In the case of the Microsoft Word screen interface in Russian and

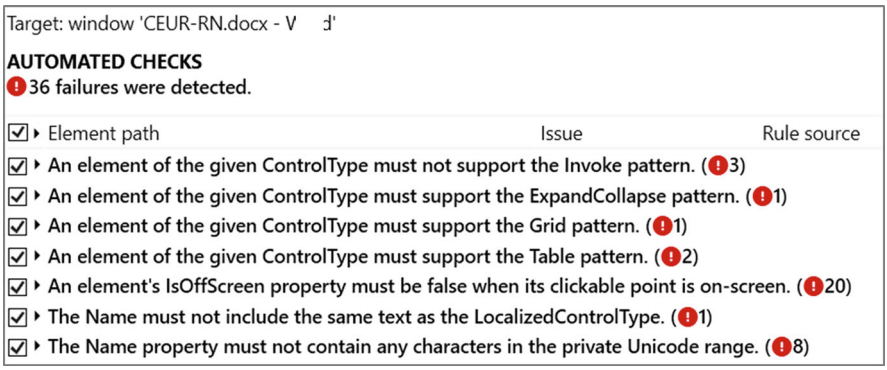

Fig. 4 Results of testing docx file of a full-text chapter with accessibility insights for Windows

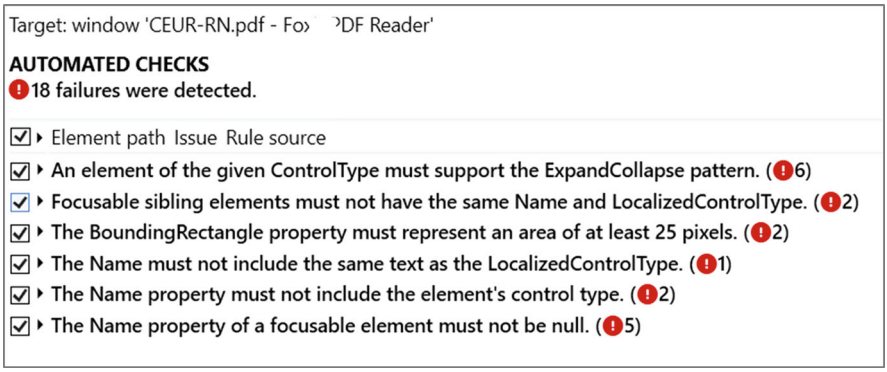

Fig. 5 Results of testing Pdf file of a full-text chapter with accessibility insights for Windows

Bulgarian, problems with header and footer identification have been reported. It is not reported that the user activates these interface elements. One of the errors is precisely with this element of the document.

To improve the digital accessibility of the applications used in the test, and of desktop applications on the Windows operating system in general, the error reporting capabilities of both the operating system and the Accessibility Insights tool can be used.

5 Conclusion

In conclusion, we should note that the problems of blind people, and others alike, on a global scale, have long been popularized, and improvements are being made in the technologies they use in every direction. The examined problems and technologies lead to the conclusion that when working with modern computer technology, blind

people mainly use two types of software applications—a screen reader and a speech synthesizer. Based on our research, we found that the most common combination of screen reader and speech synthesizer is JAWS or NVDA screen readers and the synthesizer depends on the language group.

There are also various websites that help these people and provide them with timely information on various matters of interest to them. The blind must be given a chance to access public resources so that they can achieve independence and self-reliance, which will be a condition for achieving their better professional realization and their full inclusion in modern dynamic life.

The test conducted with the accessibility of documents and applications under the Windows operating system shows that problems are found, which are mainly a mismatch between the properties of the user interface controls and Section 508. Other problems are related to the content of the files, such as the lack of alternative texts of multimedia content or unreadable content.

In order to overcome the problems of accessibility and ensure a digitally accessible environment, it is necessary to introduce approaches and recommendations in the organizations, according to international standards and good practices. Content intended to be used by people with visual impairments should also undergo additional testing with screen readers.

References

1. WHO: Disability. https://www.who.int/news-room/fact-sheets/detail/disability-and-health. Last accessed 2023/4/30
2. Yale: Types of disabilities. https://usability.yale.edu/web-accessibility/articles/types-disabilities. Last accessed 2023/4/30
3. Gordon, K.: 5 Visual treatments that improve accessibility. https://www.nngroup.com/articles/visual-treatments-accessibility/. Last accessed 2023/6/3
4. Bureau of Internet Accessibility: Five strategies for creating an inclusive design. Last accessed 2023/6/3
5. W3C: Web Content Accessibility Guidelines (WCAG) 2.0. Last accessed 2023/6/3
6. Kouhoué, A.W., Bonavero, Y., Bouétou Bouétou, T., Huchard, M.: Exploring variability of visual accessibility options in operating systems. Future Internet. **13**, 230 (2021). https://doi.org/10.3390/fi13090230
7. Statista: Global market share held by operating systems for desktop PCs, from January 2013 to January 2023. https://www.statista.com/statistics/218089/global-market-share-of-windows-7/. Last accessed 2023/4/30
8. Apple: macOS general accessibility features. https://support.apple.com/en-hk/guide/mac-help/mchl429b64a1/13.0/mac/13.0. Last accessed 2023/4/30
9. Apple: macOS accessibility features for vision. https://support.apple.com/en-hk/guide/mac-help/mchl67c83f41/13.0/mac/13.0. Last accessed 2023/4/30
10. Nacheva, R.: Current perspectives on Linux accessibility tools for visually impaired users. Икономика и компютърни науки = Econ. Comput. Sci. J. **2**, 6–11 (2019)
11. Apple: Turn on and practice VoiceOver on iPhone. https://support.apple.com/en-hk/guide/iphone/iph3e2e415f/ios. Last accessed 2023/4/30
12. Google: Turn TalkBack on or off. https://support.google.com/accessibility/android/answer/6007100?hl=en. Last accessed 2023/4/30

13. Microsoft: Microsoft active accessibility. https://learn.microsoft.com/en-us/windows/win32/winauto/microsoft-active-accessibility. Last accessed 2023/4/30
14. Disabled World: List of computer screen readers for visually impaired. https://www.disabled-world.com/assistivedevices/computer/screen-readers.php. Last accessed 2023/4/30
15. Microsoft: Complete guide to Narrator. https://support.microsoft.com/en-us/windows/complete-guide-to-narrator-e4397a0d-ef4f-b386-d8ae-c172f109bdb1. Last accessed 2023/4/30
16. Institute for Disability Research, Policy, and Practice: Screen reader user survey #8 results. https://webaim.org/projects/screenreadersurvey8/. Last accessed 2023/4/30
17. Freedom Scientific: JAWS. https://www.freedomscientific.com/products/software/jaws/. Last accessed 2023/4/30
18. NV Access: NVDA. https://www.nvaccess.org/about-nvda/. Last accessed 2023/4/30
19. Furui, S.: Digital Speech Processing, Synthesis, and Recognition, 2nd edn. Revised and Expanded. Marcel Dekker Inc (2001)
20. Holmes, J., Holmes, W.: Speech Synthesis and Recognition, 2nd edn. Taylor & Francis, Inc. (2001)
21. Aida-zade, K.R., Ardil, C., Sharifova, A.M.: The main principles of text-to-speech synthesis system. In: International Journal of Computer, Electrical, Automation, Control and Information Engineering, vol. 7, pp. 395–401. World Academy of Science, Engineering and Technology (2010)
22. Tan, X., Qin, T., Soong, F.K., Liu, T.: A survey on neural speech synthesis. ArXiv, abs/2106.15561 (2021)
23. Soe, E., Phyu, P., Thida, A.: Analysis of word-based and unit-based diphone concatenation for Myanmar text-to-speech. In: Twelfth International Conference on Computer Applications (ICCA 2014). http://onlineresource.ucsy.edu.mm/handle/123456789/59. Last accessed 2023/4/30
24. Hwang, M.-J., Yamamoto, R., Song, E., Kim, J.-M.: TTS-by-TTS: TTS-driven data augmentation for fast and high-quality speech synthesis. In: ICASSP 2021–2021 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), pp. 6598–6602, Toronto, ON, Canada (2021). https://doi.org/10.1109/ICASSP39728.2021.9414408
25. Justin, T., Štruc, V., Dobrišek, S., Vesnicer, B., Ipšić, I., Mihelič, F.: Speaker de-identification using diphone recognition and speech synthesis. In: 11th IEEE International Conference and Workshops on Automatic Face and Gesture Recognition (FG), pp. 1–7, Ljubljana, Slovenia (2015). https://doi.org/10.1109/FG.2015.7285021
26. Lukose, S., Upadhya, S.S.: Text to speech synthesizer-formant synthesis. In: 2017 International Conference on Nascent Technologies in Engineering (ICNTE), pp. 1–4, Vashi, India (2017). https://doi.org/10.1109/ICNTE.2017.7947945
27. Saito, Y., Takamichi, S., Saruwatari, H.: Statistical parametric speech synthesis incorporating generative adversarial networks. IEEE/ACM Trans. Audio Speech Lang. Proc. **26**(1), 84–96 (2018). https://doi.org/10.1109/TASLP.2017.2761547
28. Lyubenov, V.: How speech synthesizers read Bulgarian text aloud. https://bezmonitor.com/chetene/index.htm. Last accessed 2023/4/30
29. Mihov, S.: SpeechLab 2.0. https://play.google.com/store/apps/details?id=org.bacl.android.speechlab2g&hl=bg&gl=US. Last accessed 2023/4/30
30. Weitzman, C.: Russian text to speech voices. https://speechify.com/blog/russian-text-speech-voices/. Last accessed 2023/4/30
31. RHVoice: https://github.com/RHVoice/RHVoice. Last accessed 2023/4/30
32. Belarusian NLP and Speech Processing Resources: https://github.com/yks72p/be_nlp_speech_resources. Last accessed 2023/4/30
33. Speech Recognition for Ukrainian: https://github.com/egorsmkv/speech-recognition-uk. Last accessed 2023/4/30
34. Khurshed, A., Khudoyberdiev, T.M.: The algorithms of Tajik Speech Synthesis by syllable. In: Web of Conferences ITEE-2019, vol. 35, pp. 07003. https://www.itm-conferences.org/articles/itmconf/pdf/2020/05/itmconf_itee2020_07003.pdf (2020)

35. KazakhTTS RECIPE: https://github.com/IS2AI/Kazakh_TTS. Last accessed 2023/4/30
36. Sofronievski, B., et al.: Macedonian speech synthesis for assistive technology applications. In: 30th European Signal Processing Conference (EUSIPCO), pp. 1183–1187, Belgrade, Serbia (2022). https://doi.org/10.23919/EUSIPCO55093.2022.9909778
37. Abdai, T.: First speech synthesizer for blind in Kyrgyz language created in Kyrgyzstan, Bishkek – 24.kg news agency. https://24.kg/english/49791_First_speech_synthesizer_for_blind_in_Kyrgyz_language_created_in_Kyrgyzstan/. Last accessed 2023/4/30
38. Abdullaeva, M.I., Juraev, D.B., Ochilov, M.M., Rakhimov, M.F.: Uzbek speech synthesis using deep learning algorithms. In: Zaynidinov, H., Singh, M., Tiwary, U.S., Singh, D. (eds.) Intelligent Human Computer Interaction (IHCI 2022). Lecture Notes in Computer Science, vol. 13741, pp. 39–50. Springer, Cham (2023). https://doi.org/10.1007/978-3-031-27199-1_5
39. Free Software Foundation, Inc.: eSpeak text to speech. https://espeak.sourceforge.net/. Last accessed 2023/4/30
40. Lay-Flurrie, J.: Accessibility evolution model: creating clarity in your accessibility journey. https://blogs.microsoft.com/accessibility/accessibility-evolution-model/. Last accessed 2023/4/30
41. Bridge, K., Arya, H., Radich, Q.: Accessibility testing. https://learn.microsoft.com/en-us/windows/apps/design/accessibility/accessibility-testing. Last accessed 2023/4/30
42. Microsoft: Accessibility insights for windows. https://accessibilityinsights.io/docs/windows/overview/. Last accessed 2023/4/30

Game-Theoretic Methods for Analyzing the Security and Stability of Corporate Information Systems

Pavel Konyukhovskiy and Andrey Shabalin

Abstract The chapter is devoted to the problems of applying models and methods of the theory of strategic games to describe the functioning of information systems. A bimatrix game model of the interaction of an information system with an aggressive external environment is proposed, as well as possible options for its transformation into repeated games and a dynamic game with incomplete information.

The possibilities of implementing various concepts of equilibrium (trembling hand perfect equilibrium and perfect Bayes-Nash equilibrium) in relation to real problems of ensuring the security of information systems are considered.

These models can be used in subsequent studies of the stability and protection of information systems, analysis of the types and nature of threats, and development of counter strategies.

Keywords Information system · Security · Stability · Game-theoretic models of information systems security · Bimatrix games · Dynamical Bayesian games

1 Introduction

Issues of e-government systems and e-participation of citizens in the interaction with public administration are of particular importance in the era of global digital transformation.

The importance and significance of software/hardware stability and security has increased. In researching these problems, understanding the nature of threats to the

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_23

security of information systems is of particular importance. When considering them, we should pay attention to the following factors.

- Increased functionality of information systems has led to an increase in the amount of potential damage if they are hacked or rendered unusable.
- The flip side of the accumulation of operating experience becomes the accumulation of attack experience.
- Increasing complexity and scale of systems objectively leads to growth of potential weaknesses and vulnerabilities.
- The multiplication of users provides additional information and opportunities for "dishonest users." In particular, opportunities to disguise attacks due to the complication of attack source localization procedures. In this regard, it is necessary to emphasize the relevance of the dilemma between scale, on the one hand, and manageability (controllability and visibility) of the information system, on the other hand.
- The effect of "auto-generation of opposition" as the life cycle of the system naturally creates a human resource for groups of its antagonists, ready to support destructive actions against it. As a rule, these are former developers or employees, as well as IT-specialists who have not found opportunities for self-realization in legal projects.
- "Endogenous threats," that is, threats of information systems getting out of control by management personnel. The latter may occur when the personnel do not have an adequate understanding of software and hardware complexes functioning algorithms and rules due to their "immense complexity." Inconsistency of rights and competences of personnel at different levels of information systems management may also be the reason for such phenomena. Sometimes, threats of this nature receive a loud and effective name of "revolt of machines." Perhaps a more correct and adequate wording would be "loss of machine control."
- "New Exogenous Threats." The twentieth years of the twenty-first century were marked by pronounced counter-globalization trends and trends toward the segmentation of the world's economic, social, and political systems. At the moment, we are witnessing the formation of local alliances and coalitions characterized by objective conflicts of interest. This cannot but be reflected at the level of relations between the developers of software and hardware systems and their potential consumers. Indeed, in one way or another, they are affiliated with the relevant competing centers of power.

In modern conditions, adequate and constructive tools for representing the functioning of information systems are models and methods of game theory.

At the primary (surface) level, this adequacy is determined by the fact that it is the methods of decision-making under uncertainty (and not risk) that are considered. Indeed, in the case of the protection of information systems, we are dealing with the confrontation with a consciously acting opponent.

At a deeper level, we are talking about complex interconnections of infosystems with the external environment. The external environment refers to the client community, as well as competing systems.

In recent years, the problems of electronic participation of citizens in local and state governance have become one of the actively developing areas of scientific and practical research; see, for example [1]. In this case, it is advisable to mention the meaningful relationship of these issues with the problem of public (citizens) trust in the systems supporting public administration and the tasks of effective e-participation. Often distrust of digital governance tools is caused not so much by suspicions about their technical and constructive capabilities or dissatisfaction with interface solutions but by an explicit or implicit sense of alienation from the processes supported by information complexes.

Digitalization, considered in terms of its socio-economic and socio-political aspects, is primarily significant in that it provides a relative minority with the ability to control the rest of society, isolated from access to information arrays and tools to work with them.

In part, there is an analogy with the features of the feudal system. Information plays the role of land. The access to the tools for working with information is the right to own weapons. Of course, any analogies of this kind are relative and debatable. However, one cannot deny the presence of substantive components in them.

Radical changes in the system of international political and economic relations and shifts in the weight, importance, and influence of the world "centers of power" bring additional urgency to the problem of security and reliability of information systems. The clustering and segmentation of the world have actualized the problems of technological dependence and independence, bringing to the fore the concepts of digital sovereignty and, accordingly, digital vassalage. The latter implies the dependence at the basic level of information systems of states and corporations on forces external to them, that is, producers of hardware and software controlled by other states or corporations.

2 Previous Research and Related Issues

Despite the fact that game-theoretic approaches are not mainstream in scientific and scientific-practical studies of information systems security problems, a fairly representative series of publications devoted to this issue has been published so far.

Among the works closest in methods and approaches to this chapter, we should mention the study [2]. It proposes a representation of the interaction system of the party, the party protecting the info-communication object (player A) and the attacking party (player B) in the form of a matrix game. Player A has seven protection strategies: physical protection, technical protection, cryptographic protection, software-level protection, hardware-level protection, "paper security," and network protection. Player B has implemented five attack strategies (variants): password guessing, virus infection of the system, unauthorized access, spyware infection, and DDoS attack. Then classical methods of matrix games analysis are used—saddle point finding, mixed strategies solution, and solutions based on Wald,

Savage, and Hurwitz criteria. Based on the results of these studies, the author concludes that game-theoretic approaches are important for decision makers when choosing strategies for protecting info-communication objects.

The article [3] deals with a similar approach. The participants in the conflict are enterprise management (the information protection side) and attackers (the attacker side). Actually, the conflict is proposed to be modeled with the help of a matrix game. On the basis of the game model, it is supposed to solve the problem of protection system capacity allocation, maximizing the effects of attack repulsion.

The article [4] proposes a game-theoretic model with n players, which are grouped according to certain hierarchical principles. When considering information security tasks, the zero-level group is formed of users of information system, information protection system, and information security violators. The resource is the time and computing resources of the information system.

Serious attention to the problem of formalizing strategies in models of counteraction to information security intruders is given in Ref. [5]. The article systematizes threats and their corresponding vulnerabilities. Subsequently, on this basis, an original methodology for comparing classes of intruder's available types of vulnerabilities is formulated, which, in turn, allows to build a system of quantitative assessments (indicators) in accordance with the principle "the more rapid and dangerous is the penetration of an intruder, the greater the numerical value is assigned to the indicator." According to the author's opinion, the formalized model constructions developed by them can be the basis of software that solves the problems of automation of protection.

An important area of application of game-theoretic methods is to ensure the security of wireless networks characterized by a large number of sensory nodes. These nodes, as a rule, are characterized by a relatively low cost. At the same time, they are highly likely to be the object of external attacks. The paper [6] proposes intrusion detection methods (IDS) based on the concept of Quantal Response Equilibrium (QRE). It is shown that the QRE concept can be applied to select optimal IDS detection strategies.

The paperwork [7] proposes game-theoretic approaches for Cyber-Physical Systems (CPS) management. There is a significant increase in the risks of external attacks for such systems. The CPS security is structured into two levels, strategic and battlefield, by meeting ideas from game theory and Multi-Agent Reinforcement Learning (MARL). The research focuses on the symbiosis of game theory and reinforcement learning methods.

The article [8] considers the application of the concept of Bayes-Nash equilibrium in modeling the processes of protection of information objects. The authors construct a functional dependence that allows us to formulate the problem of finding the equilibrium between optimal defense and attack strategies. Also, this work proposes an applied model that simulates the situation of attack and defense.

In the context of the review of game-theoretic works, it will be useful to mention the publications in related fields, in particular, optimization approaches. The article [9] proposes a model for information security risk management, which is reduced to a linear programming problem. The variables are the costs of protection against

various threats (a finite number of threats is considered). The goal is to minimize the total risks. The goal function is the sum of the products of threat risk probabilities by the costs of counteraction to them. It is impossible to ignore the ambiguity and controversy of such a concept. The study also formulates a discrete version of the optimization model that is substantially similar to the so-called knapsack problem.

Speaking of modern or relatively modern methods of analyzing information security problems, we should not ignore the methods that have effectively and constructively proven themselves in the past. At the same time, their potential is far from being exhausted. In this context, it is possible to note the methods of decision-making under conditions of risk and uncertainty. They, in particular, were fruitfully developed in [10–12]. They propose a fundamental theoretical apparatus for decision-making under conditions of incomplete, inaccurate, and non-numerical information. On the basis of this toolkit algorithms for constructing integrated composite indicators can be formed, which is of undoubted interest from the point of view of evaluating the education results.

3 The Basic Model of Interaction of an Information System with an Aggressive External Environment

Let us explain the ideological component of the proposed system of game-theoretic models, describing the logic of the behavior of the information system, acting as an object of potential attacks.

At the initial level, the processes of information system security, the development of strategies for its behavior can be formalized in the form of an abstract bimatrix game.

Player I is the information system itself. Player II represents external threats. Of course, such an integrated representation is a significant simplification of the real threats and sources of destruction. However, from the point of view of the behavior by those who responsible for the information system, this approach has an obvious number of constructive merits. Indeed, in fact (with rare exceptions) potential sources of threats from the perspective of the system itself represent some anonymous "impersonalized force." Hereinafter the abbreviation BGMISIAEE (Bimatrix Game Model of Information System Interaction with Aggressive External Environment) will be used for short naming of the offered game model.

The formal scheme of the proposed bimatrix game is presented in Table 1. The rows of the table correspond to the strategies (actions) of player I $(s_i^1, i \in \{1, \ldots, m\})$, the columns correspond to the strategies of player II $(s_j^2, j \in \{1, \ldots, n\})$. The cells of the table represent the players' utilities (payments, wins/losses)—$u_{i,j}^1$, $u_{i,j}^2$—depending on the situations in the pure strategies (player I choose his strategy s_i^1, and player II, respectively, his strategy s_j^2).

The main areas of BGMISIAEE analysis can be suggested as:

Table 1 Bimatrix game model of information system interaction with aggressive external environment

			Player II—Aggressive external environment								
			Strategy 1		⋯	Strategy j		⋯	Strategy n		
			s_1^2		⋯	s_j^2			s_n^2		
Player I—Information system	Strategy 1	s_1^1		$u_{1,1}^2$	⋯		$u_{1,j}^2$	⋯		$u_{1,n}^2$	
			$u_{1,1}^1$			$u_{1,j}^1$			$u_{1,n}^1$		
	⋯	⋯	⋯		⋯	⋯		⋯	⋯		
	Strategy i	s_i^1		$u_{i,1}^2$	⋯		$u_{i,j}^2$	⋯		$u_{i,n}^2$	
			$u_{i,1}^1$			$u_{i,j}^1$			$u_{i,n}^1$		
	⋯	⋯	⋯		⋯	⋯		⋯	⋯		
	Strategy m	s_m^1		$u_{m,1}^2$	⋯		$u_{m,j}^2$	⋯		$u_{m,n}^2$	
			$u_{m,1}^1$			$u_{m,j}^1$			$u_{m,n}^1$		

- Nash equilibrium search in pure strategies;
- Nash equilibrium search in mixed strategies;
- analysis of stability/instability properties of equilibria;
- application of various purification concepts to found equilibria, in particular, analysis from the perspective of the "trembling hand equilibrium" [13].

Of course, algorithms, methods, and strategies for their protection are extremely diverse in the case of protecting real information systems. Moreover, the most important criterion for the success of this process is to find innovative, previously unknown solutions, which potential "hackers" will not be able to foresee. However, in the case of a simplified game model, a set of typical ("classical") methods seems a reasonable choice.

An example of a particular implementation of BGMISIAEE is given in Table 2.

In the framework of the game model under consideration as strategies of player I (defense methods) are considered:

- **A**—Hardware Priority—The main emphasis of the defending party is on technical support.
- **B**—Third-party Software—The main emphasis of the defending party is on third-party software.
- **C**—Own Software—The defending party relies on the development of its own software.
- **D**—Third-party Audit—Reliance on external expertise.
- **E**—Strict Security Policy—Emphasis is placed on strict protection policies.

The set of strategies of player II (the attacking external environment) was limited to the set of:

- **X**—Target prolonged attack
- **Y**—Random Search (randomly searching for a victim)

Table 2 Example of a bimatrix game model of information system interaction with aggressive external environment (BGMISIAEE)

			PLAYER II – Aggressive External Environment			
			Target prolonged attack	Random Search	Insider Attack, Insider Compromise	Hacking into a related system
			X	**Y**	**Z**	**W**
PLAYER I – Information System	Hardware Priority	**A**	4 / –2	1 / 4	–5 / 1	5 / –2
	Third-party Software	**B**	5 / 5	5 / 4	3 / 4	–3 / 3
	Own Software	**C**	–5 / 2	–3 / –3	–1 / 4	4 / –5
	Third-party Audit	**D**	–4 / –3	–5 / –1	–4 / –4	–5 / 0
	Strict Security Policy	**E**	2 / –3	4 / –4	5 / –3	0 / –4

- **Z**—Insider Attack, Insider Compromise
- **W**—Hacking into a related system

Thus, the game model has 20 situations in pure strategies. By analogy with Table 1 the participants' utilities $(u^1_{i,j}, u^2_{i,j})$ are located in the cells—the lower left corner is the utility of player I, the upper right corner—the utility of player II.

The utility values range from −5 (worst outcome for the player) to +5 (best outcome). They represent normalized expert evaluations.

In the bimatrix game demonstrated in Table 2 there are two Nash equilibria in pure strategies (highlighted in color). These are the situations:

- {«Third-party Software»; «Target prolonged attack»};
- {«Strict Security Policy»; «Insider Attack»}.

The value of this result lies not so much in its adequacy to the realities of the modern information environment but rather in the fact that it plausibly reflects the stable opinions of the professional environment about the patterns of information confrontations.

More meaningful in terms of revealing the patterns of confrontation between the defending and attacking parties is the study of BGMISIAEE for the existence of equilibria in mixed strategies.

In the case of bimatrix games, this is a relatively simple mathematical problem. It implies finding vectors of mixed strategies:

- $\mathbf{p}^* = (p_1^*, \ldots, p_i^*, \ldots, p_m^*)$—player I;
- $\mathbf{q}^* = (q_1^*, \ldots, q_j^*, \ldots, q_n^*)$—player II,

which satisfies the conditions

$$(\forall s_i^1 : p_i^* > 0)\, u_1(\mathbf{p}^*, \mathbf{q}^*) = u_1(s_i^1, \mathbf{q}^*),$$
$$(\forall s_i^1 : p_i^* = 0)\, u_1(\mathbf{p}^*, \mathbf{q}^*) \geq u_1(s_i^1, \mathbf{q}^*),$$
$$(\forall s_j^2 : q_j^* > 0)\, u_2(\mathbf{p}^*, \mathbf{q}^*) = u_2(\mathbf{p}^*, s_j^2),$$
$$(\forall s_j^2 : q_j^* = 0)\, u_2(\mathbf{p}^*, \mathbf{q}^*) \geq u_2(\mathbf{p}^*, s_j^2),$$

where

$u_1(\mathbf{p}^*, \mathbf{q}^*)$, $u_2(\mathbf{p}^*, \mathbf{q}^*)$—the utility of players I and II in an equilibrium situation in mixed strategies;

$u_1(s_i^1, \mathbf{q}^*)$—the utility of player I in the situation when he plays his pure strategy s_i^1, and his opponent (player II) plays an equilibrium mixed strategy $\mathbf{q}^*$;

$u_2(\mathbf{p}^*, s_j^2)$—the utility of player II in the situation when he plays his pure strategy s_j^2 and his opponent (player I) plays an equilibrium mixed strategy $\mathbf{p}^*$.

The constructiveness and fruitfulness of the equilibrium solution in mixed strategies are primarily determined by the fact that it can be implemented as a certain stable (regularly reproducible) strategic choice of the parties. At the same time, we should not ignore the depressing fact that there can be a great many (including an infinitely large number) of equilibria in mixed strategies. This, in turn, raises the natural question "to which of these will the behavior of the players converge?"

To overcome such difficulties, game theory applies methods of equilibrium purification. To date, there are quite a few of them. In particular, as applied to BGMISIAEE, the concept of "trembling hand equilibrium," which goes back to [13], deserves attention.

The main property of the trembling hand equilibrium is the property of maintaining stability when the players deviate slightly from their equilibrium strategies. The term "trembling hand" refers to a situation in which one of the players "presses the wrong button" by mistake.

It is easy to see that the equilibrium {«Third-party Software»; «Target prolonged attack»} has the properties of a trembling hand equilibrium. Indeed, assuming player I deviates and plays some mixed strategy $\mathbf{p}' = (\frac{\epsilon}{4}, 1-\epsilon, \frac{\epsilon}{4}, \frac{\epsilon}{4}, \frac{\epsilon}{4})$, where ε is some small value (the probability of deviating from the equilibrium strategy), then player II will have no incentive to deviate from his equilibrium strategy «Target prolonged attack»:

$$u_2(\mathbf{p}', s_X^1) > \begin{cases} u_2(\mathbf{p}', s_Y^1), \\ u_2(\mathbf{p}', s_Z^1), \\ u_2(\mathbf{p}', s_W^1) \end{cases}$$

for small ε.

Equilibrium {«Strict Security Policy»; «Insider Attack»} is also a trembling hand equilibrium. It is advisable to pay attention to the unequal utility of the second player in the first and second equilibrium. It is likely that questions may arise as to the meaningfulness of the equilibrium {«Strict Security Policy»; «Insider Attack»}. Its justification may be the "rational argument" that with a strict security policy, the attacker has no better solution than, after all, to try to hack the system from within.

4 Development of a Basic Game-Theoretical Model

The structural properties of BGMISIAEE provide technological opportunities for its development.

First of all, it can be implemented in the repeated games. At each stage of such a game, a confrontation of players—attack and reflection—is considered. The results of the draw of the next stage provide information for the next stages. An important quality of repeated games is those perfect subgame equilibria, not reduced to the repetition of the equilibrium of the basic game, may occur in them.

Another variant of BGMISIAEE development could be its transformation into a dynamic game with incomplete information (dynamic Bayesian game).

A circuit diagram of such a game is shown in Fig. 1. Three stages are distinguished.

1. Player II—The attacker (for the sake of continuity, we retain the preceding notations) makes a preliminary decision about the type of attack (in essence, at this step, the established system of "typical" threats is modeled).
2. Player I—The defending party decides on the method of defense. He does not have full information about his opponent's choice but is guided only by his own beliefs about him. The fact of indistinguishability for player I of the set of vertices, from which he makes his choice, is modeled by the so-called *informational set*. In the scheme (Fig. 1), the information set is shown as a dotted figure (a rectangle with rounded corners). The system of beliefs is modeled by probability distribution given on the vertices belonging to the information set:
   - θ_X^1—Player I's estimate of the probability that player II has chosen the method of attack **X**
   - θ_Y^1—Player I's estimate of the probability that player II has chosen the method of attack **Y**, etc.
   - where $\theta_X^1, \theta_Y^1, \theta_Z^1, \theta_W^1 \geq 0$, $\theta_X^1 + \theta_Y^1 + \theta_Z^1 + \theta_W^1 = 1$.

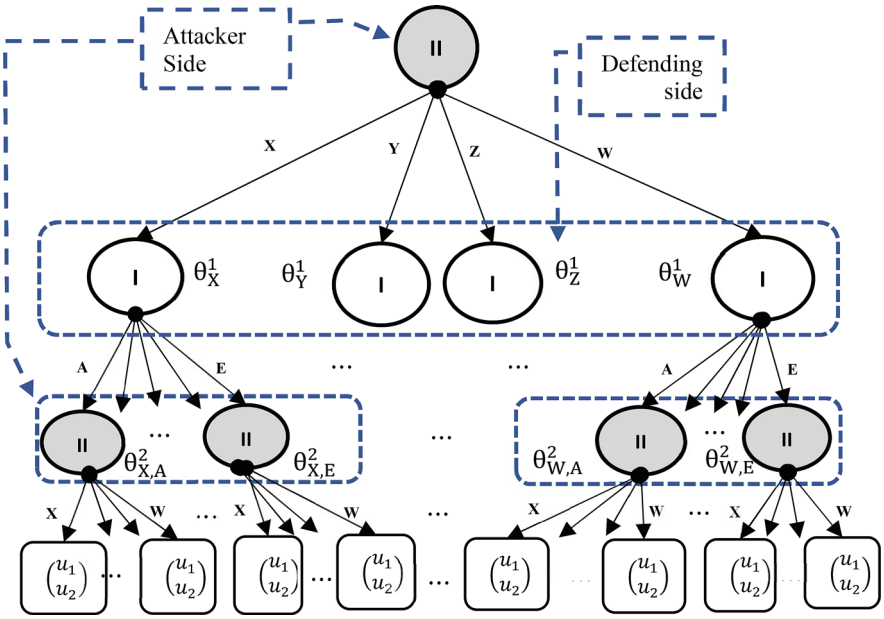

Fig. 1 Model of interaction of information system with aggressive external environment based on dynamic Bayesian game

3. Player II makes the real attack. In doing so, he has full information about the preliminary signal he sent in step 1. However, he has an exclusive system of beliefs (incomplete information) about the method of defense chosen by player I in step 2. Thus, player 2 makes his choice in one of the five information sets with the belief systems:

   – $\theta^2_{X,A}, \theta^2_{X,B}, \theta^2_{X,C}, \theta^2_{X,D}, \theta^2_{X,E} \geq 0,\ \theta^2_{X,A} + \theta^2_{X,B} + \theta^2_{X,C} + \theta^2_{X,D} + \theta^2_{X,E} = 1;$
   – $\theta^2_{Y,A}, \theta^2_{Y,B}, \theta^2_{Y,C}, \theta^2_{Y,D}, \theta^2_{Y,E} \geq 0,\ \theta^2_{Y,A} + \theta^2_{Y,B} + \theta^2_{Y,C} + \theta^2_{Y,D} + \theta^2_{Y,E} = 1;$
   – etc.

Based on the results of the sequence of actions taken, players receive utility (payments) $u_1(\circ)$, $u_2(\circ)$).

The main subject of research in such game models is perfect Bayesian-Nash equilibrium. In this case, we refrain from formulating its strict definition, which would be more appropriate in a corresponding course on dynamic Bayesian games. Let us emphasize only the following aspect. At the heart of the Bayes-Nash concept of perfect equilibrium there is the consistent rationality of the players' actions, taking into account the beliefs they have.

In other words, this equilibrium takes into account both the prehistory of the game and the participants' beliefs about this prehistory. In the tasks of analyzing the security and stability of information systems, this property of perfect Bayesian equilibrium plays an extremely important and fruitful role. Indeed, when organizing defense/attack strategies, one should be guided not only by one's own opinion of one's opponent, but also try to anticipate (predict, foresee) his opinion of you.

5 Results and Discussion

As noted above, the present study refers to a series of works that consider the possibility of applying game-theoretic methods to the problems of security management and resilience of information systems. Its fundamental difference from the previous works is the transition from matrix to bimatrix (non-antagonistic games) in modeling the conflict situation between the party that protects the information system and the party that attacks it.

This approach allows to rise to a higher level of generalization and, in particular, to take into account the cases in which the loss of one of the parties is a mirror reflection of the gain of the other. An additional argument in favor of bimatrix models is the consideration that the effects of the defender and the attacker in the case of infosystems have a different nature, and it is difficult to measure them in comparable units. Moreover, it is impossible to lead to the same measures.

Finding a solution (mixed-strategy equilibrium) for bimatrix models is a more difficult problem than in the case of matrix games. However, computationally, it is quite solvable.

At the same time, the concepts of equilibrium refinement, that is, the rules for selecting from several equilibria those that seem preferable according to certain criteria, can be successfully applied to the proposed form of models. This was demonstrated in the present chapter by the example of the trembling hand equilibrium.

In the modern world, characterized by increased volatility and instability, the task of building reasonable forecasts takes on special significance. One cannot but recognize that traditional econometric models that involve the replication of past trends and patterns turn out to be inadequate with respect to new trends and challenges. Models and methods of scenario forecasting are more attractive in this respect.

It is necessary to note the meaningful closeness between the methods of scenario forecasting and dynamic games with incomplete information (dynamic Bayesian games), into which BGMISIAEE can be transformed. In this case, there are wide opportunities for a comparative analysis of expert evaluations, traditionally used in scenario predictions, with the representations of the participants of the Bayesian game, modeling the processes of protection/attack for the information system.

6 Conclusion

The radical increase in the level of conflict in the economy and society on the international arena dramatically increases the urgency of ensuring the security and stability of information systems. A successful solution to such problems cannot be found solely at the level of everyday empiricism. It also requires fundamental scientific and theoretical developments. Stochastic nature of information systems protection problems objectively corresponds to mathematical methods of decision-making in conditions of uncertainty, in particular, game theory.

In the course of this study, it was demonstrated that approaches to modeling the patterns of confrontation between the defending and attacking parties in the information environment are promising and fruitful. The logic of the equilibrium Nash decisions allows to allocate intervals of conditional stability in a choice of protection and attack methods. At the same time, in the case of dynamic implementation, constructive possibilities for estimating the duration of stability intervals and diagnosing "turning points" open up.

The development of game approaches involves the expansion of the class of games involved in modeling information security problems, in particular, evolutionary game models, as well as methods of modern cooperative game theory.

References

1. Panfilov, G.O., Chugunov, A.V., Kabanov, Y.A.: E-participation in Russian regions: monitoring results 2020–2022. In: The State and Citizens in the Electronic Environment, vol. 6 (Proceedings of the XXV International Joint Scientific Conference "Internet and Modern Society", IMS-2022, St. Petersburg, June 23–24 (2022)
2. Klimenko, I.S.: Mathematical model of comprehensive protection of an infocommunication object based on "Game with Nature". Sovremennaya nauka i innovacii. **1**(27), 34–43 (2022) (in Russian)
3. Remesnik, E.S.: Application of game theory to enterprise information security risk assessment. Problemy informacionnoj bezopasnosti. Trudy V Vserossijskoj s mezhdunarodnym uchastiem nauchno-prakticheskoj konferencii, Simferopol'-Gurzuf, 14–16 fevralya 2019, 161–163 (2019) (in Russian)
4. Kunakovskaya, O.V., Men'shih, T.V.: Application of game theory methods to information security problems. Nekotorye voprosy analiza, algebry, geometrii i matematicheskogo obrazovaniya. **5-1**, 173–174 (2016) (in Russian)
5. Burkova, E.V., Vavilina, T.S.: Formalized model of a method for choosing a strategy to counter information security violators based on game theory. Fundamental'nye i prikladnye issledovaniya v sovremennom mire. **26-2**, 10–15 (2019) (in Russian)
6. Belavagi, M.C., Muniyal, B.: Improved intrusion detection system using quantal response equilibrium-based game model and rule-based classification. Int. J. Commun. Netw. Inf. Secur. **13**(1), 1–8 (2021)
7. Khoury, J., Nassar, M.: A hybrid game theory and reinforcement learning approach for cyber-physical systems security. In: NOMS 2020–2020 IEEE/IFIP Network Operations and Management Symposium, pp. 1–9 (2020)

8. Liu, L., Huang, C., Fang, Y., Wang, Z.: Network attack and defense game theory based on Bayes-Nash equilibrium. KSII Trans. Internet Inf. Syst. (TIIS). **13**(10), 5260–5275 (2019)
9. Rudenko, L.I., Pushkareva, E.V.: Modeling information security risk assessment. Sbornik trudov konferencii «Problemy informacionnoj bezopasnosti». V Vserossijskaya s mezhdunarodnym uchastiem nauchno-prakticheskaya konferenciya. Krymskij federal'nyj universitet imeni V.I. Vernadskogo, 163–165 (2019) (in Russian)
10. Hovanov, N.V.: Analysis and Synthesis of Indicators for Information Deficiency. St Petersburg State University, St Petersburg (1996) (in Russian)
11. Hovanov, N.V.: ASPID – a system of qualimetric assessment methods in conditions of a lack of information on the quality of complex technical objects. Metodologiya i praktika ocenivaniya kachestva produkcii L., LDNTP, 56–61 (1988) (in Russian)
12. Hovanov, N.V.: Mathematical Models of Risk and Uncertainty. St Petersburg State University, St Petersburg (1998) (in Russian)
13. Selten, R.: Spieltheoretische Behandlung eines Oligopolmodells mit Nachgetragheit. Zeitschrift fur die Gesamte Staatswissenschaft. **121**, 301–324 (1965)

What Is It Like to Be a UX Specialist in CIS Countries?

Ivan Okuskov, Anna Moroz, and Alena Suvorova

Abstract Nowadays, UX specialists are in high demand since satisfied users are crucial for the success of the companies providing informational services. The specialists analyze user behavior, design interfaces, and test systems to create products that meet user needs. In today's IT industry, good user experience is becoming increasingly important for standing out and attracting customers, leading to a growing demand for UX specialists in the labor market of CIS countries. This report analyzes the key competencies expected from UX specialists in the CIS labor market. We analyzed UX job competencies solicited in the Russian labor market based on job postings on HeadHunter, a popular recruitment platform, obtaining 3959 job postings from November 2022 to March 2023. We identified four clusters of UX competencies, development, design, marketing, and product, which may constitute a competency model for a UX specialist. The analysis also revealed a list of the least frequent UX skills appearing in job postings. These skills were concluded to be either outdated or not commonly sought after by employers due to the narrow specialization of vacancies.

Keywords Competency model · Human resources · User experience · Labor market

1 Introduction

Nowadays, more and more companies and organizations are becoming aware of the importance of investing in user experience [1] to create high-quality products and services. They understand that user experience is a crucial factor that affects the success of a product in the market. Thus, finding and hiring highly qualified user experience specialists is becoming increasingly vital to business.

In general, the development of the user experience field demonstrates that companies are evolving into more customer-oriented and comprehending that the

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_24

best products are created when developers, designers, and other specialists which work closely with users. User experience (UX) specialists play a key role in the design and development processes, helping to create products that truly meet user needs and expectations [2].

Furthermore, the user experience field is constantly evolving, and professionals must continually learn and improve to enhance their knowledge and skills, follow new trends, and apply them in practice to remain competitive in the job market [3].

In today's world, users expect products to be convenient, functional, and attractive. Therefore, the demand for user experience specialists is increasingly growing in various companies and organizations. The user experience field encompasses interface design, information architecture, and user interaction [4]. Specialists in this field have various specializations and work together to create products that meet user needs and expectations.

The growth of the UX field is driven by several factors. First, there is a wide range of devices and interaction channels available today, and users expect products to be accessible on all devices and channels [5]. Second, companies recognize that competitiveness in the product and service market depends on how well they meet the needs of their customers [2]. Third, organizations face growing demands concerning the security and confidentiality of user data, and user experience specialists play a vital role in ensuring product compliance with these requirements [6]. Finally, the evolution of technology and the development of new approaches to UX design necessitate constant learning and development for both professionals in this field and students who will soon enter the job market [7].

User experience specialists can bring significant value to companies by improving their financial performance [8]. They can help companies increase revenue by creating products that better meet user needs and have a higher degree of customer satisfaction. Such products usually have a higher likelihood of being more competitive and successful in the market, which can lead to an increase in market share and company revenue. In addition, user experience specialists can help companies reduce product support costs and enhance their competitiveness in the market, which can also lead to increased company revenue.

Thus, the development of the user experience field reflects a growing understanding among companies that the best products are created when developers, designers, and other specialists work closely with users and that customer satisfaction is paramount. User experience professionals play a key role in this process by helping to create products that truly meet the needs and expectations of users.

Exploring the competencies of UX professionals can help determine the skills and knowledge necessary for effective work in this field and identify trends in the profession's development and labor market requirements. This information can help students and young professionals who are just starting in the field to better understand the competencies they need to develop and increase self-demand in the labor market. In addition, competency research can help employers more accurately determine the qualifications and skills necessary for effective work in their company.

Studying the competencies of UX professionals can also provide insights into the skills and knowledge needed in different specializations in the user experience field,

such as interface design, user experience research, and user interaction. This can help both novice and experienced professionals determine which areas they should improve their knowledge and skills in.

Furthermore, understanding the competencies of UX professionals can help companies manage their resources more effectively and build optimal teams of user experience professionals. By knowing the necessary labor market requirements and employee specializations, companies can distribute tasks and optimize work processes more efficiently.

Finally, exploring the competencies of UX professionals can aid in developing educational programs and courses related to user experience. A more precise understanding of labor market requirements and professional competencies can help create training programs that most effectively prepare students and young professionals for work in this field.

2 Related Works

The term User Experience was first introduced by a team led by D. Norman in 1995. Initially, it was used in the field of Human–Computer Interaction (HCI) and later adopted by other areas. At that time, the term was used to describe the interaction between users and interfaces, as well as the ease of use of applications on Apple computers.

There are several reasons why the field of user experience is actively developing. These include the widespread use of technology in everyday life and the increased attention to the interactive experience of users. UX is attracting more and more people, going beyond focus areas such as marketing, graphic design, interface design, or product design [1]. This substantiates the need for research in the field.

User experience is a complex and multifaceted area that includes methods and approaches from psychology, social sciences, design, and engineering, as well as communication areas. This set of areas is necessary to understand users and their interactions with various systems [9].

The methods used by UX specialists are constantly evolving. They change in both content and quantity. There is a noticeable trend toward transferring methods from the academic field to practical applications and then to the level of corporate development of various solutions [7]. There is also a process of professionalization going on, where the boundaries of competencies for UX professionals are being defined [3, 10].

The evolution of the user experience field has been documented in various formats. In 2009, the Usability Professionals Association conducted a seminar to evaluate the maturity model of the field [11]. The authors of Validating a Standardized Usability/User-Experience Maturity Model: A Progress Report found that basic UX practices are considered initial (developing) practices strategically used to optimize the solutions being developed. Optimized (developed) practices involve

continually modernizing processes related to the design and optimization of the user experience.

In 2010, the International Organization for Standardization released standard ISO 9241-210, which defines user experience as a person's perceptions and responses resulting from the use or anticipated use of a product, system, or service. This standard also provides detailed descriptions of user experience, including physical and psychological reactions of users related to design, ease of use, brand image, representation, and functions related to users' personal goals. According to this definition, a user experience designer must possess significant knowledge and skills to achieve the design goals.

Although the ISO standard for user experience has been established for over 13 years, the field of UX and its professions continue to experience active growth and development. This is supported by various studies, such as User Experience: A concept without consensus? Exploring practitioners' perspectives through an international survey [12], which surveyed over 750 specialists from 35 countries. The results revealed that the understanding of user experience varies depending on the geographic location and background of the respondents.

These works confirm that user experience is still evolving. Even though the concept of user experience originated in the 1990s and there is an existing ISO standard, there are still various approaches and methods that are being used and understood differently by UX professionals. Therefore, the field of user experience is still considered to be in its early stages and requires further research.

In their article [13], What is it like to be a UX designer in Italy? An initial analysis of job advertisements to improve training and education in HCI, the authors investigate the Italian job market for UX designers. Using qualitative analysis of 100 job postings, the authors aimed to assess and align the academic preparation of UX professionals. In addition to their main objective, the authors highlight the potential use of the results to promote the profession within companies. The result of their study is a set of thematic clusters of competencies required for successful work, including UI design, UX design, prototyping, visual and graphics, programming, and others. This work serves as one of the sources for describing methods to research job postings for the current study from the collection stage to the visualization of results.

Another work that investigates the competencies of UX designers in Italy [13] is User Experience Design (UXD) Competency Model: Identifying Well-Rounded Proficiency for User Experience Designers in the Digital Age [14]. User experience design (UXD) as a field, according to the authors, is a new direction that is involved in many areas that use digital technologies and systems. The research emphasizes the lack of clear boundaries in the field of user experience design, which is the main premise for conducting the present research.

Based on the analysis of the work, it can be concluded that there are some gaps in the UX research field.

One of the problems in the UX field is the lack of commonly accepted methods and approaches for conducting research. Despite the ISO 9241-210 standard defining user experience, it does not cover all aspects of UX, which leads to specialists

using different methods and approaches. This makes it difficult to compare results and create common standards and methodologies for UX research. In addition, not all methods may be effective in a corporate environment, where there may be specific features and limitations. Further research is needed to determine which methods and approaches are most effective in a corporate environment and to develop appropriate methodologies.

Another problem is that companies may use different UX research methods and approaches, which makes it difficult to compare results and create common standards and methodologies for UX research. Further research is needed to determine which methods and approaches are most effective in a corporate environment and to develop appropriate methodologies.

Finally, research is needed in the area of training and preparation of UX specialists. As the Italian labor market study for UX designers shows, it is necessary to define the boundaries of competencies for UX professionals and to develop appropriate training and preparation programs. These programs should include user experience research and UX research methodologies, as well as practical application of these methods and approaches in a corporate environment.

Thus, despite the active development of the user experience field, it still needs further research and the development of commonly accepted methods and approaches. It is important to focus on practical applications of UX and corporate management in this area, as well as on the training and preparation of specialists.

3 Data and Methods

3.1 Data Collection

To collect information about vacancies, the HeadHunter website [https://hh.ru/] was used, as it is the leader in the number of job postings in the CIS and is the most popular among companies engaged in the search and recruitment of personnel.

Vacancies were collected using the public API of the website [https://dev.hh.ru/]. We collected the vacancies that were available in the general HeadHunter job posting search by the keyword UX, occurring in both the job title and job description of the vacancies. Vacancies were collected for more than 5 months (from November 2022 to March 2023) to track dynamics and select the most optimal algorithm for obtaining the largest number of vacancies. Eventually, 3959 vacancies were obtained, including both active and archived ones. Active vacancies are those that are available at the time of the request, both through the API and through the service's user interface. Archived vacancies are those that were previously available for viewing through different channels, but, at the time of the request, they are no longer provided in the search results. Because it was not possible to obtain archived vacancies through the API, such vacancies were included in the sample as active ones, and over time (over 5 months), they started disappearing from the search results, thereby becoming archived (or were removed from the service). There are

open positions available in the following CIS countries: the Russian Federation, Kazakhstan, Belarus, Armenia, Azerbaijan, and Uzbekistan.

3.2 Data Preprocessing

After collecting data on vacancies, a list of key competencies and skills for UX specialists was compiled based on an analysis of competencies indicated in those vacancies. Over 2.5 thousand competencies were collected, and those that occurred in 10 or more vacancies were selected.

The remaining competencies, which occurred less frequently, were subjected to detailed qualitative analysis to understand why they were not as popular among vacancies and companies.

The following skills may not be as high of a priority for a UX specialist role:

- Analytical skills: managing active clients, data analysis, market research
- Technical skills: .NET, Java Servlets, Spring Web MVC, Adobe Creative Cloud, and Unreal Engine 4
- Management competencies: process management, sales management, and consumer loyalty management

We suggest the following reasons why these competencies may not be as prioritized in a UX specialist role:

- UX specialists focus more on end-users rather than conducting research in laboratory settings, so analytical skills may not be as crucial.
- Technical skills may be less emphasized because UX specialists may have varying levels of technical expertise depending on their specialization and the type of project they work on.
- Management-related competencies may not be as important because UX specialists typically work as part of a team rather than leading a project.

3.3 Clustering

After obtaining lists of competencies filtered for each job in our database based on their minimum occurrence, we analyzed the co-occurrence of competencies. We calculated the number of times the combination of each pair of competencies appeared in the overall job database we had at our disposal. Based on this statistic, we formed a competencies co-occurrence matrix. After the matrix was formed, we used the K-means clustering algorithm [15] based on cosine distance to cluster competencies. It resulted in the identification of four competency groups.

3.4 Visualization

Next, based on the co-occurrence matrix and the identified competency clusters, we constructed a graphical representation of the network, where nodes represented competencies, and links between them represented the number of times a particular pair of competencies appeared in the job database. In addition, we highlighted the previously identified clusters with color for easier interpretation on the network. This visualization helped us better understand which competencies are mostly related to each other in terms of co-occurrence in UX vacancies, allowing us to infer and describe the main groups of competencies, or skills, that are most relevant for UX professionals.

4 Results

The described project resulted in a list of blocks of highly sought-after competencies and skills for UX professionals in the Russian job market. Hereinafter, the competency blocks are described with the clusters on the network visualization.

4.1 Purple (Development) Cluster

This cluster includes competencies related to software development, frameworks, programming technologies, and tools for testing and deployment.

To create smaller blocks, attention can be given to skills related to front-end development, testing, deployment, data analysis, and integrations (see Fig. 1). Within this cluster, there were technologies, frameworks, and approaches for architecture design and the development of solutions on various platforms, from mobile applications to services available on personal computers or tablets.

4.2 Orange (Design) Cluster

This cluster includes tools and technologies for interface design as well as graphic design, and characteristics that a suitable candidate must possess (see Fig. 2). The concept of design included not only user experience design but also graphic design, print design, and web design. In addition, the cluster included competencies related to the possession of certain software for design, as well as evaluation and prototyping. In addition, the personal qualities of a specialist, such as responsibility or creative thinking, were noticed in the cluster.

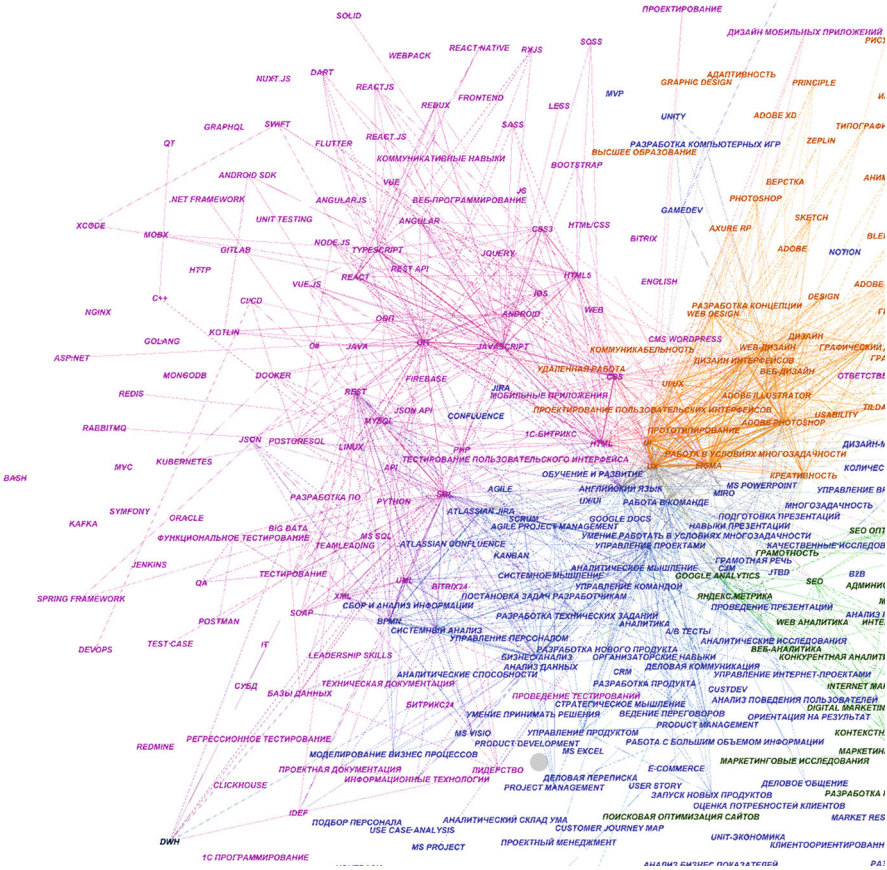

Fig. 1 Development cluster

4.3 Green (Marketing) Cluster

The cluster encompasses the necessary competencies for work in the fields of marketing, advertising, and public relations. The cluster consists of both separate competencies and programs that candidates must master (see Fig. 3). The tools include site administration systems, as well as systems for collecting and working with analytics, user behavior, and the solution as a whole.

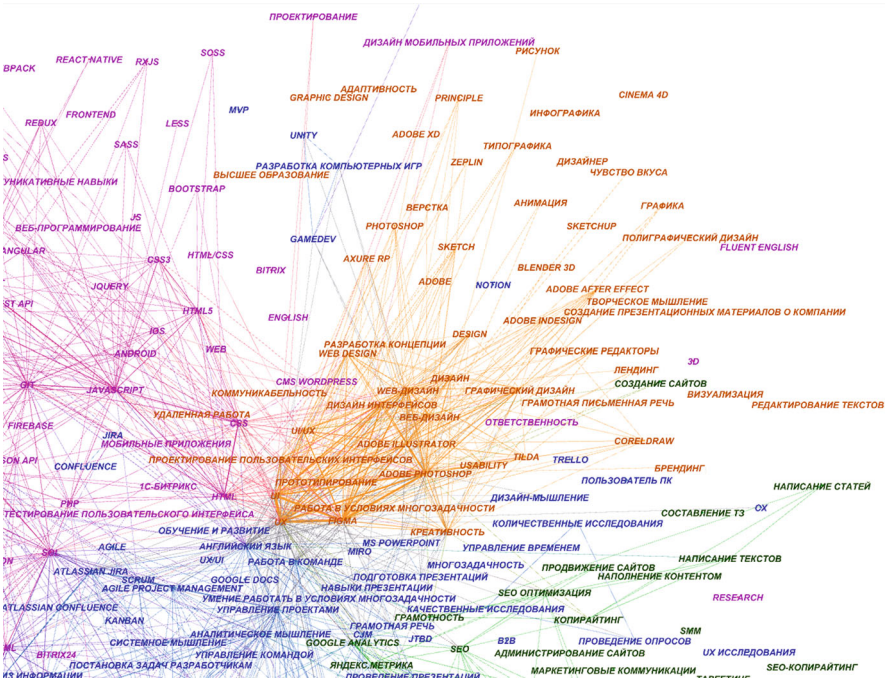

Fig. 2 Design cluster

4.4 Blue (Product) Cluster

The Blue (product) cluster includes the necessary competencies for product design, development, and market launch. Like other clusters, groups of technologies, frameworks, and skills can be distinguished within it.

Within this skills block, specific parts related to task setting and control of their implementation can be highlighted, such as project management, solution presentations, research, product management, solution design, and planning for the product's market launch (see Fig. 4).

5 Discussion and Conclusions

One of the objectives of our research is to identify issues in the field of user experience in terms of its maturity and the impact of geographical location on the hiring of specialists. In addition, we analyzed the most sought-after skills and competencies of user experience specialists in the labor market of the CIS countries and reviewed existing competency models in the field of user experience.

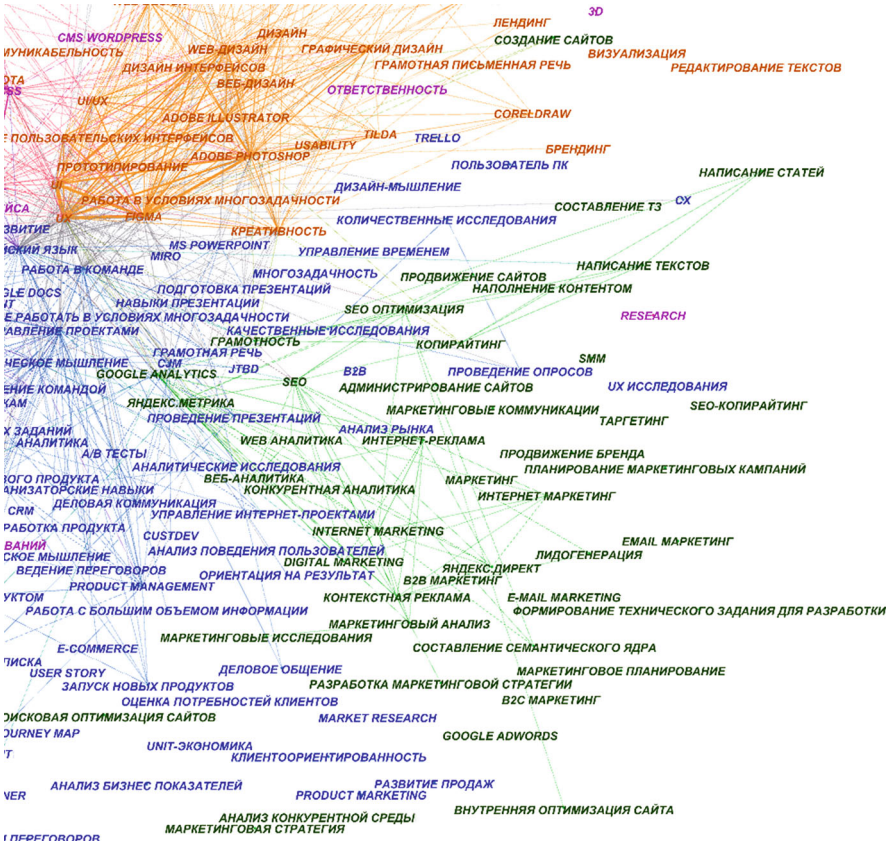

Fig. 3 Marketing cluster

Our findings confirmed the need for a wide range of competencies for UX specialists in the CIS market. This includes user interface design, user experience research, technical skills, and communication skills. These results align with those obtained in other markets [13, 14].

However, it is important to note that this research was conducted based on the analysis of job vacancies, which may not fully reflect the reality of the market. Our research is limited both geographically by the companies whose vacancies were considered and analyzed, and temporally. We allotted a sufficient amount of time to gather information and collect data on vacancies for a period of 5 months. As the field of UX is rapidly developing, we acknowledge that the current competency model may become outdated after some time.

Nevertheless, this research enables us to identify the most sought-after competencies of UX specialists in the CIS labor market, which can be beneficial for students, professionals, and educational institutions in shaping their career trajectories and updating educational programs.

