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Communications in Computer and Information Science 1242

Digital Transformation and Global Society

5th International Conference, DTGS 2020
St. Petersburg, Russia, June 17–19, 2020
Revised Selected Papers

DIGITAL TRANSFORMATION & GLOBAL SOCIETY
SAINT-PETERSBURG RUSSIA

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Preface

The 5th International Conference on Digital Transformation and Global Society (DTGS 2020) was held from June 17–19, 2020. It is the international academic forum aimed at discussing interdisciplinary issues of the Internet and Digital Transformation research. The event was hosted by the ITMO University, in cooperation with the National Research University Higher School of Economics (St. Petersburg), as well as with the PRIOR - NW Non-Profit Association.

This year we have received 108 submissions, and after careful evaluation by the Program Committee and the volume editors 36 papers were accepted for this post-conference volume. The submissions fall into several major tracks of the conference:

- E-Society: issues related to the social informatics, computational social science, and online media research
- E-Polity: e-governance and e-participation issues
- E-City: smart cities, urban governance, and planning
- Economy: digital economy, e-commerce, and consumers' behavior online
- E-Humanities: digital culture and education
- E-Health: digital transformation of healthcare

Due to the COVID-19 outbreak, the Organization Committee had to change the format of the conference. It was organized completely online as a series of synchronous moderated sessions, for all participants to present their papers and get valuable feedback from the colleagues. Also, a special online platform was created, for the participants to get themselves familiar with the materials and ask questions before the conference. Both asynchronous and synchronous parts of the conference went smoothly and provoked fruitful discussions.

The international workshop "E-Health: P4-medicine & Digital Transformation" was organized for the first time within DTGS, chaired by Anatoly Shalyto and Georgy Kopanitsa (ITMO University). The papers presented at the workshop are also included into the volume.

This year the session on Smart Cities was held in partnership with the WeGO Eurasia Regional Office. The participants of the session were welcomed by Mrs. Svetlana Openysheva, Secretary General of the organization. We would like to thank the colleagues and hope that our cooperation will continue.

As was the case last year, the Young Scholars' Forum was also organized. We received 12 papers from the young scholars. By the decision of the Award Committee, chaired by Andrei Chugunov (ITMO University), 5 best papers were accepted to the final volume after substantial revision. We thank all members of the Award Committee for their effort and excellent expertise during the forum.

Another special event of DTGS 2020 was the international online seminar "Electronic Participation: Concepts, Technologies and Interdisciplinarity." The mission

of the seminar was to discuss topical issues related to the research and practice of e-participation. It brought experts and scholars from Austria, Portugal, Russia, and Switzerland.

We would like to thank all those who made this conference possible and successful during such challenging times. We are grateful to the members of the International Program Committee, the reviewers, and the conference staff. We would like also to thank the session chairs: Yury Kabanov, Ilya Musabirov, and Olessia Koltsova (Higher School of Economics), Leonid Smorgunov (St. Petersburg State University), Alexander Riabushko (WeGO Eurasia Regional Office), Georgy Kopanitsa and Anna Chizhik (ITMO University), as well as Maxim Bakaev (Novosibirsk State Technological University). And of course we thank all the authors contributing their excellent research to the volume.

June 2020

Daniel Alexandrov
Alexander Boukhanovsky
Andrei V. Chugunov
Yury Kabanov
Olessia Koltsova
Ilya Musabirov

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E-Society: Virtual Communities and Online Activism

Cyber-Social Trust in Different Spheres: An Empirical Study in Saint-Petersburg

Lyudmila Vidiasova[1(✉)], Iaroslava Tensina[1], and Elena Bershadskaya[2]

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Abstract. Research has been proposed to determine an approach for studying cyber-social trust in different social spheres. A survey to better understand the trust Saint Petersburg citizens' have in information technologies was conducted using a Social Construction of Technology (SCOT) approach. From the 600 respondents to this survey, the sampling error does not exceed 4% with a 95% level of reliability. The research demonstrates a new approach to a cybersocial trust construction. The questionnaire contained variables to evaluate the experience of use and the level of trust in new technologies in the areas of interaction with the government, the economy, healthcare, education, and interpersonal communication. According to the survey data, the category of cyber social trust was defined as the synergy of three components: institutional, transactional, and informational trust. According to the study, the experience of respondents strongly determines their willingness to use technology in various fields.

Keywords: Social trust · Cyber-social trust · Information technology · Survey

1 Introduction

Currently, the spread of new technologies reflects into certain transformations of trust in public communications. In this regard, it is of great importance to determine the boundaries of technology penetration into human life. At the same time, the problematization of a new category as "cyber-social trust" is of particular relevance. Cyber-social trust belongs to the sphere of relations between people and complex information systems, including elements of artificial intelligence.

The use of new information technologies leads to the creation of new models of communication, socialization and cooperation. At the same time, it also contributes to the emergence of new, previously unknown threats to individual development and social change. With the development of technology, new factors of marginalization and social exclusion are emerging. In addition, the popularity of new means of communication, their diversity and updates lead to an increase in the feeling of uncertainty and mistrust in the reliability of the information content. Most studies focus on the study of trust in the sphere of direct social relations trust in individual social institutions, while the issue

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of trust in the use of new technologies remains insufficiently studied. Also, insufficient attention is paid to trust as a factor influencing the adoption of innovations and changes.

The paper presents the cybersocial trust survey findings based on the poll of Saint Petersburg residents aimed at identifying the level of cyber-social trust in different spheres. The paper structures as follows: literature review provides the existing research background in trust and information technologies sphere, research design section shows the selected approach and related research tools being implemented, the findings present the key results revealed in the survey. Conclusion and discussion shed a light on some research limitations and further prospects.

2 Literature Review

The fundamental role of trust in interpersonal relations is reflected in the works of K. Arrow [1], S.M. Lipset and W. Scheider [12], D.R. Gibb [8], N. Luhmann [13], B. Misztal [16]. F. Fukuyama defines trust as the basis of social capital, which performs the function of reproducing the social structure, accelerates the processes of social exchange and promotes the integration of society [7]. N. Luhmann notes that trust makes the world more understandable and less complex, creating a sense of reliability and predictability, and also reduces the sense of danger and stabilizes social ties [13]. In R. Putnam's three-factor model, the development of social capital is also based on trust, general norms and social ties [19]. Trust in this model is considered as the basis for the reliability and sustainability of the development of the entire system and the basis for effective interaction in modern society. J. Coleman note that trust in modern society is becoming one of the most important factors in the social integration of society, the potential for solidarity and the development of social capital [5].

Relationships on the Internet are built on trust, because the user believes that another network user will act in a predictable manner. A. Kiran and P. Verbeek noted that instead of being wary of technology, the complexity of modern development leads to their greater penetration into people's lives [10].

In a number of scientific works, groups of factors that determine the use of information technology are distinguished. On the one hand, this is knowledge in the field of IT, and on the other, the adoption of technologies by a specific user. [18]. We can talk about establishing a relationship of trust in technology when the user understands what to expect from its application and evaluates its use as reliable [11]. Trust is one of the foundations that determine the level of technology adoption and use, often reflected in technology adoption models [20, 22]. D. McKnight, L. Cummings and N. Chervany identified two types of trust – dispositional and institutional trust [15]. Dispositional trust is a concept of individual differences arising from the psychology of personality, which means a tendency to trust others. Institutional trust is a sociology concept that determines norms and sustainable structures. Both dispositional and institutional trust in technology contribute to the development of trust, intent and behavior associated with a particular technology. In fact, trust in technology is actually a form of trust in people who design and create technological artifacts.

Researchers emphasize that by establishing confidence in a technology, the uncertainty resulting from its use is reduced [6]. In case of trust in new technologies, the

researchers deal with the new object of trust that differs much from the traditional category [14]. In the case of trust in IT, the object of trust is not a specific person or group of people, but a specific technology or technologies.

Some research focus on studying the trust in information technology from a security point of view [2, 9]. The relevance of studying trust in information technology security is largely due to the growing threats and incidents of information security around the world.

Researchers note that risk and trust are important factors in the acceptance of electronic services by users. D. Mou, D. Shin, and D. Cohen, in their study, performed a meta-analysis of 67 empirical studies aimed at studying the impact of trust and risk perception by users of electronic services [17]. The findings confirm that trust has a much greater impact.

Trust in information technology is also considered in terms of their use in the educational process. It is noted that teachers do not always trust information technologies and realize their potential for education [4]. At the same time, new models of communication and new types of relationships are actively appearing among students.

A number of studies are aimed at influencing the trust in the use and adoption of public electronic services [3, 21]. As a result of a study conducted in Lebanon, was found that the introduction of electronic services is hindered mainly by weak indicators of their use [3].

In this study, cyber-social trust is understood as the user's confidence in the predictability of the «behavior» of software and hardware systems (digital technologies), their reliability, which is manifested in the willingness to delegate several tasks to various software and hardware systems. Several aspects and categories related to the topic of cyber- social trust were highlighted (see Table 1). The revealed spheres were selected for the authors' research of cyber-social trust.

Table 1. Components of trust in new technologies revealed from previous surveys. Source: literature review

Aspects of trust in IT	Authors
E-government, online services, e-dialogue with government	A. Benoit., R. Fakhoury: R. Song, L. Korba, G.Yee
Cybersecurity issues	L.V. Astakhova, L.A. Grishchenko
Social interactions, anonymity, self-presentation	R. C. Mayer, J.H. Davis, F.D. Schoorman
Education online, trust to lectures	M. Cherepanyak-Valchak, E. Pezhitska
Risks understanding	J. Mou, D.H. Shin, J.F. Cohen

Taking into account the background of previous studies, a conclusion was drawn about the need for a systematic analysis of the phenomenon of cybersocial trust. The

author's approach suggests the analysis of a single case to study the parameters of cyber-social trust and indicators of its manifestation in various subject areas. For these purposes an example of citizens in metapolicies (Saint Petersburg) was chosen.

3 Research Design

The study was based on the ideas of the Social Construction of Technology approach (SCOT). In this regard, the study of the attitude to information technology is carried out both from the perspective of user's relationships, based on their experience in obtaining certain online services, evaluations of its success, as well as confidence in the reliability and security of such communications.

The aim of the study is to identify the level of social trust in new technologies among residents of St. Petersburg. The study used the questionnaire method that was conducted by interviewers in the course of a personal survey. The survey of respondents was conducted in 6 multifunctional centers (MFCs) that provide state and municipal services.

The sample was calculated on the basis of official statistics on residents of St. Petersburg. Based on the data on the size of the general population, the sample size for the survey was calculated - 600 respondents. The sampling error does not exceed 4%, the level of reliability was 95%.

Six hundred citizens took part in the study which were divided into six age groups: 18–25 years old (15%), 26–35 years old (19%), 36–45 years old (17%), 46–55 years old (18%), 56–65 years old (16%), and over 65 years old (16%) (see Fig. 1).

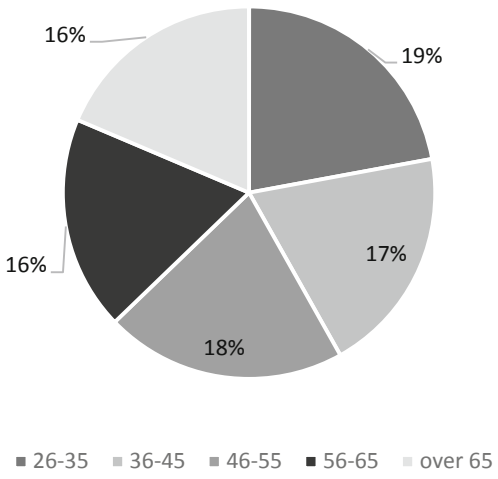

Fig. 1. Distribution of respondents by age, 2019

Most of respondents has higher or incomplete higher education (76%) (see Fig. 2).

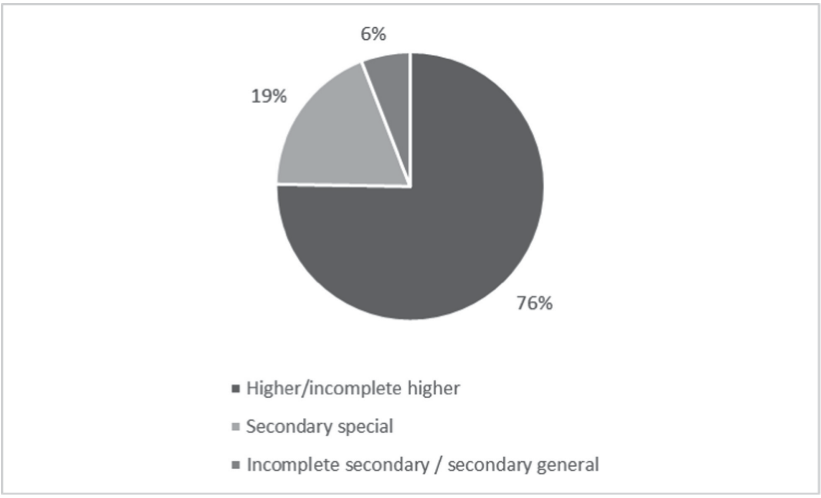

Fig. 2. Distribution of respondents by education degree, 2019

The survey was attended by respondents from various fields of employment, mainly employees and specialists. It is worth noting that this section of the data was not laid down in the sample and does not repeat the general population. (see Fig. 3).

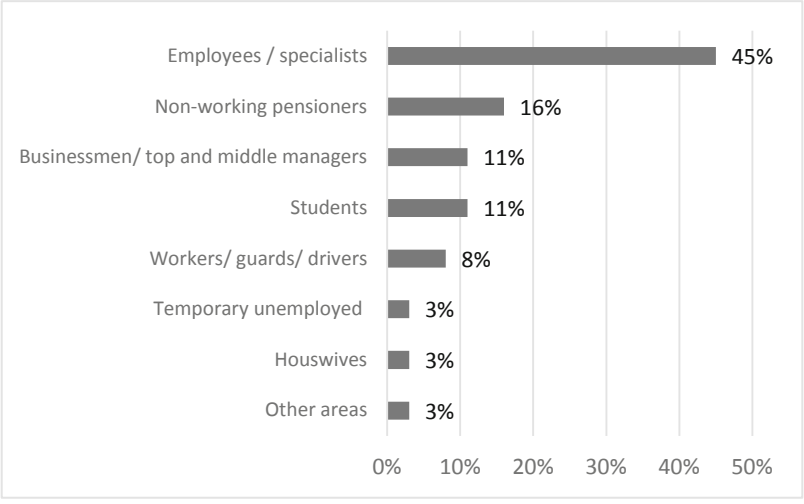

Fig. 3. Distribution of respondents by occupation, 2019

The questionnaire was compiled in the form of question-statements about personal experience in using information technologies for communication in following areas: government, society, economy, healthcare, education and security. To gradate the answer options, the Likert scale was used.

3.1 Variables of Cyber-Social Trust

Modern research demonstrates the complexity and multidimensionality of the "trust" concept in relation to new technologies. According to previous research, trust is not a constant category and it varies from one sphere to another. Based on the survey, 13 variables were selected that relate to certain aspects of cyber-social trust (see Table 2).

Table 2. Variables determining social trust/distrust in information technologies and their products

Question - statement	Variable
When I receive electronic services, I trust the available means of electronic identification of me as a user	Trust e-Identification
In general, I trust interaction with state and municipal authorities when receiving public services or submitting applications to authorities via the Internet	Trust online Government
In general, I trust communication with other users through social networks	Trust social media people
In general, I trust communication with state and municipal authorities through social networks	Trust social media government
In general, I trust the interaction through the Internet in the implementation of electronic payments	Trust online payment
I believe that information about diseases, medications, and methods of treating diseases available on the Internet is generally reliable	Trust Internet health information
In general, I trust the interaction through the Internet to receive health services	Trust e-Health
In general, I trust the interaction through the Internet for educational services	Trust e-Education
I generally trust my Internet service provider.	Trust Internet service provider
In general, I trust Russian companies selling goods and services on the Internet	Trust Russian companies
In general, I trust foreign companies selling goods and services on the Internet	Trust foreign companies
In general, I trust the administration of Russian social networks	Trust Russian social media
In general, I trust the administration of foreign social networks	Trust foreign social media

5 variables relate to the trust of certain organizations operating on the Internet: Russian and foreign Internet companies, the administration of social networks, as well as the Internet service provider. These variables relate to institutional trust.

Some of the variables are aimed at building trust between various actors on the Internet: trust in communication with citizens and the state on social networks and on

Internet sites, trust in online payments and trust in receiving electronic services through an identification system. These variables can be attributed to transactional trust, which provides transparent and honest rules for C2C and C2G interactions, as well as in the process of exchanging resources (including means of payment).

The remaining 3 variables relate to the trust in online education and the receipt of services and information in the field of healthcare. These variables are united by the fact that here the citizen acts as a consumer of the service, which mainly consists in obtaining information – new knowledge or advice and expects its completeness and credibility. Thus, these variables can be attributed to informational trust regarding the completeness, quality and reliability of information.

4 Findings

The research findings suggest the set of variables determine a cyber-social trust category, as well as distributions of Saint Petersburg citizens' attitude, experience and assessment of IT usage in different spheres: communication with government, personal contacts, education and health services online.