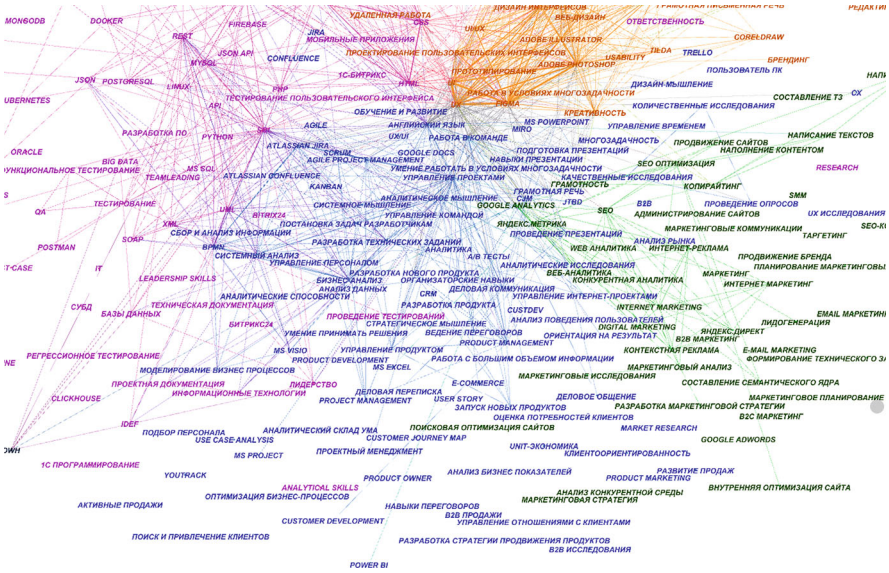

Fig. 4 Product cluster

Using a competency set can be extremely helpful for companies that develop products in the user experience field. First, it aids in identifying the necessary skills, knowledge, and personality traits for a specific position in the company. This allows the company to focus on these criteria when selecting candidates for a vacancy and choose specialists who best meet the requirements of the position.

In addition, the competency set can be used to develop training and staff development programs, as well as individual development plans. User experience professionals should constantly enhance their knowledge and skills, keeping up with new trends and technologies in their field due to the active development of this sphere. The competency set helps determine which skills and knowledge need to be developed in staff so they can effectively perform their work and accomplish their goals.

Thus, the use of a competency set can help companies working in the user experience field to be more effective and increase staff satisfaction. The competency set can also be useful for educational institutions by identifying the necessary set of skills and knowledge that students must master to succeed in the future. This can help institutions develop educational programs that better meet the needs of the labor market and employer requirements.

Moreover, the competency set can be used to evaluate students‘knowledge and skills, create individual development plans, and implement training and staff development programs. This can help institutions ensure high-quality education and prepare students for successful careers in the future.

In conclusion, the use of a competency set can help educational institutions better meet the needs of the labor market and employer requirements, improve the quality of education, and increase student and staff satisfaction.

References

1. Hassenzahl, M., Tractinsky, N.: User experience – a research agenda. Behav. Inform. Technol. **25**(2), 91–97 (2006). https://doi.org/10.1080/01449290500330331
2. Ali, B., et al.: Impact of service quality on the customer satisfaction: case study at online meeting platforms. Int. J. Eng. Bus. Manage. **5** (2021). https://doi.org/10.22161/ijebm.5.2.6
3. Kou, Y., Gray, C.M.: Towards professionalization in an online community of emerging occupation: discourses among UX practitioners. In: Proceedings of the 2018 ACM Conference on Supporting Groupwork, pp. 322–334
4. Lauer, C., Brumberger, E.: Architect, developer, designer: the anatomy of UX in industry job postings. In: Proceedings SIGDOC '14: The 32nd ACM International Conference on the Design of Communication (2014). https://doi.org/10.1145/2666216.2666234
5. Zhang, M., Williamson, P.: The emergence of multiplatform ecosystems: insights from China's mobile payments system in overcoming bottlenecks to reach the mass market. Technol. Forecast. Soc. Chang. **173**, 121128 (2021). https://doi.org/10.1016/j.techfore.2021.121128
6. Xia, W., Liu, Z.: User experience research in China: a 15-year bibliometric analysis. In: International Conference on Human-Computer Interaction, pp. 295–313. Springer International Publishing, Cham (2022). https://doi.org/10.1007/978-3-031-05897-4_21
7. Getto, G., Beecher, F.: Toward a model of UX education: training UX designers within the academy. IEEE Trans. Prof. Commun. **59**, 153–164 (2016). https://doi.org/10.1109/TPC.2016.2561139
8. Rosenberg, D.: SIGCHI lifetime practice award talk the business of UX. In: Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems, pp. 1–2 (2019). https://doi.org/10.1145/3290607.3313770
9. Gray, C.M., Parsons, P., Toombs, A.L., Rasche, N., Vorvoreanu, M.: Designing an aesthetic learner experience: UX, instructional design, and design pedagogy. Int. J. Des. Learn. **11**(1), 41–58 (2020)
10. Gray, C.M.: It's more of a mindset than a method: UX practitioners' conception of design methods. In: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, pp. 4044–4055. ACM, San Jose, CA, USA (2016)
11. Marcus, A., Gunther, R., Sieffert, R.: Validating a standardized usability/user-experience maturity model: a progress report. In: Kurosu, M. (ed.) Human Centered Design, pp. 104–109. Springer, Berlin (2009)
12. Lallemand, C., Gronier, G., Koenig, V.: User experience: a concept without consensus? Exploring practitioners' perspectives through an international survey. Comput. Hum. Behav. **43**, 35–48 (2015)
13. Butiurca, A.D., Zancanaro, M.: What is it like to be a UX designer in Italy? An initial analysis of job advertisements to improve training and education in HCI. In: CHItaly 2021: 14th Biannual Conference of the Italian SIGCHI Chapter (CHItaly '21: 14th Biannual Conference of the Italian SIGCHI Chapter), pp. 1–5. ACM, Bolzano, Italy (2021). https://doi.org/10.1145/3464385.3464714

14. Borriraklert, A., Kiattisin, S.: User Experience Design (UXD) competency model: identifying well-rounded proficiency for user experience designers in the digital age. Archives of Design Research. **34**(3), 61–79 (2021). https://doi.org/10.15187/adr.2021.08.34.3.61
15. Wang, C., Wang, L., Yang, H.: Improved Kmeans algorithm based on privacy protection. In: International Conference on Machine Learning for Cyber Security, pp. 560–567 (2023). https://doi.org/10.1007/978-3-031-20096-0_42

Machine Learning Deployment as a Web Service to Evaluate the Production Cycle of Environmental Goods: Primary Analysis of Ionic Liquids with Visualizations

Anna V. Chizhik, Vladimir Chizhik, and Alexander Trufanov

Abstract Many applied research studies require a convenient web interface that would allow making a set of hypotheses, due to the fact that the data or the operation of algorithms is visualized. This chapter describes an experiment to create such an interface. We have chosen the theme of the production of goods from recycled materials. This process involves, for example, the use of cellulose. The first cycle of working with it involves the process of dissolution. In order for this to be economically feasible, it is necessary to select an ionic liquid. It is obvious that the process of selecting a substance can be automated; appropriate algorithms are developing every year. And so that people who are not related to chemistry and physics can make decisions, it is necessary to provide them with a tool that helps in this. Thus, we have chosen a sphere where there are ML models, and the visualized conclusions of algorithms can help a nonspecialist to make decisions.

Keywords Web service · ML models · Ionic liquids

1 Introduction

In recent years, scientists and ecologists around the world have been raising the problem of the available natural resource potential depletion of the Earth and the planet's natural environment pollution [1, 2]. According to statistical data, the stocks of recyclable materials by some indicators exceed the amount of available primary materials [3, 4]. In addition, there are a number of studies [5, 6] that draw attention to the fact that, in the near future, a post-industrial society will not be able to ensure its existence completely at the expense of natural resources.All this explains the dynamics of the use of secondary raw materials. Moreover, the series of global environmental disasters actualizes the prevention of ecological problems and the development of a conservation culture among people [7]. Under these conditions, a

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_25

large number of brands draw attention to optimizing their business both through processing raw materials in the concept of the production chain and supporting customers in their desire to help the planet. Thus, scientists of all countries are making significant efforts to create, develop, and improve technologies for processing various types of waste for environmentally friendly reuse.

Human's understanding of the irreversible consequences of anthropogenic activity has led to the ecological focus of modern culture. This is reflected most acutely in the soul-searching undertaking through the awareness of the fundamental value of nature. This process leads society to the relegation of the confrontation between two systems (people vs nature) [8]. Following the ideas of K. Levi-Strauss, it can be argued that the data that are received through the senses and processed by the intellect of a person can be decoded only in accordance with the information that was embedded in their mind by the culture. Therefore, beliefs and attitudes are shaped on that basis [9]. Currently, the concept of "ecological culture" is a certain sociocultural paradigm. It includes humanitarian values (within the framework of ecology), subject–subject consciousness, and subject–object relations in the system of man–society–nature, thereby forming the ecocentric consciousness. Therefore, this type of culture is future-oriented.

The concept of sustainable development became the constructive reaction of society to the processes of nature degradation, which are observed and actively covered in scientific publications and the media under increased anthropogenic pressure [10]. These ideas were formed in the course of gradual awareness by the society of environmental, economic, and social problems that affect the state of the natural environment. On a global scale, the transition to sustainable development is inherently imperative since there is no rational alternative to it.

The determining role in the initial establishment of the concept of sustainable development was the UN Conference on the Environment, which took place on June 16, 1972 in Stockholm (Sweden). The decisions adopted by the Conference became the basis of state strategies and were integrated into the emerging global environmental movement. For the first time, it was announced that measures to address the problems of environmental degradation were included in the action programs at the governmental level. The result was the adoption of the policy statement by the participants (a declaration of 26 principles), the action plan that included 109 recommendations, and the recommendation to the UN General Assembly on the establishment of a UN Environment Program. National sustainable development strategies have different emphases [11]. Thus, in Great Britain, it is the preservation of the natural environment; in Canada, the focus is on basic human needs; and in France, it has identified the list of various priority topics (e.g., in 1995, the main goal was the development of indicators for natural problems in the cities). The strategic goal of Russia's sustainable development is to increase the population's level and quality of life using scientific and technological progress, the dynamic development of the economy, and the social sphere while maintaining the reproductive potential of the country's natural complex as a part of the Earth's biosphere using technological potential in the interests of the current and future generations [12]. Therefore, the transition to sustainable development should ensure a balanced solution to the

problems of socioeconomic development and the preservation of a favorable environment and natural resource potential in the future.

Since sustainable development is an evolutionary process, it means that its progress can be analyzed. Gradually, scientists began to use systems of indicators that could characterize the state, dynamics and trends of the economy, environment, population, and social spheres of the countries, regions, and the world as a whole in terms of sustainable development [13, 14]. There are a lot of indicator systems which are not described in detail in this research. However, a general tendency should be highlighted: sustainable development is the concept that implies the development of the economy by maintaining the environment [15–18]. This statement again leads to reflections on the topic about the efficiency of using recyclable materials in the production cycle.

In summary, the change of public attitude toward solving ecological problems instituted the emergence of a new cultural concept. The transitions to a post-industrial society and the availability of the Internet have made an impact on business principles. Digitalization and accessibility to massive data volume made a significant impact on the formation of the generation that is now at the peak of purchasing power (born in 1980–2000). The vector of their purchasing behavior significantly differs from the previous generations. Business transparency, and its responsibility and reliability (which replaced the model of brand loyalty through interaction with subconscious mind) stand out as the criteria for successful communication between a brand and consumers. In 2014 and 2018, the Nielsen agency conducted public opinion surveys that showed that a significant part of the Central Europe population (the survey included 60 countries, along with the Russian Federation) is ready to overpay for brand products that promote respect for the environment. According to a survey held in 2018, 67% of Russian consumers are (potentially) willing to overpay for goods if their manufacturers support the ideas of social responsibility or sustainable development (this means that the price can be increased up to +29% since 2014 if compared with their own study). Approximately the same ratio can be deduced for European society, focusing on the data of the GfK Consumer Life study, where +18% growth was noted between 2014 and 2017 research years. Figure 1 shows the changes in the consciousness of society based on the results of the above studies [19–21].

Change in the public attitude toward solving ecological problems instituted the emergence of a new cultural concept based on three main goals: economic development, social development, and environmental protection. According to sociological data and the case study method altogether viewed through the prism of cultural studies, it can be noted that the ecological culture is the determinant of public opinion and the major paradigm shifts in thinking of modern society.

In such a way, society motivates the country and business to reflect on the possibilities of reusing materials in favor of environmentally oriented production concepts. This is beneficial not only in terms of saving natural materials but also from the standpoint of taking into account the struggle to stabilize public opinion, which is attracted to a positive context. As it may be seen in the figure above, society

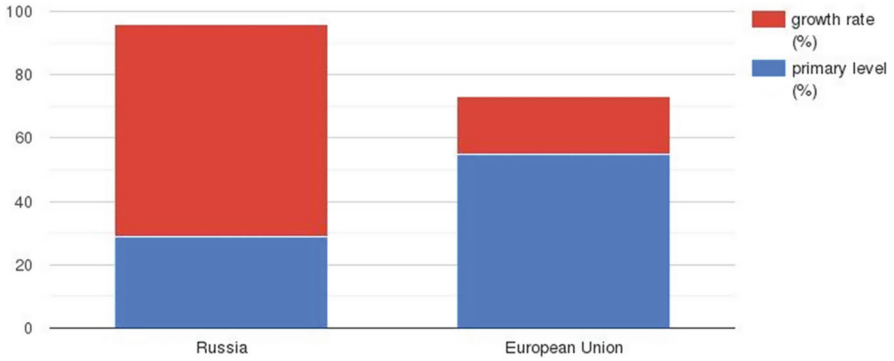

Fig. 1 Change of public opinion in favor of ecofriendly brands (2014–2018)

votes for the use of recyclable materials and the orientation toward conscious consumption.

2 Problem

The formulation of the problem in this study should be divided into two steps.

2.1 Cellulose-Based Goods

It is known that cellulose is crucial in the production of a large number of goods. In particular, it is used in the production of paper and cardboard since the mass of cellulose consists of individual fibers with high strength and the ability to form strong bonds with each other. Cellulose can be obtained in many ways, including waste paper. This means that the use of cellulose makes it possible to address sustainability within the production cycle (without using wood in the production chain).

To summarize, cellulose is a readily available material that can be used to make useful biodegradable materials from waste materials (like bagasse and the husks of sugar cane left over after processing). However, the first stage of processing is to dissolve cellulose, which is very difficult. Currently, liquid salts called ionic liquids (IL) are used to do this (they are nice solvents in terms of green chemistry as they have no vapor pressure and so can be recovered, but they are horrible solvents to handle). IL are very expensive, and the resulting cellobiose–IL mixture is very thick and hard to process. The solution to both these problems is to dilute the IL with a co-solvent (CS). The mixture of IL and CS is called organic electrolyte solutions (OESs). Thus, the problem is to figure out which CS are the best and why.

2.2 Core Business Problem

At the moment, the choice of CS is associated with several iterations of interaction between business and scientific groups. More precisely, it requires the intervention of a team of chemists who have to isolate two to three possible IL and give data on these substances. Then, received information is processed by several departments within a company in order to make decisions on economic feasibility and application strategy. Moreover, a business does not initially have a null hypothesis. Therefore, only large-scale industries can afford not to enter into additional contracts with external research centers so they can choose a chemical substance that is economically justified for inclusion in the production chain, while goods made from cellulose are not limited to large businesses and are also present in the context of small and medium-sized businesses.

Our hypothesis is that machine learning specialists are now employees of almost any company that interacts with consumers. Their responsibilities are wide-ranging: some businesses study the tendencies and behavioral characteristics of their potential clients using ML algorithms; others incorporate ML models directly into their firm's production processes. Data specialists are usually asked to multitask, and the final decisions on strategic business development are located in neighboring departments. Thus, in small and medium-sized businesses, machine learning can be used to create null hypotheses within the enterprise about the economic feasibility of applying some methods in the production or using techniques and substances. Often, for the successful implementation of this idea, there are not enough interfaces that could demonstrate the data and conclusions of ML models to specialists responsible for the implementation of new solutions in production.

Overall, the purpose of this study is to analyze the possibilities of creating a web interface that could demonstrate the results of machine learning models in the data visualization format.

To test our hypotheses, we took the above-stated problem of bringing cellulose into the form required for the production of goods and suggested that one of the possible solutions for choosing the optimal chemical is to study the data using machine learning methods and then train a linear regression model. The goal was to make a web application that would provide the ability to set a model (for delegating hypothesis generation to various specialists). In addition, the model's results should be explained by graphs.

3 Data

We used data on 11 CS (11 datasets describing the characteristics of substances were posted as part of the study [22]). All solubility tests were conducted at 70 °C. Solubility was determined by the addition of small aliquots of dried microcrystalline cellulose (MC) to mixtures of [EMIm][OAc]/CS of appropriate composition. The

Fig. 2 Solvent dataset

	solvents	chi_IL	chi_cell
0	chichi1MI	0.069929	0.098819
1	chichiDMSO	0.052296	0.056934
2	chichiDMF	0.148345	0.190658

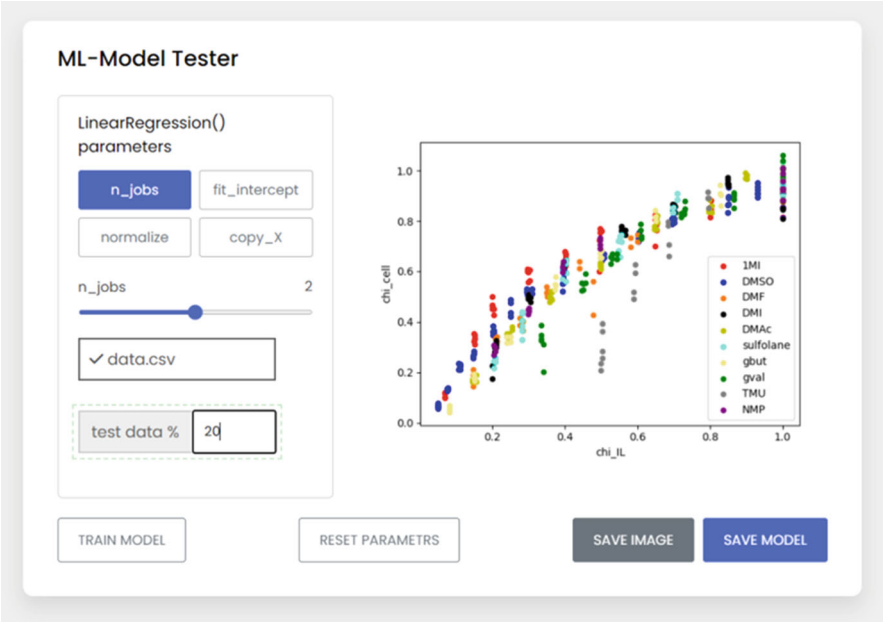

Fig. 3 Web interface and cellulose–OES dissolution curves

maximum amount of MC that dissolved and minimum amount that did not dissolve were recorded. That gave an under- and overestimate for the maximum amount of MC dissolvable. The mole fraction of IL in the OES mixture (chi_IL) is calculated and fixed in datasets, as well as the normalized value of this parameter (chi_cell). Thus, from the weight percentage, the mole fraction of the cellobiose repeat unit was calculated.

The final view of the dataset formed for our experiment is shown in Fig. 2.

4 Web Service Implementation

To develop the web application, we used a stack of Python (interaction of the ML model and data), JavaScript (user interaction with interface), CSS, and HTML. Figure 3 shows the interface of our web application. Its main goal is to hide the process of setting up a machine learning model in a user-friendly shell.

At the moment, we have been experimenting with the classic ML model, linear regression, which in the baseline is suitable for our purpose. The ultimate goal of model training is to try and understand which aspects of the CS cause this different behavior, fit the curves, and come up with a model for the typical OESs (like DMI) and the atypical OESs (like 1-MI). Therefore, the first functional solution that seemed right to us was to illustrate the data loaded into the web application. Therefore, at the moment when the csv file is loaded, the EDA function processes the dataset and outputs the cellulose–OES dissolution curves.

Next, a user is faced with the task of setting up an ML model. We are using the scikit-learn package for Python and its implementation of simple linear regression. For the Linear Regression class that is instantiated, several optional parameters can be provided: three Boolean parameters (fit_intercept, normalize, and copy_X) and integer parameter n_jobs. More details about their meaning can be found in the documentation for the library.

At the moment, the different OES systems look vastly different; the curves have different shapes and curvature. Thus, different systems require more IL in order to start dissolving the cellulose. The goal is to understand these systems and explain what is happening in which case, we should have the knowledge to replot these data such that all the OESs overlap, and then, the best fit line to that would be the explanation of why the different CS cause different behavior. And from that, we should be able to predict other solvents and other systems.

At the moment, we have settled on the following task: to understand how the efficiency measures relate to themselves. There are a couple of smaller ones found these OESs:

1. min_chi_IL is where the curves above cross the *x*-axis; thus, it is the minimum amount of IL required to get any dissolution at all.
2. max_efficiency measure: greatest mass of cellulose dissolved per unit mass of IL, i.e., the efficiency of the best OES mixture.
3. chi_IL_max_efficieny which is the point where the largest amount of cellulose is being dissolved for each mole IL (i.e., the point to run the processes to get a greater amount of profit).

In our algorithm, we used limiting quantities for the OES curves, but these values are not allowed to be adjusted by the user hands. The parameters were taken from the scientific work described above as the source of the data [22]. Our pipeline of data processing ends with a model creation and its calling. The result of the model's analysis is shown in Fig. 4.

In summary, min_chi_IL is roughly positively correlated with the maximum efficiency, which, as min_chi_IL, is the crossing point and maximum efficiency is the area under the curve, and the curve's roughly similar shape makes sense.

In the current implementation of the web application, the following important options are available: (1) saving the image of data visualization; (2) training model (when this button is pressed, the created instance of the linear regression class starts to train on the data); and (3) saving the model (we chose pickle as the way to serialize the trained machine learning model and save it to a file). In addition, the user can choose the ratio of the training and test samples.

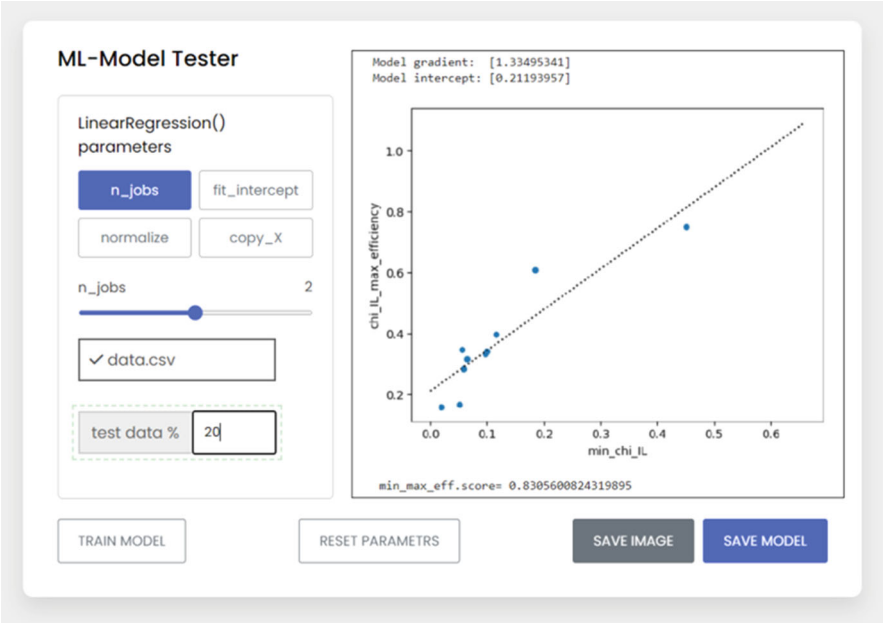

Fig. 4 Web interface and the linear regression model results

5 Conclusion

We made the web application available to be reused for other tasks with similar contexts. To test the application, the survey was conducted among small businesses (April 2023, 15 people, sports ecogoods, Helsinki, Finland). The results showed the usefulness of these kinds of applications for optimizing work in production. However, shortcomings of the current implementation were also identified. For example, now, the application is able to help choose a solvent and make an assumption about the cost of using it in production. However, outside the work of the algorithm, there is the question about CS that determines the chi_max_efficiency, which is a value of great importance . Therefore, our next step is to connect to the nonlinear fitting interface, comparing linear and higher order fits on the minimum chiIL_min data.

After a series of additional experiments, the interface will be posted on the github with a detailed description of the possibilities of its use. At the moment, we consider our task completed: the usefulness of such interfaces for working with data that requires explanation and evaluation has been tested. It seems that this is a promising concept, which consists in an attempt to give professionals that are involved in smart city projects and business development within the framework of sustainable development ideas, tools to move to a new level of data management.

Acknowledgments This study was supported by the Russian Science Foundation, grant No. 23-23-00049 "Microstructure and molecular mobility in electrolytes, promising for use in electrochemical devices of a new generation" (https://rscf.ru/project/23-23-00049/).

References

1. Ali, A.: Natural resources depletion, renewable energy consumption and environmental degradation: a comparative analysis of developed and developing world. Int. J. Energy Econ. Policy. **11**, 251–260 (2021)
2. Sonderegger, T., et al.: Towards harmonizing natural resources as an area of protection in life cycle impact assessment. Int. J. Life Cycle Assess. **22**, 1912–1927 (2017)
3. Yamamoto, T., Merciai, S., Mogollón, J.M., Tukker, A.: The role of recycling in alleviating supply chain risk–insights from a stock-flow perspective using a hybrid input-output database. Resour. Conserv. Recycl. **185**, 106474 (2022)
4. Sverdrup, H.U., Ragnarsdottir, K.V., Koca, D.: An assessment of metal supply sustainability as an input to policy: security of supply extraction rates, stocks-in-use, recycling, and risk of scarcity. J. Clean. Prod. **140**, 359–372 (2017)
5. Rees, J.: Natural Resources: Allocation, Economics and Policy. Routledge (2017)
6. Barnett, H.J., Morse, C.: Scarcity and Growth: The Economics of Natural Resource Availability. Routledge (2013)
7. Alimjanovna, X.D.: Formation of ecological consciousness and culture among young people and developing their skills of rational approach to the environment. Eur. J. Bus. Startups Open Soci. **2**(4), 4–7 (2022)
8. Kagan, M.S.: Fylosofyia kultury (Philosophy of culture). Humanytar. Un-t profsoiuzov; Spb. Hos. Un-t. Spb.: Petropolys (1996)
9. Lévi-Strauss, C.: Anthropologie Structural. Pion, Paris (1958); Liebeault, A.: Du sommeil et des etats analogues, surtout du point de vue de l'action du moral (1866)
10. Barrow, C.J.: Sustainable development: concept, value and practice. Third World Plan. Rev. **17**(4), 369 (1995)
11. Komarov, V.M., Voloshinskaya, A.A.: National strategies for sustainable development: a comparative analysis. All-Russ. Econ. J. ECO. **559**(1), 112–129 (2021)
12. Komarov, V.M., Akimova, V.V., Kotsyubinsky, V.A., Zemtsov, S.P.: Comparative analysis of approaches to the development of long-term state strategies in Russia and the world. Issues State Munic. Manage. **1**, 56–74 (2021)
13. Mitchell, G.: Problems and fundamentals of sustainable development indicators. Sustain. Dev. **4**(1), 1–11 (1996)
14. Garnåsjordet, P.A., et al.: Sustainable development indicators: from statistics to policy. Environ. Policy Gov. **22**(5), 322–336 (2012)
15. Tasaki, T., et al.: A survey of national sustainable development indicators. Int. J. Sustain. Dev. **13**(4), 337–361 (2010)
16. Rosenström, U., et al.: Sustainable development indicators: much wanted, less used? In: Monographs of the Boreal Environment Research. Finnish Environment Institute, Helsinki (2009)
17. Rinne, J., Lyytimäki, J., Kautto, P.: From sustainability to well-being: lessons learned from the use of sustainable development indicators at national and EU level. Ecol. Indic. **35**, 35–42 (2013)
18. Szopik-Depczyńska, K., et al.: The study of relationship in a hierarchical structure of EU sustainable development indicators. Ecol. Indic. **90**, 120–131 (2018)
19. The Report of Nielsen Media Research: Customer's behavior and habits. https://www.nielsen.com/us/en/insights/report/2014/doing-well-by-doing-good/ (2014)

20. The Report of Nielsen Media Research: Customer's behavior and habits. https://www.nielsen.com/by/ru/insights/article/2019/changing-consumer-prosperity-2018/ (2018)
21. The Report of GFK: Global trends and Russian consumer. https://www.gfk.com/fileadmin/user_upload/dyna_content/RU/Documents/Press_Releases/2017/Gfk-Global-Russian-Trends-Sep_2017_Report.pdf (2017)
22. Gale, E., et al.: Directed discovery of greener cosolvents: new cosolvents for use in ionic liquid based organic electrolyte solutions for cellulose dissolution. ACS Sustain. Chem. Eng. **4**(11), 6200–6207 (2016)

Part IV
Cyberpsychology, Digital Health & Active Aging

Teachers' Perspective on Mobile Devices Usage in School Environment

E. B. Spasskaya and Yu L. Proekt

Abstract The integration of mobile technology into learning process has become a challenge for education. In this study, authors aimed to identify teachers' perceptions of students' mobile devices use in school environment based on the subject they teach. Another aim of this study was to reveal the impact of teachers' experience in interacting with mobile devices and their attitudes toward mobile technologies on the perception of students' mobile devices use in school. Based on the conceptual framework of the technology acceptance model, a questionnaire was developed that identifies attitudes toward mobile technologies, perceived usefulness and perceived ease of their use, and ideas about the patterns of mobile devices use by schoolchildren. The study involved 358 teachers aged 21–75, 91.6% women. Results show that teachers generally see students' mobile devices use as a distraction, but some acknowledge its constructive use in certain subjects. Teachers' attitudes and experiences greatly affected their perception of students' mobile devices use, with positive attitudes leading to more favorable views. The study highlights the significance of understanding teachers' attitudes and experiences with mobile technology for its successful integration in education, suggesting that fostering positive attitudes among teachers may promote better integration of technology in the learning process.

Keywords Mobile devices use · Teachers · Students · Learning · Involvement · Distraction · Attitudes · Technology acceptance model · Perception

1 Introduction

The rise of technology has revolutionized many aspects of human live, including learning and education. The mobile devices usage [mobile device usage (MDU)—later] has become a common tool for students in their learning activities as it provides access to different learning materials and educational support such as

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_26

e-books, M-learning apps, learning management systems, digital school planners, and other [1]. However, the integration of mobile technology in classrooms has become a challenge for many teachers who lack technology integration skills and are negative about MDU by schoolchildren during class.

Opponents of mobile learning argue that mobile technologies can be distracting during educational activities [2], contribute to digital inequality issues [3], and pose health risks to students [4]. Supporters of mobile learning, on the contrary, highlight its effectiveness in skill development through the use of educational gamification in mobile games and competitions held in class [5–7], as well as in accessing educational resources through mobile devices [8], and personalized learning organization [9]. Researchers who take an intermediate stance argue that both prohibiting and endorsing MDU in education lack a value-based foundation. They emphasize that MDU can be beneficial for students when supervised by a teacher when the use of gadgets is appropriate for the subject matter and its tasks [10, 11]. Overall, the findings suggest the importance of adults' attitudes and personalities in developing constructive strategies for MDU in children and adolescents' education.

Despite the increasing number of studies on mobile learning, there is a lack of understanding about what factors influence Russian teachers' perceptions of how students use mobile devices in schools.

The research questions for the study were as follows:

- (RQ1) How do teachers from different disciplines perceive the ways in which students use mobile devices?
- (RQ2) How are teachers' attitudes toward mobile technologies related to their perceptions of students' MDU in the school environment?
- (RQ3) To what extent does teachers' experience in interacting with mobile devices shape their perceptions of students' MDU, and how does this relate to their attitudes toward mobile technologies?

The objective of this study was to identify teachers' perceptions of students' MDU in school environment based on the subject they teach. Another aim of the study was to reveal the impact of teachers' experience in interacting with mobile devices and their attitudes toward mobile technologies on the perception of students' MDU in school.

2 Review of Related Literature

2.1 Mobile Devices in Education

According to Mediascope CROSS WEB, in 2022, 96% of Russians aged between 12 and 17 used the Internet daily and spent around 6 h online on average. Furthermore, within this age group, mobile devices accounted for 94% of all digital consumption [12]. This data highlights the importance of the Internet and mobile devices in the daily lives of Russian teenagers. As MDU become increasingly

prevalent in modern schoolchildren's routine, the capability for learning and education on-the-go has expanded. Mobile devices are highly advanced devices that are capable of performing numerous computer-related functions. They are equipped with Internet access and have an operating system that can run downloaded applications, making them extremely versatile and useful tools [13].

Growing interest in MDU for learning has been rising due to the growth in power and capacity of each new generation of mobile devices, making them more efficient and effective for use. Furthermore, the convenience of having these devices integrated into daily life has also made their usage for educational purposes more accessible and feasible [14]. It is important to note that mobile learning offers a valuable opportunity to merge formal and informal education seamlessly. Beyond traditional classrooms and workshops, mobile devices allow individuals to learn while waiting in line, traveling, or in other everyday settings [15]. A key benefit of mobile learning is that it does not always require an Internet connection, as individuals can download materials in advance for offline use. By utilizing mobile devices, individuals can seamlessly transition between different learning environments and push the boundaries of what is possible [14, 16].

There are various perspectives and definitions of m-learning, but all of them acknowledge the importance of the use of mobile computing devices to facilitate learning that can occur anytime and anywhere [17]. Moreover, when it comes to MDU for learning specific school subjects, researchers demonstrate their high effectiveness in enhancing motivation and engagement in learning [18–20], achieving higher academic outcomes in Math [21], language learning [18, 22], and increasing educational opportunities for children with disabilities [23, 24] or from less developed countries [25]. One of the widespread models of mobile learning is the bring your own device initiative. It is a model in which students are allowed to bring their personal devices such as laptops or tablets to school for the purpose of enhancing their learning experience [26]. Allowing students to bring their own mobile devices to school is a more practical and cost-effective solution than providing school-issued devices [27]. This approach enables students to use devices they are already familiar with, thus avoiding the need to learn a new device and saving valuable learning time. By utilizing their own mobile devices, students can focus more on their studies, maximizing their learning potential [28].

However, MDU by children in school does not always lead to an improvement in their academic performance. Many researchers pointed out that distraction by digital devices in the classroom has become a serious issue in schools worldwide (see, e.g., [29]). It is clear that as technology becomes more prevalent, students may be tempted to use their phones for non-educational purposes during class. Therefore, B.R. McCoy found that students are more likely to use digital devices for non-class-related purposes when they are bored or disengaged in class. The most common non-class-related activities students engage in are texting, followed using social media, browsing the Internet, and playing games [30]. Along with that, other studies indicate that the extent of distraction caused by mobile devices is overemphasized. Sullivan, Johnson, Owens, and Conway [31] argue that using digital devices for non-school purposes in class is seen as a minor form of disruptive

behavior. The authors suggest that teachers should focus on understanding how the classroom environment influences student engagement, rather than trying to eliminate such behavior. O'Bannon and Thomas [32] found that older teachers were less likely to own digital devices and were less supportive of MDU in the classroom for school-related work. Gao et al. [33] revealed that the main differences in how teachers, parents, and students view school mobile devices policies were related to the reasons for using or not using mobile devices in school. Teachers and parents were more concerned about distractions and misuse, while students viewed phones as a legitimate tool for learning and communication. In this context, the position of the teacher comes to the fore, which determines both the focus of his perception of students' MDU and the willingness to form constructive ways of MDU in children.

2.2 Teachers' Beliefs Concerning MDU by Schoolchildren

Teachers' beliefs about teaching and learning are critical determinants of how they approach their work in the classroom [34]. As recent studies show, this is very different teachers' beliefs concerning the impact of mobile devices on students in primary and secondary schools. While some teachers focus primarily on the potential benefits of mobile devices as a learning tool, others view them as obstacles to student progress. Therefore, Domingo and Gargante [35] conducted a review that focused on the way teachers perceive mobile technology and its applications impact on learning in the classroom. They found that teachers' perceptions were centered around five key impacts of mobile technology: introducing new methods of learning, enhancing engagement in learning, encouraging autonomous learning, providing access to information, and fostering collaborative learning. They also noted relevant features of digital devices that facilitate these impacts, such as portability, interactive features, context sensitivity, connectivity, social media, and individuality. Along with that, some studies show, teachers believe that mobile devices can negatively affect student learning by distracting students from learning and decreasing their learning concentration [36–38]. Gonca [39] conducted the study with 75 Turkish teachers aiming to reveal their perceptions of the effects of mobile devices on students' academic and social behaviors. The majority of the participants saw mobile devices as having a negative impact on students' attention, academic achievement, and social interaction, with only a small percentage believing that they had a positive impact. Dinsmore [40] found that the integration of mobile technology in the classroom led to contested affordances between teachers and students. Both parties had different views on how mobile technology should be used, which resulted in tension and conflict. Teachers saw mobile technology as a potential distraction while students viewed it as an opportunity for enhanced learning. Successful integration required negotiation and compromise between teachers and students. Löfving et al. [41] also indicate that teachers face a range of challenges in navigating the boundary between students' online and offline lives. These challenges included concerns about

the appropriateness of students' online activities, a lack of understanding about the nature of students' online interactions.

Palfrey and Gasser [42] used M. Prensky terminology and identified teachers as digital immigrants and students as digital natives, requiring teachers to receive special training to educate the tech-savvy generation. It looks like that digital generation gap plays a significant role in how teachers view mobile learning.

It is important to note that, in the context of the COVID-19 pandemic, many teachers have significantly improved their digital skills, which has led to a change in teachers' attitudes toward MDU [43]. Kh.A. Dweikat and H.A. Hasan [44] found that English as a foreign language teachers generally had positive attitudes toward using smartphones in the classroom during the COVID-19 pandemic.

Similar findings were found in the study compared to teachers and students' attitudes toward mobile educational applications [45]. The main benefits identified were increased student engagement and participation, ease of use for distance learning, and the convenience of having all necessary tools in one device. However, concerns were also raised about potential distractions and the need for clear guidelines and training for effective use. Similarly, Nazari and Xodabande [46] revealed that teachers had a positive attitude toward using mobile devices in teaching, but they lacked knowledge and skills to integrate them effectively.

The analysis of recent studies has shown that teachers have varying beliefs about the impact of mobile devices on student learning, including potential benefits such as introducing new methods of learning and providing access to information, as well as concerns such as distraction and decreased concentration. The digital generation gap also plays a significant role in how teachers view mobile learning. However, the COVID-19 pandemic has led to an improvement in teachers' digital skills and a more positive attitude toward using mobile devices in the classroom. It could be said that enhancing the MDU in teaching can significantly influence teachers' attitudes toward mobile learning and their perception of schoolchildren's MDU.

3 Methods

3.1 Participants and Procedure

The study was conducted from January to March 2023 through online surveys. Letters inviting participation in the study were sent to schools in St. Petersburg and the Leningrad region, which are partners of the university. A total of 358 teachers aged 21–75 years participated in the study (with an average age of 44.94 years and 91.6% were women). The majority of the teachers had over 20 years of teaching experience (47.9% of respondents). Teachers with less than 10 years of experience made up to 29.7% of the sample, while 22.4% of the samples were teachers with 11–20 years of experience. The majority of the sample consisted of secondary school teachers (73.8%), while primary school teachers (15.4%) and other categories of teachers, including social educators, educational psychologists, and 10.8% of

participants, were teachers of extracurricular activities. All teachers were informed about the purposes and conditions of participating in the study and provided informed consent to participate in it.

3.2 Measures

The assessment of teachers' attitudes toward mobile technologies was conducted based on a questionnaire that included three blocks of statements, the composition of which was based on the technology acceptance model (TAM) by F.D. Davis [47]. Within this theory, two key criteria for good technology are considered: perceived usefulness and perceived ease of use. Studies also have shown that users' intentions to use technology are associated with positive attitudes toward it and perceived self-competence in its use [48]. Therefore, the first block concerned the perceived ease of use of mobile technologies (e.g., "I quickly and easily master new electronic devices" and "I am an advanced enough user to easily adapt to the interface of educational programs and applications"), the second block contained statements characterizing perceived usefulness of mobile technologies in education (e.g., "Using mobile devices in the learning process opens up new opportunities for professional development of teachers" and "Using mobile technologies in teaching children and adolescents is necessary, since it meets the spirit of the times"), and the third block of statements was built on negative assessments of mobile technologies and reflect the nature of the attitude toward mobile learning (e.g., "Using mobile technologies in teaching children and adolescents tends to lower the quality of education" and "Mobile learning is more utopian since its integration into the educational process is impossible in the conditions of mass education"). Respondents were asked to rate their agreement with the statements on a 7-point Likert scale (where 1—strongly disagree and 7—strongly agree).

The identification of teachers' views on the use of mobile learning by students in school was based on respondents' assessment of the frequency of manifestations of various forms of their use. The list of forms of students' use of mobile learning was compiled based on focus group discussions with students, where the main patterns of children's and adolescents' interaction with mobile learning during school hours were identified. They were divided into three groups, characterizing engagement in learning, distraction from it, and communication with others. Participants of the study evaluated the frequency of these forms on a 5-point Likert scale (from 1—almost never to 5—constantly).

Respondents were also asked to report on their experience in using mobile learning and e-learning tools in their teaching practice with the 5-point Likert scale (from 1—never to 5—constantly) and the age of the first mobile device ownership.

The proposed groups of statements showed significant internal consistency parameters, which allowed their further use as independent scales (see Table 1).

Table 1 Descriptive statistics and reliability coefficients for scales measuring attitudes toward mobile learning and perceived students' MDU in school

Scales	Number of items	Scale maximum score	Reliability		Descriptive statistics	
			α	r	M	SD
Perceived easy to use (PE)	5	35	0.90	0.89	18.73	3.93
Perceived usefulness (PU)	5	35	0.80	0.80	23.03	5.08
Attitudes (A)	5	35	0.83	0.70	21.14	6.31
Involvement (I)	6	30	0.84	0.85	17.86	4.73
Distraction (D)	7	35	0.90	0.86	22.01	6.89
Communication (C)	3	15	0.72	0.66	9.36	2.75

3.3 Data Analysis

The total sample of teachers was divided into five groups based on their subject field: primary school education (55 teachers, average age 44.7, and 100% women), STEM disciplines including Science, Technology, Engineering, and Math (96 teachers, average age 45.9, and 89% women), social sciences (52 teachers, average age 44.8, and 79% women), humanities (111 teachers, average age 45.0, and 97% women), and other supporting school staff (44 participants, average age 43.3, and 88% women). The main goal was to examine and compare teachers' perceptions of MDU and their experiences using mobile devices, taking into account their subject area.

For this purpose, descriptive and comparative analyses were conducted, using the Kruskal–Wallis test to compare data from multiple groups. Furthermore, structural equation modeling was employed to investigate the relationship between teachers' attitudes toward mobile technology and their opinions on students' MDU in the school environment. Finally, the correlation structure of all the variables was analyzed using Spearman's rank correlation coefficient.

4 Results

At the first step of the analysis, we reviewed the characteristics of teachers' experience in the MDU (see Fig. 1). The results of the comparative analysis showed a lack of significant differences in the indicators of teachers' MDU experience. Therefore, teachers, regardless of subject field, are more likely to have MDU experience in teaching ($\chi^2 = 5.47$, $p = 0.243$; $\varepsilon^2 = 0.0015$). The mean age of the first mobile device ownership also did not differ in the teachers' groups and was in the range between 22 and 27 years ($\chi^2 = 4.39$, $p = 0.356$; $\varepsilon^2 = 0.0012$).

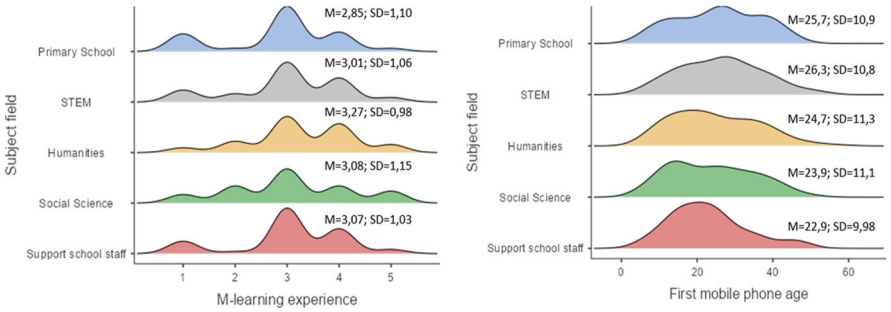

Fig. 1 Distributions of characteristics of the teachers' experience with mobile technologies

Table 2 provides descriptive statistics of teachers' assessment of the frequency of manifestations of various forms of students' MDU in school. Results point out that teachers are more likely to perceive the use of mobile devices by schoolchildren as distracting from the learning process. According to teachers, schoolchildren most often use mobile devices in school for entertainment and communication, far from an educational context. Participants in the study noted frequent use of mobile devices by schoolchildren for computer games, watching entertainment videos, and listening to music. The use of smartphones for educational purposes, in their understanding, is associated with capturing learning material on the camera and using mobile device functions related to calculations, translations, dates, etc. Among the most pronounced ways schoolchildren use mobile devices, teachers also noted communicative actions, including active discussion of distracting from learning topics, as well as receiving and sending messages. The least pronounced forms of mobile device use are for memorizing facts necessary for completing learning tasks, as well as for arguing student position in the process of group discussions of learning tasks or educational games. Teachers also rarely detect schoolchildren's desire to use mobile devices to overcome boredom or irritation caused by what is happening in the classroom.

There were revealed significant differences in almost all the variables detected teachers view on the students' patterns of MDU. Therefore, teachers whose subject field connected to primary school are least likely to notice children' MDU in school. Groups of teachers working with older children are more similar to each other in their assessments of students' MDU. However, social science teachers tend to highlight to the greatest extent such patterns of students' MDU as computer games playing, communication on irrelevant topics, websites surfing, discussing what is happening in class with other students, and other inappropriate learning behavior. Teachers from STEM disciplines field more often note the use of the functionality of mobile devices by students for solving learning tasks. Teachers whose disciplines attended to humanities field are more likely to notice students' MDU for searching relevant information connected with lesson topic.

In order to test the assumption that teachers' ideas about the forms of mobile devices use by schoolchildren are mediated by their own attitudes toward mobile

Table 2 Means and SD of teachers' perception of students' MDU in school

It happened that in school, students used mobile devices to:	Means (standard deviations) min = 1; max = 5					
	Total sample	Teachers' groups				
		1	2	3	4	5
Play computer games (D6) —$\chi^2 = 22.45$; $p < 0.001$; $\varepsilon^2 = 0.06$	3.73 (1.27)	3.18 (1.33)	3.82 (1.29)	3.79 (1.26)	4.27 (0.80)	3.44 (1.35)
Take a photo of what is written on the board or the visual materials provided during the lesson (I4) —$\chi^2 = 38.52$; $p < 0.001$; $\varepsilon^2 = 0.11$	3.61 (1.05)	2.93 (1.25)	3.71 (0.97)	3.74 (0.92)	3.9 (0.93)	3.6 (1.05)
Watch entertaining videos or listen to music (D7) —$\chi^2 = 7.93$; $p = 0.09$; $\varepsilon^2 = 0.02$	3.56 (1.20)	3.11 (1.38)	3.63 (1.16)	3.59 (1.19)	3.87 (0.86)	3.53 (1.28)
Discuss something unrelated to the learning process with other people (C3) —$\chi^2 = 24.23$; $p < 0.001$; $\varepsilon^2 = 0.07$	3.31 (1.15)	2.64 (1.22)	3.42 (1.12)	3.3 (1.12)	3.71 (1.05)	3.47 (1.01)
Keep in touch with someone through messaging (D4) —$\chi^2 = 18.36$; $p = 0.001$; $\varepsilon^2 = 0.05$	3.21 (1.14)	2.58 (1.23)	3.22 (1.12)	3.36 (1.11)	3.48 (0.96)	3.26 (1.11)
Complete learning tasks (using calculator, stopwatch, calendar, translator, etc.) (I3)—$\chi^2 = 38.52$; $p < 0.001$; $\varepsilon^2 = 0.11$	3.17 (1.09)	2.25 (1.14)	3.41 (1.03)	3.29 (0.92)	3.31 (1.11)	3.35 (0.95)
Find information related to the subject matter of the	3.16 (1.02)	2.38 (1.05)	3.22 (0.99)	3.42 (0.87	3.25 (1.06)	3.26 (0.95)

(continued)

Table 2 (continued)

It happened that in school, students used mobile devices to:	Means (standard deviations) min = 1; max = 5					
	Total sample	Teachers' groups				
		1	2	3	4	5
class (I1) —$\chi^2 = 36.99$; $p < 0.001$; $\varepsilon^2 = 0.10$						
Surf websites, wasting time (D1) —$\chi^2 = 22.26$; $p < 0.001$; $\varepsilon^2 = 0.06$	3.12 (1.3)	2.42 (1.34)	3.08 (1.28)	3.19 (1.23)	3.6 (1.14)	3.33 (1.29)
Report important events happening during class or breaks to someone (C2) —$\chi^2 = 25.80$; $p < 0.001$; $\varepsilon^2 = 0.07$	3.07 (1.11)	2.35 (1.11)	3.21 (1.14)	3.22 (1.05)	3.23 (1.00)	3.09 (0.97)
Search for ways to solve school assignments (I5) —$\chi^2 = 46.22$; $p < 0.001$; $\varepsilon^2 = 0.13$	2.99 (1.13)	1.98 (1.08)	3.2 (0.99)	3.14 (1.07)	3.35 (1.03)	3.02 (1.10)
Discuss what is happening in class with other students (C1) —$\chi^2 = 33.59$; $p < 0.001$; $\varepsilon^2 = 0.09$	2.96 (1.18)	2.18 (1.11)	3.13 (1.13)	3.04 (1.21)	3.42 (0.92)	2.81 (1.18)
Not miss important messages in the news feed of social networks (D3) —$\chi^2 = 46.37$; $p < 0.001$; $\varepsilon^2 = 0.13$	2.94 (1.24)	1.87 (1.12)	3.15 (1.17)	3.04 (1.21)	3.35 (1.14)	3.09 (1.04)
Copy from other students' homework or from the Internet (D5) —$\chi^2 = 74.19$; $p < 0.001$; $\varepsilon^2 = 0.21$	2.8 (1.28)	1.53 (0.94)	2.93 (1.16)	2.92 (1.15)	3.6 (1.16)	2.91 (1.27)

(continued)

Table 2 (continued)

It happened that in school, students used mobile devices to:	Means (standard deviations) min = 1; max = 5					
	Total sample	Teachers' groups				
		1	2	3	4	5
Overcome feelings of boredom or annoyance caused by what is happening in class (D2) —$\chi^2 = 27.46$; $p < 0.001$; $\varepsilon^2 = 0.08$	2.72 (1.27)	1.96 (1.28)	2.71 (1.22)	2.78 (1.23)	3.17 (1.12)	3.00 (1.25)
Recall certain facts needed to complete learning tasks (I2) —$\chi^2 = 34.93$; $p < 0.001$; $\varepsilon^2 = 0.10$	2.71 (1.01)	2.00 (0.94)	2.95 (0.94)	2.8 (0.98)	2.79 (1.04)	2.74 (0.93)
Argue one's position during group discussions of learning tasks or educational games (I6)—$\chi^2 = 24.13$; $p < 0.001$; $\varepsilon^2 = 0.07$	2.21 (0.99)	1.67 (0.94)	2.25 (0.95)	2.23 (1.03)	2.46 (0.98)	2.42 (0.88)

Note: 1—primary school; 2—STEM; 3—humanities; 4—social science; and 5—support school staff

technologies, structural equation modeling was carried out. Within the framework of the initially constructed assumption, the perceived usefulness and perceived ease of using mobile technologies in teaching determine the focus of perception on constructive forms of using mobile devices by schoolchildren.

The structural equation modeling conducted provided empirical verification of the model of mediation between teachers' perceptions of students' MDU in school and their own attitudes toward mobile technology (Fig. 2). The goodness-of-fit criteria showed acceptable values to support the model [$\chi 2 = 684.95$; $df = 413$; $p < 0.001$; SRMR = 0.058; CFI = 0.95; RMSEA = 0.044 (90% CI 0.038–0.05); p(RMSEA < 0.05) = 0.954]. The regression estimates were significantly related to all latent variables, while the covariances were significantly related to negative attitudes toward mobile technology being associated with perceptions of using mobile devices as a distraction from learning ($p = 0.01$). However, the associations between perceived usefulness ($p = 0.67$) and communication ($p = 0.75$) were not significant. Conversely, significant covariances were found between perceived usefulness and teachers' perceptions of constructive use of mobile technology by

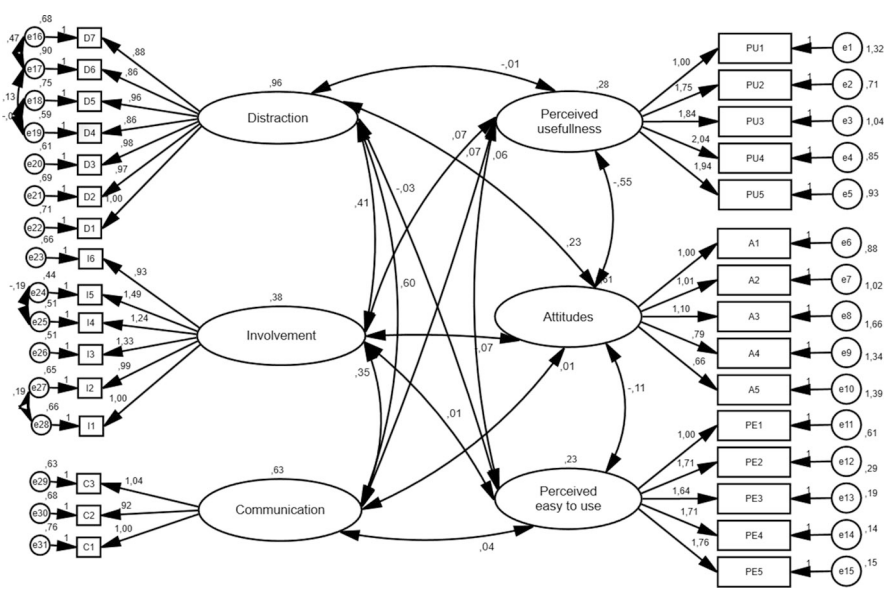

Fig. 2 Model of mediation of teachers' ideas about the students' MDU in school by their own attitudes toward mobile technologies

students ($p = 0.02$) and using mobile technology for communication purposes ($p = 0.04$), whereas no significant covariances were observed for the perceptions of destructive MDU among students ($p = 0.68$).

It is worth noting that the perceived ease of using mobile technology in teaching had practically no influence on teachers' ideas about students' MDU in terms of learning involvement ($p = 0.94$), distraction from learning ($p = 0.16$), or communication ($p = 0.30$). Moreover, inverse relationships were found between negative attitudes and perceived usefulness ($p < 0.001$) as well as perceived ease of use ($p = 0.05$), while the latter two parameters had positive covariances ($p = 0.05$). All the teacher ratings for patterns of students' MDU had significantly positive covariances. In fact, some forms of students' MDU, categorized under different patterns, were strongly related. For instance, MDU for cheating in academic work (D5) was associated at a significance level of less than 0.001 with photographing class materials (I4), while completing assignments with mobile technology (I3) was related to documenting significant school events (C2).

The next step of the analysis was to reveal relationships among characteristics of the teachers' experience with mobile technologies, perceived patterns of students' MDU, and attitudes toward mobile technologies (see Table 3). The results disclose the specifics of association between teachers' attitudes toward mobile technologies and their experience in MDU.

From Table 3, it has been clear that an earlier age of teacher's familiarity with mobile technologies associated with perceived patterns of MDU by students for learning purposes ($r = -0.14$; $p = 0.01$). At the same time, the earlier a teacher had a

Table 3 Correlation coefficients between teachers' attitudes toward MDU and characteristics of the teachers' experience with mobile technologies

Attitudes toward MDU	Teachers' experience with mobile technologies			
	First mobile phone ownership age		M-learning experience	
Distraction	−0.03		−0.02	
Involvement	−0.14	*	0.17	**
Communication	−0.09		0.09	
Perceived ease to use	−0.33	***	0.34	***
Perceived usefulness	−0.15	**	0.43	***
Negative attitudes	0.04		−0.31	***

Note: ** $p < 0.01$, *** $p < 0.001$

mobile device, the more useful he considers mobile technologies ($r = -0.15$; $p = 0.006$) and the easier it is for her or him to use them ($r = -0.33$; $p < 0.001$). Even closer connections are found between the experience of mobile learning and ideas about the constructive nature of students' MDU in school ($r = 0.17$; $p = 0.001$), perceived easy to use ($r = 0.34$; $p < 0.001$), and perceived usefulness of mobile technologies ($r = 0.43$; $p < 0.001$). In other words, the expression of ideas about MDU by schoolchildren for learning purposes is manifested in teachers who themselves have experience in using mobile technologies in education.

5 Discussion

The results of the study shed light on the complex interplay between teachers' attitudes toward mobile technologies, their experiences with MDU, and their perceptions toward students' MDU in educational settings. This study has provided valuable insights into how teachers view students' usage of mobile devices and how their own personal experiences and attitudes toward mobile technologies might influence their perception.

First, our findings indicate that teachers largely view students' MDU in school as distracting from the learning process. In their representation, students often engage in entertainment, communication, and activities unrelated to their studies when using their mobile devices at school. This is consistent with the results of previous studies, indicating a rather cautious attitude of teachers to the possibilities of mobile technologies in education and ideas about their possible negative impact on the nature of communication between children and teachers [49–51]. Teachers turn out to be active supporters of the ban on the use of mobile technologies in school. Moreover, according to teachers, the introduction of such a ban contributes to better concentration of children in the classroom and more productive practices in the educational process, although this is not supported by objective data [52]. This perception, however, is not uniform across different teacher groups; primary school teachers, for instance, are less likely to notice students' MDU in the classroom than those who

teach older students. This could be due to the different age groups and maturity levels of the students or the varying teaching styles and classroom management strategies employed by different teachers.

We also found significant differences in teachers' perceptions of the patterns of MDU by students based on their subject field. Social science teachers were more likely to observe students using mobile devices for non-academic purposes, whereas STEM teachers noted the use of mobile devices for solving learning tasks. According to the Gorghiu et al.'s study conducted with Romanian and Lithuanian science teachers, mobile teaching and learning was perceived as highly useful. The teachers recognized the potential of mobile devices to enhance student engagement, increase access to information and resources, and facilitate collaborative learning. Furthermore, the study revealed that teachers believed that mobile devices could be used effectively in both formal and informal learning settings [53]. These results suggest that the subject area taught by a teacher may influence their perception of students' MDU, as some disciplines may be more amenable to integrating mobile technology into the learning process than others.

Interestingly, our analysis revealed a relationship between teachers' attitudes toward mobile technology and their perception of students' MDU. Teachers who had more positive attitudes toward mobile technology were more likely to recognize the constructive use of mobile devices by students. These findings serve as one more confirmation of the TAM. The TAM attempts to explain factors that account for acceptance and adoption of digital and mobile technologies in education, including perceived usefulness, ease of use, and attitudes as powerful influences for comparison with other models of technology integration [20, 54, 55]. Thus, the TAM plays a crucial role in the adoption and success of educational technology. This suggests that a teacher's own beliefs and experiences with mobile technology may shape their understanding and expectations of how such devices can be used in the classroom.

Furthermore, we found an association between teachers' own experiences with mobile technology and their perception of students' MDU for learning. Early familiarity with mobile devices and experience in mobile learning correlated with stronger beliefs toward the constructive nature of students' MDU. According to earlier research, the findings we have just presented seem to be consistent [32, 56–59]. The O'Bannon and Thomas's study involving 160 teachers from different schools in Cyprus shows that older teachers hold more negative attitudes toward mobile phone use in the classroom compared to younger teachers [32]. In addition, teachers who use mobile phones in their personal lives were more likely to support their use in the classroom. Another study conducted in the USA found that older teachers had more negative beliefs about the social effects of mobile devices compared to younger teachers [56]. Tondeur, Braak, Ertmer, and Ottenbreit-Leftwhich [58] have shown that teachers who have had rich and diverse experiences with technology have been found to be more likely to have a more positive view of students' MDU in school and to embrace digital practices in their teaching curriculum. Similarly, S.W. Campbell revealed that younger students have a more positive attitude toward using mobile phones in college classrooms and were more tolerant of distracting forms of technology use compared to older students [60]. This suggests

that age and technology integration level can have an impact on perceptions of technology use in educational settings. We can say that exposure to mobile technology and personal experience with mobile learning may enable teachers to appreciate its potential benefits in the educational context.

This study highlights the importance of understanding teachers' attitudes and experiences with mobile technology to better comprehend their perception of students' MDU in school settings. Addressing negative attitudes and providing opportunities for teachers to gain experience with mobile learning could foster a more positive perception of students' MDU and promote the integration of mobile technology in education.