According to the survey, 43% of respondents are active users of the Internet. At the same time, 23% of respondents defined themselves as advanced Internet users. The survey results showed that the motivation for using Internet resources is more dependent on personal confidence in data security (31%) and significant time savings compared to the offline procedure (23%) (see Fig. 4). Least impact on motivation to use the Internet respondents noted personal previous positive experience (9%)

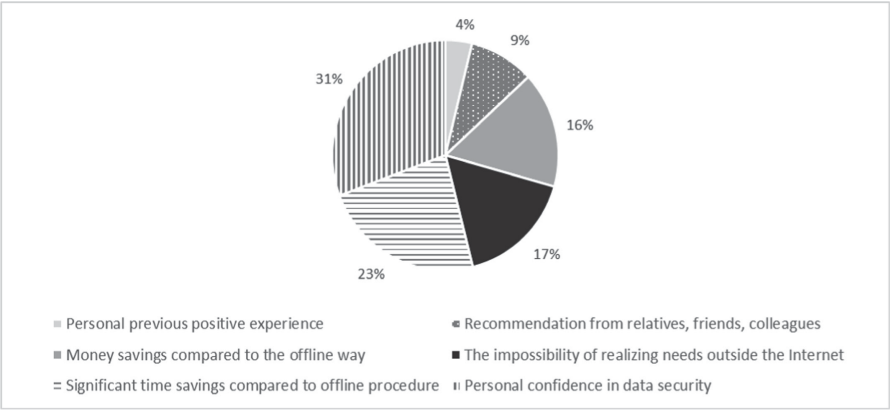

Fig. 4. Distribution of respondents' answers about motivation to use an Internet resource, 2019

The survey results also demonstrate positive attitude towards the Internet. For example, 77% disagree with the statement «I believe that the Internet represents more harm than good». According to respondents (75%), ensuring the safety of users on the Internet is the prerogative of public authorities. At the same time, measures that strengthen security on the Internet should not reduce its openness and freedom, as 77% of respondents

say. Only 44% of respondents consider current government measures to ensure Internet security sufficient.

The study also assessed the overall level of respondent's trust in communicating with other citizens, as well as the level of trust in the city authorities. According to the survey, only 23% believe that most people in general can be trusted. Almost a third of respondents (29%) trust the state and municipal authorities. 35% trust their Internet service provider, 32% trust Russian companies offering goods and services on the Internet, and 33% trust foreign companies. In general, 24% of respondents trust the administrations of Russian social networks, the same numbers were noted for foreign social networks.

According to the survey, 35% of respondents actively use the Internet to receive public services. At the same time, channels of online appeals to government bodies are less popular, 13% of respondents use them. It is noteworthy that 42% rate the exchange of data with authorities as safe and secure, and slightly more (47%) in general consider their experience in receiving public services as positive. Assessment of positive experience when applying to authorities via the Internet was given by 37% of respondents in St. Petersburg. A little more than ¾ of the respondents said that they were aware of the existence of an electronic digital signature, and about a third of respondents use it. When receiving government services, a little more than half of those polled (52%) trust electronic identification tools.

According to respondents (52%), the Internet helps to be more aware of the authorities' activities. In general, 37% of respondents trust communication with authorities when receiving services and submitting online requests (Fig. 5).

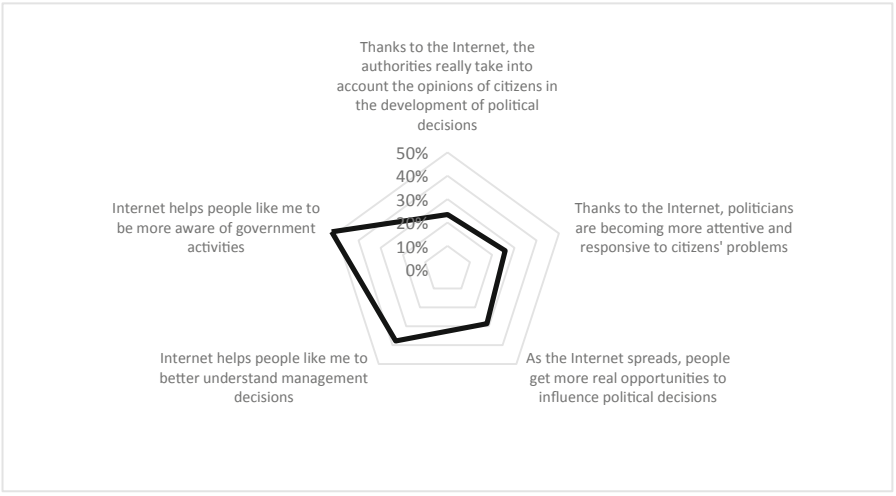

Fig. 5. The respondents' attitude toward the Internet usage in decision-making, 2019

53% consider themselves active users of social networks, and 3 out of 4 respondents rate their experience of using them as positive. At the same time, assessments of communication security and data safety when using social networks are quite low; only 19% of

respondents consider such interaction safe. About a third of respondents regularly monitor social and political content posted on social networks. However, only 11% themselves post information of such content on their pages, or leave comments. In general, 26% of city residents trust communication with other users through social networks. At about the same level (24%), user confidence in communicating with government representatives through social networks was noted.

According to the study, 60% of respondents actively use Internet banking, as well as mobile applications with connecting to accounts. Just over half of the respondents make purchases on the Internet regularly, and almost 70% rate their experience using online banking and online shopping as positive. According to the results of the survey, 61% of the survey participants generally trust in online payments.

35% of respondents use electronic health services: they sign up to doctors online and receive online consultations. However, only 8% rate such consultations as reliable. The percentage of those (18%) who rate the information on diseases, medicines and treatment methods posted on the Internet as reliable is slightly higher. One in four trusts electronic health services in general. According to the study, 25% use online learning platforms (webinars, online courses, etc.). A third of those surveyed rates their online learning experience as positive.

5 Conclusions and Discussion

As a result of the study, the category of cyber social trust was defined as the synergy of three components: institutional trust in the structures and organizations that provide services and services, transactional trust in the procedure of IT communication, informational in the quality of content and the content of the resource.

According to the study, the experience of respondents strongly determines their willingness to use technology in various fields. Personal trust in the use of technology in a particular area, including for establishing communication, is a key component and catalyst of cyber social trust.

Limitations of the study affect two important aspects. The first is connected with the place of selection of respondents, which, on the one hand, made it possible to legitimately ask questions to participants, and on the other, it limits the group of citizens who prefer to get servants online rather than in multifunctional centers. The second circumstance may be related to the posing of questions in the questionnaire, namely, the a priori assumption of the importance of personal practice based on the chosen approach.

On the example of the case of Saint-Petersburg, indicators of cyber-social trust in various fields were determined. Understanding the differentiation of users' motives in different age groups, as well as depending on the subject area, the authors consider it important to continue the research in the direction of both the most popular services and the least popular of them.

Further areas of research should be directed to multi-factor and cluster analysis, allowing to build models of the relationship of variables that determine cyber-social trust, with socio-demographic characteristics and other reliable parameters. The construction of a multifactor model of cyber-social trust will make it possible to contribute to the existing gap in the literature regarding a systematic view of the category of trust in cyber systems.

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References

1. Arrow, K.: The Limits of Organization. Norton & Comp., New York (1974). https://doi.org/10.1177/000271627541700157. 86 p.
2. Astakhova, L.V.: Trust in the security of information technology as an object of study by future information security specialists. Vestnik SUSU. Ser.: Educ. Pedag. Sci. **2**, 19–23 (2016). https://doi.org/10.14529/ped160203
3. Benoit, A., Fakhoury, R.: Citizenship, trust, and behavioral intentions to use public e-services: the case of Lebanon. Int. J. Inf. Manag. **35**(3), 346–351 (2015). https://doi.org/10.1016/j.ijinfomgt.2015.02.002
4. Cherepanyak-Valchak, M., Pezhitska, E.: The trust of teachers and students in the use of modern technologies in the learning process. Sci. Rep. BelSU. Ser.: Humanit. **6**(177), 294–299 (2014)
5. Coleman, J.: Foundations of Social Theory. Belknap Press of Harvard University Press, Cambridge (1990)
6. Ejdys, J.: Trust in technology in case of humanoids used for the care for the senior persons. Multidiscip. Aspects Prod. Eng. – MAPE **1**(1), 875–881 (2018). https://doi.org/10.2478/mape-2018-0110
7. Fukuyama, F.: Trust: The Social Virtues and the Creation of Prosperity. Free Press, New York (1995)
8. Gibb, J.R.: Trust: A New View of Personal and Organizational Development. The Guild of Tutors Press, Los Angeles (1978)
9. Grishchenko, L.A.: Assessment of confidence in the security of information technology. Quest. Sci. Educ. **7**(19), 62–66 (2018)
10. Kiran, A.H., Verbeek, P.P.: Trusting our selves to technology. Knowl. Technol. Policy **23**(3–4), 409–427 (2010). https://doi.org/10.1007/s12130-010-9123-7
11. Lippert, S.K.: An exploratory study into the relevance of trust in the context of information systems technology. Doctoral Dissertation. The George Washington University, Washington
12. Lipset, S.M., Scheider, W.: The Confidence Gap: Business, Labor and Government in the Public Mind. The Free Press, New York (1983)
13. Luhmann, N.: Vertrauen. Ein Mechanismus der Reduktion sozialer Komplexität. Lucius & Lucius, Stuttgart (1973)
14. Mayer, R.C., Davis, J.H., Schoorman, F.D.: An integrative model of organizational trust. Acad. Manag. Rev. **20**(3), 709–734 (1995)
15. McKnight, D.H., Cummings, L.L., Chervany, N.L.: Initial trust formation in new organizational relationships. Acad. Manag. Rev. **23**(3), 473–490 (1998)
16. Misztal, B.: Trust in Modern Societies. Polity Press, Cambridge (1986)
17. Mou, J., Shin, D.-H., Cohen, J.F.: Trust and risk in consumer acceptance of e-services. Electron. Commerce Res. **17**(2), 255–288 (2017). https://doi.org/10.1007/s10660-015-9205-4
18. Nazarko, J., Ejdys, J., Halicka, K., Magruk, M., Nazarko, Ł., Skorek, A.: Factor analysis as a tool supporting STEEPVL approach to the identification of driving forces of technological innovation. Proc. Eng. **182**, 491–496 (2017)
19. Putnam, R.D.: Bowling Alone: The Collapse and Revival of American Community. Simon & Schuster, New York (2000)

20. Siderska, J.: Cloud manufacturing: a service-oriented manufacturing paradigm. A review paper. Eng. Manag. Prod. Serv. **10**(1), 22–32 (2018). https://doi.org/10.1515/emj-2018-0002
21. Song, R., Korba, L., Yee, G.: Trust in E-Services: Technologies, Practices and Challenges. IGI Global, Pennsylvania (2007). https://doi.org/10.4018/978-1-59904-207-7
22. Wasiluk, A.: Trust and areas of cooperation between companies and institutions of science. In: Conference: 21st International Scientific Conference on Smart and Efficient Economy - Preparation for the Future Innovative Economy Brno: Brno University of Technology, pp. 629–636 (2018)

Offline and Online Citizen Activism in Russia

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Abstract. The article is devoted to the analysis of civic activity in modern Russia. The article presents the results of a longitudinal study of civic activity in Russia since 2014. The study is conducted by a survey of experts. Particular attention is paid to the analysis of the development of online and offline civic activity.

Considerable attention is paid to the analysis of mobilization and demobilization in civic activity. It examines what forms of organizations are most significant in civic engagement, as well as how authorities react to their activities, what tools are used to demobilize citizens.

The research show that the degree of development of civic activity has remained at approximately the same level for several years. At the same time, on-line activism is more developed than off-line. It seems that online activism is more massive and affordable, less labor-intensive for ordinary participants. At the same time, the Internet provides a fairly diverse set of tools, the application technologies of which are developing. Internet technologies are used as a mechanism by which political action can be seen by authorities and the public. At the same time, the state is forced to respond to such changes and is stepping up to regulate various forms of activity on the Internet.

Keywords: Civic activism · Internet · Mobilization · Demobilization · Protest · Network

1 Introduction

Nowadays there is a development of citizen activism manifested in various forms in Russia, such as: volunteer clean-ups, charitable assistance, organizing leisure activities, meetings, demonstrations, etc. At the same time, political practice demonstrate decrease in the involvement of citizens in traditional organizations (non-profit organizations, political parties), and an increase in the activity of informal and non-registered forms of citizen activism (crowdfunding, crowdsourcing, creating and signing petitions, blogging and pages in social networks) [1; 27].

Thus, the Internet space is actively used not only by ordinary users, but also by various actors at all levels, including the process of organization and implementation of citizen activism. The Internet is an alternative environment for public and political campaigns, which challenges traditional ways of political activism.

The gradual introduction of ICT products such as social networks, forums, blogs, video hostings and other electronic means of communication has made it possible to

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express a civic position to a wider range of people without restrictions on gender, age, location, level of education and work experience. Hypertextuality, accessibility and speed of information dissemination in social networks have made them an effective mechanism for uniting, coordinating and expressing the users' interests in the virtual space. Researchers note that the Internet has had a significant positive impact on the development of citizens' self-organization [2; 423]. However, despite the pervasive impact of new technologies on social and political processes, the topic of comparison of the real world and the virtual world, as well as the processes that take place in them, remains debatable. Thus, there is a point of view that the virtuality of the Internet, as a special environment for communication, creates a symbolic reality that replaces the objective reality [3]. Therefore there is a factor of discrepancy of the processes occurring in the online reality. Of course, the factor of virtuality really affects the perception of processes taking place on the Internet and various online platforms, however, users primarily interpret their real experience, transferring it to the virtual space, which, in turn, connects offline and online.

2 Transformation of Citizen Activism. Does It Exist?

One of the key factors required for the development of democratic legal states is the existence of various forms of self-organization of citizens [4; 233]. Broadly speaking, various forms of self-organization of citizens can be described as "a citizen activism is a form of activity of society, which is aimed at the realization of social interests, it is inherent in the individual, as well as various public associations of citizens" [5]. The peculiarity of its implementation is the dependence on many factors, such as: political, social, public and economic ones. The spiritual and cultural values of society as a whole and of each individual have a significant influence on the conditions for starting citizen activism [6; 61]. The interaction of these factors creates a certain social and political space where there are certain conditions for the implementation of citizen activism.

An important characteristic of modern conditions of citizen activism is the decrease of citizens' confidence in the government and in public associations at the same time (including political parties). In this regard, the key factor in the manifestation of citizen activism is personal interest, not belonging to any group or organization. A person does not aspire to demonstrate his citizen activism and take part in the society actions without a personal interest. At the same time, personal interest is not associated with abstract rights and freedoms, but lies in the plane of a person's personal space.

The development of information and communication technologies generally favors citizen activism, as it promotes the aggregation and articulation of civic interests, self-expression and public activities to protect their interests, as well as it helps self-organization, bypassing official institutions. K. Shirki points out that the global network has transformed the politics and citizens' activity, facilitating the involvement of new participants [7]. In addition, under the conditions of severe restrictions of opportunities for organizing public events, citizen activism is transferred to the Internet to a certain extent, which currently provides relatively broad opportunities for expressing a position without the threat of sanctions.

Thanks to the use of ICT, the mobilization of supporters becomes more dynamic, in some cases like an avalanche because social media allow you to access a significant

number of people through their accounts, thereby attracting a socially significant number of supporters and participants [8; 347].

The transformation of a virtual citizen activism in comparison with its expression in the offline environment consists in expanding opportunities for expressing one's position on the Internet. If earlier the main activity was going to meetings or protests, now the activity can only appear on the Internet and not have the development in the offline environment. In these conditions, the government is also being transformed, being able to respond more quickly to citizens' requests: monitorings of social networks are being organized; official pages and groups of public politicians and local and state authorities are being created, introducing regulation of online activity, etc.

The legislative bodies of many states regulate the citizens' activities on the Internet, in fact recognizing it as legally and politically significant. An example of official recognition of Internet activity as real actions is the decision of a court in Zurich, which sentenced a citizen to a fine for a Facebook like (since it indicates approval and agreement with the corresponding post) [9]. In June 2016, the Perm regional court issued a verdict in a criminal case on the rehabilitation of Nazism: a citizen reposted "knowingly false information about the activities of the Soviet Union" [10].

It is quite common at the moment to create groups in social networks that can actually support and to some extent replace the activities of social movements, both in terms of promoting the protection of citizens' interests and solving specific socially significant problems. Tools to create event pages with invitations to these events, as well as surveys to identify public opinion on various issues are actively used. Link and hyperlink tools allow you to navigate to the most interesting pages quickly.

As a result, there is a need to maintain pages in social networks for constant communication with your supporters and target audience. Institutional entities of citizen activism (parties, non-commercial organizations etc.) must create and maintain websites in order to retain their audience, and the recent trend has been the creation and maintenance of accounts, pages, and public pages in social networks.

Political practices demonstrate dynamic development of new forms of communication and information exchange that appear thanks to ICT. They are used for sharing experience, resources, and demonstrating the results of one's activities. These forms are the following: social networks and streaming services, messengers and professional social networks, etc.