6 Conclusion

This study has provided insights into teachers' perceptions of students' MDU and their experiences with using mobile devices in teaching across different subject areas. The results revealed that teachers generally perceive students' MDU as a distraction from the learning process, although some constructive uses were also identified. Notable differences in teachers' assessments of students' MDU were found based on the subject area they taught. The study also highlighted the importance of teachers' attitudes toward mobile technology as a factor that influences their perceptions of students' MDU in school. The structural equation modeling revealed that teachers with positive attitudes toward mobile technology, particularly in terms of perceived usefulness, were more likely to perceive constructive use of mobile devices by students. Teachers' own experiences with mobile technology significantly influenced their attitudes toward mobile technology and their perceptions of students' MDU patterns.

Despite the valuable insights gained from this study, there are some limitations that should be acknowledged. The sample size was relatively small and included a majority of female teachers, which may have impacted the generalizability of the results. Moreover, the study relied on self-reported data from teachers, which may be subject to recall bias and social desirability bias. In addition, the cross-sectional design of the study does not allow for causal inferences to be made. Longitudinal or experimental research designs could provide more robust insights into the causal relationships between teachers' attitudes, experiences with mobile technology, and their perceptions of students' MDU. However, recognizing the importance of teachers' attitudes and experiences with mobile technology is crucial for the effective integration of these devices into the learning process and for enhancing the quality of education in the digital age. Based on the results of the study, the following recommendations can be made:

1. Teachers need to be trained on the effective use of mobile learning tools and techniques to improve their attitudes toward mobile technology. Teachers who have more experience in mobile learning and those who had earlier personal

experience with mobile devices were found to be more positive about mobile learning and its usefulness.
2. Strategies that encourage constructive use of mobile devices in the classroom, such as the use of mobile devices for problem-solving activities in STEM subjects, need to be developed and implemented. Teachers' attitudes toward mobile technologies were found to be associated with their perceptions of the usefulness of mobile devices in learning, which means that positive attitudes toward mobile technology may result in a focus on constructive forms of using mobile devices by students.
3. A better understanding of the patterns of students' mobile device use for learning is essential. Teachers need to focus on the positive aspects of mobile technology use for learning and develop ways to manage and reduce potential distractions. Encouraging students to use mobile devices for constructive learning purposes may improve their motivation and engagement in the learning process and thus improve their academic performance.
4. Further research is needed to explore the relationship between teachers' attitudes toward mobile technology and their experiences in mobile learning. Understanding this relationship can help inform future strategies for the effective integration of mobile learning into the classroom.

Acknowledgements This work has been supported by the grants the Russian Science Foundation, RSF 23-28-00412, https://rscf.ru/project/23-28-00412/.

References

1. Calderón-Garrido, D., Ramos-Pardo, F.J., Suárez-Guerrero, C.: The use of mobile phones in classrooms: a systematic review. Int. J. Emerg. Technol. Learn. **17**(06), 194–210 (2022). https://doi.org/10.3991/ijet.v17i06.29181
2. Lepp, A., Barkley, J.E., Karpinski, A.C.: The relationship between cell phone use, academic performance, anxiety, and satisfaction with life in college students. Comput. Hum. Behav. **31**, 343–350 (2014)
3. Jin, W., Sabio, C.J.: Potential use of mobile devices in selected public senior high schools in the city of Manila Philippines. Int. J. Learn. Teach. Educ. Res. **17**(4), 102–114 (2018). https://doi.org/10.26803/ijlter.17.4.7
4. Chau, K., Bhattacherjee, A., Senapati, A., Guillemin, F., Chau, N.: Association between screen time and cumulating school, behavior, and mental health difficulties in early adolescents: a population-based study. Psychiatry Res. **310**, 114467 (2022). https://doi.org/10.1016/j.psychres.2022.114467
5. Galyuk, N.A., Odiyak, E.V.: Igrofikacija kak psihologicheskij instrument razvitija markerov chuvstva vzroslosti u podrostkov = Gamification as a psychological tool for the development of markers of the feeling of adulthood in adolescents. J. Pedagog. Innov. **2**(66), 47–56 (2022). https://doi.org/10.15293/1812-9463.2202.06. (in Russia)
6. Georgieva-Tsaneva, G.N., Serbezova, I.: Using serious games and video materials in clinical training in nursing and midwifery education. Int. J. Emerg. Technol. Learn. **16**(16), 231–241 (2021). https://doi.org/10.3991/ijet.v16i16.23455

7. Wang, A.I., Tahir, R.: The effect of using Kahoot! for learning–a literature review. Comput. Educ. **149**, 103818 (2020). https://doi.org/10.1016/j.compedu.2020.103818
8. Polivanova, K.N., Korolyova, D.O.: Social'nye seti kak novaja praktika razvitija gorodskih podrostkov = Social networks as new practice of city teenagers' development. RFBR Inf. Bull. **1**, 173–181 (2016)
9. Broydo, V.L., Ilyina, O.P.: M-Learning v sisteme vysshego professional'nogo obrazovanija = M-Learning in higher education landscape. In: Proceedings Sci. Conf. Information Technologies in Business, SPb, pp. 150–158. Infoda Publ (2013)
10. Callow, J., Orlando, J.: Enabling exemplary teaching: a framework of student engagement for students from low socio-economic backgrounds with implications for technology and literacy practices. Pedagog. Int. J. **10**(4), 349–371 (2015). https://doi.org/10.1080/1554480X.2015.1066678
11. Deng, Z., Cheng, Z., Ferreira, P., Pavlou, P.: From smart phones to smart students: distraction versus learning with mobile devices in the classroom. Fox Sch. Bus. Res. Paper Forthcoming. (2022). https://doi.org/10.2139/ssrn.4028845
12. Borozdina, N.: Mediascope CROSS WEB. All Russia. Population aged 12 years and above. https://mediascope.net/upload/iblock/3d8/qrlhud7t7dxyzw1rhtzxg3rwk8deg7uk/2022_%D0%98%D0%9D%D0%A2%D0%95%D0%A0%D0%9D%D0%95%D0%A2.pdf. Last accessed 2023/01/29
13. Oxford University Press: Smartphone, n. Retrieved August 24, 2019 from: http://www.oed.com/view/Entry/381083?redirectedFrom=smartphone#eid (2018)
14. Perić, N.: The impact and implementation of digital media on children's upbringing and education. In: Bulatović, L. (ed.) CRC in Digital Spaces – Chalenges and Expectations, pp. 143–164. FMK Publ, Beograd (2017)
15. Schuck, S., Kearney, M., Burden, K.: Exploring mobile learning in the Third Space. Technol. Pedagog. Educ. **26**, 121–137 (2017)
16. Cakmak, F.: Mobile learning and mobile assisted language learning in focus. Lang. Technol. **1**(1), 30–48 (2019)
17. Yu, D., Yan, Z., He, X.: Capturing knowledge trajectories of mobile learning research: a main path analysis. Educ. Inf. Technol. **27**, 7257–7280 (2022). https://doi.org/10.1007/s10639-021-10869-6
18. Hwang, G.J., Chang, H.F.: A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. Comput. Educ. **56**(4), 1023–1031 (2011). https://doi.org/10.1016/j.compedu.2010.12.002
19. Kärchner, H., Trautner, M., Willeke, S., Schwinger, M.: How handheld use is connected to learning-related factors and academic achievement: meta-analysis and research synthesis. Comput. Educ. Open. **3**, 100116 (2022). https://doi.org/10.1016/j.caeo.2022.100116
20. Nikou, S.A., Economides, A.A.: Mobile-based assessment: a literature review of publications in major referred journals from 2009 to 2018. Comput. Educ. **125**, 101–119 (2018). https://doi.org/10.1016/j.compedu.2018.06.006
21. Biber, S.K., Biber, M., Erbay, H.N.: Teachers' perceptions on technology-assisted mathematics teaching and the interactive activities. Educ. Inf. Technol. **27**, 6913–6945 (2022). https://doi.org/10.1007/s10639-022-10898-9
22. Kacetl, J., Klimova, B.: Use of smartphone applications in English language learning—a challenge for foreign language education. Educ. Sci. **9**(3), 179 (2019). https://doi.org/10.3390/educsci9030179
23. Bryant, B.R., Ok, M.W., Kang, E.Y., Kim, M.K., Lang, R., Bryant, D.P., Pfannestiel, K.: Performance of fourth-grade students with learning disabilities on multiplication facts comparing teacher-mediated and technology-mediated interventions: a preliminary investigation. J. Behav. Educ. **24**, 255–272 (2015)
24. Chelkowski, L., Yan, Z., Asaro-Saddler, K.: The use of mobile devices with students with disabilities: a literature review. Prev. Sch. Fail. Altern. Educ. Child. Youth. **63**(3), 277–295 (2019). https://doi.org/10.1080/1045988X.2019.1591336

25. Gulati, S.: Technology-enhanced learning in developing nations: a review. Int. Rev. Res. Open Dist. Learn. **9**(1), 1–16 (2008). https://doi.org/10.19173/irrodl.v9i1.477
26. Alberta Education: Bring your own device: a guide for schools. Alberta Education. http://education.alberta.ca/admin/technology/research.aspx (2012). Last accessed 2023/01/14
27. White, J.: The opinions and perceptions of K1–3 parents in relation to BYOD implementation in Japanese kindergartens. Int. J. TESOL Educ. **2**(1), 1–22 (2022). https://doi.org/10.54855/ijte2202011
28. Song, Y.: "Bring Your Own Device (BYOD)" for seamless science inquiry in a primary school. Comput. Educ. **74**, 50–60 (2014). https://doi.org/10.1016/j.compedu.2014.01.005
29. Dontre, A.J.: The influence of technology on academic distraction: a review. Hum. Behav. Emerging Technol. **3**, 379–390 (2021). https://doi.org/10.1002/hbe2.229390DONTRE
30. McCoy, B.R.: Digital distractions in the classroom phase II: student classroom use of digital devices for non-class related purposes. J. Media Educ. **7**(1), 5–32 (2016)
31. Sullivan, A., Johnson, B., Owens, L., Conway, R.: Punish them or engage them? Teachers' views of unproductive student behaviours in the classroom. AJTE Aust. J. Teach. Educ. **39** (2014)
32. O'Bannon, B., Thomas, K.: Teacher perceptions of using mobile phones in the classroom: Age matters! Comput. Educ., 15–25 (2014)
33. Gao, Q., Yan, Z., Wei, C., Liang, Y., Mo, L.: Three different roles, five different aspects: differences and similarities in viewing school mobile phone policies among teachers, parents, and students. Comput. Educ. **106**, 13–25 (2017). https://doi.org/10.1016/j.compedu.2016.11.007
34. Meschede, N., Fiebranz, A., Möller, K., Steffensky, M.: Teachers' professional vision, pedagogical content knowledge and beliefs: on its relation and differences between pre-service and in-service teachers. Teach. Teach. Educ. **66**, 158–170 (2017). https://doi.org/10.1016/j.tate.2017.04.010
35. Domingo, M.G., Gargante, A.B.: Exploring the use of educational technology in primary education: teachers' perception of mobile technology learning impacts and applications' use in the classroom. Comput. Hum. Behav. **56**, 21–28 (2016)
36. Bjornsen, C.A., Archer, K.J.: Relations between college students' cell phone use during class and grades. Scholarsh. Teach. Learn. Psychol. **1**(4), 326–336 (2015). https://doi.org/10.1037/stl0000045
37. Mohammadi, M., Sarvestani, M.S., Nouroozi, S.: Mobile Phone use in education and learning by faculty members of technical-engineering groups: concurrent mixed methods design. Front. Educ. **5**, 16 (2020). https://doi.org/10.3389/feduc.2020.00016
38. Ward, A.F., Duke, K., Gneezy, A., Bos, M.W.: Brain drain: The mere presence of one's own smartphone reduces available cognitive capacity. J. Assoc. Consum. Res. **2**(2), 140–154 (2017). https://doi.org/10.1086/691462
39. Gonca, K.C.: How mobile devices affect students according to teachers' beliefs. J. Int. Educ. Res.—Fourth QuPrensarter. **11**(4), 217 (2015)
40. Dinsmore, B.: Contested affordances: teachers and students negotiating the classroom integration of mobile technology. Inf. Commun. Soc. **22**, 664–677 (2019). https://doi.org/10.1080/1369118X.2019.1568518
41. Löfving, C., Godhe, A.-L., Lundin, J.: Teachers' dilemmatic spaces connected to students' net-based out-of-school activities. Int. J. Inf. Learn. Technol. **40**(1), 62–72 (2023). https://doi.org/10.1108/IJILT-03-2022-0042
42. Palfrey, J., Gasser. U.: Born Digital: Understanding the First Generation of Digital Natives. Basic Books, New York, (2008)
43. Fitrianingsih, W.S., Lestari, Y.B.: Teachers' adaptation to post-COVID-19 English language teaching and learning situation. In: Proceedings of the 3rd Annual Conference of Education and Social Sciences (ACCESS 2021), pp. 67–72. Atlantis Press (2022). https://doi.org/10.2991/978-2-494069-21-3_9

44. Dweikat, K.A., Hasan, H.A.: Attitudes of EFL teachers towards using smartphones in the classroom during COVID-19 Pandemic. Univ. J. Educ. Res. **9**(1), 116–128 (2021). https://doi.org/10.13189/ujer.2021.090113
45. Eryilmaz, S.: Compare teachers and students attitudes according to mobile educational applications. TOJET Turk. Online J. Educ. Technol. 20 (2021). Available online: https://www.proquest.com/scholarly-journals/compare-teachers-students-attitudes-according/docview/2478760481/se-2?accountid=48272. Accessed on 30 June 2022
46. Nazari, M., Xodabande, I.: L2 educators' mobile-related beliefs and practices: contributions of a professional development initiative. Comput. Assist. Lang. Learn., 1–30 (2020). https://doi.org/10.1080/09588221.2020.1799825
47. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance. MIS Q. **13**(3), 319–339 (1989)
48. Turner, M., Kitchenham, B., Brereton, P., Charters, S., Budgen, D.: Does the technology acceptance model predict actual use? A systematic literature review. Inf. Softw. Technol. **52**(5), 463–479 (2010). https://doi.org/10.1016/j.infsof.2009.11.005
49. Shityakova, N.P., Verkhovykh, I.V., Zabrodina, I.V.: The attitude of teachers to the opportunities and risks of spiritual and moral education in the context of digitalization. Perspektivy nauki i obrazovania – Perspect. Sci. Educ. **48**(6), 446–458 (2020). https://doi.org/10.32744/pse.2020.6.34
50. Van Praag, B., Sánchez, H.S.: Mobile technology in second language classrooms: insights into its uses, pedagogical implications, and teacher beliefs. ReCALL. **27**(3), 288–303 (2015). https://doi.org/10.1017/S0958344015000075
51. Yaron, A., Vered, E.-M.: Learning in the smartphone era: Viewpoints and perceptions on both sides of the lectern. Educ. Inf. Technol., 1–10 (2019). https://doi-org.ezproxy.liberty.edu/10.1177/0098628318816141
52. Beneito, P., Vicente-Chirivella, Ó.: Banning mobile phones in schools: evidence from regional-level policies in Spain. Appl. Econ. Anal. **30**(90), 153–175 (2022). https://doi.org/10.1108/AEA-05-2021-0112
53. Gorghiu, G., Pribeanu, C., Lamanauskas, V., Slekiene, V.: Usefulness of mobile teaching and learning as perceived by romanian and lithuanian science teachers. Probl. Educ. 21st Century. **78**, 719–733 (2020)
54. Ateş, H., Yilmaz, R.M.: A comprehensive model explaining teachers' intentions to use mobile-based assessment. Interact. Learn. Environ., 1 (2023). https://doi.org/10.1080/10494820.2023.2194928
55. Teo, T., Milutinovic, V.: Modelling the intention to use technology for teaching mathematics among pre-service teachers in Serbia. Aust. J. Educ. Technol. **31**(4), 363–380 (2015). https://doi.org/10.14742/ajet.1668
56. Cumaoğlu, G.K.: How mobile devices affect students according to teachers' beliefs. J. Int. Educ. Res. **11**(4), 217–229 (2015)
57. Makoe, M.: Teachers as learners: concerns and perceptions about using cell phones in South African rural communities. In: Berge, Z.L., Muilenburg, L.Y. (eds.) Handbook of Mobile Learning, pp. 592–602. Routledge, New York (2013)
58. Tondeur, J., Braak, J., Ertmer, P., Ottenbreit-Leftwich, A.: Understanding the relationship between teachers' pedagogical beliefs and technology use in education: a systematic review of qualitative evidence. Educ. Technol. Res. Dev. **65**(3), 555–575 (2017)
59. Yusri, I.K., Goodwin, R., Mooneya, C.: Teachers and mobile learning perception: towards a conceptual model of mobile learning for training. Procedia Soc. Behav. Sci. **176**, 425–430 (2015). https://doi.org/10.1016/j.sbspro.2015.01.492
60. Campbell, S.W.: Perceptions of mobile phones in college classrooms: ringing, cheating, and classroom policies. Commun. Educ. **55**(3), 280–294 (2006). https://doi.org/10.1080/03634520600748573

The Impact of Health Opportunities on Social Mood

Anna V. Chizhik

Abstract Large cities are complex urban spaces in which hundreds of thousands of people live and build their socio-economic relations. Megacities are always in the spotlight, because they have a significant impact on the dynamics of social well-being throughout the country. In recent decades, medium and large cities in developing countries have experienced rapid population growth. The researchers note that the governance of cities in this case turned out to be associated with a chaotic scenario, especially in terms of public health management. Health opportunities play a crucial role in shaping social mood. It is widely accepted that good health is the fundamental aspect of human wellbeing, and access to healthcare services is a critical determinant of health status. Recent studies show that if individuals have access to quality healthcare services and are healthier, then they are more productive, engaged, and optimistic. This, in turn, can create a positive mood in society, leading to greater social harmony, economic prosperity, and a better quality of life. The study described in this chapter analyzes the existence of patterns between the level of aggressiveness or positivity of discourse in district online communities and the availability of medical care and accessible sports facilities in those districts.

Keywords Emotional mapping · Sentiment analysis · Text analysis · Data intelligence · Social mood · Social well-being

1 Introduction

Health opportunities are an important factor influencing society. Their effect can be compared with a multiplier in macroeconomics, which is often called the ripple effect. It is obvious that when individuals have access to healthcare, nutrition, sport, and other health-promoting resources, they are more likely to feel physical and mental well-being. As a result, if health opportunities are available to people, then

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_27

society is made up mainly of healthy people who can work, participate in community activities, and contribute to the local economy. This can lead to greater overall social well-being, which reflects in the way of inhabitants life and leads to a more positive outlook on life and better social interactions with others. Health opportunities are the characteristics that are always bounded to a particular geographic locations, such as a city, a region, or its administrative districts.

Taking a city as the unit of such analysis, it is possible to characterize it. A city is a complex environment with specific geographic coordinates and a multitude of characteristics directly dependent on them. These characteristics include the physical landscape, social structures, economic systems, cultural traditions, and technological infrastructures. Together, these elements create a unique urban ecosystem that shapes the way people live, work, and interact with one another. Understanding and managing this ecosystem is a key challenge that helps to balance economic sustainability, social welfare, and public safety. Understanding this multidimensional space cannot be reduced to an analysis of spatial reality, because the socio-cultural context is always important. Thus, a city is the phenomenon that captures and reflects the subjective citizen's perception of the urban environment. Therefore, a city as an object of study is not only a human habitat, but also the space of constant group and individual reactions of residents. People create their images of city when they are inside the daily route, that is, in the context of everyday practices, social contacts, and emotional states. Consequently, our hypothesis is that there is the direct bound between social mood and health opportunities.

In this case, the presence of well-defined coordinates for any event occurring within the urban environment suggests that the social and emotional well-being of city residents can be explored using mapping methods. Then, another important hypothesis arises: we can search social media for a digital trace of individual and group emotions of citizens. If the geographical reference of commentators on social media is fixed, then it becomes possible to link data obtained from social networks and statistics describing specific city locations (such as the number of schools, kindergartens, hospitals, shops, etc.).

In this research, we studied the possibilities of analyzing social media discussion content [1–3] in order to detect moods of individuals and then link them to geolocation data. The further goal was to link also the statistical data describing the availability of medical care (hospitals and clinics) and opportunities for sports (public sports fields) to the map. The district was taken as a unit of the urban landscape.

2 Background

There are several successful examples of using automatic analysis of data received from social networks. For example, the graph neural network has been used to investigate the impact of virtual social communication on user preferences [4–6]. Referring to natural language processing, it should also be noted that works

devoted to topic modeling and sentiment analysis are of great importance. For example, convolutional neural network was used to create the language model for analyzing Twitter text data [7]. Sentiment analysis using neural networks has become the subject of several large studies on Twitter, Facebook, and Weibo [8].

Regarding the use of maps as a scientific method, it appeared in the interdisciplinary study framework quite a long time ago. In the middle of the nineteenth century, the British doctor John Snow resorted to the method of social mapping, finding out the reasons for the spread of cholera in London. Later, the British sociologist Charles Booth housed London according to the principle of population security [8]. Then, this method was developed by Chicago school sociologists Robert Park and Ernst Burges (20–30 years of the twentieth century). Most research works on this topic highlight the idea that urban society, in its growth and organization, is the combination of directions and events that can be mapped, that is a good for allocation of the main trend (justified by some geographical patterns) which explains the sequence of seemingly unrelated events. Currently, social mapping is the group of methods involves both spatial and graphical features, united by one object of study that is social reality [9]. In addition to fixing the features of the territorial organization of various objects, social mapping makes it possible to streamline and visualize complex and numerous social statistics data with reference to space [10, 11].

There is no clear distinction between the methods; however, socio-statistical, socio-anthropological, project-based, and social-network approaches to mapping can be separated. First of all, attention is drawn to the socio-anthropological approach, which provides for the analysis of the territory with the focus on the anthropocentric content and the subjective component of the spatial dimension [12]. The social-network approach perfectly complements this basis, because it allows supplementing the statistical data on urban livelihoods with data from social media (in both cases fixing bounds to the territory) [9]. This makes it possible to explore the correlations between the emotions of citizens and objective events surrounding them at the moment of their everyday social trajectory.

3 Data

In order to find out the emotions of citizens, we turned to posts and comments from regional online communities (using the social network VKontakte, where 18 public groups were included in the sample). The primary study of text-based data (using the Latent Dirichlet allocation (LDA) model) revealed the key topics that discussed in groups. The five most popular themes turned out to be (Fig. 1) were as follows: problems of a district (2), health issues (3), sports (1), family (6), and activities/meetings (4). Thus, in addition to the fact that the emotionality of residents of the district can be found and analyzed, it is also possible to pull data from thematic topics such as sports and healthcare and analyze the contexts.

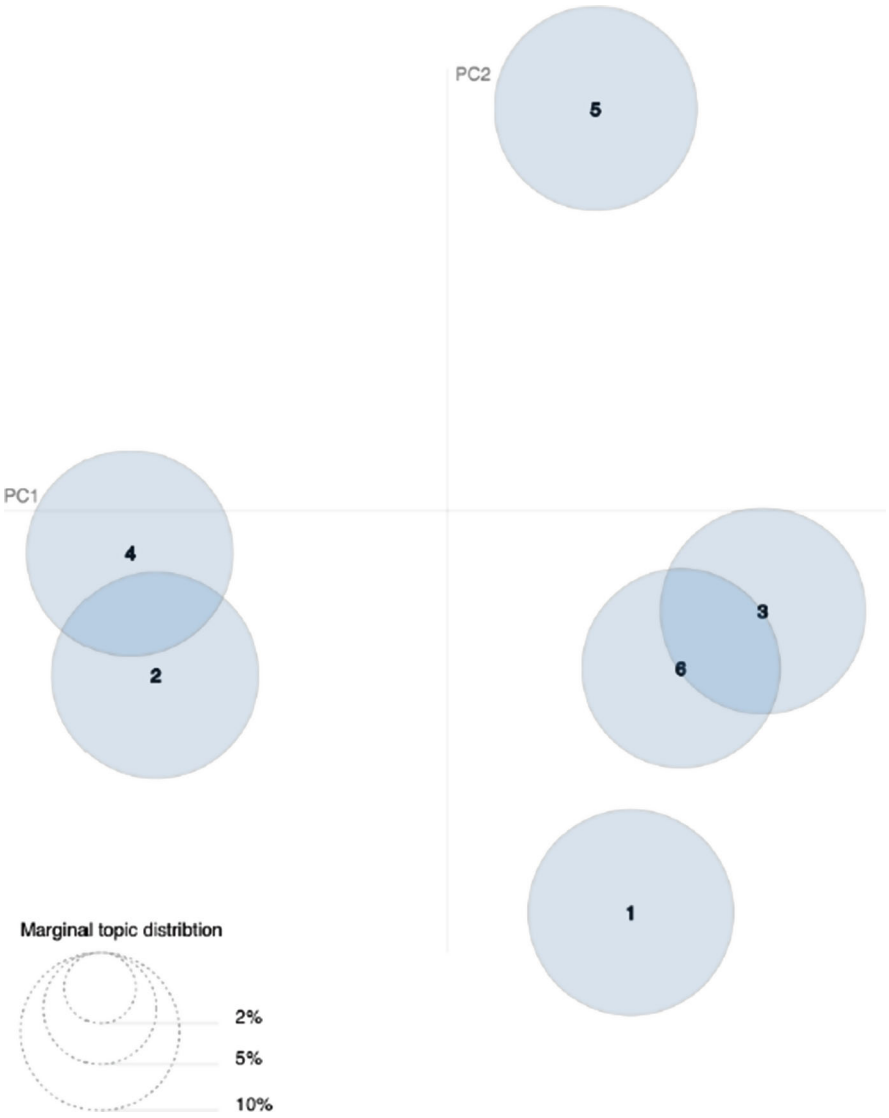

Fig. 1 Location and volume of thematic topics in relation to each other

In addition, the topic stood out, which contained disparate texts about daily events (such as lost keys, wallets, administration work schedules, etc.).

The simplest tonality dimension of messages (Dostoevsky library trained on the RuSentiment dataset) gave the idea that in most cases, messages and comments to them have neutral tone ({'neutral': 0.65, 'positive': 0.35} and this is the average value for all data in the topic). Therefore, it was decided that this thematic topic should be removed from the analyzed data. It was also decided to evaluate posts (the

	дата	реплика	комментарии	ссылка на пост
0	12.06.2021	Добрый день. Сегодня встретившись с другом, уз...	Тоже собираю, увлекательное занятиеМихаил,вы ...	https://vk.com/wall-51766355_3113523
1	10.06.2021	Еще одна несанкционированная свалка в Кудрово!...	Это просто СВИНЬЯ!!!!! это не свалка. Это строй...	https://vk.com/wall-51766355_3113499

Fig. 2 Appearance of the collected dataset

beginning of a discussion on the topic) taking into account the number of comments on them. If the post contained less than 5 comments at least 30 characters long, then it was removed from the dataset. This rule made it possible to clear the dataset from obviously enthusiastic remarks similar to "class!" or "amazing!" (as well as negative interjections and words of the same kind), thereby balancing the dataset in terms of content. We saved dates and links of posts in order to be able to manually view the discussion.

It is also important to mention that we downloaded data for the years 2018–2020. This was done because it was more reasonable to test the idea of the possibility to bound the emotional tone of individual comments and data describing urban space without noise in the data. The world and federal news agenda since COVID-19 pandemic could significantly influence topics and the tone of comments. Therefore, these years were excluded from the analysis.

The average length of the resulting sample of comments is 525 words (10–15 comments are left per post); the average length of posts is 41 words. Since the goal was to evaluate the overall tone of the reaction to a post, then comments to it were summed up and made up one unit of text data. Figure 2 shows the appearance of the collected dataset.

The collected text data was pre-processed according to the following steps: (1) tokenization; (2) removal of special characters, emojis, links, and punctuation marks; (3) removal of stop-words; and (4) normalization of tokens. The final training dataset contained 104,107 rows.

4 Methods

We decided to use the ruGPT-3 model for sentiment analysis of the final dataset. This is an autoregressive transformer language model trained on the dataset of Russian language. Based on GPT-3, this model has the potential to improve the accuracy of sentiment analysis by leveraging its natural language generation capabilities. At this phase of the experiments, we decided to use ruGPT-3 Large (760 million parameters) without additional training. In the future, we plan to come up with some scales that take smooth gradients of emotion between, for example, calm and horror, or sadness, amusement, and neutrality into account. Currently, we have used binary classification into positive and negative sentiment markers. Perplexity was used as a measure of sentiment tone. In general, the idea is based on the inverse probability of the test set, normalized by the number of words. In information theory, perplexity is a measure of how well a probability distribution predicts a sample. As model input, we submitted a pair in the format < happiness level > + <text>

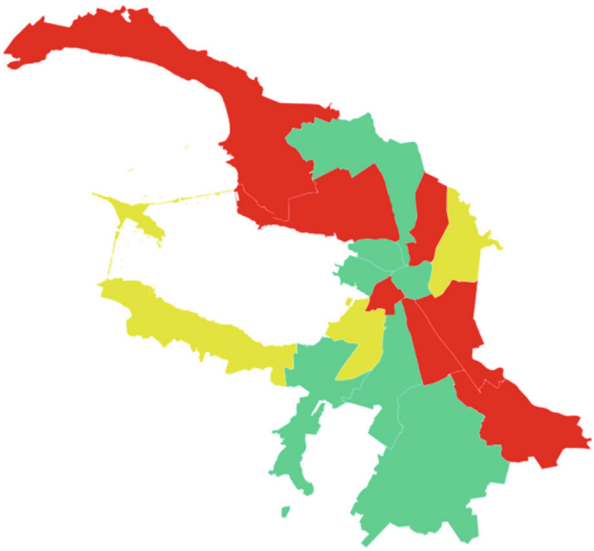

Fig. 3 Marked map of St. Petersburg, three classes of emotions: happy (2) > moderately happy (0) > sad (1)

('happy:' + sentence and 'sad:' + sentence). Furthermore, perplexity was calculated for each variant. Then, the values were compared with each other in order to find the smallest perplexity. Thus, the label was assigned.

The manually labeled dataset was used to evaluate a quality of the algorithm. On the validation sample, the following results were obtained: accuracy = 0.74 and F1-measure = 0.78.

After confirming that the general approach using the perplexity measure has proven useful, the third sentiment class was introduced, and it is "moderately happy" (tending toward neutral tonality).

Thus, we got the following scale of citizen's mood: happy (2) > moderately happy (0) > sad (1). As a result, the map of St. Petersburg was marked (Fig. 3).

The next step was the labeling of quantitative data obtained from open sources and administrations of St. Petersburg districts. In health opportunities, we decided to include three components: (1) availability of polyclinics (the number of city polyclinics in a district); (2) number of hospitals in a district; and (3) availability of sports (outdoor sports grounds, football and hockey fields, and availability of fitness centers and gyms). Quantitative data were taken from publicly available datasets and supplemented with information provided by the district administrations upon request.

Next, it was necessary to make a rule for approximating statistics into three classes (which could be compared with marking the emotions of district residents). Three classes were allocated: (0) there is no opportunity to maintain health in the district; (1) the health situation is average; and (2) all conditions have been created in a district for residents to be engaged in the prevention and maintenance of health. The class calculation formula was created. The importance of the required number of

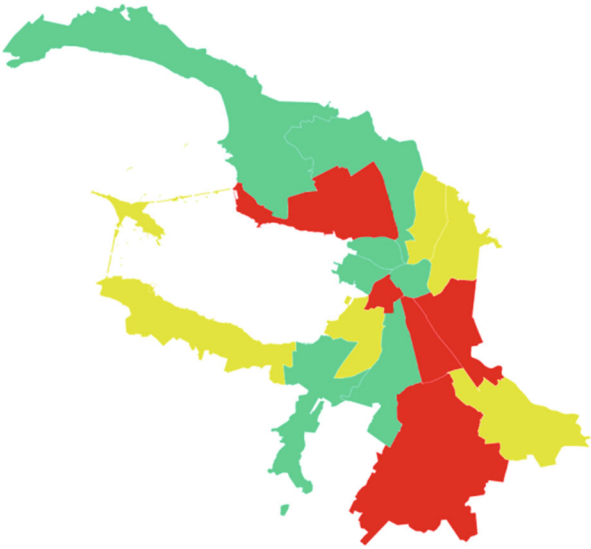

Fig. 4 Map of St. Petersburg, marked with data on health opportunities (polyclinics, hospitals, and places for sports)

policlinics relative to the number of residents in the district was taken into account. Thus, the coefficient of this factor was introduced. Figure 4 presents the results.

The results indicate that there is a relationship between access to health opportunities and the attraction of residents' emotions to negative or positive poles. However, in 2 out of 18 districts, correlations were not found. Quantitative data show that these districts are doing well in access to medicine and sports, but discourses in online communities have negative connotations. On one hand, this is an acceptable error. On the other hand, it suggests that it is necessary to find an additional statistical parameter that will explain what the aggressiveness of online communication is connected with.

5 Conclusion and Future Work

The obtained results indicate that the method is applicable for searching factors influencing the social mood of the inhabitants of the districts. However, some additional experiments are required. We plan to develop sentiment detection using several emotional scales. If at the moment, the most common palette is used (from negative to positive connotations), then in the future, it seems appropriate to check the Lövheim cube. We also plan to revise the used formula for correlating quantitative data with three selected classes. Finally, we plan to supplement the quantitative data with several more statistics: the number of pharmacies, sports schools, statistics of crimes in the districts, and records of problems with housing and communal services. It is necessary to analyze the load on sports facility in terms of the number of people using it (there are such statistics from district

administrations). We plan to implement a map on which it would be possible to compare available data by overlaying labeled data on districts.

Acknowledgments The study was supported by the Russian Science Foundation and the St. Petersburg Science Foundation, grant No. 23-28-10069 "Forecasting social well-being in order to optimize the functioning of the urban digital services ecosystem in St. Petersburg" (https://rscf.ru/project/23-28-10069/).

References

1. Wu, L., Zhang, Q., Chen, C.-H., Guo, K., Wang, D.: Deep learning techniques for community detection in social networks. IEEE Access. **8**, 96016–96026 (2020). https://doi.org/10.1109/ACCESS.2020.2996001
2. Tan, Q., Liu, N., Hu, X.: Deep representation learning for social network analysis. Front. Big Data. **2**, 2 (2019). https://doi.org/10.3389/fdata.2019.00002
3. Ramadhani, A.M., Goo, H.S.: Twitter sentiment analysis using deep learning methods. In: Proceedings of the 2017 7th International Annual Engineering Seminar (InAES), Yogyakarta, Indonesia 1–2 August 2017, pp. 1–4
4. Song, X., Tseng, B.L., Lin, C.-Y., Sun, M.-T.: Personalized recommendation driven by information flow. In: Proceedings of the 29th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, Seattle, WA, USA, 6–11 August 2006, pp. 509–516
5. Tang, X., Yang, C.C.: Ranking user influence in healthcare social media. ACM Trans. Intell. Syst. Technol. (TIST). **3**, 1–21 (2012). https://doi.org/10.1145/2337542.2337558
6. Peng, S., Wang, G., Xie, D.: Social influence analysis in social networking big data: opportunities and challenges. IEEE Netw. **31**, 11–17 (2016). https://doi.org/10.1109/MNET.2016.1500104NM
7. Severyn, A., Moschitti, A.: Twitter sentiment analysis with deep convolutional neural networks. In: Proceedings of the 38th International ACM SIGIR Conference on Research and Development in Information Retrieval, Santiago, Chile, 9–13 August 2015, pp. 959–962
8. Grishina, E.A.: Social (mental) mapping: the possibilities and limitations of the method// Bulletin of the Russian State University for the Humanities. Ser. Philos. Sociol. Art Critic. **4-2**(10), 272–277 (2017)
9. Vavilina, N.D., Skalaban, I.A.: Social Mapping: A Research Method and a Tool for the Development of the Territory. Sibprint, Novosibirsk (2015)
10. Lynch, K.: Reconsidering the Image of the City, pp. 151–161. Springer (1984)
11. Gorelova, Y.R.: The Image of the City in the Perception of Citizens: A Monograph. Heritage Institute (2019)
12. Barbash N. B., Kryuchkov Yu. A. Social mapping as a way of spatial organization of data on the socio-territorial differentiation of the composition and quality of life of the population//Predictive social design: theoretical, methodological and methodological problems. M, 1994. 115–129

Digital Health: Study of the Social Risks for the Elderly Associated with Introduction of Electronic Services

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Abstract The digitalization of the healthcare system in Russia has been actively pursued through interconnected federal and regional initiatives since the early 2000s. The elderly have long recognized customs and routines and generally opt for conventional means for accessing information and services, including telephone and face-to-face meetings, and are apprehensive about electronic services due to their reluctance to technology. The vulnerability of the elderly was further heightened during the COVID-19 disaster and subsequent free mobility restrictions, which increased the demand for many services provided through remote-controlled operations. Pilot studies were conducted in two medical institutions of St. Petersburg, and the article describes the results. Utilizing the state information system of St. Petersburg's unique objective data, the study examined the dynamics of changes in the indicators of the usage of different channels of access to the doctor's appointment service by the St. Petersburg population using different channels for different categories of appointment scheduling. It was in this way that the research was conducted on the study of the impact of digital health services on the elderly social well-being in Russia, while identifying specific steps that digital health services can influence in order to improve the elderly social well-being.

Keywords d-Health · Older generation · Use of d-health services

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_28

1 Introduction

Relevant characteristics of modern society are the processes of rapid digitalization accompanied with an ageing of the population, i.e., an increase in the number of population group that is conventionally considered to be "lagging behind" in learning modern technologies. The COVID-19 pandemic had an impact on these processes, as it expedited digital health technologies and, as a result, accelerated digitalization but also caused a significant reduction in mobility and familiar employment opportunities, which was also impacted by the digital health technologies that were developed. In this context, there is an intersection of the challenges of management algorithmizing, an increase in the number of social policy actors, and the ineffectiveness of pandemic response and recommended preventive measures in Russia.

Analysis of the trends in digital health shows that the world encounters serious barriers and risks, which are now common to most developed countries [1]:

- Permanent shortage of human and other resources (doctors, nurses, availability of diagnostics, etc.)
- Doctors facing difficulties in learning new knowledge as it increases exponentially.
- Constant shortening of norms regulating the duration of doctor's appointments in response to the rising costs of medical insurance and healthcare services.

Our analysis of social risks is based on the theoretical frameworks introduced by Anthony Giddens in "Runaway World" [2] and Ulrich Beck in "Risk Society" [3]. The global environment is experiencing new risks, such as environmental issues and natural hazards like plague, increasing risks for vulnerable populations. The risk-oriented approach, resulting from scientific and technological developments in the context of global shifts, leads to the individualization of risks, while standardized responses to them differ. All this generates serious problems, as institutions of the so-called "social state" are inherently set to react algorithmically using standard scripts and pay little attention to the process of individualization. When considering the challenges of aging in the light of healthcare digitalization, we can see that the most significant risks for the older generation are primarily related to the hazards posed by a standardized way of transitioning to electronic medical services, including informational risks. In this regard, there is an interest in projects in digital health focused on facilitating the development of personalized medicine, which can reduce the risks for the elderly.

The integration of information technologies into remote doctor–patient interactions was a new development in Russia's legal framework with the Federal Law of July 27, 2017, No. 242-FZ, introduced in 2018. While in the first stages of healthcare digitalization, the main priority was given to the informatization of the accounting and billing of rendered medical services, clinical workflow, resource management and patient flows, and professional communication between medical stuff within closed secure networks of medical institutions; currently, with the influence of

COVID-19, the focus shifted to Internet technologies of interaction with patients, use of digital services in prevention and health promotion, use of artificial intelligence, expansion of telemedicine [4–6], and the development of other new services for interacting with patients, which started with the simplest online service for making medical appointments.

The transformation of interaction with a patient, particularly an elderly one, should be supported by the increase in patient awareness and the availability of medical information. Patients are increasingly more able to make decisions about their health based on the information available to them. Interactions with these informed and demanding patients require the use of any communication channel convenient for them, the development of personalized services, providing them access to databases on the topics they need, the development of systems for feedback collection and analysis, the introduction of medical institutions ranking for making an informed choice, provisioning them with individual plans for therapy and health, and other services that should be promptly implemented based on studies into the priorities of a large number of patients [7]. Nevertheless, the increase in patients' competence challenges to the expert knowledge of doctors and is one of the risks of digitalization, as there is now more diverse information available to patients [8]. However, the readiness of the healthcare system and its personnel for such a personalized interaction is not studied.

The article presents the results of three pilot studies carried out in 2021–2022 in two medical institutions in Saint Petersburg which is aimed at revealing life strategies of patients, their experiences of using the available digital health services, and the specifics of their lifestyle to determine their active longevity mindset or the way of living out one's life. A unique aspect of this work is the inclusion of medical institutions in the research and hence the ability to correlate sociological data with the information about a specific patient stored in health information systems. Furthermore, the pilot study addresses the introduction of anonymization of patient data and elimination of the risk of violating the law on personal data, as well as the instructions and guidelines from the Ministry of Health that regulate operations with data in the healthcare system. The results of the pilot surveys will be used in more large-scale studies in 2023–2024.

2 Digital Health and Social Risks: International and Russian Context

Regular activities on the development of healthcare digitalization started in the early 2000s within the framework of the World Health Organization (WHO) working groups that assigned high priority to the issues of standards for medical data exchange and the development of guidelines for developers of corresponding national strategies. Specifically, in 2007, the EU outlined the basic eHealth priorities of the European countries [9], and in 2011, the EU published the guidelines for the

development of national eHealth infrastructure for the member states [10]. In 2012, in cooperation with the International Telecommunication Union, the WHO published the National eHealth Strategy Toolkit [11]. The definition of eHealth refers to the use of secure electronic health information systems that enable the delivery of relevant healthcare information to the appropriate recipient while also enhancing healthcare efficiency, efficacy, and accessibility for healthcare consumers. This document emphasizes the information exchange, particularly through electronic medical records, patient registries, and shared knowledge resources [11: 20]. All this stimulated the development of eHealth systems in the EU countries, which was summarized by the WHO Regional Office for Europe in 2016 [12].

In 2020, the WHO adopted the Global Strategy on Digital Health 2020–2025, which is currently the main conceptual document at the international level. This document defines four main objectives as the principal priorities for the development in this field [13: 24–38]:

- Promote global collaboration and advance the transfer of knowledge on digital health.
- Advance the implementation of national digital health strategies.
- Strengthen governance for digital health at global, regional, and national levels.
- Advocate people-centered health systems that are enabled by digital health.

In the Russian Federation, the prerequisites for healthcare digitalization started to develop in the late 1990s with the introduction of the Obligatory Medical Insurance (OMI) that require the development of personalized records of medical services. However, unified protocols for the OMI systems in the regions of the Russian Federation were adopted only in 2011 with the introduction of the Uniform State Health Information System (USHIS) [14].

Based on the analysis of the regulatory framework and Russian healthcare digitalization programs, we can outline the stages of this process as follows [15]:

1993–2005: The preliminary stage involves the deployment of personalized records of insured persons and rendered medical services as well as information interaction at the regional level (the introduction of the OHI).

2006–2010: The first stage is associated with the launch of electronic document flow in certain areas, including the barcoding of subsidized prescriptions within the new system of subsidized drug coverage and the adoption of the first Russian National Standard for electronic medical records.

2011–2012: The second stage involves the introduction of the USHIS concept within the framework of the healthcare modernization program (2011–2014).

2013–2018: The third stage involves the development of regional healthcare information systems that interact with the USHIS.

2019: The fourth and current stage involves the development of a uniform digital health network based upon the USHIS.

It can be affirmed that the digital development of Russian healthcare has come close to the practical attainability of a new paradigm of doctor–patient interaction in accordance with the WHO programs mentioned above. This will alter the nature of

interaction with a patient, as the increased awareness of patients and the increased accessibility of medical information will affect the ability to relate to them.

It should be noted that digital health is not limited to the introduction of electronic services, electronic medical records, patients' personal accounts, and electronic prescriptions. There is a wide range of work that focuses on the use of modern digital technologies in diagnostics of diseases, technology development, and telemedicine methods. Countries within the European Union progressively develop technologies and methods of remote monitoring and home-based rehabilitation of elderly patients recovering after surgery, which decreases the load on the in-patient facilities while engaging resources in family medicine. If chronically ill elderly people live alone, thanks to digital health, they have a potential opportunity to be constantly aware of the state of their health with the use of wearable devices, which constantly monitor pulse, blood pressure, breathing, and other vitals. By analyzing the received data, devices notify the owners of actions that they should take at the moment, take medicine, change the type of physical activity, etc. These readings may also be sent to the attending doctor's smartphone, who can give timely and informed recommendations. Such support for independent living is vitally important for lonely elderly people and is provided in some developed countries.

In the last 2 years, we saw rapid advances in research and development connected to the use of artificial intelligence in early diagnostics, particularly for mental disorders common among elderly people, and in predicting various situations in the healthcare system [16–19].

Although information technology is a valuable tool for the optimization of processes, there are few scientific studies demonstrating systematic risks associated with the application of artificial intelligence in healthcare [20]. The prevailing viewpoint in public opinion and the expert community of techno-optimism and belief that digital transformations are the fundamental basis for progress in the modern world is one of the reasons why digital transformations are explicitly advantageous in the modern world, which is why we think public opinion and the expert community of techno-optimism and belief has a strong position in supporting such a clear and positive shift toward digital transformations. There are, of course, considerations about the dangers of personal data leakage and potential availability of vital information about patients' health in the event of hacker attacks on national information systems. Nevertheless, developers and authorities who offer ever more sophisticated information security systems [21] counter these concerns.

Sociologists, psychologists, lawyers, and physicians are all required to participate in objective studies, which are not dependent on information system developers and involve not only healthcare and computer science specialists but also other fields like sociology. In this respect, it is hard not to agree with the opinion of the authors of the article "Artificial Intelligence in Medicine: Today and Tomorrow," published in Frontiers in Medicine journal, who concluded their review of the situation as follows: "Introduction of artificial intelligence into clinical practice is a promising area, which is rapidly developing alongside other modern areas of precision medicine, genomics and teleconsultations. However ... policy in healthcare now should

focus on addressing the ethical and financial issues associated with this cornerstone of evolution of medicine" [16: 4].

Health risks, in our opinion, should be studied with a reference to I.S. Pautov who defines them as a group of social risks "the main source of which are the disorders of adaptation of an individual/social group to the environment; these disorders may result in changes in physical and/or mental state of an individual which have various social, psychological, economic repercussions" [22: 14]. According to researchers, attitudes toward health at the level of individuals is a spontaneous process that is influenced by a complex set of factors. In particular, I.V. Zhuravleva argues that at the national level, the attitude to public health is characterized by the absence of "health ideology with the dominance of interests of sick people and attention to diseases rather than health" [23: 14]. At the individual level, in her opinion, behavioral factors are essential, namely, positive or negative self-preservation behavior, as a system of actions and attitudes mediating health and life expectancy [23: 133–134]. In our opinion, the correlation between the groups of factors influencing health and life expectancy varies according to various combinations of sociocultural, socioeconomic factors, stage of development of the healthcare system, and social support of the population.

When studying the role of digitalization in the context of positive and negative impacts on the healthcare system, we should consider the Medicine-4P concept, which recently has gained in popularity among developers of health information systems. It is based on four concepts, each beginning with the letter "P": Prediction, Prevention, Personalization, and Participation. The Ministry of Health of Russia institutionalized the Concept of Predictive, Preventive, and Personalized Medicine (enacted by the Russian Ministry of Health No. 186 of 24.04.2018) in 2018, but the concept of Participation was "dropped." The formalization of this concept undoubtedly had a positive impact on the development of methods and practices of individualization of medical services in Russia, in part due to the introduction of digital tools. E.S. Bogomyakova, for instance, records the trend of forming a model of providing medical care to a patient of a new type who is autonomous, responsible, competent, and independent in decision-making during interaction with medical professionals [24: 264–265]. In the author's opinion, the important factors influencing the success of this model are precisely the individualization of the system with the use of digital health and the state of institutional distrust, which is a serious social risk.

One of the components of the research project, preliminary results of which are presented in this chapter, is the study of the specifics of using digital health services as a factor influencing status and social well-being of elderly people in the Russian Federation. In the context of this task, we think that it is important to proceed not only from the effects in this area, but also from social risks that undoubtedly accompany the processes of digitalization of the healthcare system as applied to services for elderly people. In this respect, based on the general paradigm of the research project, we analyze these effects and risks from the viewpoint of how they facilitate or preclude the promotion of the concept of active longevity (delayed ageing).

3 Methodological Framework of the Study of the Use of Digital Health Services

As it was already indicated in the previous section, the probability of occurrence of health-related risks is a dynamic category related to social factors (such as lifestyle, environment, and healthcare system efficiency). The empirical block of the research presented in this chapter focuses on the third component with regard to the efficiency of using digital health as a tool that can have a conflicting effect on risks by mitigating or increasing them. Moreover, based on the assumption that social and demographic characteristics (such as age, gender, education, employment, income, distance from large cities, and type of settlement) have a varying influence on the distribution of risks of health deterioration, the relevance of the studies among elderly patients, in our opinion, dramatically increases.

Approaching this topic, the project working group carried out three pilot studies, one of them was a pre-project study. The studies were carried out in two medical institutions: Federal State Budgetary Institution "North-western District Scientific and Clinical Center n.a. L.G. Sokolov of the Federal Medical-Biological Agency" (NWDSCC) and the Saint Petersburg State Budgetary Institution of Healthcare "City Hospital No. 40" (CH 40):

- Demand for remote services and digital communication channels with patients (August 2022, NWDSCC).
- Active longevity of elderly patients (September–October 2022, CH 40).
- Patients' satisfaction with service on pre-planned hospital admission (December 2022, NWDSCC).
- Altogether over 900 respondents took part in these studies.

4 Study of the Demand for Remote Services and Digital Communication Channels with Patients

Starting from 2020, NWDSCC has been actively developing remote means of interacting with patients—telemedicine consultations, patients' personal accounts, and platforms for instant messaging to prompt doctor–patient interaction.

In order to assess the demand for remote services and communication channels with patients, we carried out two studies. The first was carried out in August 2021 with a remote questionnaire offered to patients with personal accounts in the information system of the Center; we received over 700 replies [25]. The survey comprised six questions about the popularity of Telegram messenger among the patients of the clinic, their exposure to chat-bots and medical bots, and their choice of the most crucial medical services and communication channels. By the results, we concluded that developing a chat-bot on the Telegram platform is promising.

4.1 Study of the Level of Patients' Satisfaction with Service on Pre-planned Hospital Admission

The questionnaire survey carried out in December 2022 focused on determining the level of patients' satisfaction with service on pre-planned hospital admission at NWDSCC. In particular, we studied patients' satisfaction with the functionality of the electronic queue system and remote services available in personal accounts on the national and regional online platforms and the system of the medical institution itself. Moreover, we set a task to assess differences in perception and satisfaction levels among patients of different age groups.

Patients were asked to independently fill out the questionnaires upon their admission to the hospital's clinical units with the use of the electronic queue system. The paper version of the questionnaire had a QR code that had a link to the electronic form.

In the study, we evaluated the performance of the digital health services.

Among the participants of the study were the respondents of 18–25 y.o.—3.7%, 26–35 y.o.—16.5%, 36–45—17.4%; 46–55 y.o.—20.2%, 56–65 y.o.—14.7%, over 65 y.o.—27.4%, 45% of the respondents were women.

The majority of the patients, 68%, have a university degree, which is explained by the population composition of patients admitted to this institution (the majority of patients have voluntary health insurance and admit on a paid-for basis). Altogether, 109 respondents took part in the questionnaire survey, including two respondents who filled out the questionnaires in electronic format (by scanning the QR code in the printed form).

5 Research Results

The main objective of the research was to determine, in practice, the main efficiency indicators of digital health, to identify the particularities and specifics for elderly people, and to mitigate potential social risks accompanying the digitalization of healthcare.

In the study of the demand for remote services and digital communication channels, among the answers to the question about the most convenient communication channels and services were: ability to make a phone call—32.8%, mobile application—22.5%, website—19.3%, Telegram bot—16.7%, and personal interaction with a receptionist—8.7%. Thus, the most convenient communication channel was the phone, which as it turned out is convenient not only for the elderly people.

In order to compare the obtained results with the data on the use of remote services by Saint Petersburg citizens, we accessed the data on medical appointments from the regional health information system (State Information System Regional USHIS, SIS RUSHIS), as presented in Table 1 for 2021 and 2022 (note that "medical appointment events" include both making an appointment and canceling

Table 1 Distribution of remote medical appointments in Saint Petersburg by channels, 2021–2022 (according to the data of the Netrika Meditsina Company—the developer of the SIS RUSHIS)

Channel for remote medical appointment	Years	Number of medical appointment events (in thousands)	Share of medical appointment events	Number of unique patients (in thousands)	Share of unique patients	Average number of medical appointment events per patient
Portal "Citizens of Petersburg Health"	2021	7120	39.5%	1740	36.8%	4.1
	2022	8878	45.1%	1835	37.9%	4.8
Medical appointment services developed within health information systems (HIS) and other regional portals	2021	5420	30.1%	1100	23.3%	4.9
	2022	7240	36.8%	1651	34.1%	4.4
Unified regional call-center	2021	4699	26.1%	1510	32.0%	3.1
	2022	2972	15.1%	1041	21.5%	2.9
Portal Gosuslugi (state services)	2021	774	4.3%	374	7.9%	2.1
	2022	585	3.0%	309	6.4%	1.9
TOTAL remote channels for medical appointments	2021	19,676	100.0%	4836	100.0%	4.1
	2022	19,676	100.0%	4836	100.0%	4.1
Incl. electronic appointments only	2021	16,704	84.9%	3795	78.5%	4.4
	2022	16,704	84.9%	3795	78.5%	4.4

it, as well as signing up for the waiting list if no appointment can made at the time, etc.).

The figures for the share of patients making appointments by phone in 2021 in Table 1—32%—confirm the results of the August 2021 survey (32.8%).

Moreover, by comparing the dynamic pattern of indicators for 2021–2022, we can conclude that electronic remote channels for medical appointments have increased in popularity—the number of patients using these services increased by 18%, notably the increase is seen for the first two appointment channels, while the number of patients using call center and the Gosuslugi portal has decreased.

As a result of the pilot study, we discovered that there is a need to identify the most convenient communication channels depending on the age of the population groups. This task was completed at the end of 2022 in the next survey.

The survey among elderly respondents in CH 40 has been carried out for a prolonged time, as the newly set research task was to combine survey data and medical data of patients. For this, we had to work through organizational and methodological issues concerning both the survey itself and obtaining data from the HIS and the regional state health information system.

In our survey, 18% of elderly individuals identified themselves as proficient Internet and computer users, 22% used the Internet for communicating with law enforcement, 26% believed that their conversations with authorities were authentic, 53% were confident that phone usage was the only convenient way to make a medical appointment and file a complaint, and approximately one-third of respondents were afraid to use the Internet.

Fifty-five percent of the elderly were able to use the Gosuslugi portal, while 18.4% used the services of "My Health" on the Gosuslugi portal, 14.6% used the "Citizens of Petersburg Health" portal, 25% created personal accounts at medical institutions, 52% made appointments on the Internet, 44% received results of medical tests and examinations in electronic form, 28% used electronic medical records, 11% used telemedicine consultations, and 8,2% provided feedback about medical services. Furthermore, those who used the listed services and applications report predominantly positive experiences.

After examining the factors and conducting more thorough expert research, we observed that it is possible to differentiate between various isolated patient populations with the following traits:

Group 1—Users who are advanced users of the "Citizens of Petersburg Health" portal, which provides access to the regional state portal of electronic healthcare services of Saint Petersburg, receive telemedicine consultations, provide feedback about rendered medical help or services, use applications to monitor health (and have similar ratings of these services), and often communicate with friends online. A large share of patients—37.9% (Table 1), who make medical appointments on the "Citizens of Petersburg Health" portal, which has all of the above-mentioned services, validates the distinction of this group. At the same time, only 6.4% of all patients who make remote appointments use the Gosuslugi portal.

Group 2—Advanced users who take the regional healthcare services of Saint Petersburg have personal accounts at medical institutions, make electronic appointments, use electronic medical records, and receive test results in electronic form (with ratings of these services by "satisfied/dissatisfied" coincide), and use fitness applications. Distinction of this group can be considered specific to state medical institutions of Saint Petersburg and is confirmed by a large share of the citizens—34.1% (Table 1), who make appointments in personal accounts at medical institutions that have introduced HIS, the developers of which provide these functions on the official websites of clinics.

Group 3—Advanced users who take the Gosuslugi portal and apparently do not have sufficient knowledge of healthcare services: they consider themselves advanced users of the Internet, easily learn new programs and applications, regularly communicate with the authorities on the Internet, trust these communications, and think that electronic services become more convenient and helpful with time. According to the SIS RUSHIS data, this group can be associated with the patients who use the Gosuslugi portal to make medical appointments—6.4% (Table 1).

Group 4—Prefer to use the phone to make medical appointments, file a complaint, etc., and are afraid to use the Internet. The share of the patients who make appointments through the unified call center according to the SIS RUSHIS data—21.5% (Table 1) validates the distinction of this group.

Therefore, these four groups should be used as a reference for the development of educational resources promoting the use of remote healthcare services—whether in electronic form or by phone, as a traditional communication channel more familiar to elderly people. Such materials should be distributed through the Internet (website and digital media) or for those who prefer talking to operators on the phone—informational brochures should be distributed in healthcare institutions or published in traditional print media.

Survey of respondents of all ages upon their pre-planned hospital admission to NWDSCC showed the following results: 70% of respondents were satisfied with their time in the admission unit; moreover, satisfaction with the functioning of the electronic queue was reported by 64 respondents out of 94 patients admitted to pre-planned hospitalization, which amounted to 68% of all respondents (respondents under 35 years were slightly more critical of the electronic queue system than of the waiting conditions in the admission unit). Service in the admission unit is organized in seven separate service points each of which has its own electronic queue system that calls for the next patient. The first point of service is the receptionist, and consequently, the patient can be directed to a separate room (service point) for additional tests, contagious isolation ward, X-ray unit, cash register to pay for separate procedures or hospital care in general, and examination rooms. Therefore, the patient's movement in the admission unit and queue management in service points requires employees to perform exact recording at all stages, yet nonetheless, patients were satisfied with the functioning of the electronic queue and the level of proficiency of the medical personnel managing it.

Among respondents of all ages 55% (18%—for elderly people in survey carried out in CH 40), consider themselves advanced users of the Internet and computer, 41% (22% in CH 40) use the Internet to communicate with the authorities, 50% (26% in CH 40) trust their communication with the authorities on the Internet, 79% (51% in CH 40) think that electronic services become more convenient and helpful with time, 28% (53% in CH40) prefer using phone to make a medical appointment, file a complaint, etc., and approximately 6% (every third respondent in CH 40) are afraid to use the Internet.

By the results of the survey, 75% (55% in CH40) used the Gosuslugi portal, 55% (18.4% in CH 40) used the services of "My Health" on the Gosuslugi portal, 41% (14.6% in CH 40) used the "Citizens of Petersburg Health" portal, 19% (25% in CH 40) created personal accounts at NWDSCC, 39% (44% in CH 40) received results of medical tests and examinations in electronic form, 24% (28% in CH 40) used electronic medical records, 15% (11% in CH 40) received telemedicine consultation from NWDSCC, and 28% (8.2% in CH 40) provided feedback about medical service in NWDSCC. Furthermore, those who used the listed services and applications report predominantly positive experiences.

Therefore, the results of the survey carried out in NWDSCC confirm the substantial difference in the average indicators for all patients admitted to hospital care and for elderly patients in CH 40.

6 Conclusion

As a result of preparation and performing the surveys among patients on a wide range of problems associated with active longevity in CH 40, we came to important conclusions regarding organization and methods of such surveys, which are planned to be carried out in medical institutions.

It emerged that the requirement to fill out a separate document with consent to the processing of personal data for a specific survey considerably complicates interviewers' efforts to engage respondents in the survey. Apparently, this is particularly crucial when it comes to surveying elderly respondents who expressed their discontent with the necessity to provide their passport details when filling out the consent form. Respondents struggled to quickly understand the content of a lengthy questionnaire and many refused to participate precisely because they were required to sign the consent form, which considerably complicated the pilot survey and added to the workload.

By the results of the pilot study, we defined methodological and organizational solutions aimed to avoid the problems and even localized conflicts like those we encountered during the survey in CH 40. Methodological recommendations can be summarized as follows:

First, sociological survey of respondents who are patients of a specific clinic coupled with an opportunity to correlate a questionnaire with personal medical data, scope, and specifics of rendered medical services (with anonymization of these data)

allows to obtain unique information only if this specific clinic has reached a sufficient level of digitalization. The maximum effect is attainable once there is an opportunity to retrieve data from the regional health information system. This can be achieved only by organizing surveys and operating data within a secure network of specific health information system. In doing so, it is necessary to design research technology in such a way that personal data would stay within the medical institutions while sociologists are able to obtain, process, and interpret anonymized data with social and demographic references for respondents.

Second, organizers of sociological research in medical institutions are advised to collaborate with those institutions where the management and personnel are interested in receiving feedback from patients in order to improve their service. It is also important whether a clinic aims to promote digitalization of processes and has a health information system with an accumulated database of patients for a specific period. Thus, for instance, regular feedback from a patient is required in the framework of such a widely renowned international method of digital transformation of a clinic and assessment of its digital maturity as HIMSS EMRAM [26]. However, it is essential to maintain the representativeness of the research sample without which there is a high chance of bias toward more advanced users, or residents of particular districts. To achieve this, at the survey development stage, it is important to refer to aggregated data from medical systems in order to form an estimate of the general statistics of the clinic patients.