Social networks can perform both a communicative and organizational function, allowing users to achieve their goals. Researchers also note that they act as a source of information [11; 335], and also allow to form an identity that plays an important role in the course of collective citizens' actions [12; 52]. In this regard, modern research shows a significant potential of social networks in the formation of group identity, which allows to mobilize activists in collective actions [13]. Professional journalist and analyst Will Kenton emphasizes that social networks are an online tool for interacting with other people who share the same interests, experiences, or interact in real life [14]. A researcher from the University of California, M. Boyd, points out that social networks are a number of services for creating accounts, profiles and public pages for communicating with a wide range of users and forming their various associations [15]. In Russian studies social networks are generally given a similar definition. Thus, I.E. Steinberg understands social

networks as communities where people can share opinions and points of view freely and form friendly relations on this basis [16; 87].

Thus, online citizen activism is a form of expressing the interests of society, aimed at solving any social problems, carried out using the Internet tools provided, implemented by both a group of individuals and just individuals. In this context, the classification of citizen activism given by E. Zuckerman [17; 159] is of interest. The researcher identifies two key characteristics:

- according to the degree of citizen involvement: insignificant (actions with their profile in social networks, signing of collective citizens' appeals on the Internet) and significant (involvement of loyal citizens in collective actions, planning and organization of collective actions);
- according to the form of activity: instrumental (activity aimed at transforming the institutional environment) and demonstrative (citizens' activity to express their opinions).

At the same time, a researchers pay attention to the specifics of the impact on activists of various content posts in social media. Studying various formats of posts and materials, R. Heiss, D. Schmuck and J. Matthes found that emotionally-colored posts attract more user attention, and mobilization posts negatively affect user engagement [18]. J. Kim and K.D. Hyun agree with this conclusion and consider the mobilization role of political discourse in social media and conclude that political agreement or disagreement with an information resource can lead to both an increase and a decrease in political activity [19].

At the same time, it should be noted that not everyone identifies online activity with offline activity. In particular, E. Morozov says that actions on the Internet do not entail mandatory participation and are not related to actions in everyday reality [20]. They only form a sense of personal satisfaction from the actions performed in virtual reality.

A similar position is held by M. Gladwell [21]. He does not consider the Internet activity to be a significant phenomenon and does not equate it with real activity, because the Internet activity excludes the possibility of threats, violence or arrest. However, you can disagree with this statement of the researcher, since there are some cases of arrests for posts in social networks or even reposts of certain publications [22]. It gives the opportunity to say that the authorities recognize activity (and statements) in social networks as significant as in traditional forms.

M. Gladwell also points out that collective action requires trust, which is formed only when individuals interact directly. However, even in this case, we can argue with the author: Z. Tafochi's researches suggest the formation of strong and long-term links between activists through communication in social networks [23; 202–208].

The need for trust is also related to the fact that many collective actions are organized on network principles. The network structure of collective actions, as one of the most successful in providing movement with resources, increases its life cycle and ability to interact with authorities or counteract them as antagonists [24; 366].

It is also noted that associations formed on the Internet cannot be characterized as stable and static because of the low cohesion of participants, low readiness for real actions, the complexity of mass formation and the constancy of actions [25].

Therefore, additional difficulties and risks are created during its implementation. Among them are the following:

- complexity of interpretation and optionality of forms of activity in social networks, which may mean that the actual results do not match the stated ones;
- simplicity of organization of monitoring activity in social networks makes the activity not only easy to track, but also available for using for the purpose of misinformation or slander;
- lack of institutionalized mechanisms for the authorities to respond to opinions expressed;
- possible bot attacks;
- blurring of information, a large number of sources of opposite information;
- blurring and indifference of the audience;
- loss of interest from the audience to the subject of activity in a situation where there are no quick results.

The need to take into account these risks leads to a complication of the process of organizing and maintaining citizen activism in social networks. Despite the simplicity of use, they can have a negative effect if there is no proper attention to the methods and forms of information dissemination, communication with like-minded people, the authorities and the media.

Summarizing all the above mentioned, it can be said that the peculiarity of online citizen activism is that it is easier to show virtual activity, and also that the responsibility for it is still minimal and is not fully realized by virtual activists. In addition, the specificity of Internet communication allows you to form trusting relationships between users and initiators of citizen activism, forming the potential for further involvement in the activity [26; 227].

3 Research Procedure

Increasing the intensity of citizens' participation in various forms of collective action forms a request to study the organization and features of collective action in modern Russia. The purpose of this paper is to identify the basic characteristics of civil activity in modern Russia at the regional level. The authors set a number of tasks:

- identify the level of civic engagement (online and offline);
- determine the nature and impact of the government's response to civil activity;
- identify the features of cooperation between public organizations and civil activists.

The authors conducted a series of surveys of experts in the subjects of the Russian Federation in order to achieve the objectives. In 2014 the study included 21 regions, in 2015 – 14, in 2017 – 15, 2018 - 14, 2019 - 15 (Table 1).

Table 1. Research sample (regions and number of experts).

Constituent entity of the Russian Federation	2014	2015	2017	2018	2019
Altai Krai	12	–	–	10	
Vladimir Oblast	12	–	–		
Vologda Oblast	11	–	–		
Voronezh Oblast	11	12	11	13	12
Irkutsk Oblast	14	11	10	11	10
Kaliningrad Oblast	11	–	11	10	10
Kemerovo Oblast				10	12
Kirov Oblast	13	12	11		11
Kostroma Oblast	10	11	11	12	11
Krasnodar Krai	10	10	–		
Nizhny Novgorod Oblast	10	–	–		
Novosibirsk Oblast	10	15	–		
The Republic of Adygea	11	11	12		11
The Republic of Bashkortostan	10	11	10	10	10
The Republic of Dagestan	12	13	11		13
The Republic of Karelia	11	–	–		
The Republic of Tatarstan	10	10	10	11	12
Rostov Oblast	–	–	14	11	11
Samara Oblast	10	13	11	13	10
Saratov Oblast	12	14	14	13	
Stavropol Krai	–	–	10	10	10
Ulyanovsk Oblast	10	10	10	10	10
Khabarovsk Oblast	10	–	–		
Yaroslavl Oblast	13	12	16	11	12
In total	233	165	172	155	165

At least 14 constituent entities of the Russian Federation were selected annually to conduct a survey of experts. A representative sample of regions was provided based on the principle of heterogeneity according to the following selection criteria:

– geographical location;
– economic development of the region;
– political system of the constituent entity of the Federation;
– social and demographic structure;
– ethnic and religious structure of the region;

– regional political and administrative regime;
– territorial belonging to a specific federal district.

Implementation of the principle of heterogeneity in the selection of regions provided a representative sample in size of more than 14 subjects of the Federation.

According to the methodology, the regions selected for the study are included in six Federal districts: from the North-West to the Siberian district (Ural and Far Eastern Federal districts are not included in the sample). Applying this approach to the analysis of citizen activism allows us to extend the findings of this study to the country as a whole.

The Central criterion for the selection of experts was competence involving:

– awareness of the nature and content of citizen activism in the region;
– knowledge of the main mechanisms of functioning of the political system of the region;
– joining a particular regional political elite group;
– experience in the field of public politics and/or state authorities and local self-government;
– knowledge of the main actors in the regional political process;
– knowledge of the political situation in the region.

The main criterion for getting into the expert group was awareness of the problem under study. Resource groups were:

1. Representatives of the authorities. This sector includes: employees of regional government bodies (executive and legislative), employees of state institutions and organizations, employees of local government bodies and municipal institutions and organizations;
2. Representatives of the socio-political elite who do not hold positions in government. This sector includes: heads of regional and local branches of political parties, heads of non-profit and public organizations, representatives of the media;
3. Expert community. This sector includes: representatives of specialized academic institutions and political experts who are not included in the above-mentioned structures.

Each of the target groups was represented relatively evenly in each of the samples (both in each constituent entity of the Federation and in the sample as a whole): representatives of authorities (about 35% of the sample), representatives of non-profit organizations and political parties (about 30%), representatives of the expert community (about 35%).

The total number of respondents for the survey of experts in each constituent entity of the Russian Federation was at least 10 people. This made it possible to obtain representative data on the situation in the region.

It should also be noted that the level of competence also depends directly on the degree of involvement of experts in the regional political process in a particular status. The above-mentioned status groups suggest a high probability that the expert is significantly involved in the political process in the constituent entity of the Federation.

The main purpose of the expert survey in the framework of the study was to identify the most significant and important aspects of collective action through the use of knowledge and experience of experts.

Statistical analysis of data in the SPSS software product was used for date handling. During processing, the method of independent characteristics was used. It allowed us to give a generalized assessment of a single phenomenon, information about which comes from several independent experts. Comparison and contrast of different opinions were held on the first stage; handling with mathematical-statistical procedures was held on the second stage, formulated conclusions were formulated on the third stage.

During the research the experts were asked the following questions:

- What do you think is the extent to which offline (traditional) and online (activity through the Internet) civic activity is developed in your region? (rate it on a scale from 0 to 10, where "0" is lack of civic activity, and "10" is large-scale civic activity)
- Evaluate the level of protest activity offline and online in your region for 2018 (rate on a scale from −5 to 5, where "−5" - a sharp decrease in protest actions, 0-without changes; "5" - a sharp increase in protest actions for each of the forms of activity)
- To what extent is political activity on the Internet significant in your region? (you can select several of the suggested options)
- How do you think the dynamics of civil online activity in your region has been affected by the activation of the state in the sphere of regulation of the Internet environment in recent years? (select one of the suggested options)
- How would you assess the changes in the direction of civil activity online in your region as a result of the state's activation in regulating the Internet activities? (select one of the suggested options)
- How does the state react to offline and online forms of civic activity? (select one of the suggested options for each of the forms of activity)
- What factors, in your opinion, contribute most to increasing the effectiveness of civil campaigns to defend the rights of citizens in your region? (select one of the suggested options)
- How does the state react to offline and online forms of civic activity (you can choose the appropriate responses for each of the forms of activity)? (select several of the suggested options for each of the forms)
- How many partners are usually united in offline and online coalitions of public organizations and civil activists in your region? (select one of the suggested options for each activity form)
- Assess how important these principles of interaction are for the functioning of cooperation between public organizations and civil activists? (on a scale from 1 to 10, where 1 is the least significant and 10 is the most significant)
- To what extent do the authorities in your region counteract offline and online protest activity? (rate on a scale from −5 to 5, where "−5" - opposition to protest activity, "0" - lack of any impact, "5" - orientation to cooperation for each of the forms of activity)
- For what reasons do you think the authorities in your region choose a particular strategy in their relations with the protesters? (select several of the suggested options for each strategy, if they are present)

– What forms of counteraction to the organization and conduct of protest events are used in your region? (select several of the suggested options)

As a result, the research revealed not only the characteristics of online and offline collective actions in modern Russia, but also the dynamics of changes in these indicators, as well as their features in various regions of the Russian Federation.

4 Citizen Activism (Off-line and On-line): Development, Tendencies, Singularities

According to the monitoring study, in 2019 the overall level of citizen activism in the constituent entities of the Russian Federation changed slightly, remaining close to the value of 2018 – 5.60 points (where "0" - lack of citizen activism, "10" - large-scale citizen activism). For the first time since the beginning of this study, i.e. since 2014, many experts refused to talk about the general increase in social activity in Russian society. Moreover, the relative stability of the indicator value was possible only due to the increase in the intensity of citizen activism in the Network (+0.30 p. in 2019), since in real life it falls (−0.39 p. in 2019). The decrease in social activity in offline mode occurs against the background of the gradual distancing of the state from its support.

It is important to note that the popularity of the Internet is not a determining factor in the development of social online activity. The results of 2019 once again prove this conclusion: in the constituent entities of the Southern Federal District and the North Caucasus Federal District the lowest expert appraisals of the development of citizen activism in the Network are observed while the level of Internet penetration is more than 80% [27].

The involvement of the state in regulating the Internet environment affects the overall dynamics and content of citizen online activism, but it is also not a decisive factor. The most optimistic experts in this issue are the organizers of online protest actions. It is important to note that the degree of influence of government measures to regulate online content on social activity on the Internet varies depending on the region. Thus, one of the most important factors determining both the dynamics and content of social online activities is the attitude of the authorities of the constituent entities to it. For example, in the constituent entities with the most pronounced dislike or indifference of the authorities to online activity, it is less developed (Voronezh Oblast, Kirov Oblast, the Republic of Tatarstan, Stavropol Krai, Kemerovo Oblast. The exception is the Republic of Adygea).

The process of moving away from "real" citizen activism to "virtual" activity observed in 2019 may indicate both the availability of other mechanisms for implementing citizen participation in society (the growth of administrative "barriers") and the reluctance of people to spend more energy than it is required by pressing the button on the keyboard.

According to the study, civil society activists in Russia either distance themselves or do not want to identify themselves with the leader(s). It is important to note that the number of public figures who chose this model of command in relation to leaders increased over the year (from 90.3% to 94.5%). For the rest, the nature of self – identification of civil activists has not changed over the specified period. It is still threefold: territorial,

value and community-based. As in 2018, in 2019 they tried to rely on specific values and ideology in their activities (30.1%). This factor of self-identification of civil society activists remains the strongest in the evaluative judgments of experts – the average expert assessment was 6.85 points on a 10-point scale (where 1 is the absence of influence of the factor, 10 is the strongest one). Every fourth expert believes that civil society activists identify themselves with a certain territory (26.4%). In 2019 the strength of this factor increased and was estimated by experts at 6.64 points. One in five participants in the study in 2019 believed that civil society activists identify themselves only with their association and their like-minded people.

In 2018 it was found that there was a serious misunderstanding and even contradictions of self-identification between the leaders of protest actions and their ordinary participants. This lack of understanding continues to be relevant in 2019. Its essence lies in the fact that the first ones often identify themselves with a certain ideology and values, and the second ones identify themselves with a certain territory, i.e. a group of citizens of one microdistrict, district, city or region.

For the second year in a row the issue of politicization of citizen activism in the constituent entities of the Russian Federation is perceived ambiguously – in 2018 and 2019 about 80% of them had doubts and did not have a clear answer to it. Thus, this process is complicated and not obvious due to the small influence of civil society activists on political processes in the country, as well as the reluctance of many of them to disclose the real goals of their activities. In general, citizen activism in the country was less politicized in 2019 than in 2018. In 2018 the rise of civil activity in the political sphere was associated with elections at the federal and regional levels.

The popularity of citizen activism on the Internet among Russian residents contributes to the raise of the role of its political component. The effect of using the Internet for political purposes is noticeable to leaders and ordinary participants of protest/non-protest actions, as well as to ordinary observers.

The effectiveness of civil campaigns to defend the rights of citizens depends on many factors. Over the past three years "support from the media, bloggers and the Internet community" and "a wide support from the population or large social groups" have been recognized as the most important experts in Russia. At the same time their importance has increased in 2019. It is interesting that the organizers of non-protest offline and online actions make their effectiveness dependent on information support, while protest actions – on the mass (number of supporters). Such a factor as "support from federal government agencies", on the contrary, loses its significance for civil activists

As already noted, the forms of the reaction of the state to various manifestations of the activity of public organizations and civil activists have an impact on the dynamics and content of citizen activism in the offline and online environment. The dynamics of expert responses to the relevant question over the past three years has revealed signs of a change in the attitude of the state (authorities) to manifestations of social activity. This trend affects both "real" and "virtual" activities of socially active citizens. Representatives of the authorities began to distance themselves from them and look at them with caution, warily. A somewhat similar situation was observed in 2013 after the Russian Presidential election in 2012, when 45% of experts reported authorities' concerns about the social activity of the population (47% in 2019). However, in 2013 there was no

clearly formulated state policy regarding civil activists and public organizations and the process of institutionalization of interaction between the state and civil society has just begun to move into an active phase.

The research demonstrate several objective reasons for changing the mood of the government in relation to activists. The first one is the impact of federal election campaigns. In 2018 there was a strong politicization of citizen activism. It became one of the pre-election technologies for the purpose of promoting a particular candidate or destabilizing the socio-political situation. The second one is that online political activity is a fairly effective "weapon". In 2019 26.7% of survey participants said that political activity on the Internet "has a significant impact on the achievement of goals by civil society activists", while in 2018 15.5% of survey participants held a similar view.

From 2013 to 2017 the positive results of citizens' participation in solving common problems often motivated government representatives to support them. According to the results of the expert survey-2019, this practice in the relationship between the "power" and "people" sectors has become much less common during the last year. So in 2017 47.9% of experts spoke about the authorities' support for offline activity, while 31.4% spoke about online activity. In 2019 the figures obtained for these parameters were significantly lower – 35.0% of experts spoke about the support of offline activity (here we are mainly talking about minor assistance), and 26.4% of experts spoke about the support of offline activity.

Let's note that the described tendencies are common to the country as a whole, each individual constituent entity has its own specifics.

The results of the study show that in 2019 formally unregistered associations of citizens were the most active in Russia. For example, local groups, social movements, Internet communities, etc. This situation is observed for the first time and is associated with the growing popularity of civil online activity. It is partly similar to 2015, when registered and unregistered public associations made equal efforts to mobilize their activities against the background of the events of the "Crimean spring of 2014". Officially registered associations were somewhat less active in 2019 than unregistered ones. In addition, after 2017 they are becoming more and more passive.