Third, when surveying in medical institutions, we recommend amending the standard consent to the processing of personal data form (compulsory for all institutions) with a approval the use of patient's personal data in surveys for the purpose of improvement in service. This will free interviewers from the necessity to sign a separate consent with each respondent, which will undoubtedly reduce the number of people declining interviews or questionnaires.

Fourth, it is better to conduct studies in medical institutions using a questionnaire with a minimal number of questions, since respondents could not answer all questions in a comfortable time and, therefore, refused to participate in a survey. Outpatient facilities are not suitable for an extensive survey, since patients spend a short time there. We recommend surveying in in-patient facilities or during functional diagnostics.

Fifth, we recommend improving the methods of survey through authorizing patients in personal accounts at medical institutions. Reaching a patient from a recognized clinic email with a request to fill out an online questionnaire also allows collecting authorized data. Large number of authorized users with personal accounts potentially allows conducting representative panel surveys. In this case, an important factor is the traditionally high level of patients' trust in healthcare institutions.

A significant number of elderly patients prefer to use a phone rather than a computer, and if possible, it is necessary to bridge the digital divide that arises with the introduction of remote electronic services, as well as to prevent a sense of separation from society, it is important to show this so that older people do not feel isolated from society and feel appreciated. Therefore, it is not worth offering

electronic services without an alternative option of making a phone call when a call-center operator will make an appointment for you.

The research was supported by the Russian Science Foundation grant No. 22-18-00461 «Delayed aging or late adulthood or in Russia: how digital development change the position of elderly in the era of COVID-19 and uncertainty» (https://rscf.ru/project/22-18-00461/).

References

1. Pugachev, P.S., Gusev, A.V., Kobyakova, O.S., Kadyrov, F.N., Gavrilov, D.V., Novitskii, R. E., Vladzimirskii, A.V.: Mirovye trendy cifrovoj transformacii otrasli zdravoohraneniya [Global trends in the digital transformation of the healthcare industry]. Natl. Health Care. **2**(2), 5–12 (2021). https://doi.org/10.47093/2713-069X.2021.2.2.5-12
2. Giddens, A.: Uskol'zayushchij mir: kak globalizaciya menyaet nashu zhizn' [Runaway World: How Globalization is Reshaping Our Lives]. M.: Ves' mir (2004)
3. Beck, U.: Obshchestvo riska. Na puti k drugomu modernu [Risk society. On the way to another modernity]/Per. s nem. V.Sedel'nika i N.Fedorovoj; Poslesl. A.Filippova. – M.: ProgressTradiciya (2000)
4. Galkin, K.: Cifrovizaciya volonterstva pozhilyh lyudej v period pandemii: vozmozhnosti i bar'ery v kontekste iskusstvennogo intellekta [Digitalization of Older People's Volunteering during the Pandemic: Opportunities and Barriers of the Artificial Intelligence]. J. Soc. Soc. Anthropol. **20**(3), 377–392 (2022). https://doi.org/10.17323/727-0634-2022-20-3-377-392
5. Karpov, O.E., Akatkin, Y.M., Konyavskiy, V.A., Mikerin, D.S.: Tsifrovoye zdravookhraneniye v tsifrovom obshchestve [Digital healthcare in a digital society]. M.: Business Express (2016)
6. Levanov, V.M.: Ot telemediciny do elektronnogo zdravoohraneniya: evolyuciya terminov [From telemedicine to e-health: evolution of terms]. Med. Alm. **2**, 16–19 (2012)
7. Orlov, G.M.: Cifrovoe razvitie zdravoohraneniya: akcent na transformacii vzaimodejstviya s pacientom [Digital development of healthcare: emphasis on the transformation of interaction with the patient]. Inf. Soc. Educ. Sci. Cult. Technol. Future. **5**, 9–16 (2021). https://doi.org/10.17586/2587-8557-2021-5-09-16
8. Grigoryeva, I.A.: Sociolog v pole cifrovizacii mediciny dlya pozhilyh [Sociologist in the field of digitalization of medicine for the elderly]. Adv. Gerontol. **35**(4), 589–590 (2022)
9. EU: eHealth priorities and strategies in European countries (2007). http://ec.europa.eu/information_society/activities/health/docs/policy/ehealth-era-full-report.pdf
10. EU: European Countries on Their Journey towards National eHealth Infrastructures, Evidence on Progress and Recommendations for Cooperation Actions, Brussels (2011) http://www.ehealthnews.eu/publications/latest/2494%2D%2Deuropeancountries-on-their-journey-towardsnational-ehealth-infrastructures
11. WHO and ITU: A set of materials on the National e-health Strategy, World Health Organization and the International Telecommunication Union, Geneva. 226 c (2012). https://apps.who.int/iris/bitstream/handle/10665/75211/9789241548465_rus.pdf?sequence=9&isAllowed=y
12. WHO: From Innovation to Implementation: eHealth in the WHO European Region, WHO Regional Office for Europe. Copenhagen, 2016. 116 p (2016). http://www.euro.who.int/__data/assets/pdf_file/0012/302331/From-Innovation-to-Implementation-eHealth-Report-EU.pdf?ua=1
13. WHO: Global Digital Health Strategy for 2020–2025, World Health Organization. – 82 c (2021). https://apps.who.int/iris/bitstream/handle/10665/344249/9789240027596-rus.pdf
14. Gomaleev, A.O.: Sozdanie mekhanizmov vzaimodejstviya medicinskih organizacij na osnove edinoj gosudarstvennoj informacionnoj sistemy v sfere zdravoohraneniya (EGISZ) [Creation of

mechanisms for the interaction of medical organizations based on a single state information system in the sphere of health care (EGISZ)]. J. Econ. Bus. **6–1**, 79–84 (2019). https://doi.org/10.24411/2411-0450-2019-10824
15. Orlov, G.M., Chugunov, A.V.: Cifrovoe zdravoohranenie: programmno-celevoj podhod i problemy stareniya [Digital Healthcare: Program-targeted Approach and the Problems of Aging]. Int. J. Open Inf. Technol. **10**(11), 113–125 (2022)
16. Briganti, G., Le Moine, O.: Artificial intelligence in medicine: today and tomorrow. Front. Med. **7**, 27 (2020). https://doi.org/10.3389/fmed.2020.00027
17. Buch, V.H., Ahmed, I., Maruthappu, M.: Artificial intelligence in medicine: current trends and future possibilities. Br. J. Gen. Pract. **68**(668), 143–144 (2018). https://doi.org/10.3399/bjgp18X695213
18. Krut'ko, V.N., Dontsov, V.I., Mitrokhin, O.V., Matveev, A.A., Ermakova, N.A., Potemkina, N. S.: Iskusstvennyj intellekt dlya zdorov'esberezheniya i razvitiya lichnostnogo potenciala (obzor) [Artificial intelligence for health saving and personal potential development (review)]. Proc. Inst. Syst. Anal. Russ. Acad. Sci. **70**(3), 86–100 (2020). https://doi.org/10.14357/20790279200310
19. Mishenichev, K.S., Borodkina, O.I.: Cifrovye tekhnologii dlya pozhilyh s demenciej: problemy i perspektivy vnedreniya [Digital technologies for elderly people with dementia: problems and prospects for implementation]. Adv. Gerontol. **35**(1), 76–84 (2022). https://doi.org/10.34922/AE.2022.35.1.008
20. Vidiasova, L., Grigoryeva, I.: Mezhdunarodnyj simpozium «Cifrovoe zdravoohranenie i perspektivy razvitiya koncepcii aktivnogo dolgoletiya» [International symposium "Digital healthcare and prospects for the development of the concept of active longevity"]. J. Soc. Soc. Anthropol. **25**(3), 259–266 (2022). https://doi.org/10.31119/jssa.2022.25.3.11
21. Bagdasaryan, N., Kravchenko, A.: Cifrovoe obshchestvo i diskursy postgumanizma [The digital society and discourses of posthumanism]. Logos. **32**(6), 245–272 (2022). https://doi.org/10.22394/0869-5377-2022-6-245-271
22. Pautov, I.S.: Riski, svyazannye so zdorov'em naseleniya v sovremennoj Rossii: sociologicheskij analiz [Public Health Risks in Modern Russia: A Sociological Analysis]: avtoreferat dis. . . . kand. sociologich. nauk/S.-Peterb. gos. un-t. SPb (2012)
23. Zhuravleva, I.V.: Otnoshenie k zdorov'yu individa i obshchestva [Attitude towards the health of the individual and society]. – M: Nauka (2006)
24. Bogomiagkova, E.: «Doveryaj, no proveryaj»: praktiki zaboty o zdorov'e v usloviyah cifrovizacii zdravoohraneniya ['Trust but Verify': Health Care Practices in the Context of Digitalization]. J. Soc. Policy Stud. **20**(2), 263–278 (2022). https://doi.org/10.17323/727-0634-2022-20-2-263-278
25. Kalinin, P.S., Orlov, G.M.: Razvitie elektronnogo vzaimodejstviya kliniki i pacienta: opyt sozdaniya i testirovaniya chat-bota v medicinskom centre [Clinic-patient Electronic Interaction Development: Project Experience and Chatbot Testing at Medical Center]. Int. J. Open Inf. Technol. **10**(11), 105–112 (2022)
26. Panichkin, N.D., Gabuniya, N.Y.U.: Model' cifrovoj zrelosti HIMSS EMRAM [Digital maturity model HIMSS EMRAM]. Qual. Manag. Med. **4**, 78–83 (2022)

Influence of Regional News Agenda on Social Mood

Anna V. Chizhik and Michail Egorov

Abstract The regional agenda revolves around topics that cover the events taking place in the city. Therefore, this is a description of the social environment in which individuals navigate their daily lives. Accordingly, when a person comes into contact with news, they experience a number of emotional states based on the effect of involvement in what is happening. In addition, regional news can reinforce a sense of regional identity among individuals. Finally, regional news can also contribute to political polarization in society. This study is an attempt to trace the strong bond between the news agenda and the moods of individuals. In order to do this, regional news tops are identified, and then, the correlations are searched for between them and discussions of these topics in social networks, and the tone of these discussions is also assessed.

Keywords News agenda · Social mood · Thematic modeling · Sentiment analysis · Social media · New media · News top

1 Problem

Most of the social reality is outside the daily life of a person; however, the individual needs to be aware of current events and their contexts. Moreover, they need to form an individual attitude to the problems of social, political, and cultural nature, thereby joining one or another social group. Therefore, mass media are the main tool for obtaining information about social reality. This means that there are three main sources of information: the media (website as their main communication channel), social media in a one-to-many type of communication (posts in social networks, publications of opinion leaders, etc.), and individuals (one-to-one and many-to-many types of communication, for example, reposting news in a private message or social media feed).

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_29

It is obvious that the information occasion flows from one type of the broadcast source to another quite quickly, "acquiring" new details and gradually losing its neutral context (even if it was originally the one). The most active discussion of informational occasions (and often the first interaction with information) takes place on social networks due to the convenience of the communicative act through them. Under such conditions, the individual cannot evaluate the information for reliability, which means that they are in the mode of either trust or distrust of their source of the information. It turns out that the main goal of obtaining information moves from the cognitive to the emotional sphere: When receiving the news, a user in the social media must quickly decide which position they will take in a discussion. It should be noted that the concept of discussion does not seem to be mandatory when obtaining information. However, social media in general provokes an individual to respond (including publicly expressing the opinion). Consequently, the projection of the version of reality in individual's minds is moving from the media (as it was at the previous stage of functioning of post-industrial society) to social groups with their public activities in virtual reality. This means that complex social phenomena are surrounded by a system of associations and stereotypes due to the communicative action taking place in an online environment.

Based on the main communication models within social media, it is obvious that the starting point for the formation of an emotional field around a social process is an individual emotional response (individual mood). Without the support of a social group, it turns out to be a rapidly fading phenomenon that does not affect the socio-cultural trends of society. However, at the moment when an individual receives approval from the social environment surrounding him/her, stable judgments are formed and adjoin ideologically to the opinion of this social group. The marker of successful integration of individual opinion into the social environment is social mood. B. Porshnev noted that it, being a whole formed from individual moods, characterizes society in all its diversity [1, 2].

Group, political, and mass moods can be distinguished as types of social mood [3]; each of them affects the state of society, and the extreme forms of its reflection are revolutionary actions, rallies, and uprisings. In summary, usually, social mood is an emotional attitude toward what stands in the way of an individual, who interferes with them, or, on the contrary, who helps to achieve a goal [4]. Thus, mood has a subject and an object. This means that two situations are possible: (1) An individual, receiving information from an accessible source, aims to transfer it to their social group, endowing it with a marker of their attitude; (2) an individual is opinion contemplator of the social group (or several groups and several opinions) about an information occasion and decides whether to join it by entering into a dialog or not.

It turns out that the root of social mood emergence can be identified in the online environment, and it appears to be the information occasions broadcasted by media. The further reaction of society is born in the public dialog between individuals. Thus, the hypothesis appears that the actual agenda of a social group should differ from the one that is positioned by the media.

Below is the analysis of discussions in social networks (correspondence of the users in the public Telegram chat) that arose during the annual cycle (from May

1, 2022, to May 19, 2023) as the reaction to the regional news agenda formed by mass media. In order to analyze the news background for the specified period, the special dataset was collected from the social network VKontakte, consisting of posts that were published on the page of the official account of the St. Petersburg TV channel. It should be noted that only one media was selected since the goal was to collect the information agenda of the region, which would be stably broadcasted through social networks and did not contain noise like federal news. At the same time, an increasing number of newsbreaks that have identical context would not be beneficial.

Experiencing the events and reflections, and not the first emotional impulse received when perceiving an informational message, was interesting in the first place. Therefore, the dataset consisting of dialogs was collected not under media posts (which was also possible), but in a neutral space (on the neighboring social network Telegram). The result of this analysis is an attempt to assess the potential of the online environment as a public field for spontaneous conversations and discussions in terms of its functional significance in social integration structure formation.

2 Data

Two datasets were collected as a part of the study.

The collection of news posts published on the official page of the Saint Petersburg TV channel on the VKontakte social network during the period from May 1, 2022, to May 19, 2023, was gathered for the experiment. The total number of words in the study collection is 141,960, and the average number of words in one post is 41.

Since the main goal of the study was to identify the correlation between the news agenda in the media and the emerging social mood, another dataset that reveals the discussions present on social media on the detected topics from the first dataset was collected for the same time period. The source was the public Telegram chat "Fontanka Chat." The participants of this chat discuss current city events against the backdrop of official news, expressing their position (and conclusions) and additionally covering the topic (giving new facts). There are 5339 users in the chat, 51.6% of them are women, and 48.4% are men; on average, participants exchange 2743 messages per day. Users are most active at 12 am and after 8 pm. This dataset includes 3,353,156 words, and the average number of words in one message is 13. The format of the collection is the text and date of its publication (thus, it can be technically compared to the first one).

3 Method

In the first stage of the study, we needed to analyze the dataset with the news posts. The dataset had two important characteristics: First, it contains texts of approximately the same length, and second, these announcements are short texts. Therefore, we could not use the most common text vectorization method (TF-IDF) [5]. So, the bag-of-words model was used. We got the document-term matrix, where each row corresponds to a news post, and each column corresponds to a separate word. Stop-words (for example, prepositions and conjunctions) were removed from the dataset in order to ensure greater representativeness of vectorization.

The text data has been preprocessed in the next order: tokenization; removal of special characters, links, and punctuation; and removal of stop-word and lemmatization. After that, the text was vectorized using CountVectorizer (scikit-learn library).

Then, the texts from the first dataset were studied by topic modeling. LDA was chosen as an algorithm suitable for the data under the study [6, 7]. It was applied using the scikit-learn library. Taking argmax for each news post in the resulting matrix, topic predictions for all objects in the sample were obtained and sorted. Mapping the clusters to two-dimensional space (Fig. 1) shows that LDA is well suited for this kind of data: Topic clusters are clearly separated from each other, and each topic is sorted into almost continuous areas.

In each detected thematic topic, the most frequently occurring words were found (for easier further interpretation) in order to search for the beginning of user discussions on these topics in the second dataset.

In the final stage of the study, six most popular topics were identified. To achieve this, each topic detected by the LDA algorithm was analyzed in terms of the number of mentions in the media (using the capabilities of the RSS file from Google News).

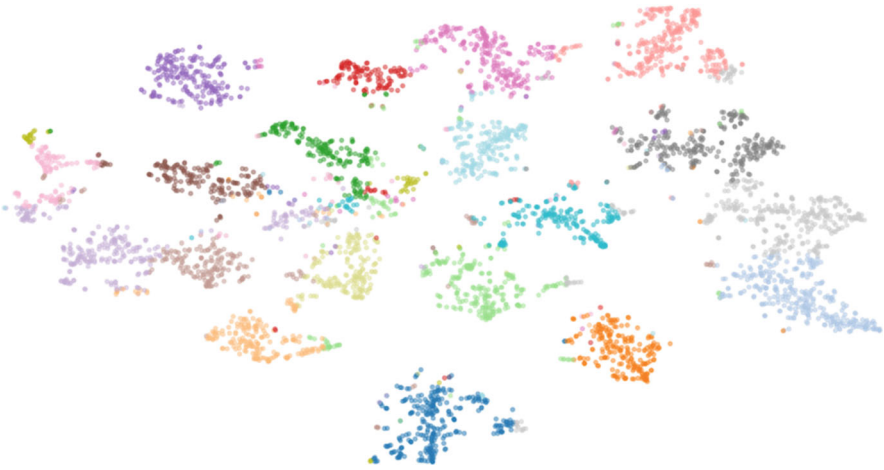

Fig. 1 Thematic cluster visualization (LDA)

Next, we turned to the second dataset in order to identify the dynamics of discussions in the Telegram chat on topics that were actively discussed in the media. The search for the beginning of the discussion was carried out using the keywords selected at the previous stage.

User tags to each other were tracked to catch the end of a discussion thread on a topic (and the presence of keywords in messages was also checked to secure further overlapping contexts).

The news life cycle in terms of discussion has a cascading view. On average, interest in information lasts for about five waves, following each other, and making up a total weekly cycle. People write about 20 comments per day on topics that emotionally hurt them. Three peak points of attention are visible on the graph: the topic of traffic jams with a peak in September and the topic of the subway with the peaks of attention in September and March. If we turn again to the analysis of the news posts, it turns out that this is the time when roadworks or a change in routes was announced in the media. As it can be seen from the visual statistics, the life cycle of discussing an informational occasion, in this case, changes and lasts in the range of a month with clear signs of the formation of the topic and the fading of interest. The average number of comments per day for these news items is 50.

It is also interesting that despite the very active media coverage of the administration's activities, as well as tourism news, residents were actually of little interest in these topics, and the activity of these discussions tends to be zero. The same situation is with the football news, in which the general public is not interested.

In the next step, we performed sentiment analysis of the comments using the Dostoevsky library trained on the RuSentiment dataset. This made it possible to evaluate user messages using three classes: negative, neutral, and positive. It turned out that outside the peaks of increased attention to the topic, the tonality tends to be neutral. While with increased attention to the informational occasion, the tonality tends to have a negative connotation. Consequently, the more actively social group is reacting to the news agenda, the more aggressive social mood becomes, at least within virtual reality.

In the future, it remains to analyze whether the news agenda and the emotional level of online discussion around it can shape the social mood offline or not. At the moment, it can be unequivocally concluded that the regional agenda has a rather serious impact on citizens, setting online public communication in motion. It should be also noted that the activeness of positioning the piece of news in the media does not affect the significance of this news in the perception of individuals. According to the chart of discussions, it is clear that the social group itself moderates the importance of the news. Thus, while influencing the social mood of individuals, the media, nevertheless, cannot set trends in the perception of the urban environment. On the contrary, individuals, uniting in discussions, create a vector of perception of urban events through circular reactions since the distractibility of passive actors into the discussion shows that the growth of negative connotations depends on the activity of the interlocutors.

4 Conclusion

The role of the media in the formation processes of mass consciousness is seen in the era of post-industrial society as more and more tangible because the media are the main providers of information occasions, which subsequently become the subject of a social communicative act. At the same time, it should be noted that by consuming content, individuals are embodied as an accomplice in the process of creating an interpretation of the event being covered. Public opinion and public mood in this case become a flexible system of views that is formed quite spontaneously. However, the interpretation of events, together with social mood as a new component of the message, is a powerful tool that allows bringing the socio-cultural landscape to transformation.

Acknowledgements The study was supported by the Russian Science Foundation and the St. Petersburg Science Foundation, Grant No. 23-28-10069 "Forecasting social well-being in order to optimize the functioning of the urban digital services ecosystem in St. Petersburg" (https://rscf.ru/project/23-28-10069/).

References

1. Porshnev, B.F.: Social Psychology and History. Progress Publishers, Moscow (1979)
2. Munné, F.: La psicologia social com a ciència teòrica. PPU, Barcelona (1994)
3. Yadov, V.A.: Social and socio-psychological mechanisms of the formation of a person's social identity. World Russ. **3–4**, 158–181 (1995)
4. Weber, M.: Basic Concepts in Sociology (1962)
5. Haihong, E., et al.: Theme and sentiment analysis model of public opinion dissemination based on generative adversarial network. Chaos, Solitons Fractals. **121**, 160–167 (2019)
6. Bellegarda, J.R.: Latent semantic language modeling for speech recognition. In: Mathematical Foundations of Speech and Language Processing, IMA, vol. 138, pp. 73–103. Springer, New York (2004)
7. Blei, D., Ng, A., Jordan, M.: Latent Dirichlet allocation. J. Mach. Learn. Res. **3**, 993–1022 (2003)

Exploring Public Interest in Psychological Help in Russia: Google Trends Analysis

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Abstract In recent years, the topic of psychological health has become more prominent in the Russian media landscape. However, available statistics provide only general estimates. In this research, we analyze the trends in search queries related to psychological help and well-being over a 10-year period (2012–2023). The main goal was to explore the dynamics of interest and to relate it to statistics on the suicide rate in Russia. As a data source, Google Trends was used as an instrument for identifying public interest. It was found that public interest in psychological help has increased over the 10-year period. Strong negative correlations between suicide statistics and search queries related to psychological help were observed.

Keywords Google Trends · Search queries · Psychological help · Suicide rate

1 Introduction

In recent years, the topic of psychological health has become more prominent in social discourse. It seems that people pay more attention to their psychological well-being and seeking psychological help has become less stigmatized. One of the possible reasons is the spread of social media, which is claimed to be a resource for getting support and affiliation with others [17]. Previous studies indicate that people with higher levels of psychological "literacy" have positive help-seeking attitudes and a higher probability of getting psychological help [16]. In the United States, the number of adults who received mental health treatment or counseling has grown from 27.2 million in 2002 to 41.4 million in 2020 [5]. A similar trend is observed in Russia. According to VCIOM, in 2022, the percentage of people who

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_30

had sought professional psychological help reached 12%, compared to 6% in 2009 [22]. There is also evidence of an increase in the number of organizations offering professional psychological help. According to 2gis (digital maps company) analytics, since 2020, the number of such companies has increased by 36% in Russia in general, with a 62% increase in Moscow, 42% in Ekaterinburg and Kazan, 41% in Nizhniy Novgorod, and 39% in St. Petersburg [7]. A similar statistic is reported in regard to the number of clients in services for providing online psychological help—Alter and Zigmund.Online. Alter reported an increase in new applicants of 400% [1], Zigmund.Online [23] mentioned 3700% with an increased number of applications by 110,000%. This growth could be connected to the COVID-19 pandemic as it was characterized by social isolation, which provoked the feeling of loneliness [6]. According to the Public Opinion Fund [24], trust in psychologists has also increased in recent years. Thus, the percentage of people who agree that professional psychologists and psychotherapists are trustworthy has increased by 10% since 2006 [24].

However, there is still a lack of studies on the dynamics of interest in psychological help in Russia. First, this could be explained by the difficulty of obtaining large-scale data of this kind. To the best of our knowledge, no organizations gather such data systematically and make it available to the broader public. Second, people might be ashamed or afraid to participate in such surveys due to the sensitivity of the topic and perceived lack of anonymity.

One of the available sources of data indicating the interest in psychological help in Russia is Google Trends analytics. It collects data on Internet queries that might represent a general interest in several topics in a specific period of time and in a specific geographic area [2, 9]. Google Trends is used quite often in studies of public interest, especially after the COVID-19 pandemic [18] as it has several advantages for researchers. First, it could be merged with other data sources [4, 12]. Second, Google Trends represents a very diverse sample of users in terms of their age, gender, social status, and geographic residence [9]. Thus, Google Trends data on users' search queries seem useful to the aims of the current study.

Another prospect of interest in the study is to trace the interrelation between the dynamics of interest in psychological help and possible objectively observed health-related changes on the societal level. The suicide rate in Russia was chosen as a macro-level indicator of the psychological health of the population. Several studies showed that the availability of psychological help could be a reason for decreasing suicide rate [13]. According to The World Health Organization, Russia is the ninth country in the world by the number of suicides per 100,000 people [8]. There is evidence that people who are interested in their mental state or have suicidal thoughts might use the Internet as a source of informational support or seek help [10]. In this study, data from the Unified Interdepartmental Information and Statistical System (EMISS) were used to capture the correlation between the interest in psychological help and the suicide rate for the period 2012–2022.

2 Methods

2.1 Google Trends

Google Trends is an instrument that estimates the level of public interest in certain topics. Google Trends allows users to filter queries by such parameters as time period, location, thematic category, popularity rate, and data modality (web search, images, etc.) [9]. Google Trends provides scholars with two types of data, namely, search terms and topics. The search term is a single request of a user to a search engine. Topics represent thematically grouped search terms. The procedure of forming the topics is unclear and performed as a "black box" algorithm of Google Trends. As this approach might render the topics incomparable, we use only the search terms in our analysis.

The Google Trends data are normalized in accordance with the Relative Search Volume (RSV) index, such that the maximum absolute value corresponds to 100. To note, Google Trends does not register a query if it does not have enough data for this term and excludes identical queries from the same users.

2.2 Selection of the Search Queries

In previous studies, different approaches for search term selection were used. The most common approach is to adopt key terms from previous works on the topic [14, 19]. The second approach is to rely on official reports and documents to construct a list of relevant terms [3, 23]. For example, in COVID-19 studies, the list of queries was constructed based on the symptoms mentioned in medical reports [15, 21]. The third approach is using similar search terms recommended by the Google Trends platform [20].

In this study, we combine all mentioned approaches. First, we adopted some core search terms in line with the studies on mental health [15, 19]. Second, we reviewed the literature to find out how the psychological well-being terminology is reflected there. Based on that, we decided to include queries on psychological mental health with negative and positive wording because well-being is supposed to be a multidimensional construct including ill-being and well-being components [11]. Third, we enriched our collection by using similar queries presented in the Russian language segment of Google Trends and Yandex Wordstat (a platform similar to Google Trends).

The final data set of search terms included 102 search queries divided into four thematic blocks. The "Psychological help" block (44 search terms) includes queries related to getting psychological help, "ill-being" (33 search terms) about psychological distress and depression symptoms, "well-being" (12 search terms) includes queries identifying good mental state, and "how to" (13 search terms) related to users attempts to improve the current psychological condition.

2.3 Statistics on the Suicide Rate in Russia

The monthly statistics on suicide rate is provided by UIISS (the Unified Interdepartmental Information and Statistical System) [25]. It is calculated as a ratio of suicide numbers divided by the average population size and adjusted by the annual dynamic.

2.4 The Final Database

The suicide rate statistics was matched with the Google Trends queries. This database covers the period from January 2012 to March 2020 and consists of 66 search terms. Extremely popular search terms (with right-skewed distribution) were excluded. The suicide statistics data were normalized using the following calculation method, which is similar to the normalization used in Google Trends:

$$\mathrm{I\,(final\ index)} = \mathrm{x1\ (original\ unit\ of\ data)/xmax\ (biggest\ value)}^{*}\ 100$$

2.5 Statistical Analysis

We demonstrate the trends in the dynamic of interest in psychological help through descriptive graphical analysis. Spearman's correlation method was used to reveal the relationship between the interest in psychological help and suicide rates.

3 Results

3.1 General Dynamic of Interest in Psychological Help

Figure 1 depicts the dynamics of interest in psychological help from 2012 to 2023 grouped according to four search terms categories described in Sect. 2.2. Across all categories, we observed the ascending trend meaning the rise of interest in psychological help. The interest in well-being and ill-being topics turns out to be seasonal, increasing from September to January. After 2020, there was a drop in the number of queries of all four categories and then a rapid increase, possibly representing the beginning of the COVID-19 pandemic in March 2020.

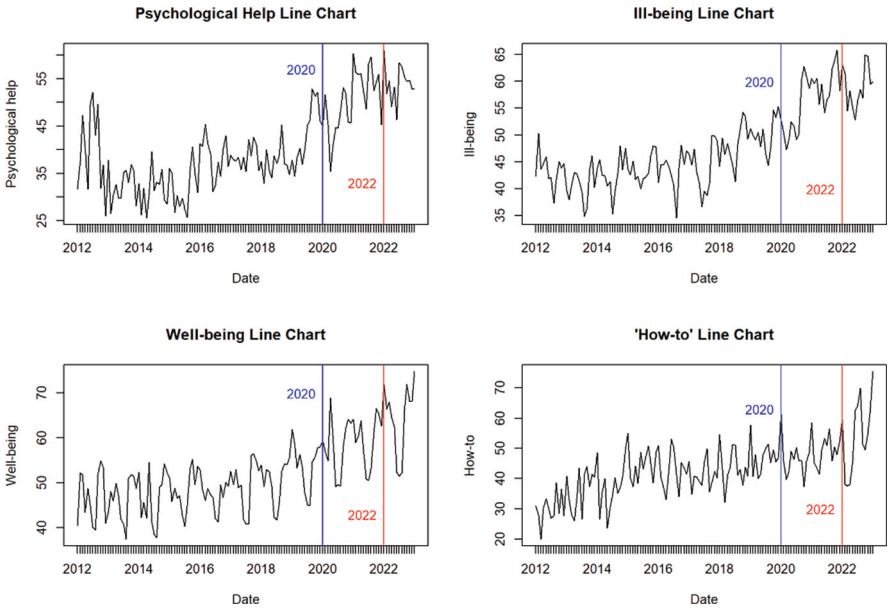

Fig. 1 Changes in interest dynamics over the period of 10 years

Table 1 Correlations between search query rate and suicide statistics

Query	Correlations
Psychotherapist	−0.89
Psychologist	−0.87
Panic attack	−0.86
Meditation	−0.84
Burnout	−0.76
Harmony	−0.70
Psychotherapist reviews	−0.64
Loneliness	0.83

3.2 Suicide Statistics

Generally, the number of suicides decreases with occasional peaks in accordance with seasonal fluctuations. Most of the queries in each of the thematically grouped blocks negatively correlate with suicide statistics. The strongest negative correlations are observed for the queries "psychotherapist" and "psychologist" (−0.89 and −0.87 respectively) (Table 1). The queries "panic attack" and "meditation" also have strong negative correlations with suicide statistics (−0.86 and −0.84, respectively). Thus, generally, these two rates are opposite: there is an increase in public interest in mental health and a decrease in suicide rates (Fig. 2).

There is an exception to the observed pattern. The interest in the query "loneliness" decreases and it has a strong positive correlation with suicide statistics (0.83)

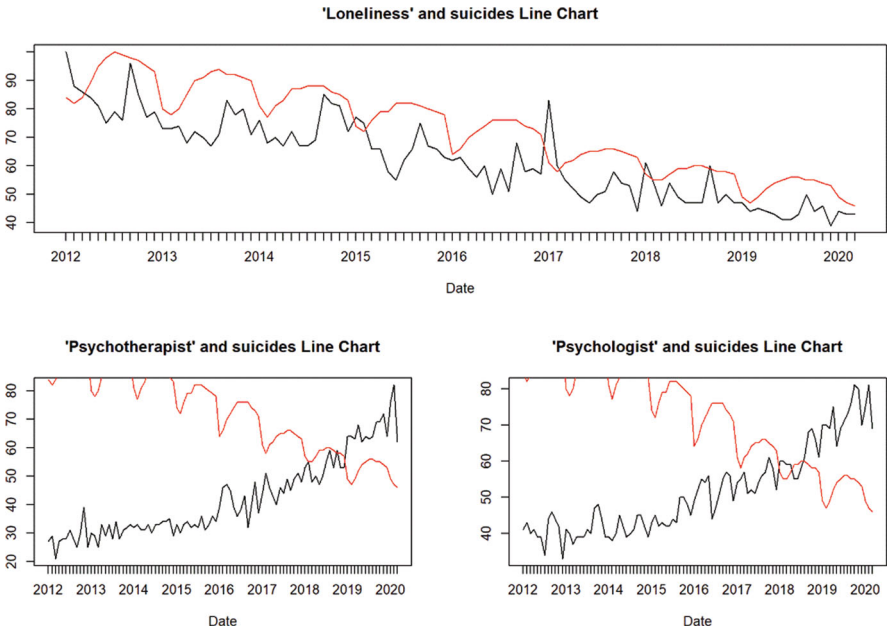

Fig. 2 Line charts of search queries (black) and suicide statistics (red)

(Fig. 2). It could be speculated that, unlike other topics, it is associated not with objective health conditions but with the self-perception. This query is of great interest to health practicians enabling them to predict suicide statistics more accurately.

3.3 Term-to-Term Correlations

The main goal of this subsection was to track correlations between psychological help queries and queries about the mental state ("ill-being", "well-being," and "how-to" blocks).

Positive Correlations

Table 2 reveals significant and positive correlations between several searches. The queries "psychologist" and "psychotherapist" have the highest correlation in the sample: 0.95. Possibly, because of the perceived similarity of these queries for users, they have generated nearly identical numbers of queries over the period from 2012 to 2020 (Fig. 3).

Table 2 Positive correlations between queries

Query 1	Query 2	Correlations
Psychologist	Psychotherapist	0.95
Psychotherapist	Meditation	0.94
Psychotherapist	Panic attack	0.92
Psychologist	Meditation	0.90
Meditation	Panic attack	0.89
Meditation	Burnout	0.88
Psychologist	Panic attack	0.87
Psychologist	Burnout	0.86
Psychotherapist	Burnout	0.86
Burnout	Panic attack	0.86
Anxiety	Burnout	0.76
Anxiety	Stress	0.74
Psychologist	Harmony	0.73
Burnout	Stress	0.70
Burnout	Depression	0.70

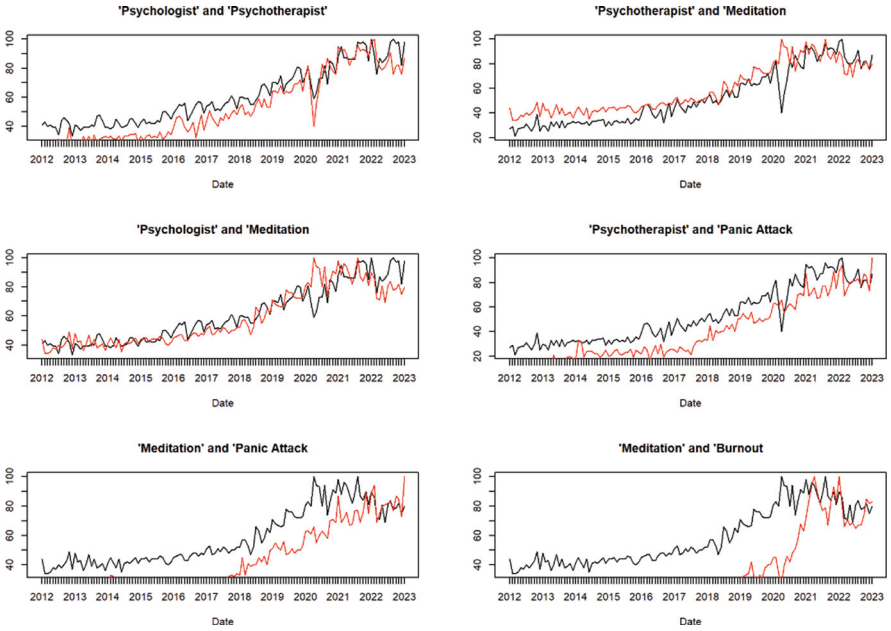

Fig. 3 Term-to-term line plots of queries with strong positive correlation

The queries from "ill-being" and "well-being" thematics correlate positively. For example, the search "meditation" highly correlates with "panic attack" and "burnout" (0.89 and 0.88, respectively). Thus, the dynamic of interest toward these thematically opposite search terms is conjunctly changed.

Another example is the queries from health-related ("ill-being" and "well-being") and "psychological help" blocks strongly correlate with each other. The strongest correlations are observed between queries "psychologist"/"psychotherapist" with the "meditation" (0.90 and 0.94, respectively) and the "panic attack" (0.92) (Fig. 3).

Negative Correlations

A strong negative correlation is observed between "loneliness" and "panic attack" (−0.81), "psychologist" (−0.76), and "meditation" (−0.76) search queries (Table 3, Fig. 4). It could be a consequence of people becoming more informed and more psychologically knowledgeable.

Table 3 Negative correlations between queries

Query 1	Query 2	Correlations
Loneliness	Psychotherapist	−0.82
Loneliness	Panic attack	−0.81
Loneliness	Psychologist	−0.76
Loneliness	Meditation	−0.76
Loneliness	Psychotherapist reviews	−0.67
Loneliness	Burnout	−0.67
Loneliness	Nervous breakdown	−0.67

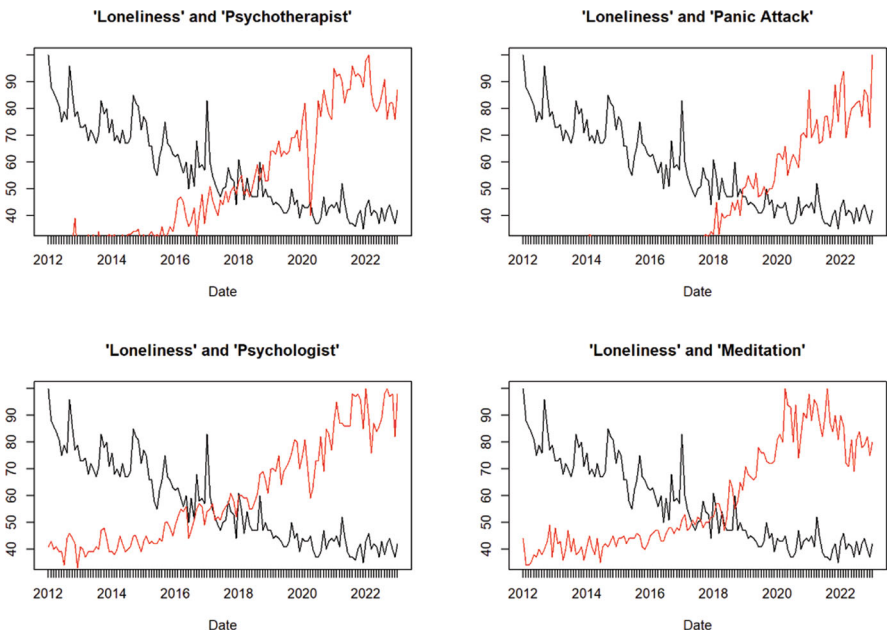

Fig. 4 Term-to-term line plots for queries with strong negative correlation

4 Discussion

The chapter aimed to fill the gap in studies exploring psychological help in Russia. Taking into account the stigmatization of the public discussion of this topic, Google Trends analytics is seen as a source where people can express their interest in an anonymized form which might reduce social desirability bias.

The first aim of the study was to examine the dynamics of interest in psychological help among the Russian population. It was found that over the period from 2012 to 2023, the interest in psychological help dramatically increased. The most intensive growth is observed after 2020. In line with Silverio-Murillo et al. [19], it is possible to suggest that COVID-19 affected the attitude of people toward psychological well-being. We also can relate this to the growing interest in healthier lifestyle as strong correlations were found between searches for psychological help and overall well-being.

The second aim of the study was to relate the interest rate captured by online statistic to the macro indicator of health-related changes on the societal level like suicide rates. Generally, it was found that these two indicators are negatively related with some exceptions. Interestingly, the correlation of suicide rates with the search query "loneliness" was strong and positive, indicating that this search might be used for predicting the suicide rate in further studies.

The study has several limitations. Firstly, the absolute numbers of queries are not represented in Google Trends; therefore, it is not possible to accurately estimate the coverage and the scope of each query. Secondly, the search terms may give a limited representation of health information-seeking behavior as it is not the only exclusive source people use [2]. Finally, only people who have Internet access are covered in our sample, which limits our ability to generalize our research results. Finally, the study identifies general trends in the public interest in the mental health field in Russia. Due to its correlational nature, it is not possible to claim causal relationships.

Acknowledgments The work of Yadviga Sinyavskaya was implemented in the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE University).

References

1. Alter: https://alter.ru. Last accessed 18 May 2023
2. Arora, V.S., McKee, M.M., Stuckler, D.: Google Trends: opportunities and limitations in health and health policy research. Health Policy. **123**(3), 338–341 (2019)
3. Brodeur, A., Clark, A.E., Fleche, S., Powdthavee, N.: COVID-19, lockdowns and well-being: evidence from Google Trends. J. Public Econ. **193**, 104346 (2021)
4. Capron, D.W., Andel, R., Voracek, M., Till, B., Niederkrotenthaler, T., Bauer, B.W., et al.: Time-series analyses of firearm-related Google searches and U.S. suicide rates 2004–2016. Suicide Life Threat. Behav. **51**(3), 554–563 (2021)

5. Elflein, J.: Mental Health Treatment or Counseling Among Adults U.S. 2002–2020. Statista (2022)
6. Fiorenzato, E., Cona, G.: One-year into COVID-19 pandemic: decision-making and mental-health outcomes and their risk factors. J. Affect. Disord. **309**, 418–427 (2022)
7. Forbes: https://www.forbes.ru/svoi-biznes/455341-cislo-organizacij-psihologiceskoj-pomosi-v-moskve-vyroslo-na-62-za-dva-goda. Last accessed 15 May 2023
8. Global Health Estimates: Suicide in the World (2019)
9. Google: About Google Trends, https://support.google.com/trends/answer/4365533?hl=en&ref_topic=6248052. Last accessed 10 May 2023
10. Guo, G., Cui, Y., Xia, Z., Hu, J., Xue, J., Huang, X., Wan, Y., Fang, J., Zhang, S.: Association between health literacy, depressive symptoms, and suicide-related outcomes in adolescents: a longitudinal study. J. Affect. Disord. **327**, 15–22 (2023)
11. Homan, S., Gabi, M., Klee, N., Bachmann, S., Moser, A.-M., Duri', M., Michel, S., Bertram, A.-M., Maatz, A., Seiler, D., Stark, E., Kleim, B.: Linguistic features of suicidal thoughts and behaviors: a systematic review. Clin. Psychol. Rev. **95**, 102161 (2022)
12. Knipe, D., Gunnell, D., Evans, H., John, A., Fancourt, D.: Is Google Trends a useful tool for tracking mental and social distress during a public health emergency? A time–series analysis. J. Affect. Disord. **294**, 737–744 (2021)
13. Korošec Jagodič, H., Rokavec, T., Agius, M., Pregelj, P.: Availability of mental health service providers and suicide rates in Slovenia: a nationwide ecological study. Croat. Med. J. **54**(5), 444–452 (2013)
14. Lee, J.-Y.: Search trends preceding increases in suicide: a cross-correlation study of monthly Google search volume and suicide rate using transfer function models. J. Affect. Disord. **262**, 155–164 (2020)
15. Lemoine, P., Ebert, D., Koga, Y., Bertin, C.: Public interest and awareness regarding general health, sleep quality and mental wellbeing during the early COVID-19 pandemic period: an exploration using Google trends. Sleep Epidemiol. **2**, 100017 (2022)
16. Nakamura, K., Batterham, P.J., Reynolds, J.: Professional help-seeking for suicide in Japan: modifiable factors influencing help-seeking beliefs, attitudes, and intentions. J. Affect. Disord. Rep. **10**, 100425 (2022)
17. Olson, C.K., Kutner, L.A.: The role of media in promoting and destigmatizing mental illness in youth. In: Child and Adolescent Psychiatry and the Media, pp. 141–151. Elsevier (2019)
18. Pérez-Cutillas, P., Pérez-Navarro, A., Conesa-García, C., Zema, D.A., Amado-Álvarez, J.P.: A systematic review on prevalence and perceived impacts of associative stigma on mental health professionals. Int. J. Afr. Nurs. Sci. **18**, 100533 (2023)
19. Silverio-Murillo, A., Hoehn-Velasco, L., Rodriguez Tirado, A., Balmori de la Miyar, J.R.: COVID-19 blues: lockdowns and mental health-related google searches in Latin America. Soc. Sci. Med. **281**, 114040 (2021)
20. Sinyor, M., Roberts, L., Spittal, M.L., Niederkrotenthaler, T.: Suicide and resilience-related Google searches during the first 12 months of the COVID-19 pandemic. J. Affect. Disord. **303**, 203–205 (2022)
21. Sycińska-Dziarnowska, M., Szyszka-Sommerfeld, L., Kłoda, K., Simeone, M., Woźniak, K., Spagnuolo, G.: Mental health interest and its prediction during the COVID-19 pandemic using Google Trends. Int. J. Environ. Res. Public Health. **18**(23), 12369 (2021)
22. Wang, A., McCarron, R., Azzam, D., Stehli, A., Xiong, G., DeMartini, J.: Utilizing big data from Google Trends to map population depression in the United States: exploratory infodemiology study. JMIR Ment. Health. **9**, e35253 (2022)
23. Zigmund.Online: https://zigmund.online. Last accessed 18 May 2023
24. Foundation "Public Opinion": Demand for Help from a Psychologist. Reputation of the Institute of Psychologists and Psychotherapists (2022)
25. The Unified Interdepartmental Statistical Information System. Mortality from suicide (3.4.2.). https://www.fedstat.ru/indicator/58547. Last accessed 22 Oct 2024

Part V
E-Governance and Political Communication

Network Analysis of Z Gen Political Participation in Youth Parliament

Irina Tolstikova, Olga Ignatjeva, Konstantin Kondratenko, and Alexander Pletnev

Abstract The chapter analyzes one of the forms of political participation of young people in the political life of society—the work in the youth parliament, which is an advisory body to the real bodies of representative power. This type of political participation is becoming an increasingly common conventional form of youth political engagement. For example, in 2022, a youth parliament was also formed under the Legislative Assembly of St. Petersburg. The purpose of the proposed study is to investigate forms of virtual networking and political participation of the young people in the Youth Parliament, using the example of the Youth Parliament of the Leningrad region, taking into account the career development and social capital of its representatives. The research has been done with the aid of methodology of network analysis supplemented. Inferences are interpreted with the aid of M. Mintrom and Ph. Norman's theoretical framework. The sample consisted 26 actors who were deputies of the Youth Parliament. As a result of the research, the following findings have been done: the body has a weak representativeness of generation Z, the informal structure of the Youth parliament coincides with a formal, there is an isolated component that indicates on some difficulties in communication within a structure.

Keywords Generation Z · Network analysis · Youth parliament · Political participation · Social media · Virtual interaction · Networking

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_31

1 Introduction

Youth issues are an important area in the activities of the political system of any state. To maintain stability in society, one should not lose sight of the needs and interests of the new generation, since over time this group will become predominant in society and the future of the country will depend on its actions. Today, generation Z and the elder group of generation Y [1–3] belong to the youth. For their successful integration, it is necessary to create conventional channels into politics aimed at co-opting talented youth into state authorities [4]. One of these channels is the Youth Parliament [5]. This study will conduct a network analysis of the structure of relations within the youth parliament at the regional level (Leningrad region).

Political participation is the action of citizens to directly or indirectly influence the selection of public administrators and their activities [6]. Despite the fact that a number of researchers of youth issues in Russia agreed that Russian youth are passive and not ready to actively defend their interests in the political process, the events of recent years have shown the opposite. The political activity of Generation Z can be differentiated into two types: conventional (participation-support) and unconventional (participation-protest). The first group implies the legal participation of young people in the political process, using mobility channels created specifically for young people and approved by state authorities and representatives of the political elite. The second group is associated with the protest activity and serves not only to articulate interests but also to put pressure on the authorities and decision-makers. The goals and objectives of this study are to assess the compliance of informal channels of communication with formal ones by means of network analysis, and on this basis to make a conclusion about the effectiveness of such a closed quasi-state structure as the Youth Parliament of the Leningrad region (a conventional form of participation).

Conventional forms of political participation of youth, especially generation Z, which becomes the most extensive cohort of this social group, are based on work in youth parliaments, governments, chambers, and activist forums, where youth problems are denounced. Representatives of the power elite encourage political activity of youth in the form of volunteer activities, promotion of projects, representation of youth interests in power structures. Youth divisions of political parties (Young Guard of United Russia—MGER, Young Socialists of Russia—Just Russia party, Youth Yabloko) have positive significance for the political socialization of Zoomers.

However, often the role of established channels of mobility to power for young people is formal and imitative in nature. Research by D.V. Trynov and Y.Y. Kazantsev showed, using the case study of the Sverdlovsk region, that only municipal elections serve as a real channel for young people to move to power, while the promotion to higher representative and executive bodies is difficult for young people [7]. A weak point in the political socialization of Generation Z in a conventional way is also the weak representation of state authorities in social networks, which are an important source of information for digital natives. A series of expert interviews among representatives of youth activists revealed the need for more active

use of online resources by state authorities to create loyalty to them among young people and their political socialization.

Consequently, the current research is a continuation of our team's longitude studies and actually, it opens the series of research devoted to Gen Z political mobilization and participation. The purpose of the current research is to estimate the productivity of the Youth parliament of the Leningrad region as a channel of penetration of generation Z to political power. Also, we plan to check the effectiveness of this structure by detecting informal connections between actors and correlate the formal and informal structures of the Youth Parliament. The object of research in this article is the youth parliament of the Leningrad region, the subject of research is the structure of informal relations within the youth parliament of the Leningrad region (convocation 2019–2022) and the gen Z participation in it. The design of the study was developed to answer the research questions: Is the Youth Parliament a reliable channel to the public authorities for generation Z? Does the distribution of formal powers within the Youth Parliament of the Leningrad Region correspond to the virtual network of informal communications? What clusters exist within the network of informal connections? This research has been done with the use of network analysis and metrics calculation that allows to make inferences more reliable.

2 Literature Review

Analysis of virtual interaction allows us to understand the specifics of political participation and the readiness of young people to be actively involved in political life. The method of network analysis is the best method appropriate for the investigation of the specific interaction among young people in a specific political organization. As soon as Youth Parliament is a locked group, the only opportunity to learn about connections and participation within it is a network analysis of relations inside social media VKontakte. This analysis was made with the aid of the methodology of network analysis indicated in the following literature [8–10].

What can be considered political participation? This question remains central to contemporary political participation research. Based on various theoretical points of view, they explore the issues of citizenship and youth participation, exploring their significance in politics, practice, and youth experience, and participation of young people in nongovernmental and youth organizations in the UK and Australia [11]. The change in the forms of political participation is considered, in particular the so-called alternative participation in the form of a boycott, squatting, ping, hacking, flash crowds, Twitter-led mobilization, etc., and their difference from traditional participation is determined [12–14]. The need to adjust traditional theory leads to theorizing about changes in the nature of political activity in terms of agencies (collective organizations), repertoires (actions commonly used for political expression), and goals (politicians whom participants seek to influence) [14]; the role of the Internet language as a proto-political phenomenon of political participation

[15]; the creation of a concept of citizenship that recognizes dissent and an ethic of political courage as vital elements of democratic participation [16] and the development of a working definition of political participation [17].

A strand of answers to this question has been built around the distinction between conventional and unconventional participation [7, 18–23]. This is objected to by other scholars who, like Marcin Kaim, argue that the dualistic understanding of political participation is reductive in that it leaves out those acts of participation that do not fit the conventional and unconventional distinction, introducing the notion of alternative political participation [24]. This category is established by conceiving the existing dualism between conventional and unconventional political participation as a continuum of options existing between polar opposites.

The future of society increasingly depends on the views, attitudes, and political orientations of young people. Generation Z becomes a significant object, which makes it necessary to study its views, attitudes, and political orientations. The study of the political attitudes of generation Z makes it possible to reduce the uncertainty of the control object and, consequently, increase the stability of the sociotechnical system, making the process of co-governing more efficient and predictable. The general conclusion of the research is a statement of some political passivity of generation Z [25, 26], which is provoked by the authorities' lack of interest in youth issues, and also by the fact that "the majority of representatives of generation Z (USA) do not consider political leaders as role models and less than 17% believe that politicians have influenced them at all" [25], in the American version of the analytics of its youth.

In Russia, the similar political passivity of generation Z in relation to the authorities is also associated with the declarative nature of solving social problems that concern citizens [27]. Trust toward the state and its institutions overall is low. The only state institutions that receive a relatively high level of trust are the president and the armed forces. The reasons for this are not quite clear but can be related to the perceived role of the president and the army as guarantors of national security, seen apart from domestic policies [2]. American researchers J. Palfrey and W. Gasser [2], D. Stillman [1], and Russian researchers [27] argue that representatives of the digital age generation spend most of their lives on the global network and do not make a distinction between life on the Internet and outside it, what matters in the context of the digitalization of politics and the organization of networked civic participation in order to increase the effectiveness of co-governing. The study of E.V. Brodovskaya and T. Huang [28], dedicated to the digital generation and conducted on a representative sample of a thousand people, indicates that despite the prevalence of passive moods among young people, where 45.3% are not interested in politics, the remaining half of the respondents are still actively interested in it. The Internet environment is an important component of the life world of generation Z, in which the political activity of young people is also realized. "The most active digital citizens of Russia have mastered the technologies and tools that allow them to compete for the interest of the audience, search for like-minded people, mobilize resources, etc." [29]. Through advancing inclusiveness in digital democracy services and e-Participation platforms, it may be possible to allow society to develop more

deliberative and equally accessible democratic processes [30]. The underrepresentation of public authorities is currently negatively affecting the political socialization of generation Z, as various political forces struggle to attract young people into their ranks [31]. "The omission of the modern Russian authorities is the extremely low representation in social networks and in the virtual space, where the opposition reigns supreme" [32].

But they also note the low activity of public authorities in the digital environment: "Today's public authorities are more inhibited, slower than individual bloggers who largely shape the opinion of young people in online communities, and this is the future: he whoever masters these tools, understands them faster, will rule the minds of young people, and therefore adults, literally in 5–10 years" [33 , p. 5]. This feature of generation Z, the phygital generation, is used by opposition bloggers, shaping the protest moods of young people. The "nonsystemic opposition," which does not have its representatives in the State Duma, widely uses the opportunities provided by the digital environment to recruit its followers among young people and form nonconventional attitudes toward the authorities. The same point of view is shared by R.V. Pyrma [33], D.V. Rudenkin [34], Saburova et al. [35], Brodovskaya, and Huang: "Young Russian users are a target group, the main addressee of protest content in the online space. 28.6% of young users once a week or more often encounter messages on social media calling for participation in civil/political protests. 48.4% encounter such messages less than once a week" [28 , p. 11].

The conclusion about the exclusively positive orientation of civic participation, based on the culture of co-participation and the consistency of the goals of various social groups and subjects, unfortunately without specifying generation Z, is made by S.F. Abramova [36] during the study of the participatory model of civic participation. A.Yu. Dombrovskaya, based on empirical research, concludes that young people are highly interested in various forms of civic activism in the digital environment and is included in various clusters of mobilization potential [37].

In general, an interesting review is the study of digital channels of interaction between government and society based on Internet resources by M.A. Vershinina [38]—digital platforms, Internet resources, sometimes quite unexpected and non-standard. So Yandex. Maps, which was not originally intended to become a platform for political statements, is now partly such—maps have become a platform for hybrid forms of statements—user reviews, political slogans, and appeals. This allows us to reach a large and diverse audience. Unfortunately there are no similar studies aimed at the especially valuable opinion of young people who are rarely willing to take the time to complete a survey or participate in a focus group.

3 Methodology and Hypothesis

With this work, a team of researchers from St. Petersburg State University, ITMO University, and St. Petersburg University of the Ministry of Internal Affairs opens a new series of studies aimed at identifying conventional channels of power for young

people in the Russian Federation and evaluating their effectiveness. The object of research in this article is the youth parliament of the Leningrad region, the subject of research is the structure of informal relations within the youth parliament of the Leningrad region (convocation 2019–2022), and the gen Z participation in it.

Hypothesis 1: The Youth Parliament of Leningrad region is a reliable channel to the political power for generation Z.
Hypothesis 2. Formal and informal leadership in the Youth Parliament coincide.
Hypothesis 3. The Youth Parliament of the Leningrad Region is a close-knit group.

To answer the research questions posed, it is necessary to build a network map showing the informal connections of the deputies of the youth parliament of the Leningrad region. There are two types of methods used in research design: data collection methods and data analysis methods. Information about the actors was collected on the basis of the content and event analysis of the social network VKontakte, biographical analysis, and separate questions were asked to the representatives of this parliament to clarify individual connections. In view of the closed nature of the structure, the researchers had a number of difficulties in obtaining information about the actors and their activities within the parliament. "In terms of personnel, the Youth Parliament of the Leningrad Region is a social group closed to entry, the unifying factor for which is the deputy mandate of the municipal level" [39, p. 72]. Information about the nodes and their connections with each other is collected from open sources on the Internet and in the social network VKontakte. Pajek software was used to visualize informal connections within the youth parliament of the Leningrad Region, and network analysis methods were used to analyze clusters and quantitative characteristics of relationships.

Network analysis appeared in the social sciences in the early 1970s, and since then has become an important paradigm not only in the field of sociology [40, 41], but also in the field of political science. R. Rhodes [42, 43] identifies three schools of political network analysis that have made a significant contribution to the development of this paradigm in political science. These are the American school [44, 45], the English school [43], and the school of continental Europe [46]. The roots of network political analysis lie in the study of the division of power between public and private actors in the sphere of political decision-making. The presence of political networks makes it possible to speak of the organizational state [47] as a characteristic of relations between various subjects of political decision-making. Network analysis makes it possible to study in detail the relationships between actors, calculate centrality indicators, determine the positions of actors in terms of brokerage and prestige, and also calculate other characteristics of the network [8]. However, collecting data for network analysis is not an easy task in the conditions of Russian society [9, 48], which the authors of this article also faced.

One of the main problems of the network analysis is a weakness of the explanation potential, that's why it is necessary to use extra theoretical models in order to explain the findings and give the correct interpretation. There are some theoretical models for this aim and we stem from the theoretical framework of Michael Mintrom and Phillipa Norman—the Conception of Political Entrepreneur [49]. Political

entrepreneurs may be in or out of government, in elected or appointed positions, in interest groups, or research organizations. Key trait: It is the desire, as in business, to invest one's resources in the hope of a return in the future. M. Mintrom speaks of these actors as "persons who, through their creativity, strategies, networks, and persuasive arguments, are able to bring new political ideas and promote a policy of change" [49]. This model has four basic ideas that explain the behavior of political entrepreneurs inside the political structure. The political actor who behaves like a political entrepreneur reflects social urgency (using political networks, understanding the motives, and concerns of others). He defines the problem identifying crisis to change the political agenda. He is capable of building a team as he has a good understanding of the importance of collaborating with coalitions to change the agenda. And the most important is that the political entrepreneur can lead by example taking the risk of innovation. Based on this theoretical model, we will try to interpret the status and behavior of informal leaders in the building network.

4 Network Analysis Results

In this work, one channel of conventional youth participation at the regional level has been analyzed—this is the Youth Parliament of the Leningrad region. "The Youth Parliament of the Leningrad Region, therefore, is an effective filter for finding suitable personnel for the municipal and public service" [39 , p. 73]. This structure is an advisory body to the Legislative Assembly of the Leningrad Region on youth policy issues. It was created to develop the political culture of young people and involve them in participating in the government of the country [7]. The Youth Institute of Parliamentarism, both at the federal level (Youth Parliament under the State Duma) and at the level of the subject of the Russian Federation, is the embodiment of the idea of parliamentarism among the youth, proposed by the Council of Europe in 1992 (European Charter on the participation of youth in the life of municipal and regional entities).

The Youth Parliament of the Leningrad Region first arose in 2012. The Youth Parliament of the new convocation includes 26 deputies [50]. The composition of the parliament is formed from two deputies of a large municipality of the Leningrad Region (ten districts in total) and one deputy each of a small municipality (eight districts in total). The maximum age of the participants in the youth parliament should not exceed 35 years. A biographical analysis of open sources showed that the composition of the youth parliament 2019–2022 convocation mainly includes representatives of generation Y (1982–1999), while for representatives of generation Z born after 2000, this institution did not become a way to enter power. Only 5% of generation Z is present in the parliament of this convocation. From the point of view of belonging to political parties, 90% of the participants in the young parliament are members of United Russia.

Pajek software made it possible to reveal the coincidence of the formal roles of the chairman and secretary of the Youth parliament with their place and role in the

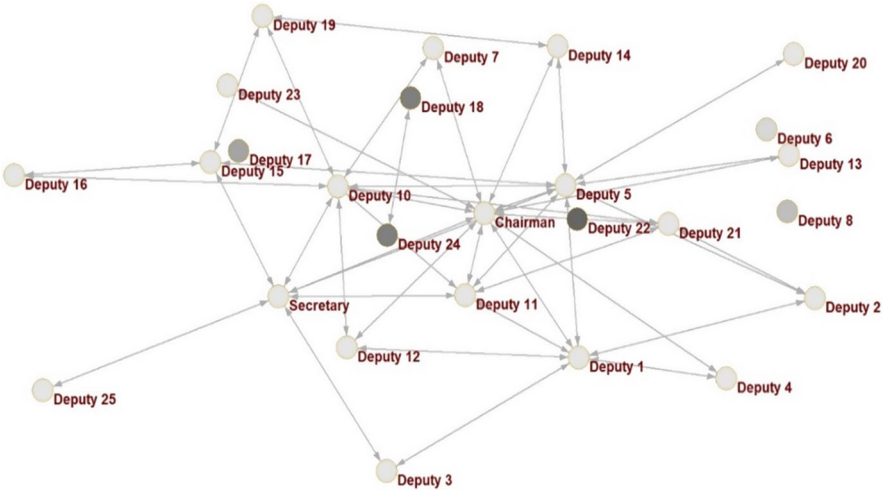

Fig. 1 The network of the informal ties in the Youth Parliament of Leningrad region

structure of informal ties (See Fig. 1). So, for example, the chairman occupies a central position in the network, most of the connections close to him. Therefore, we can conclude that the choice of this person for the position of chairman is the right decision, and he effectively copes with his functions, having solid social capital within this political structure. The secretary has a somewhat peripheral position, although a fair number of connections close to her, perhaps this borderline position is due to incomplete information about the participants, since the data was collected from open sources on the Internet.

Primary visualization also made it possible to detect informal leaders within the organization—these are deputies numbered 1, 5, 10, and 11. Most of the connections are also closed on them, which can be seen on the network map (Fig. 1). A subsequent interview with a representative of the youth parliament confirmed the status of these deputies as informal leaders of this organization.

Next, we carried out a clustering of the network of informal connections within the Youth Parliament (highlighting the strong components of the network). These clusters (components) are depicted on the network card in different colors (See Fig. 1). Figure 1 shows that the network consists of two strong components and four isolated vertices (deputies 6, 8, 17, and 22). The component with light gray vertices is the largest. It includes the chairman of the parliament, the secretary, and four informal leaders, therefore, we can designate it as a pro-government component. There is also a small component in the network, unrelated to the pro-government network, consisting of two peaks (deputies 18 and 24). This indicates the heterogeneity of relations within the organization and the possible presence of some confrontation.

Since network analysis serves not only to visualize relationships, but also to calculate indicators to confirm what is seen on the network map and identify

additional trends, our study will calculate vertex centralities, prestige indicators, and brokerage roles.

The following metrics will be used to calculate vertex centralities (vertex degree, closeness centrality, betweenness centrality, and eigenvector centrality). When calculating the degree of the vertex, it was revealed that the chairman of the youth parliament of the Leningrad Region has the highest degree (the number of incoming and outgoing arcs) (the degree is 24), the degree of the secretary is 14, which also indicates a significant social capital of this actor within the structure under study. The importance of informal leaders in communication processes also becomes apparent. So deputy 1 has degree 14, deputy 5 has degree 21, deputy 10 has degree 18, and deputy 11 has degree 12. About 20% of participants have a vertex degree equal to 2. The network density is low—14% with the maximum possible density equal to one. The degree of centralization could not be calculated, since the network contains multiple connections. Next, we calculate the closeness centrality, which determines the proximity of the network actor, taking into account the values of degree, closeness, and betweenness. The closeness centrality for the chairman of parliament is 0.56, for the secretary 0.47, and for informal leaders of parliament 0.41 (deputy 1), 0.52 (deputy 5), 0.45 (deputy 10), and 0.38 (deputy 11). Next, we calculate the betweenness centrality, i.e., how often the actor is an intermediary between any other two participants in the network, being on the shortest path between them. As a result of the calculations performed in Pajek, the following values were revealed. The chairman has the highest betweenness centrality, 0.19. This is not surprising, since he is at the center of a network of informal relationships, and many connections are closed to him. Next come the informal leaders: deputy 5 with an indicator of 0.13 and deputy 10 with an indicator of 0.11. The secretary has a betweenness centrality indicator equal to 0.09, and the other informal leaders (deputies 1 and 11) have an indicator of 0.05 and 0.01, respectively. About 46% of the nodes from the total number of participants occupy a peripheral position. Let's calculate the eigenvector centrality. This indicator demonstrates the relationship between the position of the influential actor with other influential actors in the network. Since the links are mutual, the eigenvector centrality for the receiving and sending vertices is the same. The eigenvector centrality for the chairman of parliament is 0.41, for the secretary 0.29, for informal leaders—0.28 (deputy 1), 0.32 (deputy 5), 0.36 (deputy 10), and 0.23 (deputy 11). This once again confirms the centrality of the position of formal and identified informal leaders.

When calculating the prestige of actors, it will use the proximity prestige, which is more important, the more connections the vertices have that are in contact with the vertex in focus. The speaker of parliament has the highest proximity prestige (0.56), however, other informal leaders are not far behind him either 0.42 (deputy 1), 0.51 (deputy 5), 0.50 (deputy 10), or 0.45 (deputy 11). The Secretary has a proximity prestige of 0.47. Thus, from the point of view of structural prestige, these actors have leadership positions within the network of informal connections in the youth parliament of the Leningrad Region.

The average distance between 73% of the vertices is 2, i.e., most vertices are connected to each other through 1 vertex. The most distant vertices are deputy 1 and

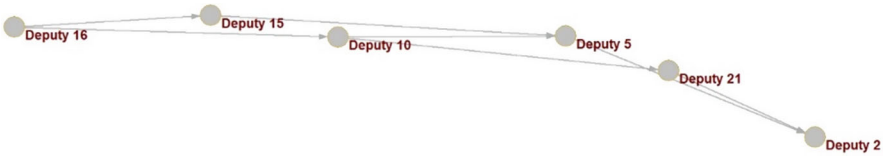

Fig. 2 Geodesic for vertices 16 and 2

deputy 19. The average distance to them is 3. A total of 85 pairs of vertices are connected by path 1, 204 pairs of vertices by path 2, and 93 pairs of vertices by path 3. The shortest distance (geodesic) between the extreme nodes of the network is (deputies 16 and 2) 3, which shows that, in general, the actors in the network interact quite actively with each other (See Fig. 2). The geodesic for the chairman of the parliament and the most distant node (deputy 16) is 2, and with the secretary is at a distance of 1 from the chairman, thus constructive relations have been established between the chairman and the secretary of parliament, not only on a formal but also on an informal level, which should positively influence on the work carried out within this structure.

Analysis of broker connections allows us to identify one bicomponent of 17 vertices (the most connected section of the network) and four bridges: secretary-deputy 25, chairman-deputy 23, deputy 5-deputy 20, deputy 18-deputy 24. At the same time, the secretary, chairman, deputy 5, and deputy 18 are cut-vertices, the removal of which leads to a break in the network and the formation of new unconnected components. Thus, four players were identified who can play brokerage roles and without which well-coordinated communication in this network is impossible. Next, we turn to the types of brokerage roles that the most influential actors in a given network can perform. There are five options for brokerage roles: (1) Coordinator, (2) Itinerant Broker, (3) Representative, (4) Guardian, and (5) Liaison. In cases (1) and (3), the actor under study is inside the group. As a result of calculations in Pajek, it was revealed that the role of the coordinator, who transfers information within the Itinerant group, is performed by informal leaders (deputy 1 and deputy 10) 20 and 28 times, respectively, by deputy 11 only 4 times. At the same time, neither the chairman, the secretary, nor the deputy 5 perform these roles. At the same time, new players appeared—deputies 19 and 21, who acted as coordinators 6 and 4 times, respectively. The role of the itinerant broker, i.e., such a broker, who coordinates outside the group, is the chairman of the youth parliament (56 roles), deputy 30 (30 roles), and secretary (10 roles). The chairman performs the role of a representative from his group to another group 13 times, the secretary 5, and informal leaders (deputies 1, 5, 10, and 11) 5, 7, 12, and 3 times, respectively. These members perform the same number of gatekeeper roles, i.e., when they decide whether their group should interact with a member of another group or not. The role of a liaison, i.e., an outsider in relation to other groups, the chairman performs 18 times, the secretary performs 8 times, and the deputy 5 performs 3 times. Other deputies of the youth parliament do not perform this brokerage role.

5 Conclusion and Perspectives

Based on the study, several important conclusions can be drawn. Firstly, the biographical method used in this study suggests that the youth parliament is a springboard to power, but not always effective. This is due to the closeness of this structure (at least in the Leningrad region), since people who have already passed the filter of the municipal government get into the youth parliament—they must be deputies of the representative body of the municipality and receive a letter of recommendation from the head of this entity. Generation Z is poorly represented in the Youth Parliament of the Leningrad region—only 5% of cases out of 100%. Consequently, the hypothesis 1 wasn't confirmed. Generation Z of the Leningrad region doesn't use the Youth Parliament as a channel to political power. However, to speak about the effectiveness of Youth Parliament as a political institute capable of integrating generation Z into power, it is necessary to investigate Youth Parliaments of other regions of Russia (for example, St Peterburg). St Peterburg Youth Parliament is a young structure. It was created in 2022. So, we need some time to speak about its effectiveness as a channel to the power for youth.

Secondly, the contradictions between the ongoing youth policy and the political participation of the youth groups themselves are explained by the difference between the technocratic and deliberative approaches to governance. In reality, it is more difficult to separate them than in theory: it is obvious that debatable moments are present in the activities of the Youth Parliament, but they are associated not so much with values, but with specific events that help young people solve a particular issue (for example, the issue of career and choice of profession).

Thirdly, the study mainly affected a group of "political entrepreneurs" who are trying to build their careers and achieve their own goals based on participation in the work of the Youth Parliament of the Leningrad Region. This group has close ties with the councils of municipal deputies of the Leningrad region, the Legislative Assembly of the Leningrad region, as well as parties, mainly the United Russia party. The concept of "political entrepreneurs" was used in the sense of a choice toward conventional political participation and active building of a political career. The group is predominantly made up of Generation Y, Millennials, and to a lesser extent, Generation Z, Digital Natives. Such a composition is justified—there is no large social gap between these generations, at the same time, the older cohort of young people probably has more legitimacy in the implementation of youth policy in the eyes of the younger cohort.

The empirical study carried out was aimed at studying network effects within the group of "political entrepreneurs." For example, it was revealed that the informal and formal roles of the chairman and secretary of the Youth Parliament coincide with each other, which indicates the right choice of these people for their positions. Clusters of the studied group and isolated nodes, on the one hand, probably coincide with party affiliation, however, on the other hand, leadership and isolation can also be explained by sociopsychological dynamics: informal leaders practically do not lag behind the chairman in terms of structural prestige. In addition, the Youth

Parliament is a fairly close-knit group, since, on average, MPs interact with each other "through one handshake." The study also showed that the chairman and secretary of the Youth Parliament are less trying to coordinate and represent the interests of their cluster and more trying to connect their cluster with other microgroups, thus performing an integrative function in the group of "political entrepreneurs."

The study of channels of political participation, and institutions for the implementation of youth policy, from the point of view of the authors, is necessary as a preliminary before longitudinal projects and large-scale studies of participation in the political life of representatives of the younger generations. So, in particular, the potential for political participation of generation Z is of interest. Previously, a team of authors highlighted the fact that Generation Z has a fairly low tolerance for uncertainty, which is typically observed in post-traumatic eras and which unites Generation Z with the Baby Boomer generation. Another aspect is the digitalization of social perception, as Generation Z does not remember the time "without social networks." It follows from this that, probably, generation Z will actively support social programs, education, career, housing, and other projects, as well as the gradual, without leaps, development of technology, the economy, and civil society. The possibility of power to construct positive relations with youth is the topic for further research.

References

1. Stillman, D.: Generation Z at Work. How to Understand Him and Find a Common Language with Him. Mann, Ivanov and Ferber, Moscow (2018)
2. Palfrey, J., Gasser, U.: Born Digital: Understanding the First Generation of Digital Natives. Basic Books, New York (2008)
3. Prensky, M.: Digital natives, digital immigrants. In: On the Horizon, vol. 9, no. 5. MCB University Press, Bingley (2001) http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf. Last accessed 10 Apr 2022
4. Komarovsky, V.S. (ed.): The Image of the Desired Future of Russia Through the Eyes of Student Youth: Monograph. Aspect Press, Moscow (2021)
5. Regulations on the Youth Parliament of the Leningrad Region (approved by the Decree of the Legislative Assembly of the Leningrad Region No. 264 dated March 28, 2012)
6. Almond, G., Verba, S.: Civic Culture. Political Participation and Democracy in Five Countries. Thought, Moscow (2014)
7. Trynov, D.V., Kazantsev, Y.Y.: Youth representation in government: do social elevators of political participation work? In: The World of Science Sociology, Philology, Culturology, vol. 12, no. 1. World of Science (2021) https://sfk-mn.ru/PDF/11SCSK121.pdf. Last accessed 23 Feb 2023
8. De Nooy, W., Mrvar, A., Batagelj, V.: Exploratory Social Network Analysis with Pajek: Revised and Expanded Edition for Updated Software, 3rd edn. Cambridge University Press, Cambridge (2018)
9. Smorgunov, L.V., Sherstobitov, A.S. (eds.): Political Networks: Theory and Methods of Analysis: A Textbook for University Students. Aspect Press Publishing House, Moscow (2014)
10. Ostoic, A.R.: Algebraic Analysis of Social Networks: Models, Methods & Applications Using R. Wiley, Oxford (2021)

11. Collin, P.: Young Citizens and Political Participation in a Digital Society. Palgrave Macmillan, London (2009)
12. Flinders, M., Wood, M.: Nexus politics. Democr. Theory. **5**(2), 56–81 (2018)
13. Grasso, M.T.: Generations, Political Participation and Social Change in Western Europe. Routledge, London (2016)
14. Norris, P.: Democratic Phoenix: Reinventing Political Activism. Cambridge University Press, Cambridge (2002)
15. Rowe, P., Marsh, D.: Between the social and the political. Democr. Theory. **5**(2), 90–98 (2018)
16. Sparks, H.: Dissident citizenship: democratic theory, political courage, and activist women. Hypatia. **12**(4), 74–110 (1997)
17. Van Deth, J.W.: A conceptual map of political participation. Acta Polit. **49**(3), 349–367 (2014)
18. Akram, S., Marsh, D., McCarrie, B.: A crisis of participation. In: Richards, D., Smith, M., Hay, C. (eds.) Institutional Crisis in 21st-Century Britain, pp. 39–59. Palgrave Macmillan, London (2014)
19. Barnes, S.H., Kaase, M. (eds.): Political Action: Mass Participation in Five Western Democracies. Sage, Beverly Hills (1979)
20. Kaase, M.: Interpersonal trust, political trust and non institutionalised political participation in Western Europe. West Eur. Polit. **22**(3), 1–21 (1999)
21. Lamprianou, I.: Contemporary political participation research: a critical assessment. In: Demetriou, K.N. (ed.) Democracy in Transition: Political Participation in the European Union, pp. 21–42. Springer, Heidelberg/New York (2013)
22. Linssen, R., Schmeets H., Scheepers, P., Grotenhuis, M.T.: Trends in conventional and unconventional political participation in Europe 1981–2008. Paper presented to the panel "The emergence of new types of political participation and its consequences" at the 6th ECPR General Conference, Reykjavik, 25–27 Aug 2011
23. Riley, S., Griffin, C., Morey, Y.: The rise of the pleasure citizen: how leisure can be a site for alternative forms of political participation. In: Demetriou, K.N. (ed.) Democracy in Transition: Political Participation in the European Union, pp. 61–75. Springer, Heidelberg/New York (2013)
24. Kaim, M.: Rethinking modes of political participation: the conventional, unconventional, and alternative. Democr. Theory. **8**(1), 50–70 (2021) https://www.researchgate.net/publication/352032123_Rethinking_Modes_of_Political_Participation_The_Conventional_Unconventional_and_Alternative. Last access 3 Jan 2023
25. Grace, M., Seemiller, C.: Generation Z: A Century in the Making. Routledge, London (2019)
26. Gudkov, L., Zorkaya, N., Kochergina, E., Pipiya, K., Ryseva, A.: Russia's "generation Z": attitudes and values 2019/2020, p. 7. https://library.fes.de/pdf-files/bueros/moskau/16134.pdf
27. Tolstikova, I., Ignatjeva, O., Kondratenko, K., Pletnev, A.: Generation Z and its value transformations: digital reality vs. phygital interaction. In: Digital Transformation and Global Society, pp. 47–61. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-65218-0. Last accessed 3 Jan 2023
28. Brodovskaya, E.V., Huang, T.: Digital generation: civil mobilization and political protest of Russian youth. Public Opin. Monit. Econ. Soc. Chang. **153**(5), 3–18 (2019)
29. Trynov, D.V.: Youth political participation: support vs. protest. Sociodynamics. **12**, 298–314 (2019)
30. Pietilä, I., Meriläinenb, N., Varsaluoma, J., Väänänena, K.: Understanding youths' needs for digital societal participation: towards an inclusive Virtual Council. Behav. Inform. Technol. **40**(5), 483–496 (2021)
31. Grishaeva, S.A., Lebedeva, A.A.: Prospects for the development of digital forms of political participation of generation Z in modern Russia. Digit. Sociol. **3**(4), 12–18 (2020)
32. Bolshunova, T.V.: Value-motivational aspect of the participation of "generation Z" in the modern political process. Bull. VSU. **1**, 63–67 (2018)
33. Pyrma, R.V.: Generation Z revolt: new political radicals. Humanities. **7**(2), 43–50 (2017)

34. Rudenkin, D.V.: Impulses for the growth of protest activity of Russian youth: the case of Yekaterinburg. Conflictology/nota bene. **1**, 1–14 (2020) https://doi.org/10.7256/2454-0617.2020.1.32326, https://nbpublish.com/library_read_article.php?id=32326. Last accessed 5 Mar 2023
35. Saburova, L.A., Blagodatsky, G.A., Stazhiloa, V.V., Vantrusov, P.V.: Factors of social mobilization in Internet communities. Bull. PNRPU. **3**, 156–170 (2021). https://doi.org/10.15593/2224-9354/2021.3.11
36. Abramova, S.B.: Digital participation: conceptualization of the concept in foreign practice of civic engagement. Digit. Sociol. **5**(4), 4–14 (2022) https://cyberleninka.ru/article/n/tsifrovaya-partisipatsiya-kontseptualizatsiya-ponyatiya-v-zarubezhnoy-praktike-grazhdanskoy-aktivnosti. Last accessed 15 Mar 2023
37. Dombrovskaya, A.Y.: Civic activism of youth in modern Russia: features of manifestation in online and offline environments (according to the results of an empirical study). Power. **28**(2), 51–58 (2020). https://doi.org/10.31171/vlast.v28i2.7134
38. Edwards, P.N.: Infrastructure and modernity: force, time, and social organization in the history of sociotechnical systems. In: Modernity and Technology. MIT Press, Cambridge, MA/London (2002) http://pne.people.si.umich.edu/PDF/twente.pdf
39. Fedotov, D.A.: The specifics of the functioning of the youth parliamentary structures of the Leningrad region. Naukosphere. **2**(12), 67–74 (2020)
40. Latour, B.: Reassembling the Social. An Introduction to Actor-Network Theory. HSE, Moscow (2014)
41. Castells, M.: The Power of Communication. HSE, Moscow (2020)
42. Rhodes, R.: Policy network analysis. In: Moran, M., Rein, M., Goodin, R.E. (eds.) The Oxford Handbook of Public Policy, pp. 423–445. Oxford University Press, Oxford (2006)
43. Rhodes, R.: Understanding governance: ten years on. Organ. Stud. **8**(28), 1–22 (2007)
44. Heclo, H.: Issue networks and the executive establishment. In: McCool, D. (ed.) Public Policy Theories, Models, and Concepts. An Anthology, pp. 263–287. Prentice Hall, Englewood Cliffs (1995)
45. O'Toole, L., Meier, K.: Desperately seeking Selznik: cooptation and the ark side of public management in networks. Public Adm. Rev. **6**(64), 1–40 (2004)
46. Borzel, T.: Organizing Babylon—on the different conceptions of policy networks. Public Adm. **2**(76), 253–273 (1998)
47. Knoke, D., Pappi, F., Broadbent, J., Tsujinaka, Y.: Comparing Policy Networks. Labor Politics in the US, Germany and Japan. Cambridge University Press, New York (1996)
48. Smorgunov, L.V.: Russian movement for "open government": issues of civic engagement in politics. Int. J. Electron. Gov. **3**(8), 211 (2016)
49. Mintrom, M., Norman, P.: Policy entrepreneurship and policy change. Policy Stud. J. **37**(4), 649–667 (2009)
50. Composition of the Youth Parliament under the Legislative Assembly of the Leningrad Region (approved by the Decree of the Legislative Assembly of the Leningrad Region 264, dated November 8, 2019)

Digital Ecosystems: How Are They Defined and Regulated in Russia?

Elena A. Isaeva, Alexander V. Sokolov, and Alexander Frolov

Abstract The rapid development of digital services and platforms creates conditions for the development of complex digital ecosystems based on them. As a result, a request is formed for adequate regulation of the new phenomenon by state-legal norms. This chapter presents the results of a study aimed at identifying the peculiarities of understanding digital ecosystems in the regulatory legal acts of federal public authorities, as well as the framework for regulating their activities provided by them. The authors analyzed the concept of "digital ecosystem" in the regulatory framework of the Russian Federation functioning at the federal level. The source base was the "Consultant Plus" database. The conducted research suggests that modern Russian legislation has not formed an adequate comprehensive response (regulation) to the intensively developing practice of creating ecosystems in various sectors of the economy and social activities. The role of ecosystems is revealed rather in departmental acts, which are poorly coordinated with each other, and rather aimed at subordinate areas. The actual law is forced to catch up with the realities and phenomena emerging in the emerging practice rather than act ahead of the curve.

Keywords System · Legislation · Internet · Digital service · Regulation

1 Introduction

The term "digital ecosystem" is increasingly being used in Russian scientific literature, statements by representatives of government authorities, the banking sector, etc. Even more often, the "ecosystem" and "ecosystem" approach are used in business. Modern companies strive to create (or designate themselves) innovative digital ecosystems. The Russian state has also taken the path of creating superservices and ecosystems (a vivid example is the Portal of Public Services).

Such innovations in the public sphere contribute to the practical implementation of e-government approaches, and the introduction of various digital services into the

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_32

public administration system. This process actualizes the understanding and formulation of basic approaches to the interpretation of the emerging digital reality, and the nature of relations between the state, business, and citizens in it. This will determine the main responsibilities and rights of the interacting parties, as well as conflict resolution procedures.

In this regard, there is an active desire to create a legal regulation of this phenomenon (in parallel with its theoretical scientific understanding). In this aspect, it should be noted that there is virtually no single center regulating this work, which should be based on a significant methodological basis that includes a fundamental understanding of the ongoing global digital transformations. Therefore, the understanding of the definition of "digital ecosystem" and the specifics of its use in the regulatory framework are being updated.

At the same time, it is important to form a request from society for adequate and prompt regulation of the creation of digital ecosystems in order to form a response to the new digital reality. The emerging management practice confirms the formation of imbalances in the rights and opportunities of participants in developing digital ecosystems (conflict in the Wildberries, leaks of personal data from their operators, etc.).

2 Theoretical Framework

The formation of many new digitalization practices predetermines the request for the development of an appropriate model of their legal regulation. However, it is not fully clear whether the traditional regulation of the digital environment by national states is possible, which is cross-border, and the phenomena of which are rapidly emerging and developing [1]. Kravchenko A.G. notes that an adequate regulation of the digital environment requires not point-to-point changes, but the development of a new legal paradigm [2].

At the same time, the problems of digital neutrality and the global role of digital platforms are increasingly being discussed. As a result, two main approaches to regulating the digital space can be formulated in the scientific discussion: Chinese and American [3].

From the position of the state, questions also arise on the regulation of various functions of business ecosystems, in particular those related to cybersecurity, suppression of violations of antimonopoly legislation, and taxation [4]. Thus, A.A. Kurdin writes that in practice, a common understanding of the main antitrust problems of the digital economy is beginning to develop, which include network effects, significant power of digital platforms, and price discrimination based on big data [5]. At the level of the European Union, two regulatory legal acts were adopted in July 2022: the Law on Digital Services and the Law on the Digital Market, which constitute a single set of rules for the protection of the fundamental rights of all users of digital services and are applied in all EU countries, creating equal conditions for

stimulating innovation, growth, and competitiveness in areas of digital services development [6].

It is important to note that in modern science there is no single understanding of the phenomenon of the digital ecosystem. It is possible to note two approaches closest to the author's understanding. Within the framework of the first approach, the digital ecosystem is understood as a system with the characteristics of stability and the ability to self-organize, formed on the basis of a digital platform that creates a single information space for a large number of users who are able to interact fairly equally with each other [7]. In the second approach, the digital ecosystem is characterized by its structure: the owner of the digital platform, who performs the function of managing it, to ensure the interaction of the creators of a certain benefit (goods, services, and content) and their consumers [8].

Within the framework of the laws, procedures for interviewing active users are designated, and if the platform or search engine has more than 45 million users, the Commission will mark the service as a "very large online platform" or "very large online search engine." These services will have 4 months to fulfill the obligations of the Digital Services Act, which include conducting and providing the Commission with their first annual risk assessment. EU member states will have to appoint digital service coordinators by February 17, 2024, when platforms with less than 45 million active users will also have to comply with all the rules of the Digital Services Act.

Issues related to the creation of national interacting digital health ecosystems (digital health ecosystem) and the possibility of their regulation at the supranational level are considered at the international level. So, Kartskhiya A. A. writes that the situation associated with the pandemic caused by the spread of the COVID-19 coronavirus infection has affected the development of digital healthcare systems and digital healthcare medicine [9]. The development of digital health ecosystems provides for the formation of a legislative framework at the international level, at least for World Health Organization member countries.

As part of the study of ecosystems, the specifics of legal regulation, including at the international level, become an important component. In particular, the UN General Assembly Resolution No. 68/167 of December 18, 2013, confirmed the thesis that human rights that exist in reality must be respected and protected in the virtual space [10].

We agree with the author that the legal status of participants in digital ecosystems is defined as classical industry legislation in the case when traditional legal relations are "transferred" by two to a digital environment (e.g., a seller and a buyer of an item in an online store). However, in general, it is undoubtedly necessary to recognize that digital ecosystems require an integrated approach to regulation [11].

The expediency of regulating global corporations is also recognized in the United States, where this problem is considered from the standpoint of supporting competition and antitrust law (in particular, in relation to Apple, Amazon, and Google) [12].

It seems that one can agree with R. Mason that the key problems in regulating digital ecosystems are the desire to ensure respect for confidentiality, accuracy, property rights, accessibility, or anonymity [13]. This is especially important in the

context of the development of cybercrime. A separate direction should be the limitation of the digital ecosystems themselves, which seek to expand as much as possible to capture all possible space [14].

The introduction of digital services into the daily lives of citizens has made it possible to formulate a legal approach in which they are interpreted and regulated by analogy with the communal sphere [15]. This approach has a right to exist due to the fact that digital services ensure the interconnection of suppliers and consumers of goods and services, and digital services themselves are thereby endowed with certain power advantages. At the same time, in some cases, digital platforms are de facto monopolists.

Thus, we can talk about a fairly rapid process of understanding the functioning of digital ecosystems and the formation of basic approaches to their regulation in legislation. At the same time, two key approaches to the interpretation of digital ecosystems are highlighted:

- As a service provided in a competitive market (thus, we can talk about the equality of the parties, where the digital service only provides an opportunity for interaction).
- As a monopolized service that requires special regulation to ensure the rights and interests of its interacting parties who are dependent on the digital platform (and therefore need protection from it).

In any case, we can say that digital platforms have the ability to determine user behavior through their own rules and procedures [16]. Thus, the request for regulation of digital services and platforms themselves is justified, including to minimize and resolve conflicts arising in connection with their use [17].

As a result, a request is being formed to analyze the emerging political and legal interpretation of digital ecosystems in modern Russia in order to understand the vector chosen by the domestic legislator for the possibility of predicting the further development of new digital phenomena and relations based on them.

3 Methods

The purpose of this study is to identify the peculiarities of understanding digital ecosystems in the regulatory legal acts of federal public authorities and the framework for regulating their activities provided by them. The analysis is intended to provide an understanding of to what extent and in what way the modern Russian state implements the legal regulation of the new phenomenon of digital ecosystems adequately to the emerging practice.

The authors analyzed the concept of a “digital ecosystem” in the regulatory framework of the Russian Federation functioning at the federal level. The source base was the base “Consultant plus.” In the course of the study, through contextual search, the current regulations were identified, including the category “digital ecosystem” and the same-root words in the synonymous form included in the database

as of November 1, 2022. Then the data of regulatory legal acts were uploaded for further analysis. The final analyzed set included 24 documents containing a meaningful description and interpretation of digital ecosystems.

During the analysis of the identified normative legal acts, qualitative methods were used: a legal and linguistic approach. They made it possible to identify and interpret the definitions of the category "ecosystem" fixed in the documents, as well as specific norms characterizing their activities.

4 Results

The issues of regulating the concept of ecosystems and processes that are associated with the development of digital platforms are actively discussed in various fields of activity. Different typologies of ecosystems and platforms are being formed, while at the level of regulatory legal acts, the concepts of "digital system" and "ecosystem" are not fully formed, there are many gaps. Thus, in the report on the key aspects of the legal regulation of the work of organizations that adhere to the ecosystem approach in their development [18] prepared by the Commission on Communications and Information and Communication Technologies of the Russian Union of Industrialists and Entrepreneurs, it is proposed to consolidate initiatives in the NPA aimed at the following: uniform consent to data processing by ecosystem participants (amendment to the Federal Law "On Personal Data"), the implementation of state support measures for Russian ecosystems, consolidation of certain provisions regarding ecosystems at the level of explanations of the Presidium of the federal Antimonopoly Service, etc.

The study of the array of existing regulations, the volume of domestic scientific literature suggests that there is no single definition of the concept of "digital ecosystem," neither those who use this term nor those who create these very ecosystems, which confirms the need to develop a single conceptual apparatus. In July 2021, ANO "Digital Economy" together with the Ministry of Economic Development of the Russian Federation held a round table on the concept of "ecosystem" and its defining characteristics [19]. It was important for the organizers of the event to differentiate the signs of ecosystems in order, among other things, to understand how this phenomenon can be regulated. A similar issue of risks of unregulated ecosystem development is reflected in the Report of the Bank of Russia, which notes that in order to reduce the negative effects of ecosystem development on the Russian market, it is necessary to develop a clear and adequate legal framework, as well as the introduction of a system of supervision over compliance with regulations [20].

Deputy Minister of Economic Development Vladislav Fedulov allowed the possibility of adopting a regulatory act (ecosystem constitution) introducing a federal regulatory framework and establishing general principles. For V. Fedulov, the defining feature of the ecosystem is the network effect, within which the number of suppliers and customers increases to the maximum among market players, a

greater predisposition to long-term investments and greater standardization of processes is formed. The author, highlighting two key criteria of the ecosystem, focuses on clear internal integration of related services, which goes against the signs of an anchor business, and stable investments in digital innovations in various fields, when it is possible that some services will be unprofitable for the development of others [21].

V. Fedulov in the noted scientific papers also highlights the risks that may threaten market participants. Specifically, the author touches on the aspect of player security and the oligopolization of the market itself. The author also highlights the political aspect, which consists of the ability to control public opinion through the created ecosystems by forming a discourse and filtering the text [22].

As part of our research, different definitions of the concept of "digital ecosystem" were identified, and in acts of different industry orientation. The analyzed terminology is used, first of all, and to a much greater extent, in the field of economic relations. Let us agree with the Doctor of Law, Professor A.V. Gabov, that economic relations are part of public relations that are most quickly "rebuilt" by digital reality [23].

The concept of the ecosystem of the digital economy, given in the Decree of the President of Russia [24], focuses on the interaction of organizations through their technology platforms, applied Internet services, and analytical systems.

The passport of the national project "Small and medium-sized entrepreneurship and support for individual entrepreneurial initiative" highlights as one of the indicators of the national project the creation of a digital ecosystem in demand by users, which would have a set of services necessary for consumers, a user-friendly interface, an addressable selection of support tools, ergonomics in terms of the number of operations.

The decree of the Government of Russia [25] uses the term "ecosystem of creative (creative) industries," by which the normative act means "a set of institutional conditions and mechanisms of interaction of entities involved in the formation and development of creative (creative) industries, including the production, distribution and popularization of creative (creative) goods and services, as well as training."

The Bank of Russia has identified the key vectors of development of the financial market of our country for 2022–2024 and has identified an ecosystem (digital ecosystem) as "a set of services, including platform solutions, of a single group of companies or companies and partners that allow users to receive a wide range of products and services within a single seamless integrated process." At the same time, it is important to note that the ecosystem may consist of closed and open platforms, and the range of services corresponds to most of the daily consumer requests. Also, an ecosystem can be centered on one or a group of needs, as a rule, these are niche ecosystems. The position of the Bank of Russia also noted that ecosystems, developing, contribute to blurring the line between financial and non-financial services within the same ecosystem [26].

In the Rules [27], the digital ecosystem is defined as "a set of services, services and solutions, including standard solutions, operating under the conditions of unity

of the data model and system architecture," and the platform is defined as "a functionally limited model of the digital ecosystem in which the services provided by the participants of the digital ecosystem are located." Another Decree of the Russian Government [28] uses the term "digital ecosystem" as a way to designate the elements of the "One Window" system. There are examples of regulations when the definition of the concept of "ecosystem" is not given, but it is used in the text to form the structure of another concept, for example, an Order [29]—when defining the concept of a state unified cloud platform.

It is important for the Bank of Russia and the Government of the Russian Federation to propose vectors and approaches to regulatory regulation of ecosystem activities. Regulators assign a significant role to antimonopoly legislation, as well as acts of the Bank of Russia in dealing with risks that may be associated with the involvement of credit institutions in ecosystem business.

An important element of the regulatory system should be the modernization of legislation in the field of access and use of data that settles in ecosystems. It is important to focus on the security of the digital environment; priority support for domestic ecosystems and the creation of an environment for fair competition; the creation of a non-discriminatory, transparent, and alternative access system for ecosystem users; ensuring the protection and ability to dispose of their ecosystem users' data [30].

The term "ecosystem" is used in the regulatory framework of Russia in various fields, for example, the Government decree [31] uses this concept in the context of the fact that improving information technology support for customs authorities and information security contributes to the creation of an ecosystem of the digital economy of the Russian Federation, in which digital data is a key factor in all spheres of socio-economic activity [31].

The term "digital ecosystem" is also used in the field of education. G.D. Demichev notes that 100% of higher education institutions subordinate to the Ministry of Education and Science of Russia have implemented a target model of a digital university, which makes it possible to create a single ecosystem of services in the field of educational process, and in the future will create a base of digital portfolios, build individual educational technologies and others [32].

The Ministry of Education of Russia [33] also uses the analyzed term in the context of the risk of insufficient development of the level and pace of digital transformation at the level of individual educational organizations or at the level of individual elements of the digital ecosystem in the field of education.

In the field of sports, the Concept [34] is noteworthy, which defines the task of forming a unified digital ecosystem of the industry, which would include various mechanisms, in particular, knowledge bases, regulatory sandboxes, industry expert support tools, and training tools. The concept also emphasizes the need to transform the approach to working with data aimed at creating an ecosystem. The regulatory act provides for the need to transform the processes aimed at obtaining, processing, and analyzing data, their safe storage, etc.

In the field of tourism, we note the Government decree [35] using the term tourism ecosystem, emphasizing that its creation belongs to one of the important

tasks for the development of domestic and inbound tourism. The ecosystem will bring together market participants on a single digital platform, develop and offer consumers a wide range of services, and promote Russian tourism products.

By the Federal State Statistics Service pursuant to the instruction of the President of the Russian Federation dated July 11, 2021. N Pr-1219 for the purpose of organizing monitoring of digital platforms, an Order of Rosstat [36] was adopted, which gave a definition to the digital ecosystem: "A set of more or less integrated digital services and/or digital platforms, formed in order to best meet the needs of a certain target audience or a set of target audiences, and having features that allow consumers of services to establish the fact that the digital services and/or platforms that are part of the ecosystem belong to the same ecosystem." The regulatory act focuses on the fact that such a set is recognized as a digital ecosystem, regardless of the method and degree of integration of elements, ownership of assets involved in the ecosystem, and the degree of affiliation of their owners; owners of assets involved in the ecosystem are characterized by commonality and interdependence of economic interests, adhere to a common family of consistent concepts and strategies for the development of individual services and an aggregate service offer.

The regulatory act identifies three types of ecosystems:

- A vertical digital ecosystem (it involves the involvement of a small group of users with a limited set of needs (e.g., a set of enterprises that have entered into production cooperation regarding the production of certain goods)).
- Horizontal digital ecosystem (it involves the involvement of a large group of users to meet the most common needs, for example, servicing the needs of households).
- A universal digital ecosystem (it involves the involvement of a large group of users to meet an unlimited range of needs).

The regulatory act also distinguishes the typology of digital ecosystems by the level of dominance of service holders into non-nuclear, based on equality and independence; single-core, assuming economic dominance, and multi-core, when economic dominance is inherent in more than one participant.

5 Conclusions

The conducted research suggests that modern Russian legislation has not formed an adequate comprehensive response (regulation) to the intensively developing practice of creating ecosystems in various sectors of the economy and social activities. In fact, economic and social actors are given freedom of action within the new digital conditions.

The role of ecosystems is revealed rather in departmental acts, which are poorly coordinated with each other, rather aimed at subordinate areas. The first attempt at comprehensive regulation and interpretation is an act of the Federal State Statistics Service, which defines the ecosystem, its typology, and topology.

At the same time, the formation of a holistic concept of understanding and regulating digital ecosystems will allow to form an e-government model that meets the expectations of citizens, businesses, NGOs, as well as the public administration system itself. Slowing down in this process creates additional risks, both in ensuring the competitiveness of service providers, ensuring an adequate combination of the rights and interests of various stakeholders, and minimizing threats to the digital transformation process.

However, there is no doubt that in the future the state will implement a comprehensive regulation of this phenomenon, which can cause significant damage to those entities (economic, social, political, cultural, social, and other spheres) that have made significant progress in understanding and developing their ecosystems that have found themselves outside the framework formed by regulatory bodies.

At the same time, adequate and timely regulatory regulation can minimize the potential costs and risks of entities that are actively involved in activities within the innovation sphere.

It can also be assumed that the use of the concept of "digital ecosystem" is more a tribute to fashion, a desire to demonstrate its innovativeness and compliance with the spirit of the times, rather than operating with a concept with a clear content, a characteristic of an established phenomenon that has adequate regulatory regulation.

At the same time, the emerging reality requires adequate legislative regulation in order to protect the interests and legitimate rights of all participants in relations related to the creation and functioning of ecosystems.

The results of the study suggest that no federal law provides a clear definition that reveals the structural elements of the concept. With regard to the concept of a "digital ecosystem", there is a traditional situation when a certain practice is formed first, and only then its regulation. The legislator does not take proactive actions, which would be the most promising (as O.A. Popova notes [37]). It should also be noted that digitalization, rapidly changing the world around it, is not always fully subject to systemic, and even more so timely legal regulation. A similar opinion is expressed by R. Tremolada, noting that states are late in regulating the emerging phenomena of digital ecosystems both in business and politics [38]. But it should also be noted that states simply cannot begin to regulate those phenomena that have not yet manifested, have not formed. In this regard, we will find ourselves in a situation of "catching up" with state regulation in this area. Therefore, it is advisable to comprehend and predict the development of digital ecosystems, the results of their functioning in order to prepare for their adequate regulation by the state.

It seems important that the state formulates its understanding of digital ecosystems, outlines the range of opportunities for interaction on digital platforms of various entities (as well as their rights and obligations toward each other), and also outlines the boundaries of monopolization of this sphere to ensure its sovereignty and ensure the rights of citizens.

Acknowledgments The research was funded by Russian Science Foundation, research project No. 22-28-01517, https://rscf.ru/en/project/22-28-01517.

References

1. Vasiliev, A.A., Shpopper, D., Stoilov, Y.B., et al.: Transformation of Law in the Digital Age. Altai State University, Barnaul (2020)
2. Kravchenko, A.G.: Legal paradigm in the era of high technologies. In: Blazheeva, V.V., Egorova, M.A. (eds.) Actual Problems of Law and Economics from the Perspective of Interdisciplinary Scientific Research as a form of International Cooperation: Monograph, pp. 67–74. Prospekt, Moscow (2020)
3. Song, A.K.: The digital entrepreneurial ecosystem—a critique and reconfiguration. Small Bus. Econ. **53**, 569–590 (2019)
4. Elmurzaeva, R.A., Skrylnikova, N.A.: Business ecosystems based on blockchain platform solutions. Bull. Altai Acad. Econ. Law. **12**(3), 646–656 (2020)
5. Kurdin, A.A.: Regulation of digital ecosystems within the framework of competition policy: an economic and legal approach. Sci. Res. Fac. Econ. **4**(42), 7–20 (2021) https://archive.econ.msu.ru/sys/raw.php?o=4433&p=attachment. Last accessed 20 Dec 2020
6. European Union: Shaping Europe's digital future. https://digital-strategy.ec.europa.eu/en/policies/digital-services-act-package. Last accessed 20 Dec 2022
7. Barykin, S.Y., Kapustina, I.V., Kirillova, T.V.: Economics of digital ecosystems. J. Open Innov.: Technol. Mark. Complex. **6**, 1–16 (2020)
8. Hein, A., Shereieck, M., Riasanow, T.: Digital platform ecosystems. Electron. Mark. **30**, 87–98 (2020)
9. Kartskhiya, A.A.: Information and legal support of the digital healthcare ecosystem. Leg. Inform. **1**, 13–23 (2021)
10. Kairbayev, L.K.: Protection of personal data in international and European law. Bull. Inst. Legis. Leg. Inf. Repub. Kaz. **5**(63), 168–174 (2020)
11. Gulyamov, S.S.: Legal and regulatory framework for the regulation of the digital economy. Natil. Assoc. Sci. **58**, 33–35 (2020)
12. Frédéric, J.: Competition law enforcement and regulation for digital ecosystems: understanding the issues, facing the challenges and moving forward. Concurrences. **3**, 38–62 (2021)
13. Mason, R.O.: Four ethical issues of the information age. MIS Q. **10**(1), 5–12 (1986)
14. Nieborg, D.B., Helmond, A.: The political economy of Facebook's platformization in the mobile ecosystem: Facebook Messenger as a platform instance. Media Cult. Soc. **41**(2), 196–218 (2019)
15. Sabeel, R.K.: The new utilities: private power, social infrastructure, and the revival of the public utility concept. Cardozo Law Rev. **39**(5), 1621–1689 (2018)
16. Balkin, J.M.: Digital speech and democratic culture: a theory of freedom of expression for the information society. N. Y. Univ. Law Rev. **79**, 1–55 (2004)
17. van Alstyne, M.: The opportunity and challenge of platforms. In: Jacobides, M., et al. (eds.) Platforms and Ecosystems: Enabling the Digital Economy, Briefing Paper. World Economic Forum (2019) http://www3.weforum.org/docs/WEF_Digital_Platforms_and_Ecosystems_2019.pdf. Last accessed 12 Mar 2023
18. Commission for Communications and Information and Communication Technologies of the Russian Union of Industrialists: Report "On key aspects of regulatory regulation of the activities of companies developing activities according to the ecosystem business model" (approved by the decision of the commission protocol no. 32 of 12/14/2021). https://rspp.ru/events/news/rspp-podgotovil-pozitsiyu-o-klyuchevykh-aspektakh-normativnogo-regulirovaniya-deyatelnosti-kompaniy%2D%2D61f960382db7a/. Last accessed 20 Dec 2022
19. The definition of "digital ecosystems" became the topic of a round table discussion between ANO "Tsifrovaya ekonomika" and the Ministry of Economic Development of the Russian Federation. 2021. https://www.interfax.ru/events/news/772787. Last accessed 20 Dec 2022
20. Bank of Russia: Ecosystems: approaches to regulation. Report for public discussions. https://cbr.ru/Content/Document/File/119960/Consultation_Paper_02042021.pdf. Last accessed 20 Dec 2020

21. Andreev, V.K.: On the ecosystem and legal issues of the digital economy. J. Entrep. Corp. Law. **1**, 15–19 (2022)
22. The government is preparing general principles for regulating ecosystems. https://www.vedomosti.ru/economics/characters/2021/09/28/888797-obschie-printsipi-ekosistem. Last accessed 20 Dec 2020
23. Gabov, A.V.: Online settlement of disputes between participants of digital platforms (ecosystems). Bull. Civ. Process. **1**, 208–235 (2022)
24. Decree of the President of the Russian Federation dated 05.09.2017 No. 203 "On the strategy for the development of the Information Society in the Russian Federation for 2017–2030". https://base.garant.ru/71670570. Last accessed 23 Dec 2020
25. Decree of the Government of the Russian Federation dated 09/20/2021 No. 2613-r "On approval of the concept for the development of creative (creative) industries and mechanisms for their state support in large and largest urban agglomerations until 2030". http://static.government.ru/media/files/HEXNAom6EJunVIxBCjIAtAya8FAVDUfP.pdf. Last accessed 23 Dec 2020
26. The main directions for the development of the financial market of the Russian Federation for 2022 and the period of 2023 and 2024. http://www.cbr.ru/content/document/file/131935/onrfr_2021-12-24.pdf. Last accessed 20 Dec 2020
27. Decree of the Government of the Russian Federation dated 08/27/2021 No. 1423 (as amended on 03/11/2023) "On approval of the rules for granting subsidies from the federal budget to the autonomous non-profit organization digital productivity technologies in order to form services using a modular multiservice industrial platform and standard solutions to increase labor productivity and the level of 'digital maturity' available to enterprises – participants of the digital productivity ecosystem". http://pravo.gov.ru/proxy/ips/?docbody=&prevDoc=602584207&backlink=1&&nd=602391252. Last accessed 23 Dec 2020
28. Decree of the Government of the Russian Federation dated 01/28/2022 No. 65 "On the procedure for the operation of the information system 'One Window'". https://www.consultant.ru/document/cons_doc_LAW_408251. Last accessed 23 Dec 2020
29. Decree of the Government of the Russian Federation dated 08/28/2019 No. 1911-r "On approval of the concept of creating a state unified cloud platform". https://www.consultant.ru/document/cons_doc_LAW_332993. Last accessed 23 Dec 2020
30. The concept of general regulation of the activities of groups of companies developing various digital services based on a single "Ecosystem". The text of the document is given in accordance with the publication on the website https://economy.gov.ru as of 05/28/2021. The title of the document is "The concept of general regulation of the activities of groups of companies developing various digital services based on a single 'Ecosystem'". https://www.consultant.ru/document/cons_doc_LAW_387363. Last accessed 23 Dec 2020
31. Decree of the Government of the Russian Federation dated 05/23/2020 N 1388-r "Strategy for the development of the customs service of the Russian Federation until 2030". https://www.consultant.ru/document/cons_doc_LAW_353557. Last accessed 23 Dec 2020
32. Demichev, G.D.: Strategy for the digital transformation of higher education: goals, objectives, directions of development. Manag. Educ. Organ. **8**, 2–13 (2021)
33. Order of the Ministry of Education of the Russian Federation dated 05/18/2020 N R-44 "On approval of methodological recommendations for the introduction of modern digital technologies into basic general education programs". https://www.consultant.ru/document/cons_doc_LAW_355762. Last accessed 23 Dec 2020
34. The concept of creation and functioning of the state information system "Unified digital platform 'Physical Culture and Sport'" (approved by the Ministry of Sports of Russia on 04/26/2021). https://www.consultant.ru/document/cons_doc_LAW_386543. Last accessed 23 Dec 2020
35. Decree of the Government of the Russian Federation dated 09/20/2019 No. 2129-r (ed. dated 02/07/2022) "On approval of the strategy for the development of tourism in the Russian

Federation for the period up to 2035". https://www.consultant.ru/document/cons_doc_LAW_333756. Last accessed 23 Dec 2020
36. Order Rosstat No. 583 dated 08/22/2022 "On approval of the form of federal statistical observation for the organization of federal statistical monitoring of the use of digital platforms". https://www.consultant.ru/document/cons_doc_LAW_424937. Last accessed 23 Dec 2020
37. Popova, O.A.: New subjects of the information society and the knowledge society: on the issue of normative legal regulation. J. Russ. Law. **11**, 14 (2018)
38. Tremolada, R.: Common carriers and public utilities in the digital ecosystem: unravelling the taxonomy on a quest for better regulation. Inf. Commun. Technol. Law. **31**(1), 35–80 (2022)

Social Media Management in the Russian State-Affiliated News Agencies: A Scoping Review

Ekaterina V. Mun and Svetlana S. Bodrunova

Abstract Russian state-affiliated news agencies play a particular role in how the interaction between the state, the media system, and the audiences is constructed. In recent years, information agencies, just as other media, have introduced social media management (SMM), including news publishing on social media. This, along with web 1.0 news publishing, contributes to a "B2C turn" of news agencies in terms of news production and dissemination. This also changes the role of information agencies in the public sphere; their roles shift from being primary news producers and gatekeepers into the roles similar to other media, thus making them take part into more intense market competition. However, for the state-owned information agencies which also perform the task of promoting the state-approved slant on events, the growing competition creates a clash of interests (commercial vs. political) which inevitably affects their SMM strategies—and this remains virtually unstudied. Our scoping review is dedicated to SMM strategies of state-affiliated information agencies in Russia, as assessed by the current media studies. A total of 12,800 academic papers on the use of social media by news agencies were identified, of which very few were on Russia. Of these few, only 23 met the criteria for inclusion in the review. We show that most papers deal with the agencies' SMM without putting it into normative perspectives and define a large gap between the Western and Russian research on news agencies' SMM, indicative of polarization within media studies.

Keywords Information agencies · News agencies · Social media management · Russian media · Public sphere

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_33

1 Introduction

In the twenty-first century, the media field has undergone significant changes, including due to digitalization and the rise of social networks. These changes have been described by the international media scholarship in a quite controversial way. On one hand, social media have allowed journalism to better reach audiences [1], measure the virality of new with precision previously unknown [2], adapt to various platforms and their varied populaces [3], and, most importantly, develop and perform new public roles via social media posting [4]. On the other hand, however, social media have brought tremendous changes to the organization of public discussion on political agendas—the changes that the scholars mostly see as negative and disruptive. In particular, the scholars question the quality of public agreement seeing the public spheres as dissonant, disconnected [5], and discontinued [6], and publics that constitute them as dissipative and subjected to anti-deliberative discussion features like user affect [7], verbal incivility [8], intentional curation of news flows [9], or computational propaganda [10].

A more neutral middle-ground between "digitalization optimists" and "digitalization pessimists" is represented by approaches that see social media users as initially neutral in terms of opinions, and opinion formation as cumulative [11, 12]. This approach echoes in practical SMM where companies build their audiences for the sake of revenue growth. However, media have a double nature of being both public institutions and commercial entities; they run into a principal conflict of interest in their social media management when their intention for revenue cultivation clashes with their public roles of informer, agora, watchdog, and other democratic functions and roles [13, 14].

In this respect, information agencies (or news agencies, as they are called more often) have seen even bigger pressures from the rise of social networking cultures. First, they have since their first rise in the nineteenth century been B2B businesses with media as subscribers, with only limited amounts of news being disseminated directly to the media consumer. However, with the rise of Web 1.0 and then Web 2.0, they have transformed in their online presence to media entities quite similar to other textual media, thus experiencing the forms of market competition that they had previously avoided. Second, news agencies as major news producers have been in peculiar relations with national authorities. Thus, in countries like Russia or China, news agencies created or fundamentally reformed during communist regimes have performed functions imposed by the state in agenda setting and framing of events. This is why, today, state-owned information agencies in Russia have encountered quadruple pressures on social media. First, they had to adapt to competitive and opinion-cumulative online environments, with the audiences gradually ceasing to visit web portals in favor of forming personalized news streams on social media [15], and, second, had to preserve their leadership in news production. Third, they had to build online presence as bearers of state ideology, which could also contradict the fourth pressure—media ethics and autonomy. Taken together, these pressing factors may have led to rethinking their accountability—both direct accountability toward

their particular social media users instead of the whole society [16] and toward the state that had to be represented in the agencies' communication with the users. This, in turn, puts under question the public sphere roles of state-affiliated news agencies online, and, in particular, on social media.

The public sphere roles of news agencies have not been a major focus of scholarly critique, unlike that of other public affairs media like national dailies or TV channels as the main segments of politically relevant media systems [13]. However, as we see today, social impact of news agencies in the countries with no long democratic tradition compares to the major channels and may exceed that of national newspapers, especially in terms of conveying messages shaped by governments and presidential administrations. For countries like Russia, there have been no books/special issues on news agencies and their public sphere roles; we only have scarce knowledge on the agencies' social media presence and how it mirrors, opens up, or constructs their public sphere roles. This is why we have posed the following questions for this scoping review:

RQ1. What are the conceptual problems that are discussed in academic papers that analyze SMM of Russian news agencies? What are the SMM strategies of the Russian state-affiliated information agencies, according to today's academic research?

RQ2. What are the public sphere roles of information agencies, as seen via their social media presence and management? Can one tell of these roles by observing today's literature on information agencies and their SMM?

2 Russian Information Agencies and Their Social Media Presence

2.1 State-Affiliated Information Agencies in Russia: Between Facts and Norms?

News agencies play a crucial role in the media space of any nation-state. Obtaining and distributing reliable, timely, socially relevant, and exclusive information is their main public duty, and such news is their basic commercial product. Today, with digitalization, news agencies have become self-sustaining search engines, news aggregators, processors, and distributors. However, the above-stated pressures, including the necessity of building audiences and maintaining their trust on social media vs. nearly inevitable political bias, may affect the agencies' behavior online, including their SMM strategies.

National-level information agencies in Russia may be divided into private and state-affiliated. The latter, such as TASS (ex-ITAR-TASS) and *RIA Novosti*, have preserved the leading market positions since the 1990s, even if, by 1995, they have found themselves amid growing competition with private and regional news agencies [17, 18: 20]. In the example of TASS, one sees how post-Soviet news agencies

have come through the relatively significant decline in the 1990s and early 2000s and rose (again) thanks to a combination of state funding and strong managerial decisions. Authors [19] document both the re-establishment of TASS as a market leader and the move of TASS to a B2C model with digitalization. Since December 2013, RIA Novosti has undergone editorial shifts and changes in proprietary status that have consolidated the political standing of this news agency as a part of a larger state-owned news conglomerate *Rossiya Segodnya*. Its title translates as "Russia Today" but the media holding does not have the TV channel "RT" in its structure; its international branch is represented by a news and radio agency called *Sputnik*. Data for April 2022 by the Russian media rating agency Medialogia show that *RIA Novosti* is the most cited Russian media on social networks, even if TASS and *RIA Novosti*, by virtue of their status, are obliged to cover those topics and information occasions that, from the point of view of private news agencies, are poorly monetized. Such topics mostly relate to social life, culture, and education.

While most Russian scholars who write on the national news agencies neutrally mention that the agencies are used for implementation of the state information policy or even state that these media work for the defense of national interests in the information space, Western research agencies frame them predominantly as a part of the state propaganda machine, both domestically and internationally. The change of ownership, editorial board, and editorial policies at *RIA Novosti* in 2013–14 has been nearly unanimously described as tightening of state control over media [20: 205].

If TASS and *RIA Novosti* are seen as instruments of domestic political influence, RT as a news agency (and the eponymous TV channel) is framed as a major source of disinformation and propaganda on the international media market. It is predominantly described as promoting anti-West ideologies and destabilizing local politics in the countries of presence by providing media space for controversial politicians [21] and conspiratorial thinking [22]. However, even the most severe critics acknowledge that RT follows the Western news styles. Before 2022, a minority of Western scholars used to see RT as an anti-establishment voice that widened the political spectra of television in Europe and beyond [23]. For Africa as a traditional region of Soviet/Russian political presence, though, RT and *Sputnik* were noted to be creating "positive stories" that countered American and European negative reporting on the African countries [24].

Internally, though, the agencies put certain effort into maintaining, at least partially, the Western standards of newswriting. They use huge resources to collect and process primary information and verify sources. The news agencies formally follow the "inverted pyramid" style of news writing, with only slight featurization in composition. They preserve editorial fact-checking practices and employ standardized practices of news preparation; however, some data tell their fact-checking time is usually minimal [25]. Recently, TASS has published the editorial guidebook [26] which contains a statement on necessary coverage of positions of all (both or more) conflict sides. RIA Novosti's guidelines are impossible to find online, though, on its portal, the agency claims adherence to providing precise information and to dealing with socially important issues. In 2003, *RIA Novosti*'s editorial principles were

described in a guidebook [27]; to our best knowledge, it was not republished ever since.

In terms of bias in news content of the Russian news agencies, there is surprisingly little research if one considers how often they are called propagandist and biased. Moreover, the results of rare attempts of content analysis do not unequivocally support the biased nature of media texts in, for example, TASS. Thus, a study on the TASS's coverage of the Ukrainian crisis in 2013–14 has found sophisticated techniques of biased framing and non-division between fact and comment [28]. However, in covering Iranian protests, TASS did not differ in framing (including problem definition, diagnosis of causes, and negative coverage of protests) from AFP, AP, and Reuters; the only notable difference was blaming the United States for catalyzing protests [29: 147–149], which, understandably, was not found in AP and Reuters' coverage.

The agencies, along with their private competitor Interfax, are also leaders of technological modernization on the Russian media market. In the 2010s, *RIA Novosti*'s Media Lab was a market leader in interactive and multi-channel content. Today, TASS and Interfax have introduced full-fledged algorithmic newswriting, which is still rare on the Russian news market; such news strictly corresponds to the neutral "inverted pyramid" style [30]. We will focus our review on the SMM strategies of the three news agencies.

2.2 News Agencies and Social Media: A Major Research Gap

With the advent of social media, news agencies began to actively use these platforms to increase the speed of content distribution. On one hand, for content distribution, social media are becoming increasingly important due to their convenience and ease of use. On the other hand, social networks are of particular importance in shaping the political consciousness of citizens and their political involvement. As stated above, the triple nature of news agencies as state ideology bearers, public sphere nods, and commercial entities with changing modes of customer relations (B2B to partial B2C) are expected to have peculiarities and controversies in their SMM.

In the 2000s, several books were dedicated to digitalization of Russian information agencies; however, since the advent and mass proliferation of social networking platforms, Russian academic research has not followed that intensely this second wave of new agencies' digital transformation. Even recent reviews of research on international news agencies (see, e.g., [31]) do not provide for knowledge on how the agencies implement SMM strategies or perform public roles on social media.

Following [32], we argue that news agencies' SMM might have followed the logic of reacting to pressures like the rise of platformized publics and the need for diversification. This is also in line with the "B2C turn" mentioned above. However, practically no research states so far what public roles news agencies deploy in their SMM strategies, being simultaneously commercial companies and bearers of state ideology.

What we know on life of news agencies online is so far truly scarce. In the 2010s, all the major agencies in the world, including TASS and RIA Novosti, have tried hard to build presence and following on social media. Thus, as of May 2020 (before some United States-based platforms were labeled undesirable in Russia), TASS had significant presence on Twitter*, Facebook*, Instagram* (*—all recognized as extremist and undesirable in Russia since 2022), YouTube, TikTok, and VKontakte (today VK.com), reaching altogether over 2,100,000 following units (users could repeat in following on various platforms; this was not doublechecked) [32: 196], which, though, was at least three times fewer than for AFP and at least seven times smaller than for AP. In 2019, it was shown that pro-state media, including TASS, RT, and *RIA Novosti*, did not form any distinct follower cluster on the major Russian-speaking social networking platform Vkontakte—unlike oppositional media with a cluster of circa 11% of the users [33].

3 Method

The scoping review methodology [34] can be used to show the range of research activities in a particular area and to determine the value of conducting research to identify gaps in it and suggest future directions for studying the issue. This scoping review is a preliminary study that, in the future, will be useful for developing a systematic review of the literature in order to understand the use of social media in the formation of the public sphere by Russian state news agencies, as well as understanding how news agencies manage their own social media in which they publish news materials. This scoping review is the first stage of a systematic review of the literature. As stated in [35], scoping reviews cover the entire area of particular interest and allow for analysis of thematically narrow but diverse range of academic studies.

In the beginning, we have defined the time frame for our review. It includes the period from the early 2010s to the present day. Within this period of time, news agencies went hybrid and began to actively use social media for content distribution.

Our scoping review is based on the analysis of 23 academic papers, the maximum number that we could find. The sample included studies that analyzed the use of social media by the Russian state news agencies and their impact on the public sphere. Based on the scoping review methodology, we have collected and summarized the available evidence. The sampling process is demonstrated in Fig. 1.

The databases from which we started our sampling were Google Scholar and eLibrary.ru, the portal that hosts the Russian Index of Academic Citing (RINTS). These two were chosen for the widest possible coverage of academic research in both Russian and English. In addition, we performed manual search, as well as read the latest review papers published in 2019–22.