In 2019 social activists recoursed to creating coalitions as often as in 2018. Every year they become more numerous and the past year was not an exception. Despite this, small coalitions, no more than 6 partners, continue to prevail among civil society activists.

The organizers of mass public actions, apart from the choice of the form of its conduction (offline or online) have different attitudes to the creation of coalitions. The first ones try to find and solicit the support of the maximum number of activists (supporters), while the second ones prefer to be limited to 2–6 partners.

Traditionally, the most important principles of cooperation between public organizations and civil society activists are recognized by experts are the following: the presence of a common interest (goal) and a voluntary nature. The role of the external communication system is gradually increasing. In general, the experts highly appreciated the importance of all the generally accepted rules of cooperation presented in the study, whether they are issues of financing, openness, equality, etc. (Table 2).

Table 2. Network characteristics of citizen activism (in 2014, the measurement was carried out on a 5-point system, then – on a 10-point system).

Guideline	2014	2015	2017	2018	2019
General interest/purpose to the cause of citizen activism	2,6	7,28	8,55	8,66	8,19
Voluntary nature of participation	4,1	7,37	7,86	8,00	7,74
Availability of a developed external communication system	–	–	–	7,26	7,51
Openness and development of the system of external relations	4,6	5,95	7,47	7,43	7,38
The basis of interaction is confidence; it is a contractual structure based on agreed formal and informal rules	3,4	6,63	7,42	7,78	7,18
Well-regulated financial questions	–	6,67	7,37	7,33	7,05
Organizing of communications that provide equal access to information for all coalition members	–	6,36	7,29	7,08	7,03
The obligatory presence of communication with the authorities	–	–	–	6,86	6,69
Equality of constituent entities, coordination without hierarchical management, formation of a joint decision on issues of interest	3,8	6,05	6,39	6,77	6,55
Lack of competition between the coalition and its members	–	5,82	6,07	6,01	6,50
Resource interdependence, i.e. a network is formed to develop agreements in the process of exchanging resources available to subjects of citizen activism	4,4	5,76	6,46	6,82	6,46
Predominance of horizontal links over vertical ones	4,5	5,74	5,88	6,71	6,05
Organizations must be protected from losing their own autonomy	–	5,48	6,17	6,57	5,98
The average	3,9	6,28	6,99	7,18	6,95

5 Mobilization and Demobilization in Civic Activism

The mobilization by unregistered public associations are developing. In 2019, for the first time in the entire study period (since 2014), the level of activity of unregistered movements exceeded officially registered organizations (by 2.1%). The growing role of social media in the citizens' life, the training of civic activists in mobilization technologies, the search for new forms of civic activism, as well as the prevalence of protests on a local problem - all together led to an increase in the activity of informal movements.

It is noteworthy that the organizers of protest and non-protest actions note the greatest activity of officially registered associations. The level of their immersion in the activities of public associations (that is, knowledge about real and virtual activity) gives grounds for this. Ordinary protesters see more activity through the prism of presence in the information field, including the Internet.

Civil offline activity over time is increasingly accompanied by online activity. Responding to forms of real and virtual activity, the state as a whole expresses little support to civic activism. At the same time, offline activity seems to be more dangerous and real, therefore it requires regulatory measures and counteraction. Online activity raises some concerns in the government and, in this regard, reluctance to interact. The fears of the authorities and officials in relation to an active public automatically lead to the need to establish mechanisms for its control, regulation, or even protection.

The presented factors influence the formation and transformation of the strategy of political demobilization of citizens in protest in modern Russia. The strategy is associated with the planning and management of political processes. A set of technologies and tools is used for its implementation. According to the study, it can be noted that the regional authorities react differently to on-line and off-line protest activity. However, it is worth noting that the actions of authorities aimed to cooperation with civic activists have a stabilizing effect. A series of protest campaigns in 2019, which have a wide resonance in society, thanks to concessions by the authorities ended in favor of activists. Among these are the case of Ivan Golunov, forest fires in Siberia, a protest against the construction of a church in Yekaterinburg. As a result of these success stories, the value of protest increases as a tool to protect civil rights and interests. Moreover, the orientation toward rapprochement of power with citizens took place as a necessary measure aimed at relieving part of the tension accumulated in society. This measure has a dual effect - both demobilization and mobilization at the same time. So, overcoming the threat of destabilizing society with an accompanying moderate level of mobilization of civic activists is a positive experience in the interaction of government and society in 2019.

As the reasons why the regional authorities choose this or that strategy in relations with protesters, experts point out the following:

– the authorities are afraid of destabilizing the situation in the region, therefore they make contact with the protest groups (cooperation strategy);
– protests are too small for the government to pay attention to them (ignoring strategy);
– the authorities see the protest rallies as an attempt by the opposition leaders to speculate on social problems without striving to solve them (counter-strategy).

The reasons presented demonstrate which strategies are used by regional authorities. The results of the study demonstrate that, starting in 2018, the regional authorities changed their strategy of influence on the protesters, more often ignoring them or cooperating with them. Earlier, until 2018, according to experts, the counteraction strategy dominated. It should be noted that the most frequently used strategies indicated by experts are, in fact, intermediate between cooperation and opposition. Cooperation here is rather forced (in view of possible destabilization in society), and the rationale for the use of opposition is the actions of opposition leaders (who can speculate on social problems). In addition, the absence of a pronounced position is an indicator of maneuvering between the regional authorities' response to protest activity. Moreover, there is a dependence on the guidelines formulated at the federal level.

The orientation of the government's strategy towards cooperation with civic activists in the context of active protest moods in the country contains a demobilization effect.

A number of realized concessions in 2019 did not go unnoticed by the public, which allows us to note the success of such a strategy.

Experts' perceptions that the protests are too small for the authorities to pay attention to them give reason to believe that mass protest remains one of the key tools to achieve the goals. In addition, the idea that the authorities are in contact with the protest groups because of fears of destabilizing the situation in the region, which is not connected with the rationality of the activists' ideas, confirms the relevance of the mechanism of mobilizing citizens into mass protest.

Thus, under the influence of a number of factors, the framework for the interaction of authorities with protest groups was established, and a general strategic direction for the development of their relations was formulated. Based on it, the planning and management of these processes is carried out using technologies and tools. By tools, we mean the target instruments of influencing the object.

The results of the study allowed us to evaluate the forms of counteraction to the organization and the conduct of protest events in the regions. The most commonly used tools for the demobilization of citizens are:

– creation of administrative barriers to the organization of street actions (71.9%);
– pressure on organizers of rallies, leaders of protest groups (35.6%);
– publication in the media of materials discrediting protest groups (33.1%);
– persecution by law enforcement agencies (30.6%).

Thus, the actor of demobilization uses its advantages: administrative research and power. In addition, the tool related to the distribution of content in the media also demonstrates the peculiarity of social processes, an integral part of which are information and communication. During the monitoring study from 2012, these demobilization tools were also the main ones. Each year, the use of this "set" of forms of counteraction varies slightly, saving the leading position of these tools unchanged. It can be noted that focusing on the cooperation strategy is implemented more precisely and applies to special cases, rather than applicable to general practice.

A feature of 2019 was the choice of experts of the answer option "other". He scored 10.6%, which exceeds the values of some other options presented. Previously, the survey participants did not mark it at all. Possible reasons are:

– practical application of new forms of counteraction;
– attention of citizens to socio-political processes in recent years has led to adaptation, a more complete understanding and isolation of a number of demobilization tools.

Under the influence of the above factors and as a result of the general orientation of the strategy of interaction between the authorities and society, the authorities developed a pronounced and significant technology for the demobilization of citizens associated with the regulation of the Internet environment. The development of online civic activity, as well as an increase in its significance in reality, contributed to the development of activity management tools on the Web. Its implementation is carried out with the help of a number of tools - regulatory, political, communicative, and power. Nevertheless, experts argue that the activation of the state in the sphere of regulating the Internet environment

as a whole did not affect either the dynamics or the content of online activity. Despite some changes in general - the presence of fears among citizens about the consequences of their actions, as well as the temporary adaptation of citizens to new conditions, the development of online activity continues.

6 Conclusion

The role of the Internet in civic activism continues to grow. Its influence occurs in different areas of civic activity and manifests itself through various relevant processes. Some of them were fixed on the basis of research data.

In general, the degree of development of civic activity has remained at approximately the same level for several years. At the same time, online activism is more developed than offline. It seems that online activism is more massive and affordable, less labor-intensive for ordinary participants. At the same time, the Internet provides a fairly diverse set of tools, the using of which are developing.

Political activity on the Internet is becoming increasingly important. The opinion of experts is gradually shifting from the absence of any of its influence in the region to the presence of a significant (26.7%) or small (62.1%) influence on the achievement of civic activists' goals. Internet technologies are used as a mechanism by which political action can be seen by authorities and the public. The public space and the political discourse emerging in it contribute to this. Thus, activity in the virtual and real activities stimulate development and increase the effectiveness of each other.

Modern socio-political processes are characterized by the involvement of the broad masses in politics. These actions are based on the Internet tools. Habitualization of the Internet tools in the process of organization of citizen activism has occurred. At the same time there is still a discussion about whether offline and online activities of citizens can be considered different types of activity, or they are only different channels of expressing one phenomenon.

With the development of ICT and the introduction of social networks, the transformation of citizen activism began in the direction of strengthening the role of the communicative component of the interaction of an individual and a group, groups among themselves, groups and authorities, individuals and authorities. Therefore, the role of the channels of these forms of communication has also increased: social networks, forums, blogs, etc.

With the change of generations, with the development and growing popularity of Internet technologies, the Internet has become a tool for self-organization of citizens in Russia.

New forms of communication, mainly via the Internet, allowed citizens who want to participate in the public life of the city and the region to find contacts and opportunities to implement an active civil position. Internet tools have made the process of integrating people into society quick and easy.

The impact of Internet technologies on the forms, methods and intensity of citizen activism is multifaceted: on the one hand, the Internet allows articulating the citizens' needs and interests; on the other hand, it allows strengthening the influence of state structures on civil society.

The increasing role of virtual activity in socio-political processes leads to increased requirements for the legality, moral and cultural compliance of this activity in relation to generally accepted norms.

It can be said that there is a gradual process of institutionalization of virtual citizen activism. Moreover, this process can be considered two-way: activists seek to ensure that their activity in social networks is taken into account by the authorities when making decisions on any issue, and the government, in turn, seeks to create tangible scopes through legislative regulation, within which this activity can start.

As a result, there is a gradual development not so much of the forms of communication of the population in the framework of a civil campaign as of the citizen activism itself as a whole. The growing awareness of the possibilities of social networks increases the ability of activists and authorities to conduct a full-fledged dialogue in order to make the most acceptable decisions for both sides. The results of the research allow us to say that today no action of citizen activism is complete without Internet technologies, i.e. they are in a certain dependence on this means of communication. As a result we can talk about replacing real online activity with actions. At the same time, the state is forced to respond to such changes and is stepping up in the direction of regulating various forms of activity on the Internet.

The COVID-19 pandemic demonstrated the existing relationship between online and offline activism. The formation of social tension in the conditions of imposed restrictions is reflected in the Internet. A striking example was the protest actions in the application "Yandex.Navigator" at April 20, 2020. They demonstrated a number of features of the protest:

- network character (originating in Rostov-on-Don, the campaign quickly and easily spread throughout the country);
- offline restrictions strengthen the online protest;
- citizens can easily figure out how to use Internet applications in order to organize protest actions;
- the government reacts to any mass protest actions.

The case of the journalist Ilya Azar demonstrates that the introduction of a self-isolation regime cannot completely restrict offline forms of protest. Moreover, the authorities' desire to bring activists to justice provoked large-scale online activity of their supporters and the formation of a negative information context.

It can be assumed that the development of the Internet is a factor that contributes to the formation of broader coalitions in the process of organizing and implementing collective actions and the increasing activity of unregistered public associations.

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References

1. Bennett, W.L.: The personalization of politics: political identity, social media, and changing patterns of participation. Ann. Am. Acad. Polit. Soc. Sci. **644**(1), 20–39 (2012)
2. Devan, R., Jang, H., Yoonjae, N.: Birds of a feather protest together: theorizing self-organizing political protests with flock theory. Syst. Pract. Act. Res. **23**, 419–441 (2010). https://doi.org/10.1007/s11213-010-9167-3
3. Demicheva, K.A.: Concept and classification of social networks in the context of interaction on the Internet. Int. Sci. Rev. **3**(4) (2015). https://cyberleninka.ru/article/n/ponyatie-i-klassifikatsiya-sotsialnyh-setey-v-kontekste-vzaimodeystviya-v-seti-internet. Accessed 31 Aug 2019
4. Kruglov, M.S.: Modern forms of citizen activism in the political process of the Russian Federation. Theory Pract. Soc. Dev. **3**, 233–236 (2014)
5. Volkova, N.V., Guseva, L.A.: Citizen activism as a mirror of political, spiritual and cultural values of society. Mod. Probl. Sci. Educ. **5** (2013). http://www.science-education.ru/ru/article/view?id=10681. Accessed 25 Aug 2019
6. Frolov, A.A.: Mechanisms for the implementation of citizen activism. Vlast 10 (2014)
7. Shirky, C.: Here Comes Everybody: The Power of Organizing Without Organizations. Penguin Press, New York (2008)
8. Lovejoy, K., Saxton, G.D.: Information, community, and action: how nonprofit organizations use social media. J. Comput.-Mediat. Commun. **17**, 337–353 (2012)
9. The court in Zurich gave the world's first sentence for "like" on Facebook». https://news.mail.ru/incident/29922788/?frommail=10. Accessed 20 Jan 2018
10. Strugov, M.: Transportation to Nurnberg. https://www.kommersant.ru/doc/3026212. Accessed 20 Jan 2018
11. Gil de Zuniga, H., Jung, N., Valenzuela, S.: Social media use for news and individuals' social capital, civic engagement and political participation. J. Comput.-Mediat. Commun. **17**, 319–336 (2012)
12. Dalton, R.J., Sickle, A.V., Weldon, S.: The individual-institutional nexus of protest behavior. Br. J. Polit. Sci. **40**, 51–73 (2009)
13. Merle, M., Reese, G., Drews, S.: #Globalcitizen: an explorative twitter analysis of global identity and sustainability communication. Sustainability **11**(3472), 1–10 (2019)
14. Social Networking Service. https://www.investopedia.com/terms/s/social-networking-service-sns.asp. Accessed 12 May 2019
15. Boyd, D.M., Ellison, N.B.: Social network sites: definition, history, and scholarship. J. Comput.-Mediat. Commun. **13**, 210–230 (2008)
16. Steinberg, I.E.: "Live" and virtual social support networks: analysis of similarities and differences. Sociol. J. **4**, 85–103 (2009)
17. Zuckerman, E.: New media, new civics? Policy Internet **6**(2), 151–168 (2014)
18. Heiss, R., Schmuck, D., Matthes, J.: What drives interaction in political actors' Facebook posts? Profile and content predictors of user engagement and political actors' reactions. Inf. Commun. Soc. **22**(10), 1497–1513 (2019)
19. Kim, J., Hyun, K.D.: Political disagreement and ambivalence in new information environment: Exploring conditional indirect effects of partisan news use and heterogeneous discussion networks on SNSs on political participation. Telemat. Inform. **34**(8), 1586–1596 (2017)
20. Morozov, E.: The brave new world of slacktivism. http://neteffect.foreignpolicy.com/posts/2009/05/19/the_brave_new_world_of_slacktivism. Accessed 20 Jan 2018
21. Gladwell, M.: Why the Revolution Will Not Be Tweeted. http://www.newyorker.com/reporting/2010/10/04/101004fa_fact_gladwell. Accessed 20 Jan 2018
22. Activist Polyudova sentenced to two years for a post in the social network. http://www.bbc.com/russian/russia/2015/12/151221_polyudova_sentence_extremism. Accessed 20 Jan 2018

23. Tufekci, Z.: The medium and the movement: digital tools, social movement politics, and the end of the free rider problem. Policy Internet **6**(2), 202–208 (2014)
24. Brantly, A.F.: From cyberspace to independence square: understanding the impact of social media on physical protest mobilization during Ukraine's Euromaidan revolution. J. Inf. Technol. Polit. **16**(4), 360–378 (2019)
25. Bondarenko, S.V.: Features of creation and functioning of public platforms of "electronic democracy". POLIS **5**, 164–178 (2011)
26. Gilbert, E., Karahalios, K.: Predicting tie strength with social media. In: CHI 2009: Proceedings of the 27th Annual SIGCHI Conference on Human Factors in Computing Systems, pp. 211–220. ACM Press, New York (2009)
27. «Life on the Internet and without it». https://wciom.ru/index.php?id=236&uid=9024. Accessed 12 Dec 2019

Key Parameters of Internet Discussions: Testing the Methodology of Discourse Analysis

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Abstract. The results of current authors' research on the role of Internet discussions in processes of political e-participation are represented in the article. The investigators discover and evaluate fundamental parameters of socio-political discussions' quality from their deliberative point of view on basis of profound content analysis of 11 online discussions on Russian pension reform. The study of such parameters allows to formulate essence of discourse participants' opinions towards various social issues (for example, support or denial of pension reform). As a result, data sets combining original author's text of posts and generalized opinion are formed. Henceforth, it lets predict a type of opinion in dependence of text content, find out plurality and ambiguity of opinions on up-to-date theme. Such parameters as argumentation and civility are extensively analyzed in the article. The research methodology, based on conception of J. Habermas, that can be used in further similar investigations is revealed in detail.