A search of the selected electronic databases revealed a total of 12.8 thousand records. Further, we have excluded materials whose names clearly indicate that the subject of study goes beyond our original scope. Thus, we selected 370 academic

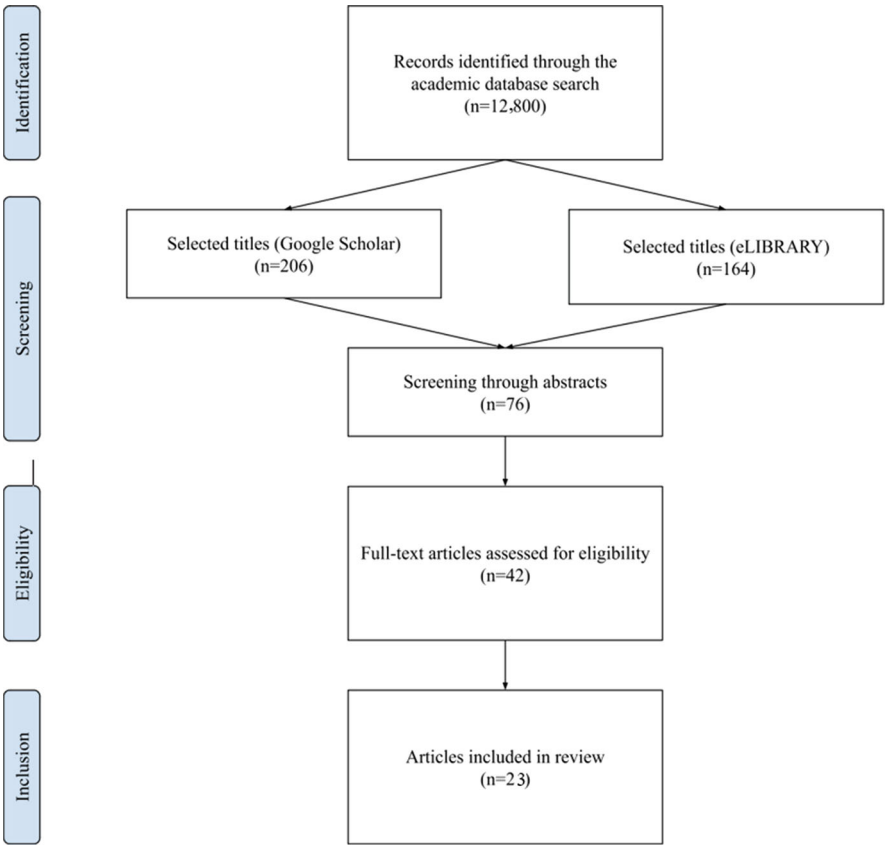

Fig. 1 The flow diagram of the sampling process

papers and chapters (206 from Google Scholar and 164 from eLibrary.ru). After that, we started studying the abstracts of these papers and selected 76 of them relevant for our study, as these had news agencies as their main scope. In the next step, we determined that all articles that fit our intended scope should include at least one of the following variables: (1) they should analyze the deliberative functions of social media of news agencies; (2) they should analyze the promotional functions of social media of news agencies. The 76 papers were read by us in full, resulting in a final selection of 23 articles.

Below, we will discuss the state of affairs in the field of research under consideration, assess whether the researchers reflect upon how the use of social media by state-affiliated news agencies affects the formation of the public sphere, and suggest potential ways to further advance the knowledge gained.

4 Results

The 23 academic papers included in this scoping review describe the use of social media such as Telegram, VKontakte, TikTok, YouTube, Facebook*, Twitter*, and Instagram* in the activities of the Russian state news agencies TASS, *RIA Novosti*, and RT. Table 1 provides an overview of the papers stating the language of the paper published, as well as the news agencies and social media in focus.

Table 1 The papers under review

Paper focus	Main results	Author(s), year
English-language papers		
Deliberative	"Reverse" impact of platforms upon Russian news agencies	Salikov, 2019 [36] Salikov, 2020 [37]
	News agencies as propaganda and/or disinformation tools of the Russian state	Al-Rawi, 2017 [38] Filatova, Volkovskii, 2021 [39] Golovchenko, 2020 [40]
Promotional	Features of newswriting in social media by news agencies	Judina, Platonov, 2019 [41]
	Content consumption of news agencies on social media	Sairambay, 2022 [42] Vartanova, Cherevko, Tolokonnikova, Dunas, 2019 [15] Rantanen, 2021 [32]
	The social media tools for user involvement, engagement, and reputation management	Lukyanova, Martyanov, 2021 [43] Judina, Platonov, 2019 [41]
Russian-language papers		
Deliberative	News agencies as propaganda and/or disinformation tools of the Russian state	Dybkina, 2020 [44] Torochkova, 2014 [45]
Promotional	Features of newswriting in social media by news agencies	Alevizaki, Aleksandrova, Kara-Murza, Slavkin, 2021 [46] Ustinov, 2017 [47] Pervih, Kaporsky, 2022 [48] Pyankova, Mitrofanova, Ergunova, 2022 [49]
	Platform dependence and platformization of content strategies by news agencies	Tsipelyov, 2022 [50] Zelentsov, 2021 [51]
	Content consumption of news agencies on social media	Dyachenko, 2016 [52] Zhukov, 2019 [53] Anisimova, 2022 [54] Dyachenko, 2014 [55]
	The social media tools for user involvement, engagement, and reputation management	Dyachenko, 2014 [55] Pervih, Kaporsky, 2022 [48] Ustinov, 2017 [47]
	Audience feedback management on social media	Zelentsov, 2021 [51] Pervih, Kaporsky, 2022 [48]

4.1 Social Media in Focus

The selected papers most often study news agencies' content distribution on VKontakte, as this social network is Russian and is the most popular among Russian-speaking users. Domestically, it is ahead of Facebook* which occupies the highest positions in the United States and Western Europe. At the same time, seven articles described the use of news agencies to publish their materials on Facebook* [15, 32, 38, 45, 48, 51, 55]. Facebook* is the world's largest social network by the number of registered users, being a large-scale embodiment of the phenomenon of social networks in the world. In one paper, the authors touched on the topic of social media management in news agencies superficially, without focusing on certain social media [52]. The rest of the articles are dedicated to the use of other social media in news agencies.

4.2 Answering the Research Questions: Topicalities of the Reviewed Papers and the Gap in Agencies-Related Research on the Russian Public Sphere

RQ1 The topicality of the reviewed papers mostly relates to the topics that mirror the transition of news agencies from B2B-only models toward B2C strategies. These are as follows: (1) organization and style of newswriting for social media; (2) content platformization; (3) content consumption as compared to other media; (4) audience strategies and feedback.

Features of Newswriting Several papers in the sample deal with how news texts are adapted for social media posting and what goals content managers may pursue. The focus is mostly on the "inverted pyramid" style that not only signals of quality but also allows for detecting linkages between text composition and news perception [41, 46], even if the texts, for example, by TASS, may be (too) brief and concise [47]. For RT, the use of multimedia allows for creating better quality of reporting [48]. Criticizing what TASS does duplicating their headlines on social networks, the authors [49] note that visual elements like photos and/or videos accompany the agency's posting in ~100% of cases.

However, we need to underline that neither the Eng-lang nor the Russian-language papers in our sample describe standards for newswriting that would include not only the writing style but also demands to information sources, ethics, or other aspects of quality in journalism. We need to mention that one paper beyond our sample [56] establishes the requirements to the content generated by the news agency on social media. The authors mix news values [57], quality demands, and adaptation requirements. In particular, the author mentions timeliness, originality, and exclusivity (as news values), literacy, understandable language, and accuracy (as quality demands), and rewriting for social media as an adaptability demand. The

paper, though, was not included in the sample, as it did not mention particular social media platforms. In addition, in [48], the authors show that the main goal of correspondents and content managers of the news agencies is to contextualize information and ensure uniqueness of each message.

Platform Dependence and Platformization of Content Strategies Several authors pay even bigger attention to content platformization, which means adapting the news to particular platforms [58, 59]. Practical SMM experience and industrial knowledge on audience needs and platform affordances force content managers at news agencies to take a differentiated approach to formatting multimedia posts for various platforms: Thus, Facebook* has its own patterns of content placement; video content is actively consumed on Odnoklassniki; an audio player can be attached to VKontakte posts; Russian audiences prefer to read longreads on Facebook; Instagram users most often watch stories [51], while Telegram wins in terms of speed and is thus very important for news agencies in particular [50]. When publishing news on Twitter, news agencies are guided by the "20-seconds rule," according to which they must be the first to spread information on an event, to attract the audience to the account within 20 seconds; this is why Twitter is mostly used for spreading breaking news. For better audience attraction, a chain of interconnected news is used, allowing for continuing a specific topic, supplementing it with the latest updates. Such a mechanism contributes to the creation of a favorable image of news agencies as working upon content production around the clock [51].

Content Consumption of News Agencies Within the "B2C turn" of the Russian information agencies as discussed in academic papers, strategies of audience attraction and involvement are the leading theme. Several papers of our sample focus on consumption of news on social media, including the news from information agencies; other papers directly deal with strategies of audience management.

In terms of news consumption, the papers mostly tell of a well-known digital divide between older and younger media consumer groups. As mentioned above, more than 75% of younger consumers in Russia get national and international news from social media while it is the least popular source of news for pensioners, the disabled, and the unemployed; youngsters are more likely to receive news online than from legacy media [42]. However, the role of platforms in news consumption varies, as VKontakte had left, for example, Twitter and other platforms much behind by 2019 [15].

Social media turn news consumption into a background activity; social media newsfeeds are mostly used for monitoring agendas [15]. In the mid-2010s, publications of news agencies in social media were the most attractive for users; on both Facebook and VKontakte, they used to have the highest engagement index in comparison with many textual media online [52]. Before the pandemic, the accounts of all the three agencies were leading among other media by user reposts and citation rates [53].

Online Branding and Audience Strategies By 2021, news agencies have emerged as active developers of their online brands and competitors to other online media

[32]; however, the efficiency of such branding is under question. The main goal for posting online for them, just as for the rest of online/hybrid media, is, till today, traffic increase via conversion [54], despite users, as we noted above, tend to more and more avoid the "flee-hopping" behavior of getting to the websites and back to social media feeds.

Elements of the SMM strategies include both those used by other textual media and those specific for the agencies. First of all, the agencies use adaptation strategies and tactics, both on the strategic level and on the level of one post. Thus, they strategically diversify their so-called content plans, posting three types of content: (1) original news identical to those that go to the B2B customers, both at TASS and *RIA Novosti* [54]; (2) technically and substantially adapted news [54]; and (3) the content especially created for social media [55], including special formats especially developed for audience attraction and involvement [54], which is a relatively new practice for news agencies.

The tools for user involvement, engagement, and reputation management include a variety of technical and content-related instruments, as well as feedback management. Technically, audiovisual additions to textual content raise user involvement [55], as well as the use of contact-establishing discursive elements (for RT) [48]. In terms of content, two papers note that the news agencies have started to go downmarket: First, they emotionalize posting and try emotional involvement [43], and second, they use entertainment content [47]. In some cases, the agencies strategically use "news values" for audience engagement. They post positive content, as they realize that it is shared by the audience eagerly [41], write about celebrities, and highlight exclusive content.

Audience feedback management is a separate area within SMM conducted by the news agencies. Used for brand management as well as for audience building [56], establishment of comment sections allows for countering negativity in news perception, raises interactivity, and allows for managing feedback perceived by [51] as a key instrument for user involvement. RT is described as especially keen on audience segmentation and establishing contact with their followers [48].

RQ2 The public sphere roles of news agencies on social media, in relation to their SMM, are discussed in the reviewed papers much less than the commercial content strategies (in only 7 papers out of 23), and rarely in relation to the commercial strategies of the agencies. That is, we virtually cannot get from the literature which content and/or audience strategies or tools may be linked to promoting state-induced agendas.

In the discussion of public roles of the Russian news agencies on social media, a gap between the English-language and Russian-language papers shows up. Three papers in English do pay attention to the linkages of the news agencies to the Russian establishment, all openly describing RT [38, 40] or TASS [39] as propaganda and/or disinformation tools of the Russian state. RT is described as polarized [38] against the positions of most mainstream media of the West [40], especially via their use of Twitter*. In VKontakte, TASS technically promotes public dialogue in comment sections but does it in support of public policies and persons in power [39]. The

paper [40] relies on content analysis and network analysis in showing the small enough impact of the Russian strategic narratives, including those created by RT, upon Twitter* users. Similarly, the paper [39] relies on a mixed-method content study, finding bias in the coverage.

Two Russian-language papers that mention public roles of news agencies on social media [44, 45] are much less critical toward particular agencies. None of the papers, though, uses content analysis to prove their view upon the agencies' political stance. The paper [44] even stated that, with the growth of social media platforms, the agencies allow for bigger audience freedom in selecting information (even if they actually speak of intentional selective exposure to news that corresponds to their pre-existing opinions), as well as for comparing different viewpoints. The second paper [45] only insubstantially, without any study at all, mentions the importance of news agencies being on social media; we have formally included this paper into our review, but, in fact, the paper does not provide any conclusions worth further mentioning.

Two more papers, both by Salikov [36, 37], tell of a reverse impact of platforms upon Russian news agencies. The author states that anonymous Telegram channels in Russia have become an alternative milieu for political discussion where anonymous political news spreads and is consumed by large audience groups, thus making major news agencies also cite anonymous channels, in order not to lose in competition for speed in news coverage [36]. The second paper traces the rise of political importance of the platforms as shapers of public opinion, which affects, *incl.*, the news agencies.

As seen from the review, the papers do not discuss the normative roles of news agencies on social media in substantial ways. The attempts to impose such roles in the Russian-language papers cannot be taken seriously without proper research, while the biased nature of Russian official claims stated by the Western research also needs to be re-assessed, as the role of news agencies is seen as state-propagandist even before the research actually starts. The very discussion on how exactly news agencies need to behave on social media within their B2C turn and their encountering large-scale competition with other B2C (mass/hybrid) media is absent from the reviewed papers.

5 Discussion and Conclusion

The scoping review presented above was dedicated to practices of social media management by three Russian news agencies. We have applied the scoping review methodology, and our analysis revealed several important research gaps in the current studies.

Social networking has further influenced the functioning of news agencies and their turn toward B2C-related revenue and audience models. Instead of newsfeed subscribers only, now the agencies are news suppliers for their social media

followers just as well, which affects their content plans and, to a lesser extent, accountability practices.

In general, the reviewed academic papers and chapters indicate that most works available both in Russian and in English at the moment do not provide for systematic and deep understanding of social media management by the Russian state-affiliated news agencies. They mainly focus upon the use of social media as a channel for content distribution and audience attraction; however, the interaction of news agencies with their audiences on social media is not studied rigorously, and the Russian-language papers are essayistic, they may state claims without strong proof for them. One cannot tell what exact roles social media management plays in brand management, audience building, and content promotion, despite the importance of the B2C turn in their practices.

The same may be stated for the public roles of SMM by the news agencies. Here, we have shown a gap that needs to be further studied, as it is also relevant for other media segments like news portals or TV. In the Western research, the scholars take the initial stand of seeing the Russian state-affiliated news agencies as propagandist and spreading disinformation, with at least partial and case-limited proof for that; however, they do not clearly link SMM in managerial terms (as an everyday practice) to computational propaganda; neither they explain the roles of the agencies in how exactly disinformation spreads, thus creating a misleading picture that TASS, *RIA Novosti*, or RT take special effort in spreading disinformation analogously to trolls or bots. In the Russian-language papers, on the contrary, content bias is not measured, and formal following of the "inverted pyramid" style is taken as a sign of proper performance and editorial independence. Neither side of this polarized science discusses the agencies' SMM against the background of journalistic norms vs. the quadruple pressures described above—that is, the B2C turn and commercial competition online, state affiliation and conveying ideology, special roles as major information suppliers within the media industry, and public service mission. In such polarized and deeply low-trust public spheres like in Russia [60, 61], this large gap in assessment of public sphere roles of news agencies online demands further research and a public dialogue that would involve not only the academe but civil servants, the media industry's representative bodies, and audiences.

When studying the management features of news agencies when working with their social media, we started from the fact that our study has limitations in that we did not consider private and regional news agencies. We relied on the information provided by the authors in the analyzed articles for further analysis of their content related to social media management. Initially, we did not assume any theory that would be in these articles, we do not consider in detail the democratic normativity in them, since we do not assume a comparison of these articles with some democratic theory.

Acknowledgments The paper has been supported in full by the project "Center for International Media Research" of St. Petersburg State University, year 3, project #94033584.

References

1. Pérez-Latre, F.J., Portilla, I., Sánchez-Blanco, C.: Social networks, media and audiences: a literature review. Comun. Soc. **24**(1), 63–74 (2011)
2. Al-Rawi, A.: Viral news on social media. Digit. Journal. **7**(1), 63–79 (2019)
3. Van Dijck, J., Poell, T., De Waal, M.: The Platform Society: Public Values in a Connective World. Oxford University Press, Oxford (2018)
4. Mellado, C., Hermida, A.: The promoter, celebrity, and joker roles in journalists' social media performance. Soc. Med. Soc. **7**(1), 2056305121990643 (2021)
5. Pfetsch, B.: Dissonant and disconnected public spheres as challenge for political communication research. Javn. Public. **25**(1–2), 59–65 (2018)
6. Smoliarova, A.S., Bodrunova, S.S., Blekanov, I.S., Maksimov, A.: Discontinued public spheres? Reproducibility of user structure in Twitter discussions on inter-ethnic conflicts. In: HCI International 2020 – Late-Breaking Posters: 22nd International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part I, pp. 262–269. Springer International Publishing, Cham (2020)
7. Papacharissi, Z.: Affective Publics: Sentiment, Technology, and Politics. Oxford University Press, Oxford (2015)
8. Bodrunova, S.S., Litvinenko, A., Blekanov, I., Nepiyushchikh, D.: Constructive aggression? Multiple roles of aggressive content in political discourse on Russian YouTube. Media Commun. **9**, 181–194 (2021)
9. Bruns, A.: Gatewatching and News Curation: Journalism, Social Media, and the Public Sphere. Peter Lang, New York (2018)
10. Woolley, S.C., Howard, P.N. (eds.): Computational Propaganda: Political Parties, Politicians, and Political Manipulation on Social Media. Oxford University Press, Oxford (2018)
11. Bodrunova, S.S.: Practices of cumulative deliberation: a meta-review of the recent research findings. In: Electronic Governance and Open Society: Challenges in Eurasia: 8th International Conference (EGOSE'2021), St. Petersburg, Russia, November 24–25, 2021, Proceedings, pp. 89–104. Springer International Publishing, Cham (2022)
12. Bodrunova, S.S.: Kumulyativnaya deliberatsiya: Novaya normativnost' v izuchenii publichnyh sfer onlain [Cumulative deliberation: new normativity in studying public spheres online]. Mosc. Univ. Journal. Bull. **1**(48), 87–122 (2023)
13. Hallin, D.C., Mancini, P.: Comparing Media Systems: Three Models of Media and Politics. Cambridge University Press, Cambridge, MA (2004)
14. Mellado, C., Hellmueller, L., Donsbach, W. (eds.): Journalistic Role Performance: Concepts, Contexts, and Methods. Taylor & Francis, London (2016)
15. Vartanova, E., Cherevko, T., Tolokonnikova, A., Dunas, D.: Changing patterns of digital news consumption among Russian journalism students. World Media J. Russ. Media Journal. Stud. **1**(1), 7–30 (2019)
16. Litvinenko, A., Bodrunova, S.S.: Russia: media accountability in a polarized society. In: Fengler, S., Eberwein, T., Karmasin, M. (eds.) The Global Handbook of Media Accountability, pp. 203–212. Routledge, London (2021)
17. Rantanen, T., Vartanova, E.: News agencies in post-communist Russia: from state monopoly to state dominance. Eur. J. Commun. **10**(2), 207–220 (1995)
18. Boyd-Barrett, O., Rantanen, T. (eds.): The Globalization of News. Sage, London (1998)
19. Vartanova, E., Vyrkovsky, A.: Between the state and the market: an analysis of TASS's fall and rise. Journalism. **21**(12), 1842–1858 (2020)
20. Becker, J.: Russia and the new authoritarians. Demokratizatsiya. **22**(2), 191–206 (2014)
21. Elswah, M., Howard, P.N.: "Anything that causes chaos": the organizational behavior of Russia Today (RT). J. Commun. **70**(5), 623–645 (2020)
22. Yablokov, I.: Conspiracy theories as a Russian public diplomacy tool: the case of Russia Today (RT). Politics. **35**(3–4), 301–315 (2015)

23. Thussu, D.K.: Reinventing "many voices": MacBride and a digital new world information and communication order. Javn. Public. **22**(3), 252–263 (2015)
24. Clifford, C., Gruzd, S.: Russian and African media: exercising soft power. South Afr. Inst. Int. Aff. Policy Insights. **125**, 1–18 (2022)
25. Sokolova, D.V.: Faktckeking i verifikatsiya informatsii v rossiyskih SMI: rezul'taty oprosa [Fact-checking and information verification in Russian media: survey results]. Mosc. Univ. Journal. Bull. **4**, 3–25 (2018)
26. Lebedev, A.V., Filimonov, M.G.: TASS Editorial Standard: A High School Student Guide Book [Redaktsionniy standart TASS: uchebnoe posobie dlya studentov vuzov]. Aspect Press, Moscow (2020)
27. Editorial principles of work of main information office of Federal State Unitary Enterprise "RAMI RIA Novosti" [Redaktsionnye printsipy raboty Glavnoy direktsii informatsii FGUP RAMI RIA Novosti]. Moscow (2003)
28. Watanabe, K.: Measuring news bias: Russia's official news agency ITAR-TASS's coverage of the Ukraine crisis. Eur. J. Commun. **32**(3), 224–241 (2017)
29. Adegbola, O., Gearhart, S., Cho, J.: Reporting bias in coverage of Iran protests by global news agencies. Int. J. Press Polit. **27**(1), 138–157 (2022)
30. Kulchitskaya, D.Y., Frolova, T.I.: Kompyuternye algoritmy v rabote rossiyskih informatsionnyh agentstv (na primere IA "Interfaks" i "TASS") [Computer algorithms used in Russian news agencies (a case study of Interfax and TASS)]. Mosc. Univ. Journal. Bull. **1**, 3–19 (2020)
31. Rantanen, T.: News agencies from telegraph bureaus to cyberfactories. In: Oxford Research Encyclopedia of Communication. Oxford University Press, Oxford (2019) https://oxfordre.com/communication/display/10.1093/acrefore/9780190228613.001.0001/acrefore-9780190228613-e-843
32. Rantanen, T., Kelly, A.: The digital transformation of international and national news agencies: challenges facing AFP, AP, and TASS. In: Dimitrova, D.V. (ed.) Global Journalism: Understanding World Media Systems, pp. 191–202. Rowman & Littlefield, Lanham (2021)
33. Urman, A.: News consumption of Russian Vkontakte users: polarization and news avoidance. Int. J. Commun. **13**, 5158–5182 (2019)
34. O'Brien, K.K., Colquhoun, H., Levac, D., Baxter, L., Tricco, A.C., Straus, S., Wickerson, L., Nayar, A., Moher, D., O'Malley, L.: Advancing scoping study methodology: a web-based survey and consultation of perceptions on terminology, definition and methodological steps. BMC Health Serv. Res. **16**(1), 2–12 (2016)
35. Levac, D., Colquhoun, H., O'Brien, K.K.: Scoping studies: advancing the methodology. Implement. Sci. **5**(69), 1–9 (2010)
36. Salikov, A.: Social media in Russian politics. Politologiya. **3**(99), 64–92 (2020)
37. Salikov, A.: Telegram as a means of political communication and its use by Russia's ruling elite. Politologiya. **3**(95), 83–110 (2019)
38. Al-Rawi, A.: News values on social media: news organizations' Facebook use. Journalism. **18**(7), 871–889 (2017)
39. Filatova, O., Volkovskii, D.: Online deliberation on social media as a form of public dialogue in Russia. In: Proceedings of the International Conference "Internet and Modern Society", June 24–26, 2021, St. Petersburg, Russia, pp. 146–156. CEUR, Aachen (2021)
40. Golovchenko, Y.: Measuring the scope of pro-Kremlin disinformation on Twitter. Humanit. Soc. Sci. Commun. **7**(1), 1–11 (2020)
41. Judina, D., Platonov, K.: Newsworthiness and the public's response in Russian social media: a comparison of state and private news organizations. Media Commun. **7**(3), 157–166 (2019)
42. Sairambay, Y.: Internet and social media use by young people for information about (inter)-national news and politics in Russia and Kazakhstan. Stud. Transit. States Soc. **1**, 56–70 (2022)

43. Lukyanova, G.V., Martyanov, D.S.: Communication strategies of emotional engagement on social media. In: 2021 Communication Strategies in Digital Society Seminar (ComSDS) Proceedings, pp. 27–30. IEEE (2021)
44. Dybkina, A.N.: Novostnye pabliki VKontakte kak faktor formirovaniya politicheskogo soznaniya [News public pages on VKontakte as a factor in the formation of political consciousness]. Skythian. **2**(42), 350–355 (2020)
45. Torochkova, P.A.: Sotsial'tye seti kak element informatsionnyh tehnologiy – noviy actor mirovoy politiki [Social networks as an element of information technology – a new actor in world politics]. Bull. RSUH. **7**(129), 116–126 (2014)
46. Alevizaki, O.R., Aleksandrova, I.B., Kara-Murza, E.S., Slavkin, V.V.: Novostnoy medianarrativ v sotsseti "VKontakte": diskursivnye osobennosti [Discursive features of news media narrative in VKontakte]. Mosc. Univ. Journal. Bull. **3**, 74–101 (2021)
47. Ustinov, V.V.: Aktualnye tendentsii razvitiya SMM-kopiraytinga v SMI [Trends of SMM copywriting in media]. Znak. **4**(26), 250–253 (2017)
48. Pervih, D.K., Kaporsky, D.R.: Kontent MIA "Russia Today" v novyh media kak primer diversifikatsii media [MIA "Russia Today" content in new media as an example of media diversification]. Mediavector. **4**, 87–92 (2022)
49. Pyankova, S.G., Mitrofanova, I.V., Ergunova, O.T.: Trendy importozamescheniya novyh media kak instrumenta vliyaniya na auditoriyu rossiyskih SMI v usloviyah sanktsiy: federal'niy i regional'niy aspekty [Trends of import substitution of new media as a tool of influencing audiences of the Russian media in the conditions of sanctionomics: Federal and Regional Aspects]. Economics. **12**(4A), 27–40 (2022)
50. Tsipelyov, D.P.: Informatsionnye agentstva v Telegram: spetsifika adaptatsii i pozitsionirovanie na ploschadke informatsionnogo agentstva TASS [News agencies on Telegram: the specifics of adaptation and positioning on the platform as exemplified by TASS news agency]. Young Sci. **15**(410), 33–35 (2022)
51. Zelentsov, M.V.: K voprosu ob opredelenii gibridnogo novostnogo formata v tsifrovoy srede [On defining the hybrid news format in the digital realm]. Commun. Media Des. **6**(3), 5–22 (2021)
52. Dyachenko, O.V.: Rossiyskie SMI v sotsial'nyh setyah Facebook i "VKontakte": analiz aktivnosti i informatsionnyh predpochteniy auditorii [Russian mass media in the social networks Facebook and VKontakte: analysis of the audience's activity and information preferences]. Mosc. Univ. Journal. Bull. **1**, 28–45 (2016)
53. Zhukov, D.S.: Formirovanie politicheskoy povestki dnya v sotsial'nyh setyah: vzglyad s pozitsii teorii samoorganizovannoy kritichnosti [Setting a political agenda in social networks: the point of view of the theory of self-organized criticality]. Eurasian J. Reg. Polit. Res. **1**(19), 27–41 (2019)
54. Anisimova, E.V.: Funktsionirovanie informatsionnyh agentstv v sotsial'nyh setyah [Functioning of information agencies on social networks]. In: Abstracts Book, II Student Conference of Institute of Social Science and Humanities, University of Tyumen, April 28, 2022, Tyumen, Russia, pp. 172–174. Tyumen State University Publishing House (2022)
55. Dyachenko, O.V.: Rossiyskie SMI v sotsial'nyh setyah Facebook i "VKontakte": praktiki vzaimodeystviya [Russian mass media in the social networks Facebook and VKontakte: interaction practices]. Mediascope. **14** (2014) http://www.mediascope.ru/1615
56. Stezhka, A.A., Shpakovsky, V.O.: Prodvizhenie informatsionnyh agentstv v sotsial'nyh setyah [Promotion of news agencies in social networks]. In: Aktual'nye problem nauki – 2014 [Current Issues in Science – 2014]: Proceedings of International Academic & Practical Conference, May 23, 2014, Kuznetsk, Russia, vol. IX, pp. 94–97, A.Yu. Sokolov Printing house (2014)
57. Harcup, T., O'Neill, D.: What is news? News values revisited (again). Journal. Stud. **18**(12), 1470–1488 (2017)
58. Nieborg, D.B., Poell, T.: The platformization of cultural production: theorizing the contingent cultural commodity. New Media Soc. **20**(11), 4275–4292 (2018)

59. Hase, V., Boczek, K., Scharkow, M.: Adapting to affordances and audiences? A cross-platform, multi-modal analysis of the platformization of news on Facebook, Instagram, TikTok, and Twitter. Digit. Journal. **11**, 1499 (2022). https://doi.org/10.1080/21670811.2022.2128389
60. Bodrunova, S.: Fragmentation and polarization of the public sphere in the 2000s: evidence from Italy and Russia. Glob. Media J. **3**(1), 1–35 (2013) https://globalmediajournal.de/index.php/gmj/article/view/103/95
61. Bodrunova, S.S.: Russia: a glass wall. In: Lilleker, D., et al. (eds.) Political Communication and COVID-19, pp. 188–200. Routledge, London (2021)

Ecosystem Approach to the Analysis of Digital Services: A Comparative Case Study on Municipalities of St. Petersburg from 2021 to 2023

Olga Filatova and Radomir Bolgov

Abstract The research presented below is a pilot study within the framework of a project aimed at solving a research and practical problem related to studying the effectiveness of digital urban services in terms of an ecosystem approach based on the case of St. Petersburg, Russia. The aim of the study is to determine the possibilities of empirical modeling of the digital services ecosystem at various levels of urban governance (primarily, municipal), in contrast to the currently dominant attention to the study of media platforms and technological tools. To categorize e-participation services, we have used as the base the methodology by the United Nations EPI index consisting of e-information, e-consultation, and e-decisions. Each municipality of St. Petersburg was studied to identify all available e-participation resources taking into account the media type, that is, official (deployed by municipal authorities), public (deployed by non-governmental organizations), and personal (deployed by private persons). In doing so, we distinguished three types of e-participation technologies (and respective media environments) in the form of Internet websites, pages on social networks, and mobile applications. The types of services are divided into services of information, cooperation, and participation in decision-making. Based on empirical data collected on the basis of 10 pilot municipalities, the authors tried to develop a model of an ecosystem of interaction between citizens and authorities, highlighting technically different types of main media and communication environments, namely, the environment of websites (portals), the environment of social networks, and the environment of mobile platforms. The authors developed and tested a methodology that made it possible to inventory digital services of interaction between the government and citizens, depending on the level of their territorial and administrative localization, in the context of the relevant media environments.

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_34

Keywords Ecosystem · Media ecology · Municipality · e-Participation · St. Petersburg

1 Introduction

Digital communications between authorities and citizens have received significant development. Various online channels for interaction with authorities have appeared, which may include both electronic reception desks, various online referendum platforms, and simply pages of authorities where citizens can leave their comments and requests. However, studies demonstrate that electronic interaction between government and citizens does not avoid the problems inherent in face-to-face methods of the public consultation. Case studies show that some regional and municipal authorities are reconfiguring online platforms, avoiding the real need to take into account the opinions of citizens in management, and also suffer from formalism, where online hearings and petitions are accepted solely to meet the requirements of the law, without real impact on the policy.

In this context, a serious problem is the poor understanding of the role of various actors and institutions involved in the development and provision of digital services at various levels of city governance, for example, both on the part of official city authorities and on the part of informal (non-government) business structures and civil society. As a consequence, issues of institutionalized trust in the services offered by their providers remain largely unresolved. Ultimately, it seems difficult to give a reliable assessment of how digitalization of relations between the state (in the broad sense) and citizens in the public urban space contributes to the long-term social effects.

In addition, it is worth noting that much of the newest digital environment is smartphone-based mobile messaging services—platforms and applications. This is changing the network landscape as "mobile messaging apps and news aggregators are becoming more important to people" [1]. There is a shift to a distributed media environment that is reconfiguring communication channels for finding information and opening up new ways of electronic participation due to rapid growing popularity of groups in messaging applications [2].

The research presented below is a pilot study within the framework of a project aimed at solving a scientific and practical problem related to studying the effectiveness of digital urban services in terms of an ecosystem approach based on the case of St. Petersburg, Russia. The relevance of the research is to use a new approach to the study of such services, to identify their effectiveness. The traditional approach involves the study of digital services as technical platforms and tools. Often, they are studied without taking into account the role of the media environment in which they are technically and organizationally implemented. This study aims not only to fill this gap through the use of the theoretical provisions of media ecology, but also to significantly expand this concept, supplementing it with the concept of information ecology. At present, these two concepts do not always intersect and are not supported by an appropriate empirical basis. The novelty and relevance of the

study also lie in the scientifically more rigorous application of the concept of consistency in relation to digital services and their media environments. This will be achieved by overcoming the limitations imposed by an overemphasis on the metaphorical understanding of the concept of ecosystem without taking into account the components and internal relationships that exist between the components of the system. To do this, digital services and their social effectiveness are studied in conjunction with a specific local context. The aim of the study is to determine the possibilities of empirical modeling of the digital services ecosystem at various levels of urban governance (primarily at the grassroots and municipal), in contrast to the currently dominant attention to the study of media platforms and technological tools, which does not take into account their complementarity.

The study presented below aims to answer the following key research questions:

RQ 1. What is the list and structure of currently available city services for interacting with citizens online, depending on the level of their territorial and administrative localization, and institutional and organizational affiliation, in the context of different media environments?

RQ 2. What changes are taking place in the structure of digital services for interaction between government and society at the local level in the context of rapidly developing means of communication?

RQ 3. How can a holistic model of the information and media ecosystem of digital services look like in the case of St. Petersburg?

The special significance of the study lies in the fact that electronic services are considered as an information and media system. Thus, formulated research approach usually is not practiced, since electronic services are studied outside of their media basis, and studies in the field of media ecology are not interested in digital interaction services as a direct subject of research.

2 Theoretical and Methodological Framework of the Study

The theoretical basis of the study is the concept of information and media ecology as an integral developing system. The ecosystem approach, usually used to theoretically justify the media ecology, is used by the authors to associate e-participation services with a multimedia environment that provides the functionality, usability, and content of such services.

The idea of applying an ecosystem approach in the field of digital governance is not new [3, 4], going back to the ideas of McLuhan [5], who introduced the term "media ecology" to refer to complex and often hybrid communication systems, defined as visible and invisible environments, in which technologies interact with cultures, values, opinions, languages, and behavior. However, recently there has been a renewed interest in the study of media ecologies as systems [6, 7]. Extending the principles of media ecosystems to the study of patterns of interaction between government and society turns out to be conceptually productive in order to

understand why, for example, citizens are more willing to discuss politics in non-political forums, while many formal e-participation initiatives fail [8–10].

However, the ecosystem approach is usually used only as a metaphor for understanding interconnected systems and their components, as well as social systems with intensive use of ICT [11], and not as a predetermined blueprint for modeling an ecosystem. As a rule, researchers study the quality of platforms, channels, and tools for electronic interaction between government and society independently of each other. Research areas include, for example, the applicability of various assessment indicators to study e-participation portals in terms of institutional design and performance [12, 13] and the presence of government institutions in social networks [8, 9, 14]. Studies of e-participation services as technical platforms and tools of citizens in management processes prevail without due consideration, on the one hand, of their mutual influence and interdependence within the framework of an integral system, and, on the other hand, the role of the local media context. Much of the research on digital services is conducted primarily by computer scientists [15].

This study seeks to go beyond the existing limits of the conceptual limitations imposed by the theory of media ecology due to its widely interpreted metaphorical nature. Such a metaphorical approach to media ecology narrows the possibilities of using the system approach tools, which require greater rigor and certainty in fixing and interpreting the described media phenomena from the point of view of their interdependence as organic components of the system. In this regard, the concept of information ecology seems to be an important addition to the theory of media ecology, since it enhances the role of the context in which actors use various media technologies as social practices, that is, localizes such use. Hence, we can see the combined term "information-media ecology." The concept of "information ecology," in contrast to the McLuhan's theory of "media ecology" and his followers, emphasizes the key role of the local context and local actors in the use of a particular communication technology. So, Nardi and O'Day define the term "information ecology" as "local habitat," thus emphasizing the importance of understanding technology in its social environment. It is "a system of people, practices, values and technologies in a certain environment" [16, p. 49]. In addition to the distinct role of the local context in the use of a particular technology, a successful information ecology also includes not only the importance of taking into account the diversity among technology users, but their cooperation (interaction) in a collaborative, complementary, and inclusive (systemic) basis. Thus, the combination of media ecosystem and information ecology approaches complements each other conceptually and is most suitable for the aim of this study.

It should be noted that the ecosystem approach still remains insufficiently theoretically substantiated [17], especially with regard to taking into account the social and behavioral aspects of digital transformation, giving preference to technical and computer factors in building the architecture of e-government and "big data," also considered mainly from technological positions [18]. The literature contains broad definitions of the concept of "digital ecosystem," which leads to confusion and ambiguity regarding its semantic interpretation. Thus, one of the definitions considers a "digital ecosystem" as an open-source business network environment,

mainly including small- and medium-sized enterprises, for effective and efficient interaction with others [19]. From the point of view of the business approach, the "digital ecosystem" is considered an open, loosely connected, clustered, demand-oriented, self-organizing, and agent environment in which each agent performs a dual role. It can be a client and a server at the same time [20]. Researchers note similar underlying technologies for digital ecosystems: advanced web services architecture, self-organizing intelligent agents, ontology-based knowledge sharing, and smart sampling-based recommender system. It is noted that digital ecosystem models are based on a natural ecosystem model, which allows us to conclude that the term "ecological approach" appeared due to the analogy of the organization system.

This chapter proposes to use the ecosystem approach as the main analytical and methodological tool for studying the digital services for interaction with residents in the context of various communication environments and technologies, including services for interaction between the residents on the issues of urban development. This will allow us to conceptualize the applicability of a systems approach to urban digital services in terms of their mutual influence and synergy in the context of rapidly developing means of communication and related media technologies.

The main hypothesis of the study is that, using the ecosystem approach, it is possible to develop a model of interaction between citizens and authorities based on digital services implemented in different media environments.

To do this, the electronic interaction services in the study presented below will be associated with various media environments in order to find out the strengths and weaknesses of the respective services.

To categorize e-participation services, we have used as the base the methodology by the United Nations EPI index [21] consisting of information services (e-information); public consultation services as an opportunity to discuss local problems in the form of public consultations and hearings (e-consultation); and services of direct participation in decision-making, such as voting (e-decisions).

We call the municipal e-participation tools as "services," as in many cases citizen engagement falls under the broader plans to provide e-services. This term implies any technically implemented tool for communication and interaction between the authorities and residents of the municipality. It can be a channel or a chat in the form of a mobile application, a menu section of a website, and a discussion group on a social network. The presence of a page in social networks was also considered a separate service [22]. Mobile application services were evaluated in a similar way.

3 Case Description

St. Petersburg is a leading region in Russia in many areas of digital transformation. At the moment, the region is implementing the "Strategy for Digital Transformation of St. Petersburg until 2024" and introducing a new model for providing digital services to citizens (Ecosystem of City Services, https://petersburg.ru/), which includes mobile applications, digital services from government and third-party

developers, as well as applications and chat bots in social networks and instant messengers. Such a digital transformation of the model for the provision of e-services entails changes in the system of interaction between citizens and authorities and has important effects that require study.

The city's territory is divided into 111 intra-city municipalities, officially named as municipal formations, comprising 81 municipal city districts, 9 cities, and 21 semi-urban settlements. For the research, 10 of 111 municipalities were selected as a research object. These municipalities were determined largely randomly, with the assumption that, for the purpose of constructing an experimental ecosystem model, a sample of research objects plays a lesser role compared to ensuring that the same modeling principles are applied. It was postulated that if the model could be built using 10 municipalities, then the research could be scaled up to 111 units using the same principles.

The research is based on the experience of previous studies of the authors. Data obtained in 2023 were compared with data from studies in 2021 [22, 23] and 2022 [24, 25].

Each municipality was studied to identify all available e-participation resources taking into account the underlying media type including its status, that is, (i) official that deployed by municipal authorities, (ii) public (deployed by non-governmental organizations), and (iii) personal (deployed by private persons). In doing so, we distinguished three types of e-participation technologies (and respective media environments): (a) in the form of Internet websites (Web technologies); (b) in the form of pages on social networks (social networking sites); and (c) in the form of mobile applications (messenger platforms/applications). The types of services are divided into services of information, cooperation (feedback and public consultations/hearings), and services of participation in decision-making (mainly, voting) [22]. It is important that the study is not so much about electronic participation technologies, but about understanding the differentiated role of various communication interaction environments in which such participation is directly implemented in practice.

4 Results of the Research

For 3 years, the change in the population can be considered insignificant (see Table 1).

The number of official websites has not changed as well: Every municipality has an official website. However, the number of pages in social networks and the number of mobile applications have grown. The growth of the latter is especially noticeable, which is quite expected and is consistent with the general trends in the growth of mobile services (see Table 2).

The number of registered members in official social networks has also increased. In general, the percentage of engagement in official social networks is also increased: The number of registered members of social networks was divided by the number of residents of the municipality and multiplied by 100 (see Table 3).

Table 1 Population

Municipalities	Number of inhabitants in 2021	Number of inhabitants in 2023
Avtovo	44,456	43,625
Admiralteysky District	22,710	22,239
Academic district	106,782	104,723
Alexandrovskaya	2728	2706
Aptekarsky Island	19,828	19,614
Beloostrov	2301	2321
Zelenogorsk	15,208	15,138
Kolpino	149,766	151,718
Komarovo	1300	1322
No. 7 District	40,595	40,103
Total	405,674	403,509

Table 2 Number of identified official media resources

	Internet websites			Social media pages			Mobile platforms, apps		
Municipalities	2021	2022	2023	2021	2022	2023	2021	2022	2023
Avtovo	1	1	1	3	1	5	1	3	1
Admiralteysky District	1	1	1	2	2	2	0	0	0
Academic district	1	1	1	3	1	4	0	2	1
Alexandrovskaya	1	1	1	1	1	1	0	1	1
Aptekarsky Island	1	1	1	3	2	3	1	0	0
Beloostrov	1	1	1	1	1	2	0	1	2
Zelenogorsk	1	1	1	0	1	1	0	2	0
Kolpino	1	1	1	3	1	1	1	2	2
Komarovo	1	1	1	1	1	1	0	2	0
No. 7 District	1	1	1	1	1	2	0	0	0
Total	10	10	10	18	12	22	3	13	7

Media resources were not studied in 2021, so the conclusions are drawn only for 2022 and 2023. However, these data indicate a significant decrease in the number of pages in the networks of social movements (more than twice). One mobile application has appeared (Table 4).

The average percentage of engagement in public social networks is significantly lower than official one in 2023 (Table 5).

In general, it can be stated that over the year the number of official resources has increased and the number of public ones has greatly decreased (Fig. 1).

The number of identified personal media resources at the level of municipalities remained minimal; however, in one municipality, the number of personal pages on social networks immediately increased three times, from 2 to 6. The percentage of engagement in personal social networks is high only in one municipality (Avtovo), where six personal pages were found. The number of services for informing, collaborating, and participating in decision-making on personal media resources has increased, which can also be associated with an increase in their resources.

Table 3 Number of registered members and percentage of engagement in official social networks

Municipalities	Number of registered members of online communities and % of engagement			
	2021		2023	
	Number of members	Engagement (%)	Number of members	Engagement (%)
Avtovo	4037	9.08	4094	9.38
Admiralteysky District	9929	43.72	6316	28.4
Academic district	7320	6.85	9237	8.82
Alexandrovskaya	150	5.49	377	13.93
Aptekarsky Island	3690	18.61	2827	14.41
Beloostrov	1155	50.19	1987	85.6
Zelenogorsk	0	0	416	2.74
Kolpino	7707	5.14	9768	6.43
Komarovo	27	2.07	0	0
No. 7 District	3139	7.73	4610	11.49
Total	37,154	9.15	39,632	9.82

Table 4 Number of identified public media resources

Municipalities	Internet websites		Social media pages		Mobile platforms, apps	
	2022	2023	2022	2023	2022	2023
Avtovo	0	0	3	2	0	0
Admiralteysky District	0	0	0	0	0	0
Academic district	0	0	2	0	0	0
Alexandrovskaya	0	0	1	0	0	0
Aptekarsky Island	0	0	0	0	0	0
Beloostrov	0	0	1	1	0	0
Zelenogorsk	0	0	2	0	0	0
Kolpino	1	0	1	0	1	1
Komarovo	0	0	2	0	0	1
No. 7 District	0	0	0	1	0	0
Total	1	0	9	4	1	2

However, in general, there are so few such resources that it was decided not to take them into account in further research.

Table 6 shows the data concerning changes in the number of information services, cooperation, and participation in decision-making on official media resources over 3 years. It was revealed that, as in previous years, in 2023 official media resources are mainly aimed at informing users. Therefore, in 2023, it was decided not to analyze the number of sections and subsections of the main menu of the Moscow Region websites, so the number of information services was conditionally taken as 100. This clearly shows the share of cooperation and decision-making services, the number of which decreased compared to the data obtained in 2021. Collaboration

Table 5 Number of participants and percentage of engagement in public social networks (2023)

Municipalities	Number of networks	Number of participants	Engagement (%)
Avtovo	2	7644	17.52
Admiralteysky District	0	0	0
Academic district	0	0	0
Alexandrovskaya	0	0	0
Aptekarsky Island	0	0	0
Beloostrov	1	996	42.91
Zelenogorsk	0	0	0
Kolpino	0	0	0
Komarovo	0	0	0
No. 7 District	1	386	0.96
Total	4	9026	2.23

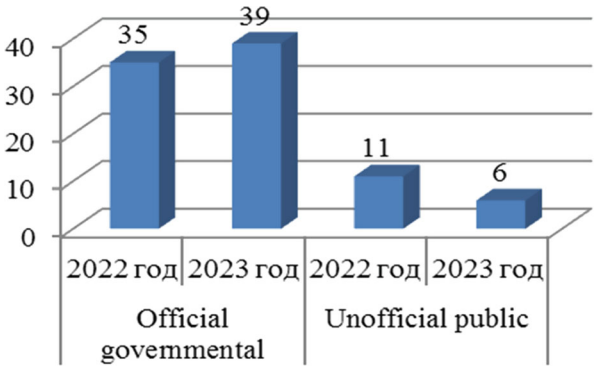

Fig. 1 Number of official and unofficial/public media resources

Table 6 Number of services for informing, collaborating, and participating in decision-making on official media resources

	Information provision			Cooperation, interaction			Direct decision-making		
Municipalities	2021	2022	2023	2021	2022	2023	2021	2022	2023
Avtovo	100	100	100	7	3	8	1	0	1
Admiralteysky District	100	100	100	1	10	2	0	3	0
Academic district	100	100	100	8	6	7	1	1	0
Alexandrovskaya	100	100	100	6	6	2	1	0	0
Aptekarsky Island	100	100	100	11	5	6	0	0	0
Beloostrov	100	100	100	4	7	5	0	1	1
Zelenogorsk	100	100	100	8	5	2	1	4	0
Kolpino	100	100	100	14	4	4	1	0	0
Komarovo	100	100	100	10	8	2	1	2	0
No. 7 District	100	100	100	3	8	4	1	4	4
Average	100	100	100	7.2	6.2	4.2	1	1.5	0.6
Total	100	100	100	72	62	42	7	15	6

Table 7 Number of services for informing, collaborating, and participating in decision-making on public media resources

	Information provision		Cooperation, interaction		Direct decision-making	
Municipalities	2022	2023	2022	2023	2022	2023
Avtovo	100	100	5	2	0	0
Admiralty District	0	0	0	0	0	0
Academic district	100	0	4	0	0	0
Alexandrovskaya	100	0	3	0	0	0
Aptekarsky Island	0	0	0	0	0	0
Beloostrov	100	100	5	2	0	1
Zelenogorsk	100	0	10	0	0	0
Kolpino	100	0	4	1	0	0
Komarovo	100	0	6	1	0	0
No. 7 District	0	100	0	1	0	0
Average	70	30	3.7	0.7	0	0.1
Total	100	100	37	7	0	1

Table 8 Relationship between participation services and the type of media environment of the municipality on official media resources (2023)

	Internet websites		Social media pages		Mobile platforms, apps	
Service domain	Official	Public	Official	Public	Official	Public
Information provision	100	0	100	100	100	100
Cooperation, interaction	8	0	29	5	5	2
Direct decision-making	1	0	5	1	0	2

services have almost halved. The interface of websites in most cases still remains not very convenient for the average user and is overflowing with information that is quite difficult to navigate.

With regard to the number of information services, cooperation, and participation in decision-making on public media resources, the decrease in collaboration services is even more noticeable here—from 37 to 7 in 1 year, that is, more than five times (Table 7). Of course, such a figure is naturally associated with a general decrease in the number of public media resources, but given the little change in the number of inhabitants, it clearly indicates a significantly reduced ability of citizens to interact with the authorities in some other way besides obtaining information about their actions.

Further, the study revealed the relationship between participation services and the type of media environment of the municipality (see Table 8).

Table 8 shows the dominance of information services in all three media environments and the predominance of collaboration services in the social media environment. Moreover, if we compare the number of collaboration services with the data of 2021, we see that it decreased in the environment of websites (by 6.5 times—Figs. 2 and 3), and it increased in the environment of social networks (by 1.5 times—Figs. 4 and 5). Similarly, the number of decision-making services decreased in the

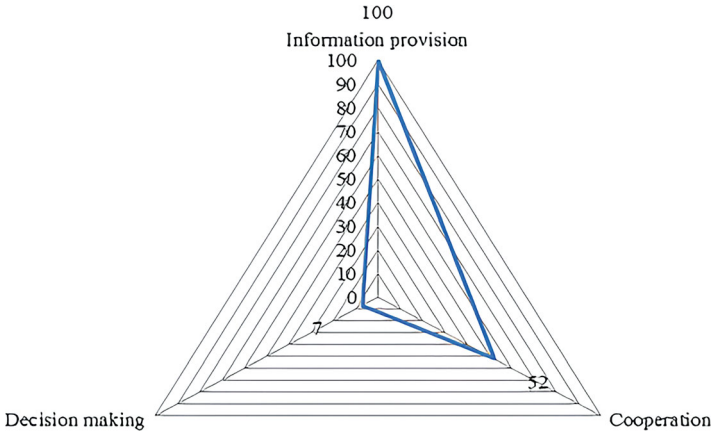

Fig. 2 Official website 2021

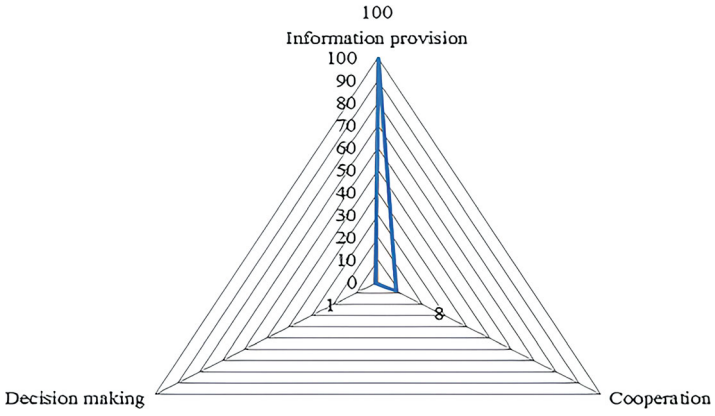

Fig. 3 Official websites 2023

environment of websites (by 7 times), while it increased by 5 times in the environment of social networks.

In 2023, the development of collaboration services in the mobile environment also increased, although slightly (Figs. 6 and 7).

Public media resources (Table 8) in 2023 are also dominated by information services, followed by collaboration services and almost no decision-making services.

In order to integrate the results of the study into a general analytical framework, it was decided to visualize the ecosystem model in the form of a cube. Such a model makes it possible to visually show the relationship between the three main parameters (Fig. 8). Three main parameters were taken as the main elements of the ecosystem: the type of media (online) environment (websites, social networks, and mobile platforms), the type of services (informing, cooperation, and

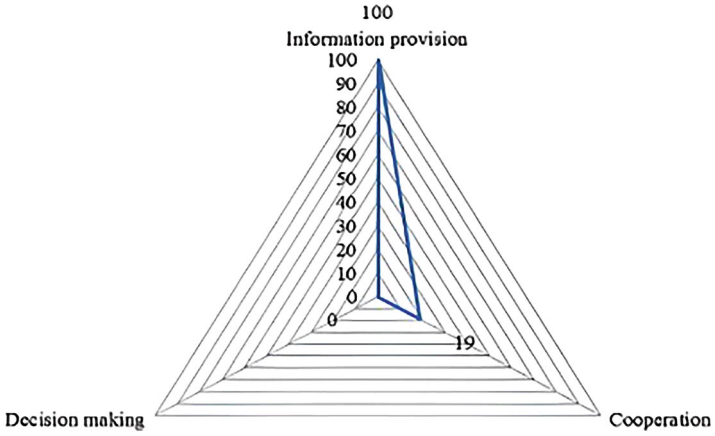

Fig. 4 Official social media pages 2021

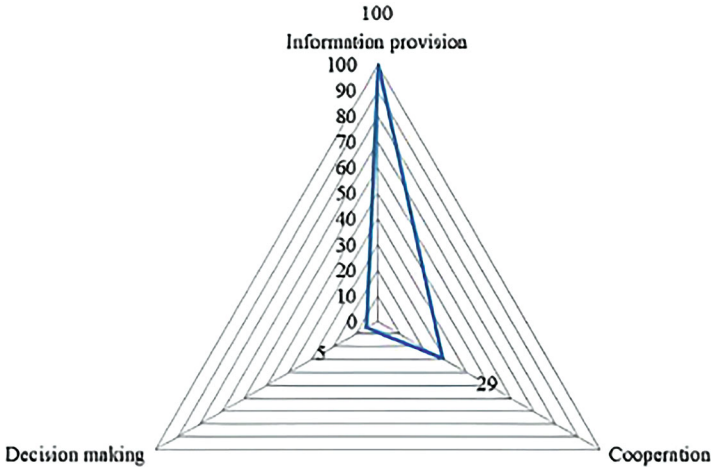

Fig. 5 Official social media pages 2023

decision-making), and the size of the municipality. The results obtained earlier [22, 23] indicate that the size of the municipality population is not a determining factor in the formation of services. At the same time, the obtained data indicate an existing relationship between the type of service and the type of online environment.

Each visible side of the cube contains a number of corresponding services. For example, the central square on the top horizontal surface of the cube with the number 29 indicates that there are 29 collaboration services in the social media environment. The leftmost row on the vertical side contains data on the number of services in the environment of Internet websites depending on the size of municipalities. The right vertical surface of the cube reflects the availability of services by population groups

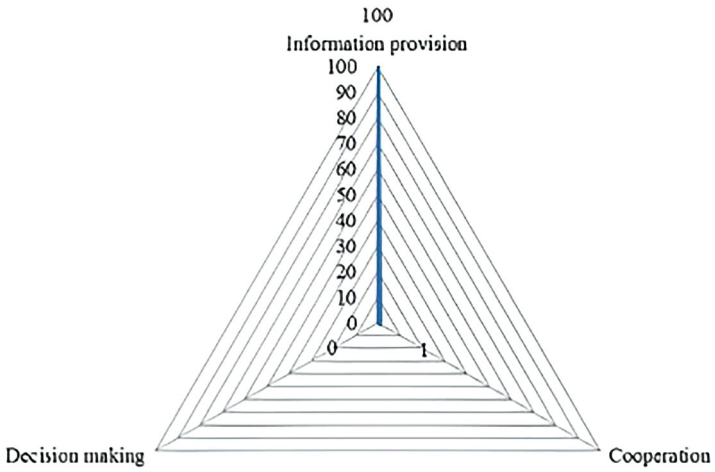

Fig. 6 Mobile apps, 2021

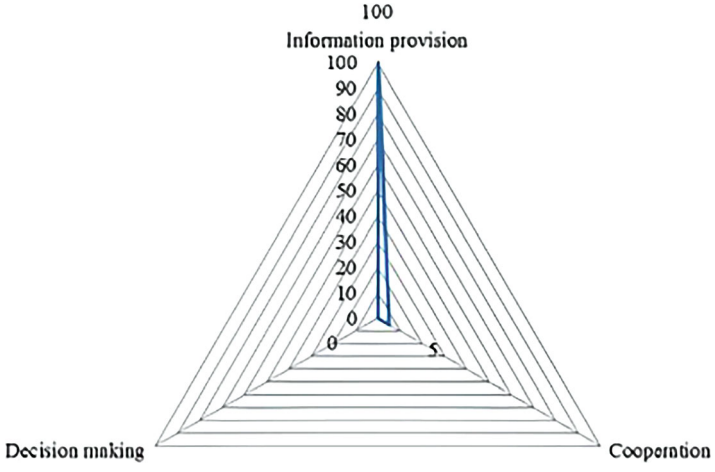

Fig. 7 Mobile apps, 2023

in the municipality. For example, there are 12 cooperation services in the group of two municipalities with a total population of 256,000 inhabitants and 9 services in three municipalities with a total population of 6000.

The model is quite complex, reflecting the main aspects of e-participation. The limitation of this model, as presented in this chapter, is the inability to go beyond the three components and combine both official and unofficial levels of services in one cube. It is technically possible to improve the cube model by filling the remaining sides, which will make it possible to supplement the model with new parameters and identify interaction in all possible directions.

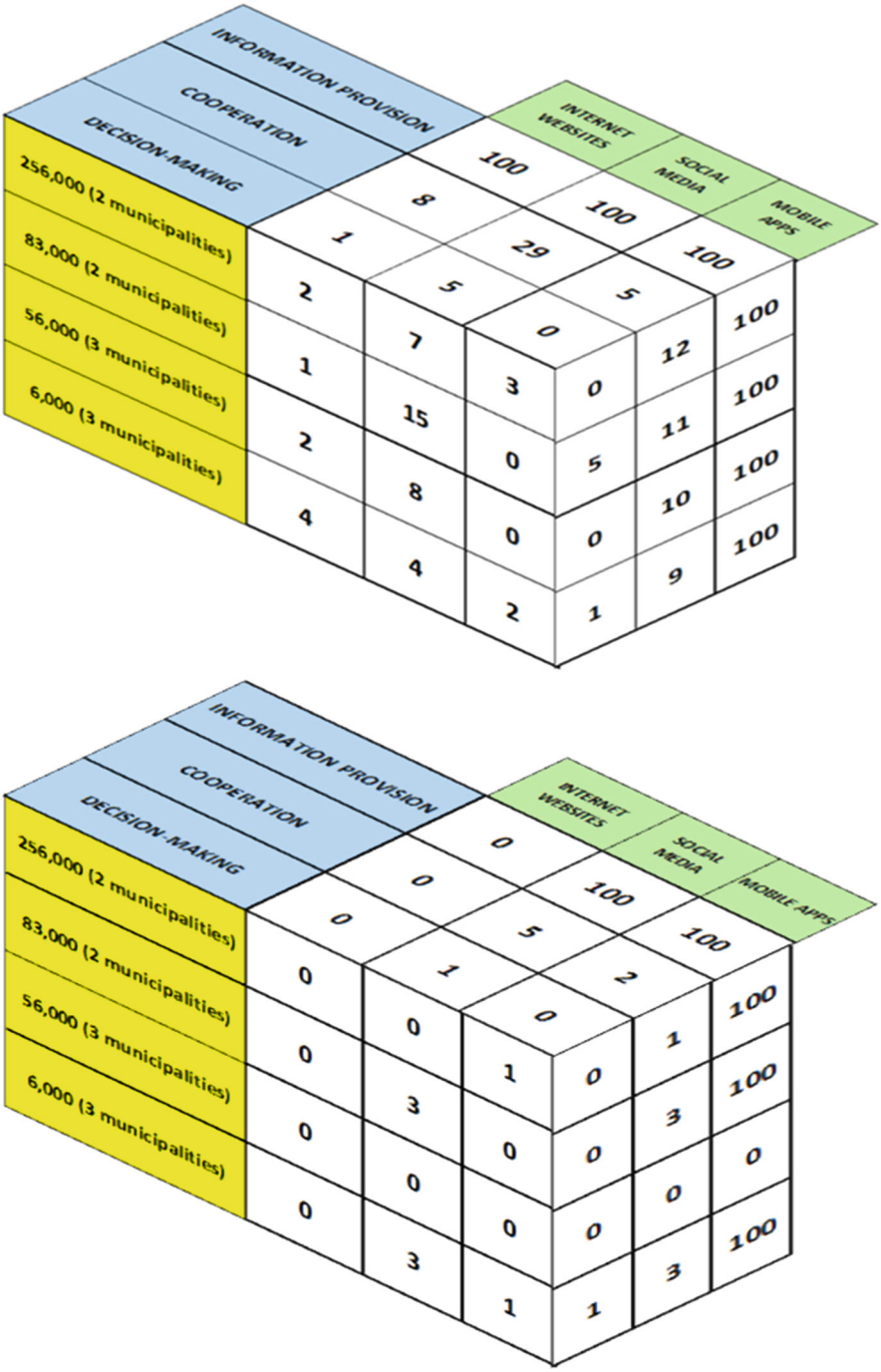

Fig. 8 3D models of the information and media ecosystem of digital services at the official (left) and public (right) levels

5 Discussion and Conclusions

The main research problem which this chapter was aimed to solve was the lack of sufficient theoretical and empirical knowledge about the state of digital services provided to residents of large cities, including an understanding of the trends in their formation as an integral system of public services.