Keywords: Deliberative standard · Discursive parameters · Internet deliberations · Discourse analysis methodology · Argumentation · Civility

1 Introduction

The majority of modern researchers points out that ICT have fundamentally transformed a public sphere and communications in all areas. Currently, social networks, Internet forums, crowdsourcing resources, web portals for collecting signatures and etc. give enormous opportunities for political participation, communication and mobilization [1]. They are becoming the leading platforms for discursive deliberation on burning social issues, diluting boundaries of public sphere and depriving media of monopoly on public opinion formation. In our point of view, an analysis of discussions on various Internet platforms can underlie taking solutions by government for pressing socio-political problems.

Nowadays, Internet discussions on various socio-political themes are becoming more relevant for researchers due to the fact that online deliberations more focus on critical discussion and reasoning of communicators' views on acute public issues. Therefore, the value of deliberations is that their participants can articulate their interests, openly express their positions and support them with significant arguments.

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Online discussions contribute to the development of democratic communication as they let participants reveal political creativity, openly argue about serious political themes and be heard by authority, lobby their interests without mediators. Thanks to exchange of views, positions on different social and political matters a public dialogue between government and society which is aimed at addressing certain problems, where citizens actively take part, forms.

Such features of Internet discourse as multiplicity and anonymity of users; diversity of their ideas and convictions; speech freedom, momentariness and efficiency of message delivery; dialogical and multilogical character of Internet content; conflict of acts, comments; plurality of messages and symbolic multiplicative characteristic of information; rapid transmitting and increasing of information; active usage of ICT make online communication between people specific and update a necessity of its detailed scientific investigation [2, p. 242].

The study of online discourse is a methodologically and empirically complicated task because of a great number of different approaches to its analysis. Many researchers from many countries deal with discourse analysis. For instance, specialists from Institute of Philosophy, Cardinal Stefan Wyszynski University in Warsaw under the leadership of Katarzyna Budzynska actively research the problematic of argumentation instruments' using. Also, Chris Reed from Argumentation Research Group of School of Computing, University of Dundee, UK studies the same field.

Berkman Klein Center for Internet & Society, Harvard University, USA is well-known by more traditional investigations of discourse analysis on Internet, in particular by network analysis methods' usage (Bruce Etling, Karina Alexanyan, John Kelly, Robert Faris, John Palfrey, and Urs Gasser). It is necessary to indicate on investigations of Fiorella De Cindio, a professor of computer science and communication department of University of Milan who uses the philosophy of Liquid Democracy for studying political processes and creating special apps, contributing to deeper comprehension of political debates and civil feedback [3].

A few scientific groups investigate separate aspects of marked issue in Russia. For example, the majority of Russian researchers, including E. I. Sheigal, O. F. Rusakova, V. G. Bazylev, T. I. Arutyunova, and M. V. Gavrilova, use a linguistic approach to analyzing discourse and base on the ideas of M. Bakhtin [4, 5]. They consider discourse as a powerful resource through which social actors can position themselves in the political sphere, actively manifest and implement their intentions. Other scientists who are the authors of this article analyze online discourse based on the concept of deliberative democracy of J. Habermas and investigation of communicative and political discussions' cores.

The basic goal of this article is to describe in detail a methodology of socio-political Internet discussions quality analysis and demonstrate the results of our research, allowing to test the methodology. Some of these results are represented in other publications [6–9]. However, this framework shows more details and conclusions.

The specific research task that needs to be solved by the research, presented in this article is to identify, evaluate and test the main parameters regarding the quality of socio-political online discussions in terms of their deliberation. Also, it is important to identify the epistemological potential of such parameters for determining public opinion

expressed in a discursive way through communication processes, considered as a source of experience, knowledge, dialogue.

Although many deliberative democracy theorists have specified the rules and procedures of deliberative discussion, in reality we have no examples and instruments to carry out discourse monitoring or estimate the level of opinion polarization.

2 Research Methodology

This method of Internet discussions' research is based on the method of discourse analysis, developed and fully described by Yu. G. Misnikov in his PhD thesis [10].

For creating a theoretical base of methodology Yu. G. Misnikov used a theory of communicative ethics of J. Habermas in terms of his deliberative democracy conception, i.e. democracy, based on debates and dialogue in public space of modern society. Habermas offered to consider a communication and discourse not only as an interaction of minimum two subjects who are able to talk and act, but as an interaction, connecting with relevant questions in social and political aspects. A communicative action is taken with a purpose of reaching an agreement towards an important for communicators question. If the agreement is impossible because of principal distinctions of positions, reaching a maximal understanding between them will be a key moment. Habermas payed attention to the fact that a communication is led exactly between subjects, not between a subject and an object. In other words, communicators have equal statuses and possibilities, therefore they construct a respectful dialogue, based on argumentation. The main criteria, determining a discourse, is conditions of public, equal in rights and natural communication, keeping in Socratic dialogue [11, p. 76].

Yu. Misnikov has created the "deliberative standard to assess discourse quality", where seven thematically different discursive parameters of the deliberative standard, corresponding to specific research issues and using for guiding the process of encoding messages of Internet discussions, are described. It is important to note that Yu. Misnikov was the first investigator to do this, since there were no direct analogues in the scientific literature at the time of his dissertations' publication. Each parameter of standard contains a set of specific empirical characteristics, intended to reflect certain discursive qualities.

The first parameter correlates with participatory equality and posting activism and contains seven characteristics: participant ID, participant username and membership status, post ID, participant post ID, post total ID and posting date. While investigating level of civil activity we have frequently come across to problem, connecting with unequal distribution of participation in discussions. Also, it cannot be denied that predominance of highly interactive, strongly personalized and often impolite features in Internet deliberations result in their weak, low and inadequate quality.

The second parameter reveals civility which is used for characterization of qualitative character of public online discussions and connected with demonstration of tolerant attitude. The civility data are not easy to interpret because of lack of universal approach, letting do it. There can be some situations when messages contain polite and impolite speech aspects at the same time. As a result, it causes difficulties in post coding. Besides the usage of rude expressions that explicitly illustrate intentional incivility, some messages can only imply unpleasant underlying theme. In some cases a response of online

discussions' subjects to such posts can be a reliable indicator, reflecting all the complexity of subjective relations that are formed between participants in the process of discussion. If we speak about polite messages, they can have a special objective. For example, such comments can be addressed to certain users in more personalized manner or with emphasis on a few aspects of topic that contributes to more involving of people in deliberation. On the whole, civility includes such expressions of attitude as:

1) civil (this kind of messages can be expressly polite or friendly welcoming, not necessarily supportive or critical);
2) normal (these messages are ambivalent or neutral, can be both critical and supportive);
3) uncivil (these messages contain expressly rude, derogatory or unfriendly, offensive or hostile moments, not necessarily critical, can be supportive);
4) other (hard to qualify because there can be different types of civility).

The following parameter is validity claim-making and consensual practices that includes propositional truth (objective world), normative rightness (common intersubjective worlds), subjective truthfulness (personal worlds), agreement (acceptance, approval, praise, positive, assent), disagreement (rejection, opposition, criticism, negative, dissent). We consider one more parameter: intent of speech acts that can be directive (direct, without any dispute and choice), commissive (there can be some corrections), expressive (predominantly emotional character).

The relevant constituents of discussions are such parameters as discursive interactivity and dialogism, covering personally addressed, including use of addressed names, to authors of seed post, 2 preceding posts or 10 preceding posts; impersonally addressed posts; direct references to other participants (including quotes); explicit responses (feedback) to other messages; quotation of seed post, 2 preceding posts or 10 preceding posts.

Dialogism conceptually emphasizes on environment and its external conditions. If a communicator has a comprehension of them and knows how to find a necessary approach to other people, he will understand himself and his communicative actions much better. However, there is a complication when self-realization and self-expression are through others. Our speech acts cannot be determined as original or terminal because they all have a preliminary history and simultaneously contain a presentiment, connecting with reactions of others on what was said or written. The dialogue is a recognition of needs and interests of others through reciprocity that includes not only agreements, but oppositions and contradictions as well.

The definition of interactivity is so close to «dialogism». Interactivity is commonly thought as a key to studying of public online discourses. In fact, it is not required for participants who are involved in public dialogue to face each other personally, they can interact remotely. Therefore, it is one of advantages of interactivity. In addition, discursive interactivity can give communicators a possibility to be dialogic and cooperative with people who have equal statuses. As a consequence, this encourages other citizens to participate in online discourse. Disagreements, polemics are considered as a part of interactivity as well. There is a dispute about participants and their possibilities to be interactive. Some researchers claim that interactive participants are those who answer

a previous message whereas others reckon that interactive participants try to give a response almost to all messages. From our personal angel, these two categories characterize participants as interactive ones, but the extent of their interactivity will differ noticeably.

We strongly believe that an overriding parameter of deliberative standard which also was investigated in our research papers is argumentation. It includes three directions:

1) facts, numerical data, statistics, conclusions, comparisons, logical inferences, generalizations, examples, other evidence presented to prove or disprove opinions;
2) references to online resources (within and outside thread, forum);
3) references to print and broadcast media.

Argumentation is variable and never static, it is primarily aimed at ensuring understanding between the participants in the discussions and maintaining a dialogue between them during interactions. The arguments are always important as they assist to see positions of consent and disagreement, which, in turn, can be democratic forms of public reasoning through interpersonal interaction.

The argumentation is an act of relative comprehension between communicators and mutual acknowledgement of other individuals and their points of views. Correspondingly, when commentators give arguments on the basis of reciprocity, their communication becomes more discursive. The quality of argumentation depends on relations between people who speak and listen because there is no sense when there is no constructive dialogue. The communication is considered as a relevant instrument when community reacts and gives a response to socially or politically important questions. Otherwise, a communicative act is useless and insensitive [5]. Isolated discourses almost have no sense for being analyzed, particularly in polarized socio-political relations since their participants are not enough represented as rhetorically persuasive and dialogically adaptive [12].

The final parameter is thematic diversity. The themes of discussions can be correlated with state and government, society and politics, economy, social problems, Russian regions, foreign relations (ex-USSR), foreign relations (overseas), culture and lifestyle, media and Internet.

This methodology, based on the conception of Habermas and significantly developing it (Habermas never quantified his results), was chosen because of a few reasons. First of all, we study online discourse from positions of political public relations, so a communicative aspect of discussions that we can investigate thanks to selected approach is important to us. The certain aspects of studying deliberations (argumentation, interactivity, dialogism, activity of participants, rationality, civility and etc.), aiding to describe a discussion, its members, and identify civil positions and their content were marked by scientists. Secondly, the procedure is clear and simple, there is no problem to make use of it by Excel program. When we research users' comments from Internet debates we give a three-unit code to each comment. As a result, it assists to determine a row of posts in chronological order and their authors, and also allows to see a quantity of posts that were made by the same author. Hence, these characteristics can be used during counting a number of posts and their producers. When it is about detecting the aspects of online discussions, mentioned above, there is a special method to note a

position. If there is something that we aim to investigate (for example, theme, content, comment, argumentation extent and etc.), we fix a position by writing «1» in space of program Excel. If there is nothing necessary, a space in Excel is empty. Making up overall conclusions, a general quantity of registered positions is counted and significant inferences are indicated. Thirdly, hand-operated data estimation and their coding can be brought to machine training that, undoubtedly, will accelerate and facilitate a work of researchers. Henceforth, it lets predict a type of opinion in dependence of text content, find out plurality and ambiguity of opinions on up-to-date theme.

3 Research Framework

For testing the methodological approach, Internet discussions on plans of Russian authorities to implement a pension reform were used (for analysis we chose Internet discussions on graft law on increasing of pension age). The research was conducted in December 2018–March 2019. Selecting Internet platforms with a purpose of studying online discussions, we used the typology of digital news media, proposed by Spanish scientist R. Salaverría [13]. In accordance with his approach the Internet sources can be divided by geographical characteristic. The investigator distinguishes global, national, local and neighbouring online sources. In our work we decided to modify that approach and adapted it for specific nature of Russian cities' geography.

In our research we selected the most popular Internet platforms of 11 different of Russian cities (in population), where the topic of raising the retirement age was discussed. According to the Code of Rules on Urban Planning, Planning and Development of Urban and Rural Settlements of the Ministry of Economic Development of the Russian Federation [14], cities are divided into the largest, large, big, medium and small. To analyze online discussions on pension issues we took two cities from each group. The sample included St. Petersburg and Volgograd (the largest), Kaliningrad and Sevastopol (large), Bratsk and Nalchik (big), Belorechensk and Snezhinsk (medium), Borovichi and Uryupinsk (small), a separate attention in our research was paid to Moscow due to the largest population in Russia. Sampling was based on next conditions.

Firstly, we selected the most popular urban platforms because they must be attended by citizens most of all (we have chosen the platforms which were higher in search results). Secondly, the priority was given to platforms where discussions on pension reform were conducted (not other close to pension question themes, a name of discussion and introducing to problematic post were checked). Thirdly, discussions on marked theme were filtered, at that a number of comments should have been a hundred and more.

When we were searching urban Internet forums for analyzing online discussions, our research interests came across the limitations, connected with Internet platforms' selection. It was found out that not all Russian cities have their own forums where the discussions on social and political topics, in particular pension reform, exist. However, if there are some Internet platforms where the question of pension age increase is discussed, the quantity of comments is less than 100. This fact causes additional restrictions for our sampling. Generally, we analyzed 5,405 comments written by 454 participants. The following gives a summary of all links on discussions (Table 1).

The methodology is universal and can be used to research not only Internet forums, but other types of Internet resources, including studying discussions on social networks

Table 1. Links on discussions

Cities and link on discussions	Number of comments and participants	
Moscow https://forum-msk.org/material/news/14733656.html	126	85
St. Petersburg https://www.spbtalk.ru/threads/43211/	1793	42
Volgograd https://www.forum-volgograd.ru/threads/96503/	284	67
Sevastopol https://forum.sevastopol.info/viewtopic.php?f=1&t=1368662&p=29429220&hilit=%D0%BF%D0%B5%D0%BD%D1%81%D0%B8%D0%BE%D0%BD%D0%BD%D1%8B%D0%B9#p29429220	123	38
Kaliningrad https://www.newkaliningrad.ru/forum/topic/368296-obsuzhdenie-pensionnoj-reformy/	561	23
Bratsk http://forum.bratsk.org/showthread.php?t=297973&fbclid=IwAR18K-_QjjAobA2MkG_N9i9E5baNOiuerNYjqBkxS_f-9k3AxSIK0Hu7B-Q	120	35
Belorechensk https://belorechensk.net/threads/povyshenie-vozrasta-vyxoda-na-pensiju.17340/	178	19
Snezhinsk https://forum.vega-int.ru/threads/povyshenie-pensionnogo-vozrasta.113243/page-18?fbclid=IwAR1HoJMtysXAEiBgYY_tg8-jYSXNcKiIiH-AlqXndWGogUdaeQLDqDtpXBQ	801	45
Uryupinsk https://forum.urup.ru/threads/povyshenie-pensionnogo-vozrasta-za-i-protiv.75437/page-3?fbclid=IwAR0q3pJANjcSGhPnYVsJgNU128LmkvQVeiw2yci0HeUaLFXokw3Cc6cZ27I	424	29
Borovichi https://forum.borovichi.ru/viewtopic.php?f=2&t=181076&start=270	312	44

(Facebook and etc.). In this case we have chosen Internet forums for analysis because a forum is a discussion on always certain theme where the topic is a center of deliberation. The quantity of participants is not restricted, a communication and multidirected relations are built. The forum represents a difficult and complex contact where people can express their opinion, argue and provoke a discussion. As a result, a communication on forums is more vivid and interesting for studying. Social networks are an environment where, first of all, social connections are formed and maintained; where people more frequently interact with only one communicator. It can be assumed that a forum is not just a conversation, but a social platform that is more like a cafe where people can see each

other and talk. Though people also express their thoughts and it can be learnt, a tendency, correlating with a shift from forums to social networks will be increasing in the future.

4 Research Results

We started with studying the activity of participants. It was significant to check how equally people take part in discussing and whether there are dominating panelists. Our hypothesis was that a lot of people leave plenty of comments and not many people write relatively a modest number of messages. During a research of posting periodicity it was defined that if there are 35 participants on forum, a person leaves nearly from 1,5 to 3 posts, so the discourse has a democratic character. However, if there are less than 35 users, a number of posts for a person varies from 8 to 15. The discussions on such forums are less democratic than others where a number of comments is minor and approximately equally distributed among participants as uneven proportions of participation in deliberations lead to deterioration of their quality.

In our work we distinguished a few groups of participants: inactive (1 post), moderately active (2–3), active (4–5), very active (6–9) and hyperactive (more than 10 posts). Then we investigated a relationship between participants' activity and argumentation of their positions towards pension reform. It was found out that approximately 70% of posts (minimal quantity of posts per one person – 10, maximum – 176) belong to hyperactive users. Hence, their argumentation is much more significant rather than argumentation of other users due to a quantitative measure. Hyperactive participants, leaving many comments, are able to navigate discussions in favorable thematic direction.

We analyzed argumentation of hyperactive participants accordingly to next positions:

1) subjective conclusions, analysis, conclusions, reasoning, generalizations;
2) subjective recommendations, suggestions;
3) any examples, cases, comparisons, events, dates, winged expressions;
4) objective facts (narrative, quantitative);
5) references to political figures (their actions are implied);
6) links on various online resources, print media, radio and TV.

The total percentage of argumentation was about 44,7% of all posts of hyperactive participants, however, it is worth mentioning that some posts contained several types of argumentation, some contained only one, and the rest did not. Conclusions, generalizations and reasoning associated with raising the retirement age, the consequences of the reform were used most of all (see Fig. 1).

It is curious that participants of online discussions often referred to politicians (for example, Putin, Medvedev, Zuganov, Grudinin, Navalny, Matvienko, Kudrin, Sobchak, Brezhnev, Elcyn, Gorbachev, Stalin, Lenin) and various information resources (about 95% were online sources, including social networks (mainly Facebook, Twitter, VKontakte and YouTube), online media (mainly articles and statements political figures), websites of political parties (United Russia, the Communist Party of the Russian Federation) and individual politicians (Navalny), online statistical resources, legal documents; TV and print media were rarely mentioned).

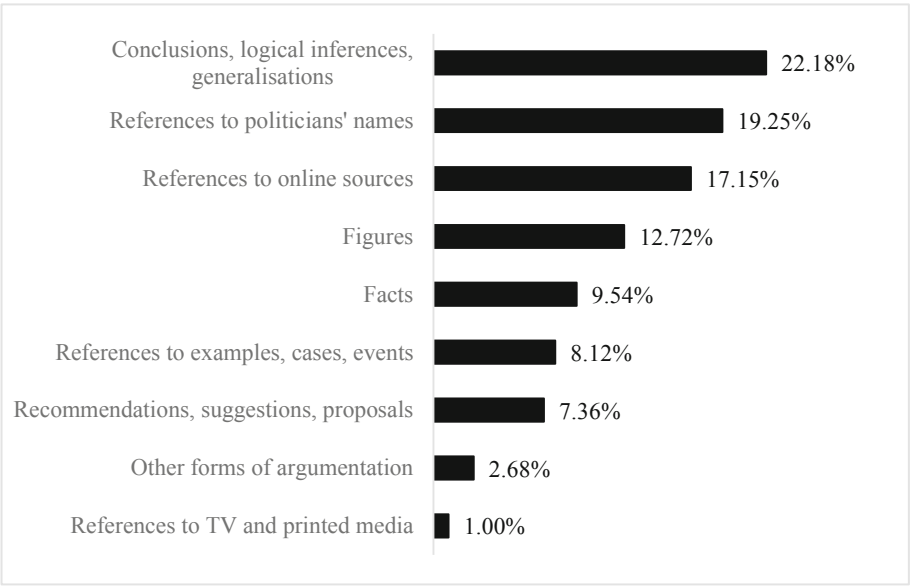

Fig. 1. Distribution of argumentation types on basis of all online discussions' analysis

We also based on classification of cities' types while assessment of hyperactive participants' argumentation level (see Table 2).

Table 2. The argumentation levels of hyperactive participants on different online platforms of Russian cities accordingly to classification

Type of cities	Number of participants	Facts, figures, examples, cases, politicians' names	Explicitly formulated arguments as conclusions or recommendations	References to broadcast media and other offline resources	All types of argumentation
The largest	12	17,8%	7,7%	7%	32,5%
Large	9	9,4%	6,8%	1,1%	17,3%
Big	15	24,2%	13,8%	9,7%	47,7%
Medium	24	20,7%	9%	12,4%	42,1%
Small	20	36%	32,2%	8,2%	76,4%

The data are ambiguous. For example, big (47,7%) and small (76,4%) towns have figures over average percentage (44,7%) whereas percentages of largest (32,5%), large (17,3%) and medium (42,1%) cities are lower. The highest percentage of argumentation

was reached by small cities. It can be explained by the fact that there is a good number of participants who predominantly discussed on pension reform. We can notice another pattern when dealing with argumentation of large cities. The quantity of participants is the lowest, but it is not the main reason of such a down level of argumentation. The highest level of interactivity among participants was marked in Kaliningrad (83%). However, their discourse was mainly not about pension reform. Factually, these participants sorted out their relationship, that is why their deliberations are full of negativity, insulting, abuse and rude expressions which significantly influenced on argumentation level. Instead of constructive dialogue with qualitative arguments we saw emotional feedback out of rationality.

We presume that argumentation level partly depends on civility and its characteristics (connecting with arguments or expression of emotions). It is possible to claim that argumentation and civility are primary discursive options (in our point of view, argumentation is the most considerable part of discussions) as they can be catalysts or decelerators of interactivity, activity levels of participants, etc. Therefore, argumentation and civility are qualitative parameters that can have a tremendous positive or negative impact on discourse and its direction while interactivity is quantitative and strongly dependent one.

We analyzed civility, figured out in deliberations on pension reform, in three directions with their characteristics:

1) interpersonal character = posts are directly addressed to other participants by name or personal expressions:
(a) posts are thematically empty, i.e. they are not about main theme and have exceptionally a personal character (this category includes only phrases or sentences with indication on interpersonal characteristics and any communications (neutral too));
(b) posts are obviously rude or offensive towards person, nationality, religion, ideology, place of living, etc. (differ from irony, humor, sarcasm);
(c) posts are explicitly polite and respectful towards participants (they can include irony, humor, sarcasm of inoffensive character);
2) posts do not include an explicit mention of participants' name, it can be directly or indirectly addressed to a certain person, someone else or all people:
(d) whether posts contain obviously rude or abusive expressions and vocabulary (irony, humor and sarcasm are excluded);
(e) whether posts are explicitly polite and respectful (including intentional politeness, irony, humor or sarcasm of inoffensive character);
3) posts are devoted directly or indirectly to pension reform:
(f) posts are on subject but rude towards a certain person;
(g) posts are on subject but rude, impersonal.

The total percentage of civility was near 50,61% of all posts, however, it is necessary to add that some posts contained a few types of civility, some contained only one, and the rest did not. The thematically empty posts (with indication on users' name and without direct or indirect mention of pension reform) constitute the majority of posts with civility (see Fig. 2). Commentators used posts on subject with rudeness towards a certain person less frequent than other posts (4,03%).

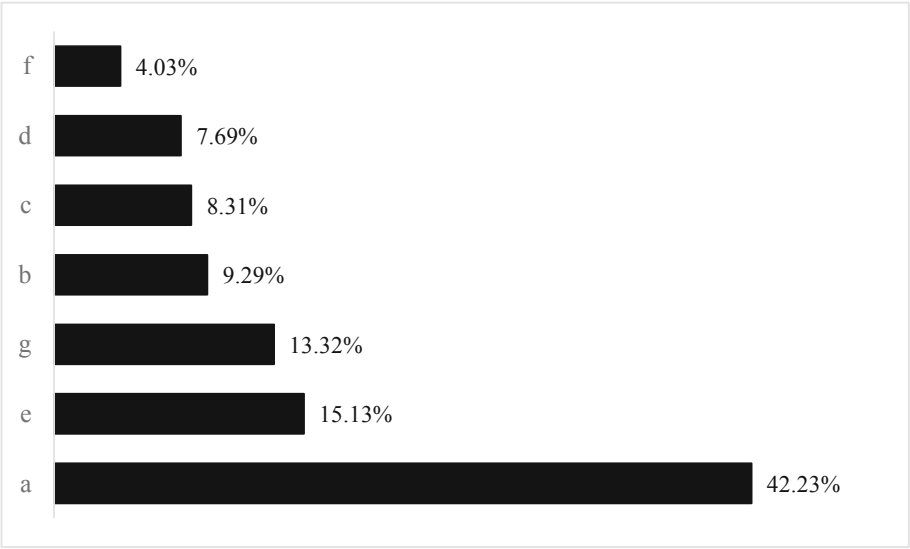

Fig. 2. Distribution of civility types on basis of all online discussions' analysis

If we try to explain argumentation patterns on basis of civility types' usage, we can see that thematically empty posts are used most of all by communicators. Consequently, it can be a reason of low argumentation levels in some towns. However, it is important to learn deliberations of every city and every classification separately and in detail as they have peculiarities and represent sometimes different communicative worlds.

We also used classification of cities' types while assessment of civility levels (see Table 3). The highest figures for civility were in the largest cities (78,94%). Large and small towns had almost the same numbers (73,53% and 76,4% respectively). The lowest figures were in big and medium cities (34,12% and 26,87% respectively). It is interesting to figure out why we e can see three different patterns of civility. To explain it we need to address to argumentation data.

Table 3. The civility levels of all participants on different online platforms of Russian cities accordingly to classification

Type of cities	Interpersonal character = posts are directly addressed to other participants by name or personal expressions	All types of civility
The largest	63,5%	78,9%
Large	48,7%	73,5%
Big	10,8%	34,1%
Medium	4,9%	26,9%
Small	49,9%	76,4%

First, start with big and medium cities. The argumentation levels of big (47,7%) and medium (42,1%) cities are so close to average percentage (44,7%). Their civility levels are less near 1,5 than argumentation levels. We take in our mind a numerical indicator if we analyze these cities.

The second pattern is connected with cities where we saw lowest argumentation levels: the largest (32,5%) and large (17,3%). We can reckon that due to a lack of number and quality of arguments civility levels on forums of these cities are higher than average. Therefore, we need to check one hypothesis about interdependency of argumentation and civility: the lower level of argumentation, the higher level of civility and vice versa. However, there are some peculiarities we cannot exclude. We mean intensity of arguments in posts, percentage of posts with interpersonal character because there are no discussions on theme.

The third pattern is curious because it is dual. For example, good numbers of civility levels in the largest and large cities whereas their argumentation levels are ones of the lowest. The percentages of posts that are directly addressed to other participants by name on forums of these cities are high (the largest – 63,5% from 78,94%, large – 48,68% from 73,53%). These figures significantly influence on general figures of civility and argumentation respectively. If we compare with small cities where we see the same high levels of argumentation (76,4%) and civility (76,4%), the tendency is different. The percentage of interpersonal posts without mention of topic is 49,86%. However, participants on forums of small towns offered more posts with arguments where we could identify a few types of argumentation at once. That is the reason why we can partly explain this high indicator of civility. The number of posts with argumentation is not enormous but the intensity of arguments is high on online platforms of small cities.

5 Discussion and Future Research Avenues

To sum up, we have to agree with the conclusions of other investigations that "even if political discussions on Internet are more subtle and civil than discussions on other issues," they are usually far from the rational civil discussion that Habermas spoke about [15]. The participants are often distracted from the main topic of discussion, use disrespectful and even insulting language and attacks, make statements that are not supported by arguments, or completely refrain from rational argumentation and use their social position in this platform to delegitimize opposing views.

Conducted investigations allow us to judge (only to a limited extent) the applicability of the deliberative research project for the complex process of political communication in the modern digital space. It should be marked that the study is not about a structured and purposeful discussion on a problem, but only a politically oriented conversation - every day political talk. Figuratively speaking, it is like a conversation in the kitchen, so it is almost natural, for example, that people deviate from the theme. Perhaps, many things depend on the topic of discussion, to what extant the topic touches people and, accordingly, whether it is a moral discourse or pragmatic discussion, where a large role is played by technical aspects people do not always want to penetrate into.

Of course, methodology, used in our research, is needed to be developed and improved. Despite its advantages, we found some disadvantages. For example, the first

drawback is about representativeness of results and its value. There is a huge question about to what extent the outcomes reflect a real pattern of communicative situation and whether they can be regarded as argumentative and authentic ones. In addition to this, there is a problem with identification of communicators' and public groups' characteristics that are exceedingly necessary for consideration while taking political decisions. In fact, it leads to one more disadvantage dictated by technological possibilities. Meanwhile, we are not able to define whether posts are written by real people or robots. No doubt, it influences on the investigation results. Therefore, directions of further researches predominantly connect with improvement of computer and machine possibilities and technologies of discussions' processing, their analysis and exposure of real existed users, specially modified instruments for creating artificial comments. If this problem is solved, there will be new perspectives and processes of deliberative investigations will be accelerated. For instance, we will be able to explain excessive activity of participants, quantity and quality of arguments. As a result, the value of online discussions as a communicative and political resource will increase.

For more detailed description of discussions and explanation of their trends and patterns it is necessary to study each parameter and correlations of argumentation, civility, interactivity, dialogism, activity of participants with each other, their interdependency. Further investigations will open each parameter and their features more extensively. Perhaps, some hypothesis will be confirmed and new formulas will be received. We hope that thanks to computer program breakthrough we will be able to research parameters much faster and deeper. As a consequence, the algorithms of how to investigate online deliberations and their characteristics will be created and fully described.

We strongly believe that the results of Internet discussions can be implemented into all stages of political process: problems' articulation and political objectives' design, making political decisions, decisions' fulfillment and results' evaluation. Most of all we are interested in the second one. However, nowadays, the results of civil online deliberations are seen but not considered by Russian government while taking political decisions that is mainly explained by the specific of Russian political regime.

Therefore, there is an assumption that the Habermas' conception in European countries with other political regimes works another way. For proving this thesis it is necessary to conduct further researches based on online discussions on any actual socio-political issues between Europeans on European online platforms. Confirming or rejecting our hypothesis we plan to compare Russian and European Internet deliberations, how people communicate there and whether their polemics are heard by authorities, the way Habermas' conception works in Russia and European countries, and offer some recommendations how to improve the process of political decisions' making on basics of Russian and European scientific experience.

6 Conclusions

In the article we represented a methodology of public discourse studying that can be adapted to other researches of public discourse on significant socio-political events on Internet. The main goal of empiric investigation where the methodology was tested is aimed at analyzing Internet discussions accordingly to various parameters of deliberative

standard (the accent was made at such discursive characteristics as activity, argumentation and civility). As a result, we can claim that illustrated methodology confirmed its efficiency as an analytical tool for evaluation of online discussions deliberativeness quality.

Our research can become an example of multidisciplinary investigations, correlating with studying public discourse on Internet. A represented work, not having a comprehensive status, is called upon to show that Internet discourse is a method of discussion on problems in democratic society and based on democratic principles when different social groups are involved into wide deliberation on actual issues. The texts and speeches that are produced by discourse participants are generated taking into account social background of participants, they are full of context. This is what let us consider a discussion as a democratic discourse.

Talking about attitude to pension reform of Internet users expressed on Internet platforms of 11 Russian cities, approximately 91% of respondents are against the pension reform while almost 8,875% are in favor. In the national sociological poll a total number of people, having a negative attitude to the idea of pension age increase, is 92%. It means that our figures from online discourse analysis is so close to survey results. We suppose that opinions out of Internet environment coincide with participants' opinions while online deliberations on forums (numerical indicators can differ, but the direction of thought is the same). Comparing with official data of national sociological survey reveals ambiguity of views that were expressed by people while discussing on pension problem. So, there is a difficulty in making decisions and implementing them by government as it is relevant to include all different opinions of active participants on Internet platforms. Honestly speaking, it is a widespread issue that makes us think of creating systems and models of supporting political decisions.

The significance of presented discourse analysis lies in the opportunity of structuring posts in way that helps undertake a semantic analysis by identifying a basic sense and text intention and investigate interactive depth of intersubjective solidarities of participants (in terminology of Habermas). In terms of discursiveness the participants' positions are not important, their actualization is a key aspect, i.e. it is not relevant what an author wanted to tell, much more significant is in what way other communicators interpreted his message and its content. The sense of comments is constantly specified by subsequent communicators through continuous and interactive process of checking posts. As a result, a wider epistemologically substantial basis of public sphere, landscape of public knowledge (this is called by Habermas as background information and knowledge) forms.