Based on empirical data collected on the basis of ten pilot municipalities, the authors tried to develop a model of an ecosystem of interaction between citizens and authorities, highlighting technically different types of main media and communication environments, namely, the environment of websites (portals), the environment of social networks, and the environment of mobile platforms. The development of such environments leads to a greater variety of opportunities for interaction and participation, thereby changing and complicating the behavioral preferences of urban residents and their attitudes toward urban governance institutions. Insufficient consideration of such transformations reduces the usefulness, efficiency, and effectiveness of the existing and future ecosystem of digital services.

Answering the first research question (RQ1) about the list and structure of services for interaction between authorities and citizens, we emphasize that information services, both in 2021 and 2003, are not just the main ones, but defining and largely redundant in all municipalities, without exception, regardless of their size and institutional affiliation. It can be assumed that such a large number of information services (primarily on the pages of official websites) are caused not so much by the information needs of residents, but by the understanding of such needs by the authorities of the Moscow Region and following the language of law. Also in all cases, collaboration services and especially participation in decision-making are low in all three online environments, although social networks are used to organize informal discussions to a greater extent compared to websites. Services in the mobile application environment are few in number.

Answering the second research question (RQ2) regarding the changes that have taken place, it should be noted that the number of pages in official social networks and the number of mobile applications have increased, as well as the number of subscribers and engagement in social networks developed by the municipal government. However, at the same time, the number of collaboration and decision-making services decreased in 2023 compared to the data obtained in 2021. A characteristic feature is the fact that cooperation and decision-making services are almost not presented on the websites of the Moscow Region. However, such an opportunity is provided by external resources of a citywide or federal nature, links to which are provided on the websites. This can be called one of the significant changes in 2023. A study of 2021 indicated that they either did not work or were not used for local needs. This state of affairs raises the question of whether the ecosystem of digital services at the municipal level should be supplemented with new parameters that show their relationship with services of another level of government.

It is also an important observation regarding the situation in 2023, indicating a significant decrease in the number of pages on the social networks of social

movements and an even more significant decrease in collaboration services on public media resources.

The answer to the third research question (RQ3) about the possibility of building a model of digital services on the case of St. Petersburg was confirmed. Visualization in the form of a cube, used before, has confirmed its effectiveness. It turned out to be fundamentally possible to build a three-dimensional model of the information and media ecosystem of digital services based on the size of the municipalities, services, and their carriers. Visualization of such a model makes it possible to identify the relationships (or lack) between the three elements of the ecosystem.

It can be assumed that the further spread of mobile platforms and applications (channels, chats, and communities) may lead to more significant differences between services and the media environment. For example, chatbots can become an important communication tool, which will force us to reconsider approaches to using local websites for this purpose over time. Further research is needed to understand the extent to which existing services and media environments reflect the needs and preferences in the context of social groups in order to develop new technical solutions to expand the possibilities of electronic interaction between government and citizens. One direction for future research could be to explore how an ecosystem can be changed when external resources are included. Obviously, the factor of demand for services by the population of the Moscow Region and the city as a whole will play a key issue in this regard. First of all, this concerns the services of public consultations and hearings, which are technically difficult to implement, but even more difficult to convince residents to use them as social practices. This will require additional research on participation in a larger sample.

Acknowledgments The research was supported by the Russian Science Foundation and St. Petersburg Science Foundation Grant No. 23-18-20079 "The Social Efficacy of Electronic Interaction between Citizens and the Government: The Case of Urban Digital Services in St. Petersburg" (https://rscf.ru/en/project/23-18-20079/).

References

1. Rainie, L., Smith, A., Schlozman, K., Brady, H., Verba, S.: Social Media and Political Engagement. Pew Research: Internet Project. Pew Research Center, Washington, DC (2012)
2. Marquart, F., Ohme, J., Möller, J.: Following politicians on social media: effects for political information, peer communication, and youth engagement. Media Commun. **8**(2), 197–207 (2020)
3. Park, K.-G., Han, S., Kaid, L.L.: Does social networking service usage mediate the association between smartphone usage and social capital? New Media Soc. **15**(7), 1077–1093 (2013)
4. Light, B., Burgess, J., Duguay, S.: The walkthrough method: an approach to the study of apps. New Media Soc. **20**(3), 881–900 (2018)
5. McLuhan, M.: Understanding Media: The Extensions of Man. Gordon, W.T. (ed.). Gingko Press, Corte Madera (2003)
6. Charalabidis, Y., Loukis, E.: Transforming Government Agencies' Approach to e-Participation through Efficient Exploitation of Social Media. ECIS (2011)

7. Wahid, F., Sæbø, Ø.: Affordances and effects of promoting eParticipation through social media. In: Tambouris, E., Panagiotopoulos, P., Sæbø, Ø., Tarabanis, K., Wimmer, M.A., Milano, M., Pardo, T. (eds.) Electronic Participation, vol. 9249, pp. 3–14. Springer (2015)
8. Alarabiat, A., Sá Soares, D.: Electronic participation through social media. In: ICEGOV '15–16: Proceedings of the 9th International Conference on Theory and Practice of Electronic Governance, March 2016, pp. 191–194. ACM, New York (2016)
9. Alarabiat, A., Sá Soares, D., Estevez, E.: Municipalities e-Participation initiatives through Facebook: citizens perspective. In: ICEGOV 2020: Proceedings of the 13th International Conference on Theory and Practice of Electronic Governance, pp. 551–559. ACM, New York (2020)
10. Kalogeropoulos, A., Fletcher, R., Nielsen, K.: News brand attribution in distributed environments: do people know where they get their news? New Media Soc. **21**(3), 583–601 (2019)
11. Dawes, S.S., Vidiasova, L., Parkhimovich, O.: Planning and designing open government data programs: an ecosystem approach. Gov. Inf. Q. **33**(1), 15–27 (2016)
12. Cali, D.: Mapping Media Ecology: Introduction to the Field. Peter Lang, New York, Bern, Frankfurt, Berlin, Brussels, Vienna, Oxford, Warsaw (2017)
13. Scolari, C.: Media ecology: exploring the metaphor to expand the theory. Commun. Theory. **22**(2), 204–225 (2012)
14. Graham, T.: Beyond "political" communicative spaces: talking politics on the "Wife Swap" discussion forum. J. Inform. Tech. Polit. **9**(1), 31–45 (2012)
15. Stamatis, A., Geronta, A., Dasyras, A., Tambouris, E.: Using chatbots and life events to provide public service information. In: ICEGOV 2020: Proceedings of the 13th International Conference on Theory and Practice of Electronic Governance, September 2020, pp. 54–61. ACM, New York (2020)
16. Nardi, B., O'Day, V.: Information Ecologies: Using Technology with Heart. MIT Press, Cambridge, MA (2000)
17. McBride, K., Misnikov, Y., Draheim, D.: Discussing the Foundations for Interpretivist Digital Government Research SocArXiv k53a8. Center for Open Science (2021)
18. Draheim, D., Krimmer, B.: Architecture of digital government ecosystems: from ICT-driven to data-centric. In: Special Issue in Memory of Roland Wagner. Transactions on Large-Scale Data- and Knowledge-Centered Systems. Springer (2021)
19. Ferronato, P.: Introduction to the digital business ecosystem project. MDA Technical Forum, Tokyo (2004)
20. Chang, E., West, M.: Digital ecosystems: a next generation of the collaborative environment. In: iiWAS. The Eighth International Conference on Information Integration and Web-based Applications Services, 4–6 December 2006, Yogyakarta, Indonesia (2006)
21. UN E-government survey. https://publicadministration.un.org/en/research/un-e-governmentsurveys
22. Misnikov, Y., Filatova, O.: E-participation services in St. Petersburg municipalities: testing the ecosystem approach. State and citizens in the electronic environment, 5. In: Chugunov, A.V., Filatova, O.G. (eds.) Proceedings of the XXIV International Joint Scientific Conference "Internet and Modern Society", IMS-2021, St. Petersburg, June 24–26, 2021, pp. 92–113. ITMO University, St Petersburg (2021). https://doi.org/10.17586/2541-979X-2021-5-92-113
23. Misnikov, Y., Filativa, O., Trutnev, D.: Empirical modeling of e-participation services as media ecosystems. In: Social Computing and Social Media: Experience Design and Social Network Analysis – 13th International Conference, SCSM 2021, Held as Part of the 23rd HCI International Conference, HCII 2021, Proceedings Lecture Notes in Computer Science, 12774 LNCS, pp. 87–104. Springer Nature (2021). https://doi.org/10.1007/978-3-030-77626-8_6
24. Misnikov, Y., Filatova, O.: e-Participation as mediated ecosystem? A case study on municipalities of St. Petersburg, Russia. In: Meiselwitz, G., et al. (eds.) HCI International 2022. Interaction in New Media, Learning and Games Lecture Notes in Computer Science, 13517, pp. 81–96. Springer Nature Switzerland AG (2022). https://doi.org/10.1007/978-3-031-22131-6_7

25. Misnikov, Y., Filatova, O.: Infrastructure of electronic participation at the level of municipalities of St. Petersburg: media-ecological approach. State and citizens in the electronic environment, 6. In: Chugunov, A.V., Filatova, O.G. (eds.) Proceedings of the XXV International Joint Scientific Conference "Internet and Modern Society", IMS-2022, St. Petersburg, June 23–25, 2022, pp. 72–84. ITMO University, St Petersburg (2022). https://doi.org/10.17586/2541-979X-2022-6-72-84

Unveiling the Role of Political Regime: How E-Governance Shapes Quality of Governance in Democratic and Non-Democratic Countries

Alena Teplyshova

Abstract This chapter examines the influence of e-governance on the quality of governance (QoG) in democracies and non-democracies. Previous studies have yielded inconsistent findings regarding this relationship, overlooking the potential moderating role of political regime. To address this gap, I present a theoretical framework based on the different institutional contexts and motivations of political leaders in democracies and non-democracies. By considering the limitations of prior research methodologies, I conduct a panel analysis covering 179 countries from 2009 to 2021. Surprisingly, the findings reveal that non-democracies benefit from e-governance more, with e-government development and e-participation level having higher impact on administrative effectiveness than in democracies. Thus, the study confirms that political regime acts as a significant moderating variable in the relationship between e-governance and government effectiveness, though in quite an unexpectable way. These results contribute to the debate between technological optimists and pessimists, suggesting that the effects of e-governance on QoG vary depending on the political context, highlighting both the limitations and potential benefits of technology in governance processes.

Keywords e-governance · e-government · e-participation · Quality of governance · Democracies · Non-democracies · Administrative capacity · QoG

1 Introduction

The application of Information Communication Technology (ICT) in the public sector, known as e-government, has transformed the way governments deliver services and interact with citizens and businesses [42]. While traditionally associated with democracies, non-democratic countries have also embraced e-government initiatives, catching up with their democratic counterparts [44]. However, the impact

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_35

of e-governance on the quality of governance (QoG) remains a topic of debate. Some scholars believe in the transformative potential of technology in improving governance [45, p. 163], while others remain sceptical, citing limited evidence of its effectiveness [32]. Additionally, the political regime can influence the relationship between e-governance and the QoG, warranting its consideration in the analysis.

This article aims to explore the potential effect of the political regime as a moderator between e-governance and QoG. Thus, the research question will be the following: what is the difference in the impact of e-governance on the QoG between democracies and non-democracies? In this study, e-governance refers to "the use of ICTs to support public services, government administration, and relationships among citizens, civil society, the private sector, and the state" [13, p. 86], and QoG refers to the degree to which a government or public institution can effectively formulate and implement policies and achieve desired outcomes, regardless of political regime [25, p. 9].

The remainder of this chapter proceeds as follows: a literature review will provide the necessary background, followed by the presentation of a theoretical framework based on core differences between democracies and non-democracies. Hypotheses derived from these differences will be presented, positing the moderating effect of the political regime on the relationship between e-governance and QoG. A panel data analysis using fixed-effects models will be conducted, examining 179 countries from 2009 to 2021. The results will be presented and discussed, followed by concluding remarks.

2 Literature Review

2.1 Quality of Governance and Its "Close Relatives"

There is a profound academic discussion regarding the definition of terms such as QoG. There are three main understandings of the QoG concept: first, as "good governance" including such principles as accountability, transparency, participation, rule of law, and responsiveness which is mostly represented by Worldwide Governance Indicators [31, p. 4] and which is heavily criticised by some scholars [11, 39, p. 1141; 20, p. 97]; second, as impartiality of the governing institutions while exercising power as coined by Rothstein and Teorell [38]; and third, as the interplay between capacity of the executive branch and bureaucratic autonomy, proposed by Fukuyama [21]. Meanwhile, Fukuyama believes that QoG should not conceptually overlap with the political regime, and while authoritarian countries can be governed well, democratic ones can be governed poorly [21]. Since in this chapter I am making a comparison between the impact of e-governance on QoG in different political contexts, it is essential that the dependent variable (QoG) is not biased in favour of democracies or non-democracies, so I propose to follow Fukuyama's example by operationalising QoG through capacity.

In general, state capacity is understood as the ability of the state to execute its core functions, objectives, or policies [25]. Though it can be categorised into many distinct facets, Hanson and Sigman attempted to reduce this number, and as a result, they arrived at three aspects of state capacity, namely extractive capacity, coercive capacity, and administrative capacity [25]. In my work, I will focus on the administrative capacity which relates to the state's ability to organise itself in terms of policy development, public service delivery, and regulation [25]. Since the purpose of my work is to compare the impact of e-governance on the performances of democracies and non-democracies, the conceptual distinction between my DV (QoG) and the moderator (political regime) is of particular importance to me, so that the most important requirement for the definition of QoG is its independence of political regime. Thus, drawing on the definition of Hanson and Sigman, I will define Quality of Governance as the degree to which a government or public institution is able to effectively implement policies and achieve desired outcomes, regardless of political regime. This includes the ability to efficiently allocate resources, provide public services, and regulate economic and social activity [25, p. 9]. Now, I turn to discussing my independent variable.

2.2 E-Government, E-Governance, and E-Participation: How to Tell the Difference?

The increasing significance of ICT in governance is a crucial aspect of modern governance. This has led to the emergence of several concepts such as e-government, e-governance, e-participation, e-voting, digital government, and others, which highlight the potential of new technologies [7]. The definitions of these concepts often overlap, making it challenging to establish clear boundaries between them [37, p. 186]. Despite this, each concept has its unique implications, and thus, it is essential to differentiate them [37]. In this chapter, I will argue that the term e-governance is a broader one as it includes both e-government and e-participation.

The most state-centric concept among all of the aforementioned is e-government [35]. Broadly speaking, e-government is understood as the mere digitalisation of governmental operational functions [8, 19]. As Janowski points out, e-government is the second stage of the digital government evolution, characterised exclusively by improvements to internal government processes [26]. According to the author, this is frequently implemented as a component of a broader administrative reform, with the aim of enhancing internal efficiency, effectiveness, simplification, and other reform-oriented objectives [26]. Thus, by referring to e-government, I will mean the use of ICT in the public sector "to enhance the access to and delivery of government services to benefit citizens, businesses and employees" [42, p. 1].

Meanwhile, according to Janowski, e-governance follows e-government as the next stage in the evolution of digital government [42]. Compared to e-government, the primary objective of e-governance is to transform the interactions between the

government, citizens, businesses, and other non-government entities with the help of ICTs. Moreover, in contrast to e-government, the goal of e-governance is not only to enhance the accessibility, convenience, and efficiency of public service delivery systems, but also to engage citizens in political and civil matters, which is why this stage is also called the "engagement stage" [26]. Therefore, building on the definition of Dawes but excluding the reference to political regime, I will refer to e-governance as "the use of ICTs to support public services, government administration, and relationships among citizens, civil society, the private sector, and the state" [13, p. 86]. In other words, I will consider e-governance as a broader concept that encompasses both e-government (which involves the digitalisation of public services) and e-participation (which involves the digitalisation of citizens' involvement in public affairs) [7]. Having separated these concepts and achieved conceptual clarity, I will consider e-governance as an independent variable capable of influencing various aspects of QoG.

2.3 The Impact of E-Governance on Different Aspects of Quality of Governance

In this section, I will review the literature that has investigated the impact of e-governance on the various aspects of QoG highlighted in the previous section. To begin with, much of previous research has indicated the possibilities for e-governance to mitigate corruption [4, 50, 51]. As Chen and Aklikokou argue, e-governance creates the conditions for reducing corruption, as the former helps to solve the principal-agent problem [9]. Moreover, Kalesnikaite et al. claim that e-governance contributes to reducing bureaucratic corruption since it decreases direct interactions between citizens and bureaucrats, thereby lowering bureaucrats' discretion [28]. Besides control of corruption, another area of research considers the relationship between e-governance and transparency and accountability [16, 48]. However, Bannister and Connolly argue that the potential of digitalisation in governance can be overestimated, since it may have only partial effects [5].

Finally, a considerable body of literature explores the relationship between e-governance and administrative performance. Previous studies have found a positive correlation between the development of e-governance and the effectiveness of public administration [43]. Likewise, Wandaogo concludes that e-governance does improve government effectiveness in both developing and developed countries, although the effect is greater in developed countries [47]. Moreover, Dobrolyubova et al. found that e-government is positively correlated with the quality of public administration [14]. However, Durkiewicz and Janowski claim that the levels of electronic and traditional government must be comparable. For example, for e-governance to produce positive results, the initial level of government effectiveness must be high [16]. At the same time, some authors have found that while the use of

ICT in government has significantly increased effectiveness, it has little impact on efficiency [36].

Meanwhile, different authors have different explanations for why e-governance can impact government performance. First, according to some academics, e-governance allows easier interaction between different segments of the administration, which also helps to prevent the duplication of functions between different government agencies [23]. Second, the digitalisation of government provides greater storage capacity for various documents, which ensures greater efficiency than before [18]. Third, the improved efficiency of government is since e-governance allows the administration to facilitate interaction with individuals and companies, which in turn leads to greater transparency [17].

To conclude, there is no clear consensus on the impact of e-governance on states' administrative effectiveness, so follow-up reconsiderations are needed to better investigate and clarify this relationship. Moreover, as most studies either concentrate on single cases or include only a small sample of countries, there is a need to conduct more cross-national large-N analysis. In addition, many authors in their studies have looked at the impact of e-governance on the QoG using cross-sectoral data, ignoring the potential dynamics in the interaction between e-governance and QoG and the direction of influence between the two variables. What is also surprising is that the political regime has been quite neglected in studies on the impact of e-governance on the QoG, although it can be a potentially crucial and moderating variable. Thus, this chapter aims to address all the gaps and contribute to this field of research.

3 Theoretical Framework

3.1 What Is (Non)Democracy? Drawing a Line Between Democracy and Non-Democracy

To begin with, there are a great number of different definitions and typologies of political regimes. In this chapter, however, I will follow a dichotomous logic, deliberately simplifying the complex messiness in classifying political regimes in real life into a simple one, dividing the huge range of political regimes into democratic and non-democratic. The former would include both full liberal democracies and backsliding democracies, also referred to as electoral democracies. The latter would include various types of non-democratic regimes, from closed autocracies to more loose hybrid authoritarian regimes.

In this chapter, I will draw the dividing line between democracies and non-democracies based on Dahl's criteria, namely election of officials, fair, free and frequent elections, freedom of expression, access to various sources of information, freedom of association, and inclusive citizenship [12]. Hence, I will argue that first, in democratic regimes, executives and legislatures are chosen through fair and free elections, whereas in non-democratic regimes although the elections may be present

and held regularly, they are not free and fair, with opposition candidates often denied resources and media coverage. Second, in democratic regimes, all adult citizens have the right to vote, while in non-democratic regimes, the critics of the government and opposition politicians may be threatened and even arrested. Third, in democratic regimes, civil and political liberties and rights are protected, while in non-democratic, members of the opposition and civil society organisations may be jailed, exiled, or even killed. Finally, in democratic regimes, elected authorities have the power to govern without interference, whereas in non-democratic regimes, the authority to govern is distributed among members of the closed group of political elite.

3.2 The Impact of E-Government on QoG in Democracies and Non-Democracies

Comparing democracies with non-democracies, we can first see differences in political systems and government commitment to using technology for public service delivery. First, because a political system in a democracy is more open, transparent, and accountable due to the presence of the system of checks and balances, and an active civil society serving as a watchdog over incumbents [44], the introduction of e-government in a democratic context helps to boost government responsiveness, which ultimately leads to more effective policy formulation and implementation. At the same time, non-democratic regimes do not necessarily seek to increase transparency and accountability [27]. On the contrary, the introduction of e-government in non-democracies can be used to strengthen authoritarian rule with more control over information and citizens [30, 44] rather than increasing responsiveness to citizens' needs.

Despite the different contexts, the goals of democratic and non-democratic leaders in adopting e-government may be compatible. In both democracies and non-democracies, the main goal of political leaders is re-election and regime survival, respectively, which can be achieved by enhancing the output legitimacy, which is about the quality of decisions to "effectively promote the common welfare of the constituency in question" [40, p. 7]. Thus, the adoption of technology in the public sphere is an excellent means of achieving this objective [44]. At the same time, while democratic leaders may be more committed to using technology to improve the quality of government services, autocrats may use these technologies for other purposes. For example, e-government programmes can be seen as another democratic façade which is introduced to show the outside world their modernity [34]. Such a legitimisation effort can help autocrats to raise their image in the international arena and show their aspirations for democratisation, even though this may not be their real goal [34]. Instead, their aim is often to attract foreign investment to boost economic growth [34, 44]. To summarise, while democracies have a greater emphasis on public service delivery and stronger institutions,

non-democratic leaders also seek to increase administrative capacity, which is why I assume that:

Hypothesis 1: *Higher e-government performance will have a stronger positive impact on the administrative capacity in democracies than in non-democracies.*

3.3 The Impact of E-Participation on QoG in Democracies and Non-Democracies

Since democracies are founded on the sovereignty of the people, they seek additional instruments of political participation from civil society groups, and e-participation can enhance the input legitimacy by increasing the capacity of citizens to participate, expanding the space for dialogue, and enabling discussion among actors in democratic contexts [40]. At the same time, in non-democracies, the stricter the regime, the more limited are the opportunities for the people to participate in decision-making [6]. Thus, due to the repressive nature of non-democratic rule, residents may be afraid to openly express their opinions, so they prefer to abstain from participation. That is why, most often, in non-democratic contexts, e-participation is only introduced as a democratic façade to provide the absent input legitimacy inherent in democracies, but not to actually empower people [8, 29, 44] as it may be too costly for autocrats because of the actual possibility of democratisation [44]. Therefore, even if in some non-democratic countries e-participation mechanisms are present, the possibilities to use technology may be limited, which makes them a mere "Potemkin e-villages" [38].

Also, without providing real involvement but limited to a few consultative functions, e-participation in non-democracies allows leaders to gather information about the attitudes and grievances of the population [29, 46], which helps to partially solve the "dictator's dilemma" [40]. However, this does not mean that once information about the discontent of the population is gathered, the feedback mechanism will work as in democracies, where the government adjusts its policies. They may, however, give people a sense of greater transparency and responsiveness [29], which leads to greater internal legitimacy for the dictator. In addition to internal legitimacy, as in the case of e-government, authoritarian leaders also seek, through the introduction of e-participation, to enhance their image in the international arena to ensure the flow of investment and improve the country's economic performance [6, 8, 46]. Thus, e-participation in non-democracies is either underdeveloped or refers to fictitious or merely routine interaction that do not result in real citizens' empowerment [29]. Therefore, the ability of e-participation to influence administrative capacity in authoritarian regimes must be questioned [44].

Summing up, when comparing democracies and non-democracies, the discrepancy between their objectives in implementing e-participation becomes apparent: whereas in democracies the main purpose is to raise inclusiveness to enhance the quality of governance, in non-democracies it is only a façade designed to raise the

legitimacy of government in the eyes of both domestic and international audiences and to collect data on citizens and their attitudes for the ultimate goal of prolonging the regime. That is why I assume that:

Hypothesis 2: *Higher e-participation level will have a stronger positive impact on the administrative capacity in democracies than in non-democracies.*

4 Data Description and Methodology

The dependent variable of my study is QoG operationalised through administrative capacity, which I will measure using the Government Effectiveness from Worldwide Governance Indicators produced by the World Bank [31]. The main independent variable in my analysis is e-governance operationalised through e-government and e-participation, which I measure by referring to the most used research index provided by the United Nations Global E-Government Survey [3]. To measure e-government development, I use the first sub-index—the Online Services Index [46, p. 189], and to measure e-participation, I use the UN E-Participation Index [46, p. 200]. It is important to point out that one peculiarity of this index is that the data are coded in the year previous to the publishing year, e.g. the data for 2020 actually reflect the data for 2019. For this reason, the data must be lagged back by 1 year. The fact that the data are only released every 2 years is also an issue, resulting in regular missing values. In my analysis, I have filled in these omissions with the average values of the previous and subsequent years.

To distinguish between democracies and non-democracies, I use a dichotomous variable constructed based on the Regimes of the World (RoW) from the Varieties of Democracy (V-Dem) dataset. The RoW variable measures the level of democracy and non-democracy according to the presence of competition in trying to attain power, as well as the presence of liberal principles, and is divided into four levels: closed autocracy, electoral autocracy, electoral democracy, and liberal democracy [10, p. 287]. For my part, I combine levels 0 and 1, representing closed autocracy and electoral autocracy, respectively, to classify the regime as non-democracy, and combine levels 2 and 3, representing electoral democracy and liberal democracy, respectively, to classify the regime as democracy.

To assess the impact of e-governance on administrative capacity, I also include a number of control variables such as logged GDP per capita [1], logged total population of the country [2], Human Capital Index [46], political stability [31], Civil Society Participation Index [10], and public sector corruption [10]. Those factors were identified in previous studies as having an impact on government effectiveness [15, 22, 33, 36].

To test the hypotheses, I use panel data analysis. Panel data imply data containing the same observations for a certain period [49, p. 9]. It is worth noting that panel data analysis can be conducted using fixed or random effects. In this work, I use the fixed-effects model that assumes that the individual effects are fixed and constant over

time. In the empirical analysis, I consider several model variations: first, I consider a model of the impact of e-government development and e-participation level on government effectiveness without including control variables. Then, I examine a model with the interaction effect of e-government development and e-participation level with the political regime, respectively. Afterwards, I also include control variables in the models. After selecting the best model, I test it for heteroskedasticity and serial correlation and then describe the results.

5 Results and Discussion

Looking at the results of the third model (see Table 1 Model 3), we see that e-government itself has no significant effect on the dependent variable, while the political regime is statistically significant at a significance level of 0.01 and with the coefficient −0.104. This suggests that if a country has a non-democratic regime, its government effectiveness score is 0.104 units lower than that of countries with a

Table 1 Regression results for the fixed-effects model (e-government)

	Dependent variable		
	Government effectiveness		
	(1)	(2)	(3)
E-government	0.115^{***}	−0.017	−0.061
	(0.031)	(0.040)	(0.040)
Regime type (non-dem)		-0.132^{***}	-0.104^{***}
		(0.032)	(0.030)
Human capital			0.207^{***}
			(0.069)
Civil society			0.251^{***}
			(0.063)
GDP per capita (log)			0.203^{***}
			(0.019)
Population (log)			-0.146^{**}
			(0.058)
Public sector corruption			-0.191^{***}
			(0.069)
Political stability			0.158^{***}
			(0.014)
E-government:regime type (non-dem)		0.288^{***}	0.327^{***}
		(0.056)	(0.053)
Observations	2145	2145	2145
R^2	0.007	0.020	0.165
Note	$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$		

democratic regime, all other things being equal. Moreover, all control variables are also statistically significant at different levels of significance.

The object of particular interest in the context of this chapter is the interaction effect of e-government with regime type. The result of this model shows that the interaction effect is statistically significant at the 0.01 significance level. This means that the effect of e-government on government effectiveness depends on the political regime of the country, and this effect is stronger in non-democratic countries. The coefficient of 0.327 means that per unit increase in e-government, government effectiveness in non-democratic countries increases by 0.327 more than in democratic countries. Meanwhile, after checking the model for heteroskedasticity, I found its presence. However, after adjusting for heteroskedasticity and serial correlation, the interaction effect remained statistically significant and positive. Thus, it can be concluded that the implementation of e-government may be more effective in non-democratic countries.

This result is quite interesting and can be interpreted as follows. First, it can be assumed that in a non-democratic regime, e-government can play a more significant role in improving the quality of public administration, as it can be a more effective tool for controlling and monitoring the activities of officials. Accordingly, because of the automation of many processes and increased scrutiny of the actions of civil servants due to the introduction of e-government, corruption could be reduced. As I highlighted in the literature review section, the introduction of e-government leads to less discretion for bureaucrats and hence fewer situations in which bribes can be taken and given [28]. As countries with lower levels of corruption tend to have higher levels of economic development and hence government effectiveness [24, 41], accordingly, reducing the level of corruption in non-democracies may increase administrative capacity. At the same time, as in theory democracies are generally less associated with corruption than non-democracies, the effect of introducing e-government on increasing administrative capacity may not be as noticeable as in non-democracies. I now move on to the results of the fixed-effects model for e-participation (see Table 2 Model 3).

Looking at the results of the third model (see Table 2 Model 3), we see that e-participation is a statistically significant predictor, but only at a significance level of 0.1. The coefficient value of −0.052 indicates that if the value of the e-participation variable increases by one unit, government performance decreases by 0.052 units, other things being equal. We also see that the undemocratic regime, as in the previous model, also negatively affects government effectiveness, while all control variables are statistically significant.

Speaking about the interaction effect of e-participation with regime type, the value of 0.260 means that when the value of e-participation variable increases by one unit, the change in the government effectiveness increases by 0.260 if the political regime is non-democracy. This coefficient is significant at a significance level of 0.01. Thus, it means that increasing the level of e-participation in government processes has a positive effect on government effectiveness, but this effect is amplified if the political regime is non-democratic. After correcting the heteroskedasticity and serial correlation issues, the interaction effect between

Table 2 Regression results for the fixed-effects model (e-participation)

	Dependent variable		
	Government effectiveness		
	(1)	(2)	(3)
E-participation	0.061***	−0.033	−0.052*
	(0.022)	(0.027)	(0.028)
Regime type (non-dem)		−0.093***	−0.059**
		(0.026)	(0.025)
Human capital			0.234***
			(0.072)
Civil society			0.242***
			(0.063)
GDP per capita (log)			0.204***
			(0.019)
Population (log)			−0.135**
			(0.057)
Public sector corruption			−0.181***
			(0.069)
Political stability			0.159***
			(0.014)
E-participation:regime type (non-dem)		0.235***	0.260***
		(0.043)	(0.041)
Observations	2145	2145	2145
R^2	0.004	0.019	0.165
Note	*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$		

e-participation and political regime remained significant. Thus, in the presence of a non-democratic regime, increasing e-participation may help to improve government effectiveness more significantly than in the case of a democratic regime.

This interesting finding goes against my expectations, but one possible explanation for this result could be that in non-democratic countries e-participation can help to improve the quality and efficiency of public administration through the availability of e-consultation, which citizens can use to leave complaints or express any initiatives. Because it can be done online and sometimes anonymously, e-participation and e-consultation channels complement or even substitute traditional channels of citizen participation in the governance process, which are not used effectively due to the fear of being punished for taking an alternative position. At the same time, in democracies with already high levels of transparency, openness, and citizen participation in decision-making, the effect of e-participation on government effectiveness may be less pronounced.

6 Conclusion

In this chapter, I have explored the difference in the impact of e-governance on the quality of governance between democracies and non-democracies. Since previous studies have shown different and often contradictory results for the impact of e-governance on QoG and have not paid enough attention to the political regime as a potentially important variable that can moderate the impact of e-governance on QoG, I fill this gap by exploring this question in more detail.

The empirical analysis revealed quite interesting and unexpected results. Despite more favourable political context in democracies, both e-government and e-participation have a greater effect on QoG in non-democratic countries than in democracies, rejecting both my hypotheses. Thus, while confirming that the political regime is indeed an important moderating variable between e-governance and QoG, I refute that the democratic context is more conducive to the role of technology in making government more effective since non-democratic countries gain more benefits from e-government development and e-participation for administrative capacity as reflected in the models. Summarising these results and projecting them onto the debate between technological optimists and pessimists, the results obtained for non-democracies echo the assumptions of technological optimists who argue that the introduction of technology into the governance process has the potential to qualitatively improve the effectiveness of administration, while the opposite can be said about democracies, where the effect of technologies on QoG is not that pronounced.

Thus, in view of these results, which run counter to my assumptions, there is still a need to develop causal mechanisms to help explain the observed difference in the influence of e-governance on the quality of governance in democracies and non-democracies. Moreover, since the political regime is found to be indeed important, a more detailed typology of political regimes needs to be considered instead of a dichotomous approach.

References

1. GDP Per Capita: All Countries and Economies. The World Bank. Accessed 7 May 2023. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD
2. Population, Total: All Countries and Economies. The World Bank. Accessed 7 May 2023. https://data.worldbank.org/indicator/SP.POP.TOTL
3. UN E-Government Survey. United Nations. Accessed 7 May 2023. https://publicadministration.un.org/egovkb/en-us/Overview
4. Andersen, T.B.: E-government as an anti-corruption strategy. Inf. Econ. Policy. **21**(3), 201–210 (2009)
5. Bannister, F., Connolly, R.: New problems for old? Defining e-governance. In: 2011 44th Hawaii International Conference on System Sciences, pp. 1–10. IEEE (2011)
6. Bougherra, M., Shaikh, A.K., Yenigun, C., Hassan-Yari, H.: E-government performance in democracies versus autocracies. Int. J. Organ. Anal. **31**(3) (2022). https://doi.org/10.1108/IJOA-01-2022-3124

7. Cahlikova, T.: Defining e-Government. In: The Introduction of e-Government in Switzerland: Many Sparks, No Fire, pp. 19–43. Springer International Publishing, Cham (2021)
8. Carter, L., Bélanger, F.: The utilization of e-government services: citizen trust, innovation and acceptance factors. Inf. Syst. J. **15**(1), 5–25 (2005)
9. Chen, L., Aklikokou, A.K.: Determinants of E-government adoption: testing the mediating effects of perceived usefulness and perceived ease of use. Int. J. Public Adm. **43**(10), 850–865 (2020)
10. Coppedge, M., Gerring J., Knutsen, C. H., Lindberg, S.I., Teorell, J., Altman, D., Bernhard, M., Cornell, A., Steven Fish, M., Gastaldi, L., Gjerløw, H., Glynn, A., Hicken, A., Lührmann, A., Maerz, S.F., Marquardt, K.L., McMann, K., Mechkova, V., Paxton, P., Pemstein, D., von Römer, J., Seim, B., Sigman, R., Skaaning, S.-E., Staton, J., Sundtröm, A., Tzelgov, E., Uberti, L., Wang, Y.-t., Wig, T., Ziblatt, D.: V-Dem Codebook v11.1. Varieties of Democracy (V-Dem) Project (2021)
11. Croissant, A., Pelke, L.: Measuring policy performance, democracy, and governance capacities: a conceptual and methodological assessment of the sustainable governance indicators (SGI). Eur. Policy Anal. **8**(2), 136–159 (2022)
12. Dahl, R.A.: Polyarchy: Participation and Opposition. Yale University Press (2008)
13. Dawes, S.S.: The evolution and continuing challenges of E-governance. Public Adm. Rev. **68**, S86–S102 (2008)
14. Dobrolyubova, E., Klochkova, E., Alexandrov, O.: Digitalization and effective government: what is the cause and what is the effect? In: International Conference on Digital Transformation and Global Society, pp. 55–67. Springer, Cham (2019)
15. Duho, K.C.T., Amankwa, M.O., Musah-Surugu, J.I.: Determinants and convergence of government effectiveness in Africa and Asia. Public Admin. Policy. **23**(2), 199–215 (2020)
16. Durkiewicz, J., Janowski, T.: Is digitalization improving governance quality? Correlating analog and digital benchmarks. In: Proceedings of the 18th European Conference on Digital Government ECDG, pp. 48–56. (2018)
17. Falk, S., Römmele, A., Silverman, M.: The promise of digital government. In: Digital Government: Leveraging Innovation to Improve Public Sector Performance and Outcomes for Citizens, pp. 3–23. Springer (2017)
18. Fichman, R.G., Dos Santos, B.L., Zheng, Z.: Digital innovation as a fundamental and powerful concept in the information systems curriculum. MIS Q. **38**(2), 329–A15 (2014)
19. Finger, M., Pécoud, G.: From e-government to e-governance? Towards a model of e-governance. Electron. J. E-Gov. **1**(1), 52–62 (2003)
20. Fukuyama, F.: Governance: what do we know, and how do we know it? Annu. Rev. Polit. Sci. **19**, 89–105 (2016)
21. Fukuyama, F.: What is governance? Governance. **26**(3), 347–368 (2013)
22. Garcia-Sanchez, I.M., Cuadrado-Ballesteros, B., Frias-Aceituno, J.: Determinants of government effectiveness. Int. J. Public Adm. **36**(8), 567–577 (2013)
23. Garson, G.D. (ed.): Information Technology and Computer Applications in Public Administration: Issues and Trends. IGI Global (1999)
24. Goel, R.K., Nelson, M.A.: Causes of corruption: history, geography and government. J. Policy Model. **32**(4), 433–447 (2010)
25. Hanson, J.K., Sigman, R.: Leviathan's latent dimensions: measuring state capacity for comparative political research. J. Polit. **83**(4), 1495–1510 (2021)
26. Janowski, T.: Digital government evolution: from transformation to contextualization. Gov. Inf. Q. **32**(3), 221–236 (2015)
27. Johnson, E., Kolko, B.: e-Government and transparency in authoritarian regimes: comparison of national-and city-level e-government web sites in Central Asia. Digit. Icons: Stud. Russ. Eurasian Cent. Eur. New Media. **3**(3), 15–48 (2010)
28. Kalesnikaite, V., Neshkova, M.I., Ganapati, S.: Parsing the impact of E-government on bureaucratic corruption. Governance. **36**, 827 (2022)

29. Katchanovski, I., La Porte, T.: Cyberdemocracy or Potemkin e-villages? Electronic governments in OECD and post-communist countries. Int. J. Public Adm. **28**(7–8), 665–681 (2005)
30. Kneuer, M., Harnisch, S.: Diffusion of e-government and e-participation in Democracies and Autocracies. Global Pol. **7**(4), 548–556 (2016)
31. Kraay, A., Kaufmann, D., Mastruzzi, M.: The worldwide governance indicators: methodology and analytical issues. Policy Res. Work. Pap. (2010)
32. Kraemer, K., King, J.L.: Information technology and administrative reform: will e-government be different? Int. J. Electron. Gov. Res. (IJEGR). **2**(1), 1–20 (2006)
33. La Porta, R., Lopez-de-Silanes, F., Shleifer, A., Vishny, R.: The quality of government. J. Law Econ. Organ. **15**(1), 222–279 (1999)
34. Maerz, S.F.: The electronic face of authoritarianism: E-government as a tool for gaining legitimacy in competitive and non-competitive regimes. Gov. Inf. Q. **33**(4), 727–735 (2016)
35. Makarava, Y.: Friends Without Benefits: Critical Assessment of the Relationship Between E-governance and Democracy. (2012)
36. Nam, T.: Does E-government raise effectiveness and efficiency? Examining the cross-national effect. J. Glob. Inf. Manag. (JGIM). **27**(3), 120–138 (2019)
37. Paoli, A.D., Leone, S.: Challenging conceptual and empirical definition of E-government toward effective e-governance. Int. J. Soc. Sci. Humanit. **5**(2), 186 (2015)
38. Porumbescu, G.A.: Placing the effect? Gleaning insights into the relationship between citizens' use of e-government and trust in government. Public Manag. Rev. **18**(10), 1504–1535 (2016)
39. Rothstein, B., Teorell, J.: What is quality of government? A theory of impartial government institutions. Governance. **21**(2), 165–190 (2008)
40. Scharpf, F.: Political democracy in a capitalist economy. In: Governing in Europe: Effective and Democratic, vol. 7. Oxford University (1999)
41. Serra, D.: Empirical determinants of corruption: a sensitivity analysis. Public Choice. **126**(1–2), 225–256 (2006)
42. Solinthone, P., Rumyantseva, T.: E-government implementation. In: MATEC Web of Conferences, vol. 79. EDP Sciences (2016)
43. Srivastava, S.C., Teo, T.S.H.: E-government payoffs: evidence from cross-country data. J. Glob. Inf. Manag. (JGIM). **15**(4), 20–40 (2007)
44. Stier, S.: Political determinants of e-government performance revisited: comparing democracies and autocracies. Gov. Inf. Q. **32**(3), 270–278 (2015)
45. Tapscott, D.: The Digital Economy Anniversary Edition: Rethinking Promise and Peril in the Age of Networked Intelligence. McGraw-Hill, New York (1995)
46. United Nations: United Nations E-Government Survey. United Nations, New York (2022). https://desapublications.un.org/sites/default/files/publications/2022-09/Web%20version%20E-Government%202022.pdf
47. Wandaogo, A.-A.: Does digitalization improve government effectiveness? Evidence from developing and developed countries. Appl. Econ. **54**(33), 3840–3860 (2022)
48. Wong, W., Welch, E.: Does e-government promote accountability? A comparative analysis of website openness and government accountability. Governance. **17**(2), 275–297 (2004)
49. Wooldridge, J.M.: Introductory Econometrics: A Modern Approach. Cengage Learning (2015)
50. Zhao, X., Hua Daniel, X.: E-Government and corruption: a longitudinal analysis of countries. Int. J. Public Adm. **38**(6), 410–421 (2015)
51. Zheng, Y.: The impact of E-participation on corruption: a cross-country analysis. Int. Rev. Public Adm. **21**(2), 91–103 (2016)

Crisis Communication and Reputation Management of Russian Brands on Social Media

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Abstract This chapter examines the crisis communication strategies of Russian brands on social networks, taking the crisis of the VkusVill brand as a case. Crisis communication is an essential part of a company's reputation management; today, much of the crisis usually happens on social media where users express their discontent. However, unlike Western research, Russian cases of online crisis management are much understudied. Moreover, the methodologies of efficiency assessment of crisis management are not elaborated in academic science and are scarce in the social media management (SMM) industry. To address these gaps, we create a semi-automated method of assessment of a company's behavior during a crisis that includes automated data collection, sentiment analysis, discussion mapping, and manual coding for the detection of company strategies. Our study has shown that the crisis dynamic is cumulative, which means that negative comments and reactions tend to grow and escalate rapidly, and strategic denial is inefficient. We emphasize the need for brands to respond more efficiently to cumulative crises in order to prevent further damage to their reputation. Overall, the results provide valuable information for companies seeking to improve their crisis communication strategies in the digital age.

Keywords Brand reputation · Crisis communication · Social media · Cumulative deliberation · Online discussion · Social media management · Efficiency evaluation

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_36

1 Introduction

Russian brands from time to time find themselves in crisis situations related to their activities on social networks. However, at the moment, there are very few case studies that would explore the crisis experience of Russian companies on Russian digital platforms relying on scientific methods, despite the critical interest of the industry in finding efficient behavioral patterns of crisis management. The industry's interest is evidenced by the presence of a large number of publications on crisis communications of Russian companies on professional online portals for entrepreneurs, such as vc.ru, as well as analytics provided to Russian businesses by data analysis companies, including IQBuzz, Wobot, and Brand Analytics. Meanwhile, foreign researchers have been systematically studying cases of crisis communications of global brands for a long time and are working on creating recommendations on efficient counter-crisis behaviors of businesses on social networks.

Studying Russian cases may be crucial due to several reasons. First, before 2022, the Russian social media market used to be one of the richest in the world in terms of the number of social communication platforms, where both transnational and local social media were actively present [1]. However, recently, many platforms have been declared undesired, which has made many B2C brands change their online residence and choose Russian platforms such as VK.com (VKontakte); audiences have followed suit. This makes VK.com a preferential platform for user communication with and on brands for the near future in Russia. Second, VK.com is also relevant for several other post-Soviet states. Third, both domestic businesses and audiences reside within specific legal, historic, and sociolinguistic contexts that need to be taken into account in efficiency assessment; in the future, cross-country analysis would be both possible and necessary. Fourth, the weakness of standards of due behavior online by brands allows for massive application of practices such as cleaning out negative comments on company accounts or employment of "rapid rebuttal" and denialist strategies, which diminishes the overall social trust to Russian brands online. We argue that our results may partly help prevent trust destruction if more responsible crisis management activities are employed by companies and if the professional business and SMM communities engage in a public debate on the best practices of online crisis management, to which we wish to contribute.

In our assessment of user/company communication, we build upon the recent findings of online public discussion studies, especially on the concept of cumulative deliberation suggested earlier by Bodrunova [2]. The latter implies that deliberative public discussion does not take place on social media; instead, public opinions are cumulative, and they gather and die out with specific cumulative dynamics beyond substantial discussion on alternatives over a public issue. If applied to a brand crisis, this concept predicts that opinion dynamics may, too, be cumulative and demand respective prevention and in-crisis management, but this needs to be double-checked and assessed academically.

This is why we have posed the following research questions:

RQ1: What is the deliberative nature of an online brand crisis?
RQ2. What does the brand's reputation dynamics look like on a company's VKontakte official account, and what markers can be set to evaluate it?
RQ3: What strategies may a given company employ in communicating with unhappy users, and which of them are successful?

We use the VkusVill scandal as a case study. On June 30, 2021, the company published a post "Recipes for family happiness" about their customers' families, including a lesbian family, on their website and social media. Within 48 hours, the company's social media accounts were full of negative comments from people who did not support LGBT. On July 4, VkusVill deleted the post and published another one, with apologies for an inappropriate story. The company claimed the whole thing happened due to the unprofessionalism of individual employees. In its turn, the new post caused dissatisfaction among LGBT representatives and people who supported this agenda. This case is worthy of analysis because of an enormous number of users' comments and the company's poor crisis management. Besides, the whole crisis happened on social media and was caused by VkusVill's behavior online.

To explore the case, we use automated data collection with the help of a web crawler elaborated for our earlier studies (for the earliest account, see [3]). We have collected 3577 user posts and 42,607 comments marked by the lexeme "VkusVill" and 6074 VkusVill's own posts and comments that appeared within 2 months around the most active phase of the crisis. We have applied sentiment analysis to detect user moods and the company's reputation dynamics; then, we have visualized the marked data taking into account the discussion structure, to see whether the crisis had a deliberative or cumulative nature. After that, we have applied coding to a vocabulary-based selection of crisis-related user comments and the company's responses, to detect the response strategies and user reactions to them. We have qualitatively assessed the coding results.

The remainder of this chapter is organized as follows. In Sect. 2, we address the gaps in the academic literature and assess the offerings of online data assessment companies, to show that the field needs to elaborate on methods of crisis description and efficiency assessment. In Sect. 3, we describe our methods. Section 4 presents our results. In Sect. 5, we conclude by formulating crisis management recommendations for brands.

2 Crisis Communication and Cumulative Deliberation

2.1 Crisis Communication and Social Media: An Emergent Theory

Crisis communication is defined as the collection, processing, and dissemination of information required to address a crisis situation [4]. A range of theories have been

suggested on how to manage communicative crises; some are applicable to social media.

One of the most well-known theories of crisis communication is the situational crisis communication theory (SCCT) suggested by Coombs [4]. It suggests that crisis managers should match strategic crisis responses to the level of crisis responsibility and reputational threat posed by a crisis. Coombs identifies three main strategies for companies to respond to a crisis that he calls "deny," "diminish," and "rebuild." The denial strategy implies that the company completely denies its guilt for the occurrence of a crisis and refuses to take responsibility for what is happening. The diminishment strategy is based on downplaying the crisis and admitting that the company is only partially responsible for the crisis. The rebuilding strategy is the most complex and implies that the organization takes full responsibility for the crisis and actively works with all stakeholders, apologizes, and acts as actively as possible, wanting to correct the situation.

Diers-Lawson [5] suggests the following classification of reputational crises: (1) *paracrisis*, a potentially recurrent crisis with low-level impact, from complaints to gaffes on social media; (2) *rumor*, dissemination of false information aimed at harming the organization; (3) *challenge*, confrontation of dissatisfied stakeholders who claim that the organization acted incorrectly; and (4) *shifting political attitudes*: as political views change, various products, services, values, etc., become less desirable for stakeholders.

The author also describes the crisis management process. It includes several key stages, such as scanning, monitoring, decision-making, and evaluation. By identifying potential problems, monitoring their impact, making informed decisions, and evaluating responses, organizations can better manage the risks associated with potential crises and maintain positive stakeholder relationships.

The socially mediated crisis communication model (SMCC) [6] is, too, among the main crisis communication models for social media. It was designed to provide evidence-based recommendations for crisis communication professionals on whether, when, and how to respond to influential media. It recognizes the influence of both traditional media and online word-of-mouth communication. The theory describes the relationship between a range of key concepts: organization, key populations, social networks, traditional media, and offline word of mouth before, during, and after crises.

The SMCC model identifies three main groups of people who seek, produce, or share information before, during, and after crises, namely social media influencers, social media followers, and social media "inactives." Content creators develop and publish crisis information online; subscribers receive this information and share this information online and offline. People who are inactive on social media do not receive crisis information directly from social media but learn about it from other channels, including traditional media and word of mouth, social media followers, content creators, or other inactive people. It is useful for identifying risk groups and how to reach them during a crisis. In our opinion, the SMCC very aptly emphasizes that, in times of crisis, a company must take into account that its active audiences can spread their opinions on the situation via verbal communication, and inactive users

can also learn about it via other channels, such as traditional media. This must be taken into account by PR professionals during the development and adjustment of communication strategies.

There is also a model of crisis communication on social media called STREMII [7] developed to help organizations get social media communications right during times of crisis. STREMII is a cyclical process of six interrelated elements that organizations engage in when communicating with the public: social listening, target audience, response, monitoring and evaluating, interacting, and implementing changes.

One of the most recent models is the interactive model of crisis communication (ICC) [8]. It focuses on the interactive nature of communication during times of crisis and suggests that organizations need to be proactive and transparent in their communication strategies. The ICC model emphasizes the importance of using social media as a communication tool and the need for organizations to listen to and respond to feedback from their stakeholders.

A systematic review by Eriksson of social media crisis communication research provides insights into how organizations can use social media to efficiently manage crises [9]. The review shows that social media can help organizations reach a wider audience, provide timely and accurate information, and assist in controlling the narrative in times of crisis. This chapter also highlights the need for organizations to have a well-defined crisis communication plan that includes social media. Eriksson performed a systematic content analysis of 104 peer-reviewed journal articles and conference proceedings published between 2004 and 2017. This has allowed for identifying five general "lessons" that can help business representatives build effective crisis communication on social media: (1) using the potential of social media to create a dialogue and choosing the right message, source, and time; (2) doing pre-crisis work and developing an understanding of the logic of social networks; (3) using social media monitoring; (4) maintaining the priority of traditional media in crisis situations; and (5) just using social media in strategic crisis communication.

In conclusion, the literature reviewed in this chapter shows that social media is an important tool for crisis communication. Organizations that use social media in their crisis communication strategies can reach a wider audience, provide timely and accurate information, and control the narrative during a crisis. However, the use of social media during a crisis also creates new challenges that organizations need to be aware of and prepared to address. Also, creating models of response to crises is hardly the best way to look deep into the nature of crises as dependent on user communication. Thus, none of the models provides for quantitative or qualitative metrics, based on which managerial key performance indicators (KPIs) may be recalculated.

2.2 Business Analytics of Social Media as a Crisis Management Tool

Digital homogenization of the media landscape and the relative simplicity of media activity monitoring have brought to a new level the commercial offers in the area of automated text analysis, including those based upon neural network artificial intelligence. A decade ago, brand analytics would be done manually, focused upon various types of mentions, overall text tonality, and some secondary text features. Today, combined (automatic plus manual) media analysis covers approximately ten qualitative parameters, including the thematic structure of the information field, the structured media presence, and the dynamics of information activity, media interest, sentiment, positioning, negativity, and speaker activity.

Despite the abundance of proposals for automatic monitoring of mentions, professionalized reputational audit for large brands operating in a highly competitive environment is carried out via combined methods. The solutions offered by media analysis services are adaptable to the customers' requests and are supplemented with what is known as "manual analytics." This practice also remains relevant for long-cycle reputation management, with manual adjustment of automatic media markup offered by most of the largest media analysis systems. This includes clarification of increasing/decreasing attention coefficients for different types of media, clarification of stop words, and definitions of negative and positive sentiments applied to a specific brand.

The automated or mixed-method brand analysis serves four major goals including long-term reputation management, reputational crisis prevention and/or in-crisis monitoring, situational PR and/or newsjacking in order to join positive agendas, and search for industry (product, marketing, and reputation) insights via analysis of competitors. Social media are increasingly used today for two more tasks that analysis of traditional media cannot capture properly; these include (1) detection of the real connection between the media field and the perceptions/actions of the target audience and (2) support of communication decisions in conditions of incomplete data and the associated high uncertainty. However, a global trend in the practice of brand reputation management is the prevalence of *outtakes* metrics (which record the quantitative reaction of target audiences to brand communication) over *outcomes* metrics (which capture essential communication results), as based upon the AMEC classification. This is partly a result of the inclination toward the maximum optimization of analytical interfaces for the customer.

Thus, when solving the voluminous tasks of reputation management in the long term (such as image building on new markets, repositioning support, or reputation profiling), the analytical customization tools offered by media analytics systems are not enough. Moreover, during rapid crises, the analytical systems do not provide for a deep understanding of the communicative nature of the emergent crises and do not take into account the connections between ordinary social media users, on the one hand, and influencers and/or legacy media, on the other hand, often seeing tiny communicative actions [10] as independent units of analysis. Their

recommendations cannot build upon knowledge of user psychology or traditions of media coverage, which need to be part of the contextual analysis in managing communication crises.

Today, the Russian market of media analytics comprises six leader companies, two focusing more on monitoring and analysis of traditional media, including their presence and citation metrics on social media (Integrum and Medialogia), and four focusing directly on social media (IQBuzz, Brand Analytics, Awario, and Angry Analytics). They all understandably follow the logic of interface ease of use and offer additional manual labor upon selected criteria of analysis; however, they do not offer analysis on whether a company crisis management strategy was successful, as they leave this judgment to the customer. We, however, aim at offering another logic, which would include setting the parameters for strategic efficiency assessment built into the analysis, to offer a chance for independent strategy evaluation for company management.

2.3 Relations with Users and the Nature of Online Communication

To achieve the goal of creating a set of efficiency evaluation parameters, we start with offering our theoretical vision upon the nature of online communication. We argue that it may help understand the user-based crisis dynamics, as well as help offer independent markers for strategic efficiency evaluation.

Due to the hybridization of public spheres [11] and the rise of the user-generated content, some researchers document the quality reduction of online discussions. The process of public communication aimed at searching for inclusive solutions to collective problems and establishing a common good shared by all is called deliberation [12]. Its main principles are publicity, inclusiveness, dialogicity, high-level rationality in reasoning, and formal and de facto equality of partakers [13].

The theory of deliberative democracy [12] suggests that participants of an online discussion seek consensus. However, we believe that this theory places too high demands on the discussion participants, and the real communication of users does not meet such expectations. Their speech may be—and has a full right to be—meaningless, biased, emotional, and deprived of any deliberative purpose [2]. At the same time, the discussions are discontinued [14] in terms of who takes part in them: Online, the participants constantly change, so many researchers consider discussions on social media as chaotic, unpredictable, and devoid of internal integrity, while it is their natural state.

In our opinion, the most relevant approach to study both quality and dynamics of discussions on social media is the concept of cumulative deliberation [2]. Cumulative deliberation is (1) the process of accumulation, redistribution, and dispersion of opinions created by the participation of Internet users of various institutional statuses in online discursive activities and (2) the influence of accumulated opinions upon the

positions of institutional actors and discourses, including the work of the media and policymaking.

Particular attention should be paid to such features of online discussion as non-dialogicity and non-controversial expression of opinions. People do not seek consensus; they express their opinions not always caring about how others will react to them. As a result, the accumulation of diverse opinions of an unlimited number of users occurs. Thus, the discussion structure can be very complex. Users can communicate with each other, address their comments to authors of posts, or write things non-related to the discussion topic; there may be phatic communication, expressions of aggression, and white noise.

The concept of cumulative deliberation is based on the overwhelming evidence collected in previous research, including the "spiral of silence" theory [15]. The latter suggests that, in a situation of open discussion, people are more likely to speak out when their opinion coincides with the majority. Otherwise, they are less likely to speak out, fearing social isolation and rejection. This leads to a "spiral of silence" where the majority opinion becomes more and more dominant and the minority viewpoint becomes less noticeable. The majority opinion begins to be falsely perceived as the only one in the discussion. We need to ask whether such dynamics is also true for online crisis development.

Analyzing the users' statements in online discussions can cause difficulties, since they rarely include clear "yes/no" opinions; however, with the help of modern automated text analysis models, scientists are trying to simplify the linguistic shape of users' statements and "translate" them into a sociologically/politically significant language of numbers and visual representations. This, however, may also be partly misleading if the scholars represent statics as dynamics, like via the popular Gephi-based graph representations of discussion [2]. To understand what *cumulative consensus* in an online discussion looks like, we need to build discussion visualizations that would reflect the temporal dimension of the communicative process—that is, *both* the structure and the dynamics of a discussion, "freezing" certain moments in order to evaluate the discussion as dynamic crystallization of majority/minority opinions [16: 49]. In dynamics, such a picture would resemble a fluctuating Solaris where certain discussion segments "rise" and "fall," become denser or looser, accumulate and disperse, grow to stand out from the discussion as popular topics, and fade away together or one after another.

We believe that the methods of analyzing online discussions, including those linked to systems theories (such as the dissipative structure theory [17] or descriptions of affective publics [18]) can be applied for studying crisis communications of brands on social media. With their help, it is possible to see how the discussion on a crisis develops; just as well, one can draw conclusions on the impact of the companies' strategies and their interaction with the audience on the brands' reputational dynamics.

3 Method

3.1 The Case Under Scrutiny

In this chapter, we only start to approach the goals set above, basing our research on only one case study. We decided to conduct the case study of a crisis situation that occurred with a Russian brand called VkusVill, analyzing the company's communication to the audience of their VKontakte official account. VKontakte is a Russian social media platform that allows users to exchange messages, create their own profiles and communities, share images and audio and video recordings, transfer money, and play browser games. It also positions itself as a platform for promoting business and solving everyday tasks using mini-applications. We analyze the crisis situation that happened to VkusVill, a Russian chain of supermarkets that positions itself as selling alimentation for healthier diets. On June 30, 2021, they published a post "Recipes for family happiness" on their customers' families, including a lesbian family, on both their website and social media. Within days, the company's social media accounts were full of negative comments from people who do not support LGBT. On July 4, VkusVill deleted the post and published one with apologies for an inappropriate story. The company claimed the whole thing happened due to the unprofessionalism of individual employees. This caused dissatisfaction among LGBT representatives and people who supported this agenda.

3.2 Data Collection

We have chosen VKontakte as a platform to analyze, because it is the only original and popular Russian social network that allows users to connect through various communities and have active public discussions on different matters. It is also actively used by Russian brands for communication with their customers, especially after February 2022. To evaluate VkusVill's case, we used the web crawler that had been developed for earlier studies [3, 19] and has adaptable modules capable of collecting data from various social networking platforms including VKontakte.

We gathered all the posts and comments by the company and their customers posted between May 30 and July 30, 2021, and created Dataset 1. We also created a list of keywords to find the posts and comments on the very crisis. The list was based on our preliminary reading of the posts and comments related to the crisis and included words such as LGBT, lesbian, gay, values, apologies, hate, shame, bottom, violence, non-traditional, gender, homosexuals, orientation, propaganda, hetero, aggression, homophobes, hypocrisy, and disappointment. As a result, we created a reduced target Dataset 2 that only contains the posts and comments with the abovementioned words.

The overall sample includes 3577 posts and 42,607 comments from the audience and 6074 posts and comments by VkusVill and its employees. Dataset 2 includes

440 posts and 7766 comments by the audience and 58 posts and 121 comments by the company.

3.3 Data Analysis

To address the RQs, we have used the following research design. First, we have addressed RQ2, to see the overall structure of the crisis and to trace VkusVill's reputational dynamics. This has allowed for suggesting the efficiency markers for crisis management, as based on the duration of the crisis and its sentiment shape. Then, we have looked at how the discussion was structured in terms of deliberative/cumulative patterns (RQ1), in order to see whether VkusVill has put efforts into organizing a meaningful discussion. Then, we have manually assessed the company's posting and user reactions to define the strategies that were employed.