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References

1. National Coalition for Dialogue & Deliberation. Engagement Streams Framework (2014). http://www.ncdd.org/files/rc/2014_Engagement_Streams_Guide_Web.pdf. Accessed 21 Jan 2020

2. Klyuyev, E.V.: Political discourse in mass communication: analysis of public political interaction. Direct Media, M.-Berlin (2016). (in rus.)
3. De Sindio, F. Guidelines for designing deliberative digital habitats: learning from e-participation for open data initiatives. J. Community Inform. **8**(2) (2014). http://ci-journal.net/index.php/ciej/article/view/918/910/. Accessed 21 Jan 2020
4. Rusakova, O.F., Maksimov, D.A.: Political discourse: subject field, theoretical approaches and structural model of political discourse. Polis. **4**, 27 (2006)
5. Bakhtin, M.M. The text problem in linguistics, philology and other humanities. The experience of philosophical analysis. In: Bakhtin M.M. (ed.) Aesthetics of Verbal Creativity. M., Art, pp. 297–325 (1986)
6. Filatova, O.G., Volkovskii, D.V.: Internet Discussions as a Form of Electronic Participation in Politics: Regional Aspect. PR and Advertising in a Changing World: Regional Aspect, No. 20–21, 6–16 (2019)
7. Filatova, O.G., Volkovskii, D.V.: The socio-political discourse in the era of digital transformations: the experience of Internet discourse research. La communication actuelle: le discours de transformations, Paris, pp. 8–18 (2019)
8. Filatova, O.G., Volkovskii, D.V.: Electronic participation as a socio-political discourse: research methods and directions. In: Proceedings of the XXII International Joint Scientific Conference "Internet and Modern Society", IMS-2019, St. Petersburg, pp. 102–115 (2019)
9. Filatova, O.G., Volkovskii, D.V.: Internet discourse as a form of electronic participation: a research methodology as an example of discussions about pension reform. In: Proceedings 21st International Conference, Minsk, pp. 400–405 (2019)
10. Misnikov, Y.: Public activism online in Russia: citizens' participation in webbased interactive political debate in the context of civil society. development and transition to democracy: Ph.D. thesis. Leeds (2011)
11. Habermas, J.: Involvement of the Other. Essays on political theory. St. Petersburg: Science (2001). (in rus.)
12. Habermas, J.: The Theory of Communicative Action. Reason and the Rationalization of Society, vol. 1, Beacon, Boston (1984)
13. Salaverría, R.: Typology of digital news media: theoretical bases for their classification. Mediterr. J. Commun. **8**, 19–32 (2017)
14. SP 42.13330.2011 Urban planning. Planning and development of urban and rural settlements. Updated edition of SNiP 2.07.01-89 (2011)
15. Misnikov, Y., Filatova, O., Chugunov, A.: Converting the outcomes of citizens' discourses in the cyberspace into policy inputs for more democratic and effective government. In: Paulin, A., Anthopoulos, L., Reddick, C. (eds.) Beyond Bureaucracy. PAIT, vol. 25, pp. 259–287. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-54142-6_15

Generation Z and Its Value Transformations: Digital Reality Vs. Phygital Interaction

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Abstract. The impact of phygital reality on generation Z is the focus of this article. Phygital is understood as a system of interaction in the new world when digital space penetrates the physical and integrates with a person. For researchers, as well as for representatives of business, education, and media culture, the question of how phygital reality practices influence formation of the values of the most active digital audience - generation Z is becoming more and more relevant. Issues of value system are commonly seen among a typical representative of the generation Z that lives in St. Petersburg. The change in the value priorities of modern society is investigated. An analysis of the results made it possible to obtain the image of generation Z from generation Y viewpoint, to study the hierarchy of values of generation Z and to draw inter-generational analogies. It is shown that some features attributed to this generation are not supported by data. The results of the study of the value system of a typical representative of generation Z in St Petersburg are in some contradiction with the value system of generation Z in other countries. The authors believe that generation Z studies present valuable material for developing governing solutions in terms of desired goals and actions to achieve a developed digital society.

Keywords: Generation Z · Generation Y · Phygital reality · Values · Values transformation

1 Introduction

The intensive development of modern communication technologies, primarily the Internet, gave rise to cardinal changes, not only in all areas of society, but also in the values and goals of individuals. In the context of phygital-interaction, the value system and landmarks of modern individuals are changing.

The phenomenon of phygital reality, which is related to the blurring of boundaries between physical and virtual worlds, has been discussed in the scientific community for over ten years. Sometimes it generates a semantic noise that leads away from the main question: if changes in value orientations of representatives of generation Z lead to

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destructive changes in society or if the dynamics of change is in the nature of cumulative innovation and launches a new mechanism of group dynamics?

Already in the early stages of phygital reality, it is extremely important to put the scenarios for which it will be created under social and moral control, there, at least partially, preventing its negative consequences.

A constructive approach to studying the dynamics of changes in the value orientations of modern youth consists of developing dispositive recommendations for changes in education [1, 2], marketing [3, 4] and media space [5, 6], and taking into account the regulatory and ethical regulations of digital society.

This circumstance necessitates the identification of a system of values and value priorities of the new generation that determines its ideological and communicative characteristics, as well as development trends. These allow determining opportunities for effective management for the formation of the necessary value system of the digital society members to understand the possibilities of interaction with it in various areas of society. This circumstance necessitates the identification of a system of values and value priorities of the new generation that determines its ideological and communicative characteristics, as well as development trends. These allow determining opportunities for effective management for the formation of the necessary value system of digital society members to understand the possibilities of interaction with it in various areas of society.

The main thesis is that the study of value guidelines should help to overcome the problems of internet addiction, digital divide, privacy and intercultural communication, as well as to aid in finding sustainable solutions for the digital age. The main problem of the study is in determining the characteristics of the value orientations of generation Z, that lead to special practices resulting in the process of interaction being disrupted.

This allows us to formulate the following research question: how does the phygital environment change the scale of values of generation Z compared to previous generations? This question is asked in order to understand the possibilities of using the Internet as a tool for influencing representatives of generation Z. In this regard, a 2019 study of 300 generation Z representatives, who were first-year university students from St. Petersburg, was conducted.

The researchers have not conceded on the year in which Generation Z commenced but the border varies from 1991 to 2001, depending on the different levels of technology development across the world. In our study, the year 2000 was chosen based on the realities of Russian society [7, 8]. The focus of this work is the synthesis of new generation Z installations generated by continuous inclusion of network interaction. From this point of view, the generation Z's perception of responsibility and the attitude towards individualism, collectivism, instrumental rationality and communication skills are considered.

The basis of this study is the theoretical and empirical interpretation of the concept of "value orientations as shared by the individual social values" by Russian sociologist V.A Yadov. These values act as the goals of life and the main means of achieving them. Value orientations serve as the criteria for making vital decisions in situations of moral choice [9].

2 Literature Review

The study of generation characteristics and the specific conditions of their sociocultural existence is a topic that has deep historical roots and theoretical foundations. However, a comprehensive theoretical analysis of the problem appeared relatively recently - in the joint work of American scientists N. Howe and V. Strauss, the first of which is "Generations: A History of the Future of America" (1991) [10].

The authors came to the general conclusion that the value system of people who grew up in different historical periods is different. This is because human values are formed not only in the family, but also under the influence of social life and the whole context of the social environment that a child is raised in.

As a result, they identified several types of generations, including those representing the XX century and the beginning of the XXI century, and described in detail the collective image of a typical representative of each generation of the American nation. Moreover, according to this theory, the values of the younger generation were formed at the age of 12–14 years. The Howe-Strauss Generation Theory is widely recognized, not only in the United States, but also far beyond the borders of the North American continent.

Today, generational themes and their specifics under the conditions of a new reality are widely represented in the works of famous authors such as D. Tapscott [11], M. Prensky [12], M. Bauerlein [13], N. Carr [10, 14, 15] G. Small and G. Vorgan [16], D. Stillman [17] and others. In particular, the name of the Canadian scientist D. Tapscott is associated with the introduction of the concept of "network generation" (NET- generation or N-generation), the profile of which he described in his books "Growing in the Digital Age: The Emergence of the Network Generation" and "Growing in the Digital Age: How the Network Generation Changes Your World" [11].

Simultaneously, with D. Tapscott's second book, the book J. Pelfrey and W. Gasser "Born Digital: Understanding the First Generation of Digital Natives" [18], was published in the US and discusses the main trends associated with the formation of the digital generation. Like D. Tapscott, relying on the results of serious sociological research, their "identikit" was composed of digital natives. On one hand it was a synthesis of their activity, the desire for creativity and innovative activity, and on the other, their penchant for internet addictions, acts of aggression, harassment, ignoring copyright and an uncritical acceptance of information.

However, the development of the theory of Howe and Strauss led not only to an in-depth study of the theory of generations by the world scientific community, but also to the appearance of various synonymous names of the same generations. The Mil- lennium generation was named thanks to the book of Hove and Strauss "Millennials Rising: The Next Great Generation" [19], dedicated to the generation that was supposed to finish school in the new millennium, later a second name appeared, "generation Y". Today, this name has the main citation index, since it allows us to identify the next generation, generation Z as coming after generation Y.

At the same time, there are other synonymous names for these new generations, which reflect the specifics of the time. For example, generation Y is often defined as the Next generation, N-geners, the selfie generation, and generation Z have been called centennials, the generation of numbers, the phygital generation. None of the previous

generations have held as many names as Generation Z, for example names such as, i Generation, Gen Tech, Generation online, After the millennium, the generation of Facebook, switches, and "always clicking". Generation Z is also known as the C Generation, - an expression that comes from the term "Connected", as its representatives are "connected to the Internet", and Generation R, which comes from the formation of responsibility or the Responsibility generation. [20, p. 45].

For a better understanding of generation Z and its digitalization, it should be emphasized that "they were born and grew up in the 2000 s at the time of the most pro- found changes that exist in the world of the web, the Internet, smartphones, laptops, freely accessible networks, and digital media" [13]. The most significant of the differences in generation Z, according to experts, is that "the new generation does not see the difference between the virtual and the real" [21, p. 38]. Its appearance is due to the new qualitative characteristics of Web 3.0, in particular, a new type of interaction - Phygital as a union of two realities – physical and digital. Among specific features, we can mention non-linearity, the ability to transmit voluminous multifaceted information that is available at anytime, anywhere, not only for perception but also for further transmission through posts, stories, live broadcasts, etc. As part of the generational theme, Phygital is considered by analysts from the standpoint of civilizational content, and is defined as a key characteristic of the Z generation, which does not only not see the difference between the virtual and the real, but also does not think of itself outside the phygital environment, hence its new name – the phygital generation.

3 Theoretical Grounding and Methodology

The team of authors conducted research with a main task of revealing the generation Z value orientations that had formed under the influence of a phygital environment. We used a focus-group method involving generation Y - an older age category (undergraduates) and a survey method for representatives of generation Z, the lower time limit of which is the year 2000. The sample for the focus group was directed and consisted of nine people who were representatives of Generation Y and who acted as experts evaluating Generation Z. The questionnaire involved working with a random sample of 300 first year students from four St. Petersburg universities.

For developing the design of this study, the approach of social constructivism of P. Berger and T. Luckman was used. The epistemological orientation of our research is interpretivism, which implies the inductive logic of research (from the collection of facts to the construction of the theory). Interpretation of the facts is based on the concepts of generational analysis by N. Howe, V. Strauss, D. Stillman, D. Tapscott, M. Prensky and other leading researchers in this scientific field.

The method for this study consisted of the following steps. First, a focus group was used to study, in detail, generation Y's ideas regarding the next generation Z, and the features of the interaction of Z and the internet environment. Second, a survey of 300 students from St. Petersburg universities, who are representatives of generation Z was done. Third, a comparison of the results of the two empirical studies in order to identify the value characteristics of generation Z and their manifestations in the internet environment was made.

The study limitations were associated with the specific features of the object. It is difficult to separate the specific factors affecting the entire generation from the specific factors of the youth. There are concerns that specific factors of youth may be mistaken for specific factors of generation Z, and these limitations were understood.

4 Empirical Research of Generation Z Value Orientations

The logic of our empirical research implies the use of a qualitative method of focus groups and a quantitative method of surveys. We began with focus group conduction utilizing representatives of generation Y to understand their perception of the next generation. Then we continued with a survey of generation Z to reveal their value orientations.

The analysis of the results of the focus group using the method of narrative structuring made it possible to obtain the image of generation Z from the point of view of generation Y, to study the hierarchy of values of generation Z and to draw inter-generational analogies.

The generation Y participants of a focus group were presented by postgraduate students of social science faculties of St Petersburg State University. They were in the age of twenty five to thirty years old. The group consisted of both male and female.

Informants determined self- to be the main value of generation Z. Representatives of generation Z differ from older generations in a special way of self-expression, the main area of which is the digital environment. Even if self-expression takes the form of real practices, such as extreme selfies or extreme sports, its main goal is to attract attention on the Internet. For them, "the thirst to tell everyone is prevailing than the extreme sensations themselves". Self-expression as such for generation Z means creating a positive image of yourself and gaining popularity in a certain environment. This image has a weak relation to reality but allows the young man to express himself as unique and unlike like other people.

The second most important value of generation Z is freedom, determined by informant opinion. The theme of freedom is closely linked to the discourse of responsibility and anonymity. From the perspective of generation Y, freedom for gen Z is a lack of responsibility. This understanding of freedom was formulated by informants as: "my freedom, I say that I want, I am not responsible for what I say. There are no frames". An important condition for freedom in the digital environment is the anonymity of the generation Z, which allows them to express their opinions more openly. A negative consequence of this freedom is the phenomenon of bullying or "hate" when anonymity is used to insult users who identify themselves. Also, the use of fake accounts contributes to the erosion of the identity of representatives of generation Z and worsens the quality of communication. Informants noted that complete anonymity is an illusion, and in this case, we can only talk about anonymity from other users impersonality.

An important value of generation Z, again according to informants, is financial success. They are pragmatic, consider education as the beginning of a career and are ready to study uninteresting disciplines to obtain a diploma useful for employment. Many of them choose these disciplines for reasons such as, "I will tolerate these 4 years, I will suffer, and then I will have a good career". Such beliefs strongly distinguish them from generation Y, whose representatives are inclined to choose education according to

their interests. The professional socialization of generation Z is a consequence of these value orientations.

It is noteworthy that the conviction of generation Z that modern knowledge and skills are necessary to achieve financial success and build a successful career is accompanied by a decline in the authority of educational institutions. Generation Z seeks to gain practically useful knowledge that will make it possible to earn money right here and right now [16]. This skeptical attitude of young people towards classical education is also fueled by popular culture, which often broadcasts success stories like "I dropped out of school at 15 and became a millionaire on blogs". They tend to choose remote work and do not seek out teamwork. This indicates their orientation towards individualistic values. Additionally, representatives of this generation do not seek to obtain general educational knowledge from the classroom as they believe that they can always be found through Google [14].

Informants also note that generation Z considers time as valuable. For generation Z, time is a resource, and very limited one. One of the consequences of this is the desire of generation Z to quickly acquire knowledge. These young people tend to choose books and video files for training, "so that in 15 min you can read and understand everything" [15]. Of course, this approach provides only superficial knowledge, but it saves valuable time.

For generation Z, family is also a value. However, they see it as a project that requires a substantial amount of time, effort and money to obtain. As a result, the creation of a family in generation Z individuals is postponed to a later age.

One of the most important general characteristics of generation Z, according to in- formants, is its constant immersion in information flows [18]. From 3–5 years old, representatives of this generation have learned to use digital devices, and they are well versed in their use. They are interested in many topics and quickly find large amounts of information, but they cannot selectively highlight the main thing in it or learn how to filter it. If generation Y was a virtual space explorer, then generation Z is more likely users [12].

Representatives of generation Z are prone to trends, and are always striving to keep abreast of the latest developments. Even their appearance indicates their commitment to these trends. The young man declares himself to the world as fashionable and modern, thanks to branded clothing, an iPhone, a gyro scooter and other items of a similar nature. Many are ashamed not to know the meaning of a meme or a new word. This is a positive feature of generation Z, as they live in a world that is constantly changing.

An essential feature of generation Z as noted by informants is its infantilism and non-independence. Representatives of this generation form their own opinions, but are influenced by friends and parents in practical activities. Also, representatives of generation Z poorly control aggression in conflicts and have weak domestic skills. All this is a consequence of the fact that their socialization in Russian society took place in a much calmer and more comfortable time than the socialization of generation Y.

Communicatively, these young people are included in social networks [21]. However, the social network does not connect them but becomes a place of ineffective communication in which everyone feels a sense of loneliness. However, many representatives of generation Z often seek to avoid real communication in favor of the Internet. In real

communication, they fear being misunderstood or receiving a negative reaction towards themselves. While on the Internet this problem is solved simply by putting the person on the blacklist.

In general, representatives of generation Y describe generation Z as extreme individualists, and they do not mention such values as mutual assistance. This contradicts the results of the survey, which gives a slightly different image of the values of generation Z from their own point of view.

Four universities took part in the survey. The majority of the sample of 300 respondents were teenagers aged 18 years (56%), the gender distribution of the sample was as follows: 45% of the respondents were female and 55% were male. This proportion of sample is in accordance with the gender structure of Russian inhabitants in the age from 15 to 30 years old [22].

Perhaps the most difficult moment in terms of processing empirical data was the identification of a value system shared by generation Z. The data was encoded on the basis of one (yes), zero (no). The unit was assigned to the value, selected first from the set of six proposed values. Thus, of the 302 responses, the following scale of values was obtained for representatives of generation Z: self-expression (32%), mutual assistance (24%), career building (14%), empathy (13%), tolerance (11%), recognition (6%). This construction was tested on a random sample of twenty respondents (five freshmen from each of the four universities participating in the study). A thorough recalculation of the data, with a ranking of the value system of each of the twenty participants, allowed us to build a value profile for the average representative of the digital generation, which completely coincided with the value profile obtained through binary coding. Our empirical results confirmed that representatives of generation Z consider self-expression to be the most significant value. This is a purely individualistic value, although the second most popular value is mutual assistance. This apparent contradiction completely disappears if we recall the features of the world of generation Z, for which self-expression occurs in the collective space of phygital co-experience.