For RQ1 and RQ2, automated sentiment analysis was employed, as developed at our Center for International Media Research of St. Petersburg State University [3]. We have also used data visualization for all posts and comments published by the company and its audience in VkusVill's official VKontakte account from May 30 to July 30, 2021, which is 1 month before and 1 month after the crisis started. Sentiment analysis helped us find out the ratio of positive, negative, and neutral posts and comments, in order to assess the overall reputational dynamics of the company, to suggest indicators of the pre-crisis and post-crisis states, to track what has changed over the given period, and to see how the crisis developed and whether it dissipated in 1 month—that is, whether indicators came back to the pre-crisis state (which can be considered a successful resolution of the conflict), or whether the crisis was still relevant to the audience in the long term. Via another type of visualization that linked posting/commenting activity to the discussion structure, we have shown the nature of opinion aggregation.

To tackle RQ3, quantitative-qualitative content analysis as offered by Krippendorff [20] was deployed. We looked at how the company builds a dialogue with its audience and compiled a codebook that allowed us to identify the brand's crisis strategies, as well as qualitatively analyze the audience's reaction to them. To create a codebook, we used the situational crisis communication theory (SCCT) [4] as inspiration for developing our codes based on the "deny," "diminish," and "rebuild" strategies. Combining the suggestions from [4, 20], we have coded each company's post/comment for complete denial of the crisis (−2), understatement of the importance of the crisis (−1), no strategy (0), maintaining positive relationships with users without actively dealing with the crisis (1), and rebuilding and active work on the crisis (2). We looked through the company's posts and comments and assigned a numerical value to each of them in order to calculate the means and make conclusions on peculiar features of VkusVill's crisis response. In combination with the users' marked-up sentiment, this has allowed for defining the relative success of the strategies that showed up in the company's posting.

As a result of our assessment, several KPI-building indicators have been suggested.

4 Results

4.1 Reputation Dynamics

RQ2 As the result of sentiment analysis, we identified the active crisis phase—it lasted from July 2 to July 5, 2021. During these days, the number of overall posts and comments on VkusVill's wall was five times higher than both before and after this short period. So, we can state that the crisis was solved in 4 days. We also counted the number of positive (17,454), negative (13,555), and neutral (15,175) posts/comments (see Fig. 1).

As one can see, there are substantially fewer negative messages than positive and neutral messages, which makes us think the crisis was not only about the audience being offended by the company. This came as a surprise to us. We discovered that, actually, VkusVill had a lot of loyal followers who supported the company's position. Before July 4, when the company's apologies were posted, many LGBT-friendly people showed their respect to VkusVill, and starting from July 4, people with more traditional views supported the brand, too. Interestingly, with the growth of the overall number of comments, the proportion of positive, negative, and neutral comments did not change much. July 4 was also the peak day of the crisis. More than

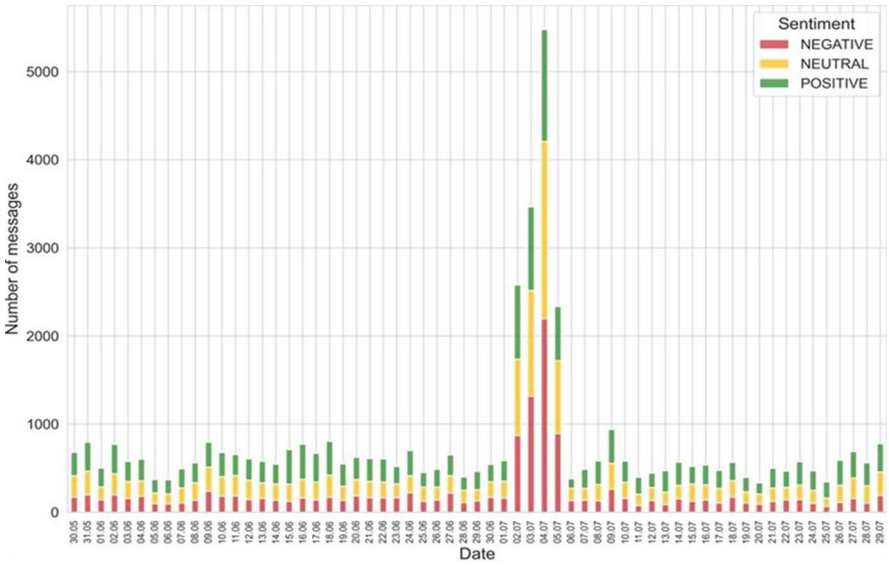

Fig. 1 Sentiment of posts and user comments in the period from May 30 to July 30, 2021

5000 posts and comments were posted that day. However, the number of negative comments might be less than that of positive and neutral comments, as some posts and comments were irrelevant to the crisis. The company's activity during the 2 months was as follows: 6074 posts and comments, among which 623 were posted on behalf of the company and 5451 on the personal accounts of VkusVill's employees.

To select the crisis-related posts and comments, we formed a keyword vocabulary (LGBT, lesbian, gay, queer, queer family, values, professionalism, hatred, shame, bottom, insults, violence, non-traditional, gender, homosexuals, orientation, propaganda, hetero, women, aggression, homophobes, bullying, hypocrisy, and disappointment). We found 440 posts and 7766 comments posted by the audience. Among the comments, 6533 referred to posts with keywords, and the remaining 1233 had keywords but were left beneath posts without keywords. There were 2849 neutral, 1761 positive, and 3596 negative posts and comments. As one can see, the number of negative publications is now higher than that of positive and neutral publications, but if we put positive and neutral comments together, their number amounts to 4610, which is still bigger than the number of negative comments. It is a sign of an intense discussion on the crisis where a loyal audience is better represented. There were 58 posts and 121 comments by the company and its employees with keywords, representing VkusVill's crisis response, which seems not enough to build efficient communication with such a big amount of audience messages.

To sum up, the company's reputation dynamics shows that the crisis significantly increased the overall number of posts and comments on VkusVill's official VKontakte account. This became possible thanks to the company's information openness policy and the VKontakte platform affordances [21], which allowed the audience to publish not only comments but also posts on VkusVill's account. The company's reputation dynamics returned to the pre-crisis state 4 days after the start of the crisis, which is quite fast. The number of negative posts and comments was high, but the number of positive and neutral posts and comments together was even higher. This means that there was an active online discussion that needs to be studied in more detail.

Our analysis has allowed for suggesting several markers of overcoming the crisis and the company's efficient crisis management:

- The ratio of pre-crisis negativity vs. post-crisis negativity within a given reasonable period of time, e.g., a month, within which the crisis should be eliminated; indirectly, it also tells of lasting reputation damage
- The time when the markers of discussion intensity come to their pre-crisis volume—that is, the speed of crisis resolution
- The time when the markers of discussion sentiment (in %) come to their pre-crisis distribution (which may not correspond to the previous metric)
- Causality between the company's posting/commenting volume and the speed of crisis resolution

- Causality between the company's posting/commenting sentiment and the changes in user sentiment during the crisis

4.2 The Structure of the Online Crisis Discussion

RQ1 To get a deeper view on the nature of the crisis-based online discussion, we have built a graph showing the distribution of posts and user comments in the VkusVill community containing keywords (Dataset 2) during the active phase of the crisis.

On the graph (see Fig. 2), all posts (crosses), comments (circles), and their sentiments (green: positive, gray: neutral, and red: negative) go along a bottom-up timeline. We see a huge rise in the users' post numbers; however, only two of them sparked tiny discussions (circled), so there was almost no discussion, just a cumulation of various opinions.

The brand's reaction to the crisis was next to invisible. The company only replied to a small percentage of comments and did not engage in interaction with the users during the active attack of negative posts and user comments.

Both figures demonstrate a large-scale cumulation of users' opinions. Thus, the nature of an online crisis is evidently cumulative, in line with what the theory of cumulative deliberation suggests. Users express their discontent and do not engage in further discussion. We have also detected VkusVill's poor crisis management that showed up engaging in non-responding and non-organizing a meaningful discussion on the issue.

One more marker of crisis efficiency evaluation rises from what we have said about the discussion structure. It is the relative growth of user engagement in non-cumulative discussion practices at the beginning and end of a crisis. This may be measured, e.g., via a ratio between root posts and the overall number of posts/comments; the lower the ratio, the better the users are engaged in discussing. As we know from our previous research [19], aggression diminishes with the growth of deliberative engagement in user discussions, which may be highly beneficial for a company in crisis.

Unfortunately, the poor posting activity on behalf of VkusVill has deprived us of a chance to detect whether their posting could directly influence user opinions, which will be a focus of our further studies on other cases.

4.3 The Company's Communication Strategy

RQ3 Even if the overall activity of the company was regretfully low, we could use the collected data to assess whether VkusVill had a strategy of response and what it was, if any. The company was most active in responding to user opinions on July

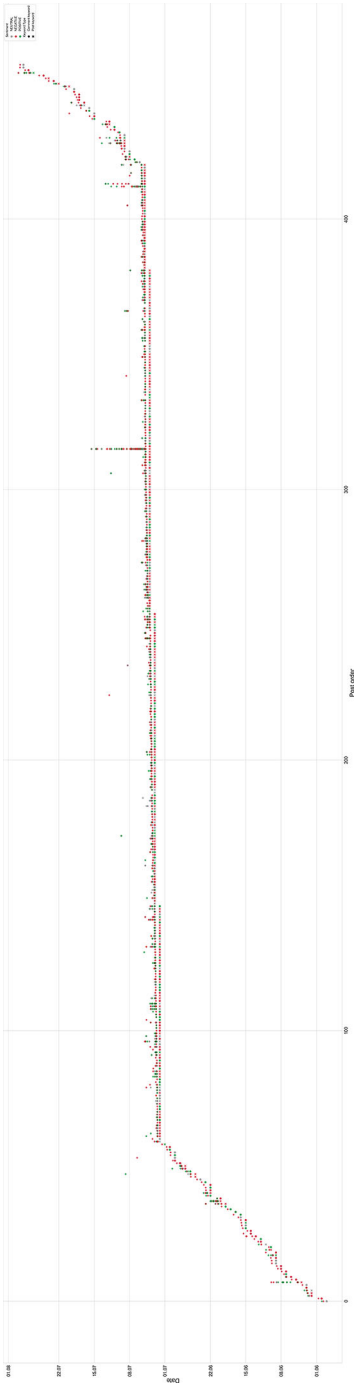

Fig. 2 The discussion structure

2, mostly denying (−2 in our codebook) the existence of the crisis and claiming that the post "Recipes for family happiness" was completely innocent and kind; just the audience did not understand it correctly. VkusVill also tried to make fun out of the situation, not taking the users' negative comments seriously and thanking people who liked the post idea and left supporting comments. The average rate of the strategic response on July 2 was −0.83, clearly pointing out the denial/diminishment strategy.

On July 3, the average strategy orientation rate changed to −0.4. The company kept the same strategy of denial and thanking loyal customers, but the number of thanking messages was a bit higher than that of the denial messages. On July 4, however, VkusVill published a post with apologies signed by all company's top managers. It could be considered as rebuilding and active work on the crisis (2), if only the company did not stop replying at all and only showed up on July 5 with one comment, saying they loved all their customers, no matter the sexual orientation. This can also be considered as rebuilding (2), but the overall silence in commenting clearly points out the diminishment strategy, as engaging in commenting might have been considered a risk of further flaming of the conflict. Our conclusion is supported by the fact that, on July 6, VkusVill closed its account for users' posts and comments for 24 hours, re-opening it on July 7, obviously with the goal of stopping the flame. After that, the crisis dissipated and customers were happy to come back to sharing their meals and thanking VkusVill for good products. However, this does not mean that the crisis was solved successfully. Closing the account, the company did not really work on the customers' opinions, which caused the reputational damage and lots of discussions outside of VkusVill's official account. Some experts still discuss this case as a big mistake of the brand.

The total average crisis response rate is −0.42, which shows the reluctance of the company to engage in rebuilding practices.

From the company's behavior, we could make a conclusion that the application of certain strategies may also be an independent marker of the SMM efficiency during a crisis. Thus, the use of denial is not at all recommended, as it may foster further accumulation of negativity in an outburst way; the number of denialist comments should tend to zero. The diminishment- and rebuilding-oriented posting/commenting may be equally employed, but there must not be rebuilding without supporting comments; silence periods should be avoided, especially during rebuilding. Thus, several more markers may be suggested for independent evaluation of online crisis management:

- The mean strategic orientation of the comments on denial/diminishment vs. rebuilding (ideally, tending to +2)
- The number of denialist posts/comments by the brand under scrutiny (ideally, tending to zero)
- The presence/absence of technical breaks of opinion cumulation supported/non-supported by massive commenting aimed at rebuilding

5 Discussion and Conclusion

With the help of automated data collection and sentiment analysis, we were able to reflect the overall reputational dynamics of VkusVill during its crisis of 2021, identify indicators of the pre-crisis and post-crisis states, and track what changed during this period, how the crisis developed, how long its dissipation took, and what the nature of the crisis was.

Quantitative and qualitative content analysis helped us evaluate how VkusVill built (or, rather, did not build) a dialogue with their audience; we found signs of their crisis strategy. We also studied the structure of the online crisis-related discussion and revealed the cumulative nature of the critical public opinion. We came to the conclusion that organizations should not allow uncontrolled accumulation of opinions expressed by users on social networks, as it can become a serious threat to the brand's reputation.

As a result of our research, we were able to suggest several markers for efficiency assessment of the SMM-based crisis management. Among them, there are ratios of the reputation damage and user engagement, time of crisis overcoming, dependence of the crisis dynamics upon the company's activity and sentiment, and strategic orientation of the company's online behavior. These markers need further elaboration and testing.

We also formulated recommendations for Russian brands on behavioral patterns on social networks during reputational crises. Our recommendations are as follows:

1. Each company needs to pre-develop a crisis response plan based on modeling possible crisis situations.
2. As soon as users of social networks begin to leave mass negative reviews on a given activity of a brand, the brand needs to react instantly to this and take the discussion on the issue under control via actively responding to the maximum number of comments, directing the discussion, and organizing it in a meaningful way to involve the users into deliberative practices that diminish aggression and discontent, in order to prevent a huge and uncontrolled accumulation of opinions that are harder to work with.

Acknowledgments This research has been supported fully by the Center for International Media Research of St. Petersburg State University, Russia, year 3, project #94033584.

References

1. Bodrunova, S.S., Litvinenko, A.A.: Four Russias in communication: fragmentation of the Russian public sphere in the 2010s. In: Dobek-Ostrowska, B., Glowacki, M. (eds.) Democracy and Media in Central and Eastern Europe 25 Years On, pp. 63–79. Peter Lang (2015)
2. Bodrunova S.S.: Kumulyativnaya deliberatsiya: novaya normativnost' v izuchenii publichnyh sfer onlain [Cumulative deliberation: new normativity in studying public spheres online].

Vestnik Moskovskogo Universiteta. Seriya 10. Zhurnalistika 1, 87–122 (2023). https://doi.org/10.30547/vestnik.journ.1.2023.87122
3. Bodrunova, S.S., Litvinenko, A.A., Blekanov, I.S.: Influencers on the Russian Twitter: institutions vs. people in the discussion on migrants. In: Proceedings of the International Conference on Electronic Governance and Open Society: Challenges in Eurasia, pp. 212–222. Association for Computing Machinery (2016)
4. Coombs, W.T.: Ongoing Crisis Communication: Planning, Managing, and Responding, 2nd edn. Sage, Thousand Oaks (2007)
5. Diers-Lawson, A.: Crisis Communication: Managing Stakeholder Relationships, 1st edn. Routledge, London (2019)
6. Jin, Y., Austin, L.L. (eds.): Social Media and Crisis Communication, 2nd edn. Routledge, London (2022)
7. Stewart, M.C., Wilson, B.G.: The dynamic role of social media during Hurricane #Sandy: an introduction of the STREMII model to weather the storm of the crisis lifecycle. Comput. Hum. Behav. **54**, 639–646 (2016)
8. Cheng, Y.: How social media is changing crisis communication strategies: evidence from the updated literature. J. Conting. Crisis Manag. **26**, 58–68 (2018)
9. Eriksson, M.: Lessons for crisis communication on social media: a systematic review of what research tells the practice. Int. J. Strateg. Commun. **12**(5), 526–551 (2018)
10. Margetts, H., John, P., Hale, S., Yasseri, T.: Political Turbulence: How Social Media Shape Collective Action. Princeton University Press (2016)
11. Chadwick, A.: The Hybrid Media System: Politics and Power. Oxford University Press (2013)
12. Habermas, J.: Political communication in media society: does democracy still enjoy an epistemic dimension? The impact of normative theory on empirical research. Commun. Theory. **16**(4), 411–426 (2006)
13. Pavlova, T.V.: Deliberation as a constitution factor of modern politics field. Politicheskaya nauka [Polit. Sci.]. **2**, 73–94 (2018)
14. Smoliarova, A.S., Bodrunova, S.S., Blekanov, I.S., Maksimov, A.: Discontinued public spheres? Reproducibility of user structure in Twitter discussions on inter-ethnic conflicts. In: Stephanidis, C., Antona, M., Ntoa, S. (eds.) HCI International 2020 – Late Breaking Posters. Communications in Computer and Information Science Series, vol. 1293, pp. 262–269. Springer, Cham (2020)
15. Noelle-Neumann, E.: The spiral of silence a theory of public opinion. J. Commun. **24**(2), 43–51 (1974)
16. Mouffe, C.: The Democratic Paradox. Verso, London (2000)
17. Prigogine, I.: Dissipative structures, dynamics and entropy. Int. J. Quantum Chem. **9**(S9), 443–456 (1975)
18. Papacharissi, Z.: Affective Publics: Sentiment, Technology, and Politics. Oxford University Press (2015)
19. Bodrunova, S.S., Litvinenko, A., Blekanov, I., Nepiyushchikh, D.: Constructive aggression? Multiple roles of aggressive content in political discourse on Russian YouTube. Media Commun. **9**(1), 181–194 (2021)
20. Krippendorff, K.: Content Analysis: An Introduction to its Methodology. Sage Publications, London (2018)
21. Bucher, T., Helmond, A.: The affordances of social media platforms. In: Burgess, J., Marwick, A., Poell, T. (eds.) The SAGE Handbook of Social Media, pp. 233–254. Sage Publications, London (2017)

Platform Adaptation of Russian News Media Content

Svetlana S. Bodrunova and Daria Savchuk

Abstract This chapter explores adaptation of news content of two Russian quality media, *Kommersant* and RBC, to three digital platforms. Content platformization takes place everywhere in the world, and Russia is not an exclusion. However, there is a huge research gap in Russia as to how news production companies adapt their content to various platforms with the regard to topicality, sentiment, introduction of interactive features, and "news values" (i.e., content selection criteria). If they adapt significantly, this would pose a question on how they preserve their roles as gatekeepers of public agendas. To explore the combination of the adaptation variables for the two papers on three platforms (Telegram, VK.com, and Instagram), we draw conclusions on whether these quality media preserve their roles as the quality standard carriers. We show that their adaptation strategies provenly differ, RBC fostering the same approach across platforms and *Kommersant* developing a platform-per-platform strategy in terms of news values. At the same time, technical adaptation to platform affordances and interactivity is very similar and shows the signs of "platform normalization."

Keywords Quality media · Journalism standards · Platform adaptation · News values · Multimedia · Interactivity · Russian newspapers · Telegram · VK.com

1 Introduction

In various parts of the world since the mid-2000s, the experience of hybrid media (former newspapers and magazines) on social networks has been studied. Social media management (SMM) has already proven to be a successful tool for promoting

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M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5_37

a newspaper brand and expanding its reach and core readership. On social networks, legacy media have become part of both public and interpersonal communication, elaborating and forming new ties with the audiences, new accountability formats [1], new forms of trust [2], and new standards of reporting. The latter, though, may and need to be questioned and investigated academically, as platform affordances (e.g., of Twitter or Snapchat) [3] do not leave much space for traditional elements of the "strategic ritual of objectivity" [4] like balance of sources or the "inverted pyramid" news style [5].

This question is especially sharp for countries like Russia where democratic standards of reporting have not been developing as grassroots since the 1860s, as in several European countries [6], but have been partially implanted from the West in the 1990s, interiorized only partly by the journalistic community [7], and opposed a much longer tradition of opinionated and "enlightening" journalism and *Publizistik* [8]. Thus, the weakness of traditions of objective reporting clearly meant they might be shaken by the plethora of platforms that posed additional limitations upon how news texts could look like, how they could get to the audiences, including secondary (audience-based) [9] and tertiary (algorithmic) [10] gatekeeping, and how media could perform their public roles.

On the other hand, for over a decade before 2022, Russia used to be a rich social media market with a variety of actively used platforms bigger than in most countries of the world [11]. This has allowed for experimenting with platform affordances [12] for the mutual benefit of audiences and editorial offices. Most of these experiments, just like elsewhere, have led to the so-called platform normalization [13], including Twitter[1] [14] and Telegram [15], when optimal forms of platform use for media seemed to be discovered. However, it was also well-known that the Russian platforms differed not only in terms of affordances but also in terms of audiences who, in some cases, formed nationwide political echo chambers [16] and varied in terms of politicization [17] and news consumption [18], making platform adaptation of news content clearly necessary.

Moreover, in 2022, Meta platforms were declared undesired in Russia (including Facebook[1], Twitter, and Instagram[1]), which caused a yet new "migration" wave of Russian Internet users to Telegram and VKontakte. This much accelerated the need for large federal news media to be strategically represented on these platforms. They have renewed their publishing policies and have put attention to the efficiency evaluation of the platform use. However, in journalism, pursuing monetary efficiency may mean going downmarket [19], which endangers professional standards of quality journalism. This is why one needs to ask whether, given the rapidly changing circumstances, Russian rare quality media preserve the standards of reporting and how they adapt to platform differences, including the affordances and the audiences.

Despite the importance of news media standards for the quality of political discussion in a given country, the research on news standards and their

[1] In 2022, the platform has been recognized as extremist and undesirable in Russia.

platform-based fluctuations is next-to-absent in the Russian media studies. We aim at partly covering this gap by looking at adaptation strategies of two Russian outlets of quality news reporting, namely, *Kommersant* and RBC. Both the products of the 1990s they have approached media standards differently, the former being more oriented to insider information and off-the-record reporting due to building trust with politicians and in-depth coverage, while the latter preserving a vector toward neutral business reporting. Both media at some points in their history had significant clashes with the establishment but still remain invaluable parts of the carcass of the Russian news market and maintain professional media practices. We look at how they adapt to three very different platforms, namely, Telegram, VKontakte, and Instagram. For that, we collect their news on these platforms within 1 month, 429 altogether, and code them for ten adaptation variables. Then, we use descriptive statistics to assess their adaptation strategies.

The remainder of this chapter is organized as follows. Section 2 sets the theoretical framework in short, including the news values theory and platform adaptation strategies. It also sets our research questions. Section 3 presents our methods of data collection and analysis, with the focus on content analysis and descriptive statistics. Section 4 presents our results, and Sect. 5 discusses them and concludes the paper.

2 Journalism Standards and Platform Adaptation of News

2.1 Standards of Quality News Reporting in the Twentieth Century

Before the twenty-first century, two paradigms of journalistic professionalism co-existed in democracies [20]. The "advocacy" paradigm appeared in the late eighteenth century; it links dependence on an owner/sponsor/founder to advocating particular interest in politics, economy, or social life. However, in the nineteenth century, several new factors shaped newspaper consumption, including the growth of primary education and spread of literacy among poorer citizens and women, invention of linotype and rotational printing machines, speeding up of business life that demanded daily news supply, and scoop journalism that had created first consumer-dependent journalism models [21]. These new conditions allowed for creating high-circulation press that relied on consumer loyalty more than on founders' money. The search for long-term consumer trust has led to formation of a new paradigm of media's public service, including new standards of reporting and news selection. This paradigmatic shift took over half a century [6].

In the twentieth century, professional standards for quality journalism have been formulated. First, in 1921, Charles P. Scott of *The Guardian* set two basic elements of the standard, namely, the division of factual reporting and commenting ("Comment is free but facts are sacred") and presence of two or more conflicting positions in a given news piece. Later, more elements of news standard were elaborated that

eventually formed what Tuchman [4] called a "strategic ritual of objectivity." Its essence is that, to maintain consumer belief in quality reporting, journalists perform several crucial routines and shape the texts in peculiar genre forms. Thus, they verify sources and show it in their writing (the two-source rule that serves for both representing the conflict sides and double-source verification), as well as deprive their texts of signs of subjectivity which includes both advocacy and emotionality, which leads to formation of the "inverted pyramid" style of "hard news" reporting [22], emblematic for quality media.

The same goes for news selection. In the world with over-abundance of events, quality media perform the gatekeeping (filtering) [23] and agenda-setting (news hierarchization) [24] functions in order to create the daily news picture, meaningful yet feasible to consume. This implies that they establish news selection criteria that serve both their commercial success and public mission—which, however, contradict each other. In the 1960s, it became clear that, to select news, editorial offices use a range of "news values" [25] that serve both the political and commercial nature of dailies. However, the "news values" discovered by Galtung and Ruge were set for foreign news reporting, which largely shaped the "news values" list. The "values" they tested were 12 abstract criteria such as intensity, unambiguity, meaningfulness (whatever it could be), predictability, cultural proximity, continuity, or reference to elite nations. In 2001, this was amplified via studying domestic British press [26]; "news values" for domestic public affairs were defined, such as conflict, drama, reach, and relevance. Despite their seeming neutrality and commercial orientation, "news values" in mainstream press tend to mirror the dominant values of elites [27]. The distortions in news selection (still aimed at objectively reproducing reality) come from structural biases such as journalists' own identity [28] and also from the disparities in public impact cast by various political actors, thus privileging mainstream ones and further marginalizing nonmainstream ones [27].

2.2 *The "Emotional Turn" in Journalism Versus News Standards*

Since the 1980s, the news standards have started to erode under commercial and political pressures. First, the expansion of television and, later, of Internet speeded up the news cycle [29], pushing newspapers toward analysis and commenting. This partly blurred the like between fact-based and analysis-based genres. Second, competition pressures fostered media tabloidization and "dumbing down" [30] across Euro-Atlantic. Third, the advent of Internet and the exaggerated expectations from its content distribution powers, in combination with lack of knowledge on how to work online, led to massive investment and revenue losses. In the 2000s, a full-scale newspaper crisis followed. The "black years" of papers, with experiments in major quality dailies, from qualoids (*Welt Kompakt*, Germany) to format shifts (*The Times*, the UK) to closure of offline versions (*San Francisco Chronicle,* the USA) to

division of offline and online editorial offices (*Le Monde*/*Le Monde Interactif*, France). Gradually, monetization models for hybrid media emerged, news standards shaken but not fundamentally.

However, the pressures continued. They included the growth of political polarization and populism which divided the audiences who no longer demanded balance of sources and viewpoints—rather, they demanded support to their polarized views, which clearly reshaped the news appeal in many media, including those in Europe and the USA. They also included the advent of media prosuming [31] and new modes of gatekeeping [23, 24], including blogs as milieus of user-generated news, social media as milieus where news spread, and platforms as bearers of varying platform affordances [32], and algorithms that redefined news supply principles [33], largely based on immediate consumer preferences (and, thus, the content that is capable of keeping user attention) rather than on journalistic mission or roles.

Under all the aforementioned pressures, a large-scale "emotional turn" has been detected in journalism in the 2010s [34]. The growth of speed, volume, and complexity of information flows, growth of competition, and reliance on webometrics in assessment of news consumption patterns have led to penetration of emotional elements into news texts [35] and the overall growth of the role of emotions in news production [36]. However, very little is known for sure whether and how exactly the "news values" have been affected by the "emotional turn." The scarce research that exists points out the growing role of the emotion-oriented "news values" such as drama or conflict, but there are no large-scale cross-country (or even single-country) studies of the shifts in the news selection criteria; only single-case studies exist.

Thus, we ask if today's Russian quality media preserve the classic "news values"; moreover, we ask how they work on various social networking platforms.

2.3 Platform Adaptation: The "Physical" Shape of News Texts

Another dimension of platform adaptation deals with how a news piece looks like and what its technical, structural, and psychological shape allows for. This includes several subdimensions oriented to catching bigger audiences via easier spread of news, holding consumer attention, and rolling news consumption.

Thus, today's "news values" detected in 2001 and in later works by Harcup and O'Neill [37] include technical features of texts, such as the accompanying visuals. Also, some influential research has emphasized new technical features of texts such as multimedia and hypertextuality that are considered to be parts of how media construct their interactive relations with online consumers [38]. Platform affordances largely differ exactly in preferences to text vs. (audio)visual content, as well as in limitations on text length, which leaves little space, say, on Twitter for preserving the two-sources principle or the "inverted pyramid" style.

Nonetheless, quality media which had initially preferred plain text to flashy pictures and shorter well-structured news formats to long narration have a chance for preserving the standards, even if partly, on nearly all the platforms that allow for at least some volume of text. Thus, we ask how quality media adapts to new technical possibilities and whether the platforms differ in their use.

To conclude the section, we would also state that an intermediary between the editorial decisions and the news features is the topicality of news. That is, political news may differ from economic, social, or recreational ones in how the "news values" are employed, which platform they are placed on, and how interactivity works. This is why we also check how the adaptation features relate to the topics of the news pieces.

2.4 The Research Questions

Given the aforementioned previous findings, we in this paper pose several research questions that deal with how quality media manage the adaptation of their news content to various social networking platforms:

RQ1. Do quality media in Russia adapt their content differently to various social networking platforms?

- *RQ1.1*. Does each media adapt differently to the platforms of presence in terms of news selection criteria? Do they employ varying "news values"?
- *RQ1.2*. Does each media adapt differently to the platforms of presence in terms of technical adaptation, namely, hypertext and multimedia use?
- *RQ1.3*. Do they shift from neutrality in their coverage?

RQ2. Do the media preserve the standards of quality news reporting in terms of news selection criteria, especially in the use of emotional "news values" and the tone of voice?

RQ3. To the media differ in strategic adaptation to the platform variety? In other words, can one detect similar patterns in news content adaptation of two newspapers?

3 Method

3.1 Sampling and Data Collection

As stated above, we have collected news pieces by two Russian quality media, namely, *Kommersant* and RBC, from three platforms, in particular Telegram, VKontakte, and Instagram. The data collection was carried out in a two-week period

from March 1 to 14, 2023. The study included data collected from 9 to 11 am, the most active news hours.

The overall sample included 429 news pieces, of them 146 from the *Kommersant* accounts and 283 from the RBC ones.

3.2 Data Analysis

We have employed mixed-method (qualitative-quantitative) content analysis as suggested by Krippendorff [39]. We have developed a codebook which consisted of the following variables for coding our units of analysis (the news pieces on the platforms):

- Interactivity/user involvement: Multimedia, Hypertext (both 0/1)
- Topic (coded "politics" = 1, "economy" = 2, "social issues" = 3, and "other" = 4)
- "News values": Timeliness, Elites, Reach, Drama, Conflict (all 0/1)
- Sentiment: Positive, Negative, Neutral (all 0/1)

The coded data underwent descriptive statistics. We have employed Spearman's rho and Student T-criterion for independent samples to see whether the patterns of use of text features differ within one media and across them. Our results are presented below.

4 Results

4.1 Representation of Findings

First, we have assessed the overall presence of the adaptation variables in the news texts (in %)—see Fig. 1 for *Kommersant* and Fig. 2 for RBC. Then, to provenly detect the platform- and topicality-related differences within each media's platform presence, we have employed Spearman's rho. For *Kommersant*, see Table 1; for RBC, Table 2.

We have also compared means for all platforms for all variables—first for *Kommersant*, then for RBC, and then the media were compared on the use of the same platforms (see Table 3). Here, we have divided "Topicality" into four categories ("Politics," "Economy," "Social issues," and "Other" for culture, sports, entertainment, and religion).

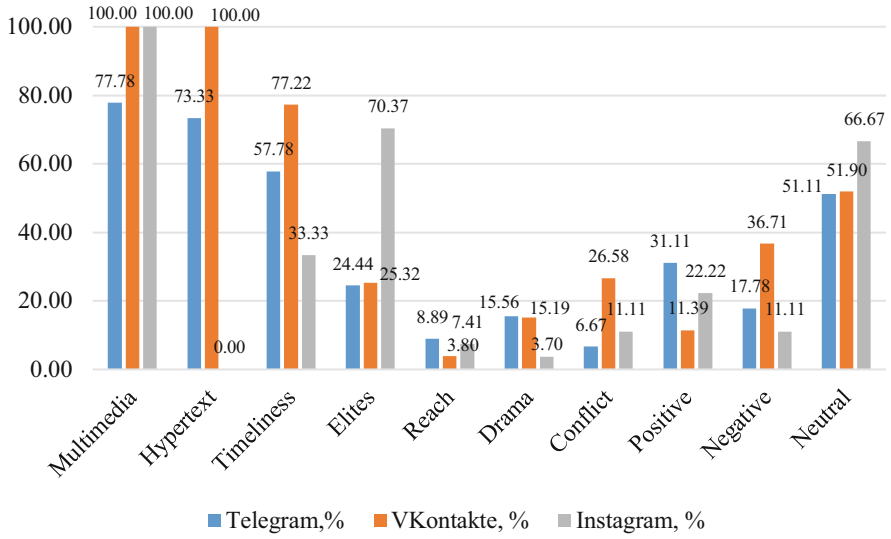

Fig. 1 Distribution of presence of adaptation features, %, *Kommersant*

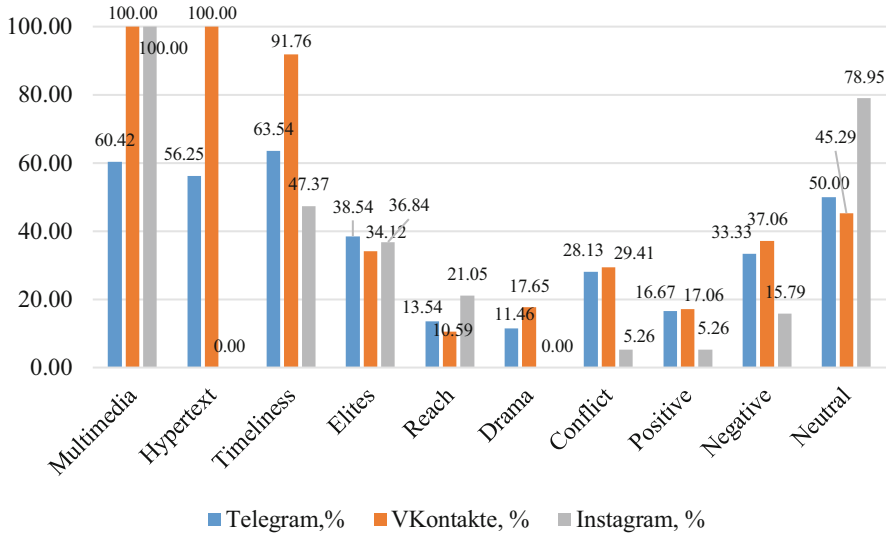

Fig. 2 Distribution of presence of adaptation features, %, RBC

4.2 Interpreting the Results

Figures 1 and 2 provide the following picture. In terms of technical text features, the papers look really similar, completely avoiding hypertext on Instagram and implementing both features on VKontakte to the maximum and in over 60% of the

Table 1 Correlations of the variables (Spearman's rho), *Kommersant*

Platforms	Multi	Hyper	Topic	Timely	Elites	Reach	Drama	Conflict	Posit.	Negat.	Neutr.
Platform	**.357****	**−.397****	.172*		.276**						
Multimedia	1000		.174*								
Hypertext		1000	−.237**	.245**	−.292**					.251**	
Topic			1000	**−.328****				**−.409****	.246**	**−.309****	
Timeliness				1000				.174*		.174*	−.270**
Elites					1000			−.181*		**−.327****	.213**
Reach						1000	**.326****			.170*	
Drama							1000	.226**		**.385****	**−.392****
Conflict								1000	−.184*	**.621****	**−.377****
Positive									1000	−.293**	**−.539****
Negative										1000	**−.633****
Neutral											1000
Telegram	Multi	Hyper	Topic	Timely	Elites	Reach	Drama	Conflict	Posit	Negat	Neutr
Multimedia	1000		**.385****	**−.349***							
Hypertext		1000									
Topic			1000	**−.410****							
Timeliness				1000			**.367***				−.296*
Elites					1000						
Reach						1000	**.728****			**.467****	**−.319***
Drama							1000				**−.439****
Conflict								1000		**.342***	
Positive									1000	**−.312***	**−.687****
Negative										1000	**−.475****
Neutral											1000
VKontakte	Multi	Hyper	Topic	Timely	Elites	Reach	Drama	Conflict	Posit	Negat	Neutr
Topic	N/A	N/A	1000	**−.428****				**−.406****	.286*	**−.343****	
Timeliness	N/A	N/A		1000							−.268*
Elites	N/A	N/A			1000			−.284*		**−.323****	
Reach	N/A	N/A				1000					
Drama	N/A	N/A					1000	**.304****		**.483****	**−.451****
Conflict	N/A	N/A						1000		**.731****	**−.526****
Positive	N/A	N/A							1000	-.273*	**−.382****
Negative	N/A	N/A								1000	**−.759****
Neutral	N/A	N/A									1000
Instagram	Multi	Hyper	Topic	Timely	Elites	Reach	Drama	Conflict	Posit	Negat	Neutr
Topic	N/A	N/A	1000	**.479***				**−.479***	**.416***		
Timeliness	N/A	N/A		1000							
Elites	N/A	N/A			1000	−.436*					
Reach	N/A	N/A				1000	**.693****				
Drama	N/A	N/A					1000				
Conflict	N/A	N/A						1000			
Positive	N/A	N/A							1000		**−.756****
Negative	N/A	N/A								1000	**−.500****
Neutral	N/A	N/A									1000

Note. Only significant correlations are shown ($p < 0.05$). Green: positive correlations; red: negative correlations. Correlations over 0.3 and lower than −0.3 are highlighted. N/A: data not available, as one of the variables did not vary. For VKontakte and Instagram, "multimedia" and "hypertext" did not vary; thus, the lines are excluded from the table

* and ** specify the p-value cutoff for correlation coefficients

Table 2 Correlations between the variables (Spearman's rho), RBC

Platforms	Multi	Hyper	Topic	Timely	Elites	Reach	Drama	Conflict	Posit	Negat	Neutr
Platform	**.520****	.190**		.141*							
Multimedia	1000	**.380****									
Hypertext		1000		.213**							
Topic			1000	–.134*	–.211**			**–.344****			
Timeliness				1000			.193**	.170**		.288**	–.274**
Elites					1000			.256**			
Reach						1000	.236**			.150*	–.140*
Drama							1000	.163**		**.324****	**–.310****
Conflict								1000	–.165**	**.327****	–.185**
Positive									1000	**–.318****	**–.431****
Negative										1000	**–.711****
Neutral											1000
Telegram	Multi	Hyper	Topic	Timely	Elites	Reach	Drama	Conflict	Posit	Negat	Neutr
Multimedia	1000	.274**									
Hypertext		1000							–.225*		.252*
Topic			1000		–.242*						
Timeliness				1000			.272**			**.444****	**–.454****
Elites					1000			**.314****			
Reach						1000					
Drama							1000	.284**		.231*	**–.360****
Conflict								1000		.246*	
Positive									1000	**–.316****	**–.447****
Negative				–						1000	**–.707****
Neutral											1000
VKontakte	Multi	Hyper	Topic	Timely	Elites	Reach	Drama	Conflict	Posit	Negat	Neutr
Topic	N/A	N/A	1000	–.151*	–.227**	.181*	.178*	**–.410****			
Timeliness	N/A	N/A		1000	.170*			.193*			
Elites	N/A	N/A			1000			.216**			
Reach	N/A	N/A				1000	.292**				
Drama	N/A	N/A					1000			**.380****	–.297**
Conflict	N/A	N/A						1000	–.224**	**.360****	–.172*
Positive	N/A	N/A							1000	**–.348****	**–.413****
Negative	N/A	N/A								1000	**–.698****
Neutral	N/A	N/A									1000
Instagram	Multi	Hyper	Topic	Timely	Elites	Reach	Drama	Conflict	Posit	Negat	Neutr
Topic	N/A	N/A	1000	**–.570***		N/A				**–.544***	
Timeliness	N/A	N/A		1000		N/A					
Elites	N/A	N/A			1000	N/A	**.456***		**.456***		
Reach	N/A	N/A				1000					
Drama	N/A	N/A				N/A	1000				
Conflict	N/A	N/A				N/A		1000			
Positive	N/A	N/A				N/A			1000		**–.456***
Negative	N/A	N/A				N/A				1000	**–.839****
Neutral	N/A	N/A				N/A					1000

Note. Only significant correlations are shown ($p < 0.05$). Green: positive correlations; red: negative correlations. Correlations over 0.3 and lower than −0.3 are highlighted. N/A: data not available, as one of the variables did not vary. For VKontakte and Instagram, "multimedia" and "hypertext" did not vary; thus, the lines are excluded from the table

* and ** specify the p-value cutoff for correlation coefficients

Table 3 Comparing means (the Mann-Whitney metric), *Kommersant* vs. RBC

Variables		*Kommersant*			RBC			*Kommersant* vs. RBC		
		Telegram vs. VK*	Telegram vs. Instagram	VK* vs. Instagram	Telegram vs. VK*	Telegram vs. Instagram	VK* vs. Instagram	Telegram	VK	Instagram
Interactive	Multimedia	**0.000**	**0.009**	1000	**0.000**	**0.001**	1000	**0.043**	1000	1000
	Hypertext	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.053†	1000	0.233
News values	Timeliness	**0.023**	**0.046**	**0.000**	**0.000**	**0.031**	**0.000**	0.513	**0.001**	0.808
	Elites	0.914	**0.000**	**0.000**	0.470	0.148	0.251	0.101	0.164	**0.001**
	Reach	0.247	0.827	0.447	0.472	0.090	0.137	0.431	0.073†	0.230
	Drama	0.957	0.124	0.118	0.180	0.422	0.168	0.498	0.631	0.801
	Conflict	**0.007**	0.512	0.099†	0.824	0.108	0.081†	**0.004**	0.646	0.951
Sentiment	Positive	**0.007**	0.418	0.165	0.935	0.203	0.183	**0.052**	0.248	0.119
	Negative	**0.027**	0.450	**0.013**	0.543	0.131	0.066†	0.057†	0.958	0.646
	Neutral	0.826	0.200	0.224	0.461	**0.021**	**0.006**	0.902	0.248	0.368
Topicality	Politics	**0.034**	0.166	**0.001**	0.824	**0.041**	**0.045**	0.096†	0.362	0.678
	Economy	0.138	0.880	0.190	0.060†	0.378	0.818	0.846	0.946	0.361
	Social	0.452	0.787	0.741	0.406	0.175	0.312	0.777	0.534	0.417
	Other	0.138	**0.000**	**0.002**	0.746	**0.000**	**0.000**	0.667	**0.042**	0.927

Note. Significant correlations are highlighted ($p < 0.05$). Correlations close to significance are marked with † ($0.1 < p \leq 0.05$). VK* is for VKontakte

news on Telegram. As to "news values," we see that the pattern is really similar, with "Timeliness" being present in over ¾ of texts on VKontakte but in only over 50% of texts on Telegram, and being used exactly equally on Instagram, in 1/3 of the texts. We see that "Reach" does not shape the choice, which may indicate that reach is perceived more as a tabloid feature ("reaches more people as it is relevant for everyone beyond the political and economic elites"). "Elites," however, shape the news choice visibly more, in circa 25% on Telegram and VKontakte by *Kommersant* and 34–38% on them by RBC; its rocketing to 70% on *Kommersant*'s Instagram is due to celebrity coverage. "Conflict" is similarly important for both outlets on VKontakte but much less so on Instagram.

As to neutrality of coverage, we, indeed, detect the prevalence of neutral sentiment but only slightly over 50% of texts for *Kommersant* and 45–50% for RBC on textual platforms, which is a meaningful deviation from the expected levels of neutrality. However, not all nonneutral news is negative. Moreover, *Kommersant* places a bigger percentage of positive news on Telegram than of negative and more than on other platforms; on VKontakte, negative news is two times more frequent in percentage than on Telegram. Meanwhile, RBC keeps the levels of negativity (just as positivity) nearly perfectly equal. In general, RBC is very consistent in keeping the same levels of "news valuers" and sentiment on Telegram and VKontakte, while *Kommersant*'s approach varies in conflict and positive/negative sentiment.

We interpret the correlation analysis results for Kommersant as follows:

1. Topicality and interactivity weakly to medium-strongly correlate with "Platform"; thus, affordances may affect how the text is prepared for each platform, and audiences are seen as varying in terms of their preferred topics. Technical adaptation, though, is conducted in provenly differing ways: If multimedia content increases from Telegram to Instagram, hypertextuality, on the contrary, decreases. Of "news values," only "Elites" weakly vary; *Kommersant* employs the presence of elites variably. However, in general, the news selection criteria are non-related to the "Platform" variable, which indicates the integrity of the newspaper's strategy for selecting news on social networks.
2. "Timeliness" "Conflict," and general sentiment vary in relation to the topical diversity. Expectedly, conflict and negativism decrease from politics to culture, sports, and entertainment. Technical adaptation is also connected to topicality: Multimediality grows with the growth of "general interest" topics, as such topics are mostly present on Instagram. Hypertextuality, on the contrary, somewhat decreases, maybe also due to the Instagram affordances. Thus, the platform audience looks like a significant factor that shapes topical preferences and the respective "news values," not only tech features.
3. "Conflict" is the "value" most linked to other selection criteria. It manifests in current news; however, its use is unexpectedly inversely proportional to "Elites." "Elites" also negatively correlate with negative tone; they are provenly covered more neutrally. This shows the position of the newspaper as a part of Russian political establishment.

4. On the platforms, the pattern of combination of technical features and "news values" does not repeat. On Telegram and VK, multimediality decreases if a news is timely, but on Instagram it grows. On Telegram, "Drama" links to "Timeliness" and "Reach"—that is, the news for Telegram should be acutely timely and dramatic but not conflicting, while, on VKontakte, "Conflict" and "Drama" are interlinked but not elites-oriented. Moreover, on Instagram, the paper abandons covering elites and focuses on nonpolitical drama to maximize reach.
5. On text-oriented platforms, the news sentiment closely relates to the presence/absence of drama and conflict (and, of course, their presence determines negativity in coverage), but no such dependence is noted on Instagram.

In general, the adaptation strategy is more focused on the technical side of news texts, and the data do not indicate a strategic link between different "news values" on platforms (either all together or individual ones).

We interpret the correlation analysis results for RBC as follows:

1. "Platform" correlates with technical features—stronger with "Multimedia," weaker with "Hypertextuality." The technical variables also intercorrelate strongly enough, which indicates a tendency to divide news into plain text vs. multimedia texts with a greater role of hypertext in the latter ones. Of "news values," "Timeliness" weakly correlates with "Platform," which points to a strategy for platformized curation of the news flow. Combined, the two correlations indicate a visible strategy of content adaptation.
2. As one moves from political topics to entertainment, "Conflict" (−0.344**), "Timeliness," and "Elites" expectedly decrease. However, unlike in *Kommersant*, the tone of publications does not depend on the topic.
3. In general, RBC news demonstrates a closer connection between the "news values." Thus, "Timeliness," "Reach," "Drama," "Elites," and "Conflict" all strongly enough correlate in pairs, which points out the classic approach to news selection in public affairs press and proximity to the classic news standards. Moreover, negativism only weakly correlates (and neutrality very weakly positively correlates) to "Timeliness" and "Reach" but not to "Drama," "Elites," or "Conflict," which further confirms the emotional neutrality and avoiding negativism in describing conflictual agendas. This also shows a strategic choice of the tone, regardless of the factors that can attract a wider audience.
4. We note intriguing differences in the platformized choice of "news values." Thus, on Telegram, the selection criteria do not correlate with topicality in any way (i.e., there may be a set of "news values for Telegram" that does not depend on the subject matter), whereas topicality affects all the "news values" on VKontakte very much: With the growth of nonpolitical topics, "Reach" and "Drama" grow, but not "Conflict" (that falls sharply) or "Elites." This may indicate that the audience on the platform is perceived by the editorial board as a mass audience that does not need conflicting political news.
5. Instagram, as in *Kommersant*, plays the role of a "relaxation" platform, where negativism sharply decreases with the growth of nonpolitical topics, the editorial board can afford irrelevant news, and they say *aut bene aut nihil* on the elites.

We interpret the data on comparing means in Table 3 *as follows*:

1. In both *Kommersant* and RBC, all platforms differ in the use of hypertext. In both media, Instagram and VKontakte are equally multimedialized, while Telegram is significantly different from both VKontakte and Instagram. Similar patterns of technical adaptation work in high-quality press, and they are clearly platform-dependent. The platform affordances are employed by the two media in a similar way.
2. At the same time, topicality (in particular, presence of political topics) and "news values" use of Telegram in the two media differ. In *Kommersant*, politics is present significantly differently on Telegram than on other platforms (which confirms our thesis that *Kommersant* sees VKontakte as a depoliticized platform), whereas at RBC, it is Instagram that differs due to the absence of politics, and the two other platforms do not differ. Instagram in both media also clearly differs in topicality from the two other platforms, as Instagram, as our coding demonstrates, is a place for covering entertainment topics and the lives of stars or socially significant events of a nonpolitical nature.
3. The use of platforms by the two editorial offices practically does not differ in terms of classic "news values"—"Reach," "Drama," and "Elites." On Telegram, the degree of conflict that they allow for in their news varies, and on VKontakte, the degree of timeliness does. However, in general, the similarity of "news values" indicates that high-quality media remain within the same format niche.

4.3 Answering the Research Questions

RQ1.1 In general, the pattern of use of "news values" in both quality dailies is very similar: "Timeliness" and "Elites" are the most salient and decisive in terms of adaptation. "Timeliness" provenly varies on all the platforms for both media, and "Elites" vary for *Kommersant*, due to Instagram being home for celebrity coverage. "Conflict" is the next popular selection category, but it does not at all prevail. "Drama" and "Reach" are definitely not what defines the news selection for both media equally, which hints that the "emotional turn" has not captured these media. The use of these three "news values" is provenly similar on all the platforms, except for a significantly lesser use of conflictual reporting on *Kommersant*'s Telegram, which, in combination with substantial presence of positive reporting, shows that Telegram may play the role of elite milieu, while VKontakte is seen as depoliticized; political reporting there is quite conflictual but counterbalanced by nonconflictual reporting on nonpolitical issues.

RQ1.2 Both media are very similar in their overall patterns of technical adaptation to audiences and platform affordances. They use multimedia features in 100% of cases on VKontakte and Instagram, while leaving a large number of texts on Telegram (23 to 40%) non-multimedialized. The pattern for hypertext is also very similar: 100% on VKontakte, 0% (!) on Instagram, and 56 to 73% on Telegram.

*Kommersant'*s Telegram is slightly more technically advanced than the RBC's one, but the difference is slight, even if the Mann-Whitney criterion proves multimedia use to differ on Telegram. Thus, we see that Instagram differs from other platforms in terms of use of hypertext, and Telegram is, again, slightly less multimedialized.

RQ1.3 The sentiment is where the media fluctuate from the standards and somehow differ from each other. Interestingly, for *Kommersant*, Telegram differs in positive coverage from the two other platforms, as well as from RBC. This tells us of possible differing strategies for employing negativity on various platforms; this is cross-proven by the fact that Telegram and VKontakte also differ in negativity for this paper. RBC, though, is consistent in preserving the same tone of publications on textual platforms. However, dominance of neutral texts is still there, and, unexpectedly enough, it is Instagram that is the platform with neutral, rather than scandalous, reporting. This brings on new input on how quality media use Instagram if they care about journalism standards.

Thus, **RQ1** may be altogether answered as follows. The two media outlets show notable similarity in how they use the platforms in technical features, "news values," and sentiment. Their main instruments of platform differentiation are the multimedia and hypertext features, as well as the varying understanding of timeliness for various platforms. For *Kommersant*, Telegram is a "positive" platform and VKontakte is negative even if depoliticized, while, for RBC, Instagram is the "neutral" platform, as circa 50% of content on other platforms is positive/negative. Another adaptation instrument is topicality, with political coverage located mostly on textual platforms and entertainment on Instagram. This shows that platform affordances and the habitual use of a platform in a given society may limit its full-fledged employment for news coverage.

RQ2 In general, the two media still belong to the quality dailies' tradition and do not move downmarket in terms of the use of dramatic/conflictual reporting or general interest news. They also stick to the standards of neutral reporting in 43 to 78% of their coverage on various platforms, and the deviation from neutrality is, in effect, nearly 50/50 positive and negative. However, we need to note that some relevant "news values" could be missing from our analysis, which needs more research.

RQ3 As stated above, we have detected very similar patterns of how the two outlets adapt in technical terms, fostering multimedia and hypertext on VKontakte, reserving it a bit on Telegram, and depriving Instagram of hypertext whatsoever. However, in terms of news selection and the tone of voice, the differences lie in two strategic areas. First, Kommersant sees Telegram and Vkontakte very differently; it does not use conflict and negativity on the former, contrary to expectations, and allows for much more conflict and negativity on VKontakte, while RBC follows the same news selection strategy on these platforms. Second, Instagram is mostly used by *Kommersant* for covering celebrity life, while RBC continues there with a variety of its habitual topics. Taken together, this indicates a more platform-by-platform strategy for *Kommersant* and more consistent platform-independent strategy for the presence of RBC on social media.

5 Conclusion

To our best knowledge, the study presented above is the first comparative study of platform adaptation of Russian quality media outlets. We have shown that, while fostering quality preservation in terms of tabloidization and dumbing down, they still show the signs of the "emotional turn"—not in dramatization but in their tone of voice that fluctuates to both positive and negative sides. Both media have mastered instrumental user engagement via multimedia and hypertext, and their use of the three platforms in this respect mirrors each other. However, the insider-oriented nature of *Kommersant* shows up in how it distributes conflict and negativity, localizing its elite readers on Telegram, while RBC follows the agenda and not the affordances/audiences logic in the use of "news values" and negativity. Thus, strategic adaptation is possible for quality media—from platform-to-platform adaptation to strategic replication of one approach.

The limitations of our study include low number of "news values" that we employed, our qualitative judgment on how the "news values" and sentiment were assigned, and unequal numbers of texts from each platform, as we preferred the time frame over the equal number of news in our sample. This research needs to be continued, and automated methods of textual analysis may be employed for it in future.

Acknowledgments This chapter has been supported in full by the project "Center for International Media Research" at St. Petersburg State University, year 3, project #94033584.

References

1. Litvinenko, A., Bodrunova, S.S.: Russia: media accountability in a polarized society. In: Fengler, S., Kreutler, M., Karmasin, T. (eds.) The Global Handbook of Media Accountability, pp. 203–212. Routledge, London (2021)
2. Strömbäck, J., Tsfati, Y., Boomgaarden, H., Damstra, A., Lindgren, E., Vliegenthart, R., Lindholm, T.: News media trust and its impact on media use: toward a framework for future research. Ann. Int. Commun. Assoc. **44**(2), 139–156 (2020)
3. Hase, V., Boczek, K., Scharkow, M.: Adapting to affordances and audiences? A cross-platform, multi-modal analysis of the platformization of news on Facebook, Instagram, TikTok, and Twitter. Digit. Journal., 1–22 (2022)
4. Tuchman, G.: Objectivity as strategic ritual: an examination of newsmen's notions of objectivity. Am. J. Sociol. **77**(4), 660–679 (1972)
5. Poettker, H.: News and its communicative quality: the inverted pyramid – when and why did it appear? Journal. Stud. **4**(4), 501–511 (2003)
6. Tsfati, Y., Meyers, O., Peri, Y.: What is good journalism? Comparing Israeli public and journalists' perspectives. Journalism. **7**(2), 152–173 (2006)
7. Anikina, M.E.: Journalism as a profession in the first decades of the 21st century: the Russian context. World Media: Yearb. Russ. Media Journal. Stud. **4**, 233–252 (2014)
8. Bodrunova, S., Nigmatullina, K.: Journalistic cultures: new times, new gaps? In: Davydov, S. (ed.) Internet in Russia: A Study of the Runet and its Impact on Social Life, pp. 121–147. Springer, Cham (2020)

9. Singer, J.B.: User-generated visibility: secondary gatekeeping in a shared media space. New Media Soc. **16**(1), 55–73 (2014)
10. Napoli, P.M.: Social media and the public interest: governance of news platforms in the realm of individual and algorithmic gatekeepers. Telecommun. Policy. **39**(9), 751–760 (2015)
11. Bodrunova, S.S., Litvinenko, A.A.: Four Russians in communication: fragmentation of the Russian public sphere in the 2010s. In: Dobek-Ostrowska, B., Glowacki, M. (eds.) Democracy and Media in Central and Eastern Europe 25 Years On, pp. 63–79. Peter Lang (2015)
12. Judina, D., Platonov, K.: Newsworthiness and the public's response in Russian social media: a comparison of state and private news organizations. Media Commun. **7**(3), 157–166 (2019)
13. Lasorsa, D.L., Lewis, S.C., Holton, A.E.: Normalizing Twitter: journalism practice in an emerging communication space. Journal. Stud. **13**(1), 19–36 (2012)
14. Bodrunova, S.S., Litvinenko, A.A., Blekanov, I.S.: Please follow us: media roles in Twitter discussions in the United States, Germany, France, and Russia. Journal. Pract. **12**(2), 177–203 (2018)
15. Parfenova, V.V.: Funktsional'nye gruppy rossiyskih SMI po urovnyu adaptatsii kontenta na platforme messendzhera Telegram [Functional groups of Russian mass media as based on the level of content adaptation on the platform of Telegram]. Vek Informatsii. **2**(3), 11–15 (2018)
16. Bodrunova, S.S., Litvinenko, A.A.: Fragmentation of society and media hybridisation in today's Russia: how Facebook voices collective demands. J. Soc. Policy Stud. **14**(1), 113–124 (2016)
17. Reuter, O.J., Szakonyi, D.: Online social media and political awareness in authoritarian regimes. Br. J. Polit. Sci. **45**(1), 29–51 (2015)
18. Cherevko, T.S., Dunas, D.V., Tolokonnikova, A.V.: Novosti v usloviyah internetizatsii: analiz novostnogo potrebleniya studentov. Vestnik Moskovskogo universiteta. Seriya 10. Zhurnalistika. **1**, 3–25 (2018)
19. McNair, B.: Journalism and democracy: a millennial audit. Journal. Stud. **1**(2), 197–211 (2000)
20. Hallin, D.C., Mancini, P.: Comparing Media Systems: Three Models of Media and Politics. Cambridge University Press, Cambridge (Mass.) (2004)
21. Bodrunova, S.S.: Paradigmy 'advokatirovaniya' i 'arbitrazha' v zapadnoj zhurnalistskoj etike i ih tsennostno-normativnoe napolnenie [Paradigms of advocacy and arbitrage in the Western journalism ethics and their values-based and normative essence]. Sociologiya i pravo. **1**, 16–23 (2014)
22. Thomson, E.A., White, P.R., Kitley, P.: 'Objectivity' and 'hard news' reporting across cultures: comparing the news report in English, French. Jpn. Indones. Journal. Journal. Stud. **9**(2), 212–228 (2008)
23. Nielsen, R.K.: News media, search engines and social networking sites as varieties of online gatekeepers. In: Peters, C., Broersma, M. (eds.) Rethinking Journalism Again, pp. 93–108. Routledge, Abingdon (2017)
24. Kiousis, S., McCombs, M.: Agenda-setting effects and attitude strength: political figures during the 1996 presidential election. Commun. Res. **31**(1), 36–57 (2004)
25. Galtung, J., Ruge, M.H.: The structure of foreign news: the presentation of the Congo, Cuba and Cyprus crises in four Norwegian newspapers. J. Peace Res. **2**(1), 64–90 (1965)
26. Harcup, T., O'Neill, D.: What is news? Galtung and Ruge revisited. Journal. Stud. **2**(2), 261–280 (2001)
27. HeMan, E.S., Chomsky, N.: Manufacturing Consent: The Political Economy of the Mass Media. Random House (2010)
28. McQuail, D.: McQuail's Mass Communication Theory. Sage Publications (2010)
29. Rosenberg, H., Feldman, C.S.: No Time to Think: The Menace of Media Speed and the 24-Hour News Cycle. A&C Black (2008)
30. McNair, B.: News and Journalism in the UK. Psychology Press (2003)
31. Toffler, A.: The Third Wave: The Classic Study of Tomorrow. Bantam (1980/2022)
32. Bucher, T., Helmond, A.: The affordances of social media platforms. In: Burgess, J., Poell, T., Marwick, A.E. (eds.) The SAGE Handbook of Social Media, pp. 233–254. Sage (2018)

33. Swart, J.: Experiencing algorithms: how young people understand, feel about, and engage with algorithmic news selection on social media. Soc. Media + Soc. **7**(2), 20563051211008828 (2021)
34. Lünenborg, M., Maier, T.: The turn to affect and emotion in media studies. Media Commun. **6**(3), 1–4 (2018)
35. Wahl-Jorgensen, K.: The strategic ritual of emotionality: a case study of Pulitzer Prize-winning articles. Journalism. **14**(1), 129–145 (2013)
36. Wahl-Jorgensen, K.: Emotions, Media and Politics. John Wiley & Sons (2019)
37. O'Neill, D., Harcup, T.: News values and news selection. In: Hanitzsch, T. (ed.) The Handbook of Journalism Studies, pp. 213–228. Routledge, London (2019)
38. Kaul, V.: Changing paradigms of media landscape in the digital age. J. Mass Commun. Journal. **2**(2), 1–9 (2012)
39. Krippendorff, K.: Content Analysis: An Introduction to Its Methodology. Sage (2018)

Index

M. Bakaev et al. (eds.), *Digital Geography*, Springer Geography,
https://doi.org/10.1007/978-3-031-67762-5