In order to study specific features of generation Z, the team of authors worked out the questionnaire[1] that were given to the first year students in the offline regime. We used SPSS software to process the results of a survey. The basic method we used for most questions processing was frequency analysis from the descriptive statistics section.

The features of generation Z are largely due to the special structure of their life. The younger the people, the less likely they are to separate the events of the real and virtual worlds, therefore interaction in the modern world is a financial interaction, and representatives of generation Z are often called representatives of the phygital generation [21]. Phygital is an acronym for the two English terms “physics” and “digital”. The constant exchange of information between young people determines the continuing empathy of each other’s life events. This gives rise to the phenomenon of feeling like a participant in an event, even if participation in this event consisted only in the perception of information from the Internet. This unique phenomenon of the formation of co-experience, which is uncharacteristic for older generations, makes representatives of generation Z form communities that have little contact with representatives of older

[1] https://vk.com/doc928026_552607993?hash=4b39f01ee44f78c6f4&dl=99495814197a7c36bd

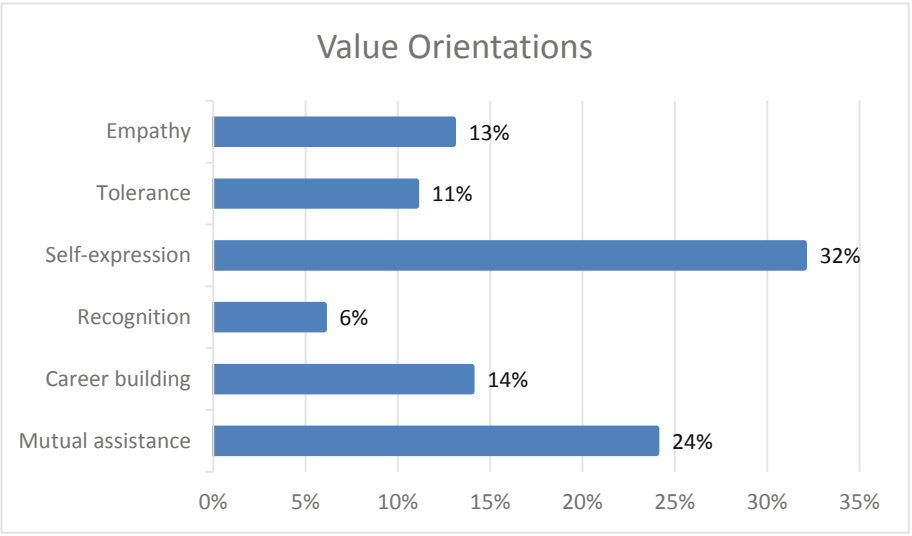

Fig. 1. Z-generation value profile.

generations. According to our field data, only 3% of representatives of generation Z have friends or close acquaintances over the age of 40 on the Internet.

The value system of a typical representative of generation Z in St Petersburg, obtained from the survey, contradicts the value system of generation Z in the USA, which is considered in Stillman's works [17]. Stillman claims the importance of feedback (recognition) for the younger generation. Among the interviewed representatives of the digital generation in St. Petersburg, only 6% put the value of recognition in first place. A similar answer was received when analyzing the answers to questions regarding the importance of "likes" used in the interaction process. Only 5.3% of respondents confirmed that "likes" are truly important for them, while the majority of respondents said that having "likes" in principle is not significant (45.3%) or that it does matter, but not significantly (48%).

The predominance of individualistic values (self-expression, career-building) in the profile of a typical representative of generation Z in St Petersburg, obtained from this empirical research, allows us to speak about the formation of a "generation Z" in Russia, but presumably with Russian specifics. It is because the value profile is not exempt from collectivist values (mutual assistance-24%, empathy-13%), which took second and fourth places in the value system of representatives of generation Z respectively. The answer to the question of the other opinion importance in the interaction indicates the independence of the young generation, since according to the survey, 74% of the participants consider the opinions of others when making decisions, but still put their own opinion in the first place.

The features of the life world of generation Z that were revealed by us contribute to the fact that the emotional and meaningful content of the Internet is significantly more important for them than for the representatives of previous generations. This conclusion is fully confirmed by both domestic and Western empirical data. In order to receive findings

(Fig. 2), we used a frequency analysis in SPSS. According to the results of our study, for representatives of generation Z in St Petersburg, the most popular Internet resources are VKontakte (23%) and Instagram (18%). Both of these resources are related to posting your photos and other types of self-expression [23], getting "likes" and reposts, which subjectively testify to a certain social significance of this young person. Ultimately, the personality of generation Z is more flexible and multifaceted than that of older generations. The representative of generation Z defines himself rather situationally than once and for all unambiguously [24]. The facets of his personality may vary depending on social environment and circumstances.

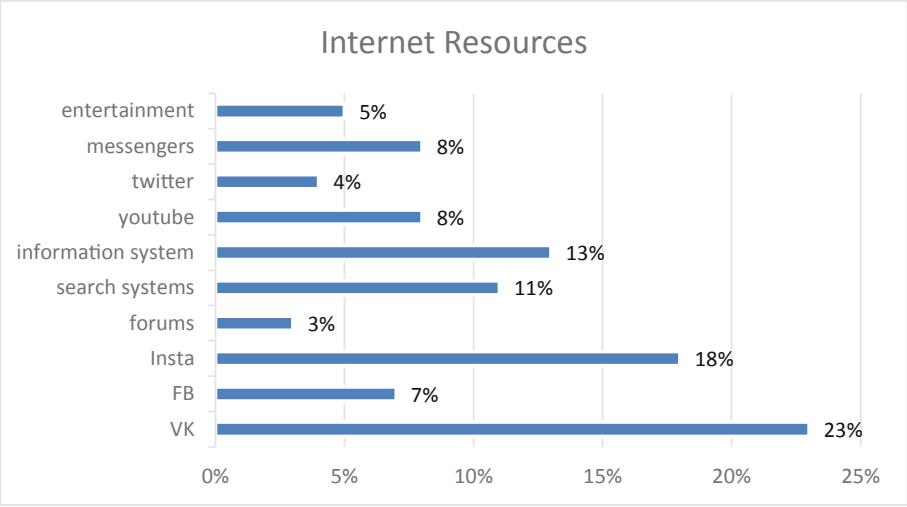

Fig. 2. The Internet resources rating

American researchers J. Palfrey and W. Gasser [18] argue that representatives of the digital age spend most of their lives on the global network and, as a result, do not distinguish between life on the Internet and outside of it. Indeed, according to the results of our empirical study, the bulk of the representatives of generation Z started using the Internet and related gadgets starting at ages 6–12, which coincides with the beginning of their education at school. Of the 91% of respondents, 55% started using the Internet at the ages of 9 to 12 years, and 36% in the period from 6 to 8 years. Most of the interviewed representatives of generation Z cannot do without the Internet. The maximum period of time they can life without internet use is one month, and then only in the presence of interesting activities that can compensate for the absence of such a familiar part of everyday reality. D. Stillman [17] also claims that generation Z does not see the difference between the real and virtual worlds. This statement is confirmed in our study by the question regarding the number of friends in the real and virtual world. 35% of respondents reported that in the real world they have more friends while indicating the number of friends in the virtual world, which significantly exceeds the total number of friends in real life.

The high importance of building a career in the generation Z profile of values is associated with its characteristic, according to D. Stillman [17], of practical or even pragmatically rational. This is also confirmed by answers to the question regarding reasons for choosing a career, to which 40.7% of respondents answered that the choice of a profession was connected with the desire to quickly make a lot of money.

The inclination of generation Z towards individualization and personalization (according to Stillman) is confirmed not only by the choice of self-expression as a leading value. It also concerns the preferred form of work, in which the individual form of work, in its various manifestations (work as a team, but remotely; in the office, but individually; individually and remotely) accounts for 65% of respondents.

In assessing the moral component of the younger generation Z, there is some ambivalence. On the one hand, they understand that moral norms act as regulators of interaction, and try to focus on them, at least when communicating on the network (71.3% of the respondents) and negatively relate to extremist content and violent scenes, therefore they refuse to viewing (87% of respondents). But on the other hand, representatives of generation Z do not mind violating intellectual property rights by downloading copyrighted content from pirated sites (94.6% of respondents). Also, the digital generation demonstrates some frivolity regarding the use of obscene language. As a result, 65.3% of respondents use it in the communication process, while the remaining 32.7% do not mind when it is used in their presence.

Also, the lack of a firm understanding of what is good and what is poorly illustrated by the answer to the question regarding the possibility of trolling on the network. The opinions of the respondents were divided: 54% of respondents believe that trolling is acceptable, while 46% consider it to be unacceptable under any circumstances. This ambiguity in the moral assessment of behavior is explained by a decrease in the influence of the family on generation Z, who as their important others are not parents but close friends (57.3% of the respondents) and for whom the Internet space has become an important part of their life world. 78.3% of respondents cannot do without the Internet, at least for longer than a month (of which 23.7% cannot imagine their life without ICT).

To overcome the revealed ambivalence, it is necessary to intensify the efforts of society, especially in the sphere of higher education. It should overcome the excessive influence of the Internet on the representatives of the digital generation and compensate for a decline in the impact of traditional socialization institutions, which include family and school.

Thus, the results of the survey demonstrate presumably some of the national specifics of the formation of generation Z in Russia. Despite the tangible individualization of the digital generation, it nevertheless retains its value profile the elements of a collectivist culture (mutual assistance in second place, empathy in fourth place), that are characteristic of our mentality. Also, the new generation has some idea of the importance of moral regulators in the process of communication. Despite the decline in the role of the family in the process of socialization, a close influence on behavior is exerted by close friends, with whom representatives of generation Z consult when making decisions. For a clear distinction of the understanding of ontological good and evil among a generation entering the rights of full members of society, efforts on society's part and the system of secondary and higher education are necessary.

Following the logics of our research, we would like to present the comparative analysis of the results received with the aid of our generation Y focus group and the generation Z survey. The self-image presented by generation Z, which was obtained as a result of our research, differs significantly from the image of generation Z represented by generation Y. The most significant difference is the set of basic values. In the image of generation Z, from generation Y viewpoint, completely collectivist values lack generally. At the same time, generation Z considers mutual assistance, empathy and tolerance, which are collectivist, to be significant values. This significant difference in scores may be due to several factors. First of all, it is necessary to distinguish between the values declared by the individual and those values that are the basis of his actual behavior [9]. Probably, respondents seek to present themselves in a positive light and tend to give socially acceptable answers. Moreover, an individual's choice of values is rarely accompanied by a serious reflection on whether he follows these values in real life.

Secondly, the determination of which practices can be considered as a manifestation of mutual assistance or empathy could seriously influence the assessment of the correlation of collectivism and individualism in the value structure of generation Z. For the younger generation insignificant things can be considered manifestations of mutual assistance, such as giving a classmate notes from a missed lecture, while for the older generation, mutual assistance can be considered a manifestation of more serious help in essential things.

Thirdly, and this is more obvious, the representatives of generation Z can be under the influence of national culture, for which collectivist values play significant roles. This is more inherent to the older generations especially those who grew up in Soviet Union [8].

Analysis of the hierarchy of generation Z values from the viewpoint of the two generations also allows us to determine the characteristics of the life world of generation Z. Representatives of this generation in their values did not mention the value of time or the practicality of their actions, which they are guided by [17]. For generation Z, time savings and practical actions are not values as such, but a natural order of things [18]. From their point of view, a waste of time or aimless actions looks silly and is not considered an alternative behavior. The described features of the lifeworld of generation Z are a consequence of modern society, which is characterized by a fast pace of life and constant changes [19].

An analysis of the role of friendship in the life world of generation Z based on the qualitative and quantitative data we have obtained indicates that under the word friendship generation Z can mean two different concepts [11]. On one hand, it is a friend and like-minded person in a digital environment with whom a young person can often interact. But on the other hand, generation Z also uses the traditional concept of a friend as a reliable partner in real life.

It is with this that the contradictions described above in the answers of generation Z about the number of friends in the real and virtual world are connected. This is confirmed by the results of the focus group, according to which many young people avoid real communication in favor of the virtual. It is obvious that they avoid personal close relationships with those who are not friends in the traditional sense. This is a very

interesting conclusion, since the correlation in the life world of generation Z the new phygital concepts and the traditional concepts could be the subject of a separate study [21].

5 Discussion, Conclusion and Outlook

The study clearly showed the difference between the perception of generation Z by generation Y and the self-perception of generation Z, and also revealed some aspects of the interaction of generation Z and the Internet environment. The study revealed that representatives of generation Y view generation Z as an inferior generation (poorly socialized, infantile, Internet-dependent, spiritless, with clip thinking, individualistic). However, the results of the study showed that data received in the focus group, conducted among representatives of generation Y about the flaws in the socialization of generation Z, is not entirely justified. Additionally, the survey among generation Z representatives showed that this generation differs from the western generation Z with presumably Russian specifics connected to the existence of collectivist values in their value profile.

At the same time, the study raises some questions, the most important of which is whether it revealed the values of generation Z, or whether it identified the value priorities of generation Z, since respondents can be convinced of the priority of certain values, but in practice may not follow them. And even more than that - there are big doubts about the adequacy of the respondents' understanding of the questions asked. If we consider that the oldest of the respondents is only 19 years old, in practice it may well turn out that by self-expression many of them mean posting photos on social networks, and by mutual assistance - sending abstracts to their classmates. However, this is a matter of interpretation and psychological research.

Another issue that may be addressed by other studies is the nature of the connection between generation Z and the Internet environment. At the moment, all the opinions of scientists, cited in this paper related to phygitalization, "digital natives" and the inseparability of the virtual and real worlds, seem to be nothing more than beautiful theoretical constructions and plausible hypotheses. To clarify this issue, it is necessary to conduct at least a longitudinal study, which, through the dynamics of the development of human interactions and the sociotechnical environment, will indicate the ontology of this interaction.

A detailed study of this interaction will be able to answer a number of practical questions: how professional competencies should be formed among representatives of generation Z? How to involve youth in public policy? How to consider the specifics of the younger generation in the labor market? These questions are the subject of future research.

Finally, it is worth noting a significant limitation of the results of the study, namely the specifics of the generation Z in St Petersburg. As soon as St Petersburg students come from different parts of Russia, we can conjecture that the research findings can cover all youth in Russia. However, this hypothesis will be tested in the future research of this problem. It's necessary to notice that the value characteristics and some aspects of the interaction of representatives of generation Z and the Internet environment relate to Russian reality with its inherent features, such as the conflicting nature of intergenerational relations, high-level digital inequality, later, compared with Western countries, the

digitalization of the society. However, in this regard, the authors do not want to belittle the merits of the results obtained during the research, since clarification of the value characteristics of generation Z is generally important for generational studies.

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References

1. Scholz, C., Grotefend, L.: "Generation Z in Germany: The (Un)Typical German?". Generations Z in Europe (The Changing Context of Managing People), pp. 169–197. Emerald Publishing Limited, Bingley (2019). https://doi.org/10.1108/978-1-78973-491-120191017. Accessed 24 Dec 2019
2. Schwieger, D., Ladwig, Ch.: Reaching and retaining the next generation: adapting to the expectations of Gen Z in the classroom. Inf. Syst. Educ. J. **16**(3), 45–54 (2018). https://files.eric.ed.gov/fulltext/EJ1179303.pdf. Accessed 26 Dec 2019
3. Hebets, S.: What do Millennials and Gen Z want for the holidays? A look at the attitudes and purchasing decisions of Gen Z and Millennials in 2019. Quirk's Media, December 2019. https://www.quirks.com/articles/what-do-millennials-and-gen-z-want-for-the-holidays. Accessed 14 Jan 2020
4. Van den Bergh, J.: How brands can engage NextGen consumers, Quirk's Media, November 2019. https://www.quirks.com/articles/how-brands-can-engage-nextgen-consumers. Accessed 14 Jan 2020
5. Balmaeva, S.D., Shlegel', E.V.: Kul'turny'e navy'ki rossijskogo pokoleniya Z [Cultural skills of the Russian « generation Z »]. In: Yaroslavskij pedagogicheskij vestnik [Yaroslavl Pedagogical Bulletin], vol. 4(109) (2019) http://vestnik.yspu.org/releases/2019_4/32.pdf. Accessed 28 Dec 2019
6. Vyugina, D.M.: Osobennosti mediapotrebleniya cifrovogo pokoleniya Rossii [Features of media consumption of the digital generation of Russia]. Mediaskop [Mediascope], **4** (2017). http://www.mediascope.ru/2386. Accessed 05 Jan 2020
7. Dergunov, T.: Teoriya pokolenij [Generation theory]. In: Formula menedzhmenta. Prakticheskoe posobie nachinayushchego rukovoditelya [Management Formula. A practical guide for a novice leader], Mann, Ivanov and Ferber, Moscow (2015). https://psixologiya.org/razdely/biznes/2155-teoriya-pokolenij.html?start=4. Accessed 15 Jan 2020
8. Shamis, E., Antipov, A.: Generation theory. https://www.psycho.ru/library/2581. Accessed 24 Dec 2019
9. Yadov, V.A.: Samoregulyaciya i prognozirovanie social'nogo povedeniya lichnosti: Dispozicionnaya koncepciya [Self-regulation and prediction of social personality behavior: a dispositional concept]. Center for Social Forecasting and Marketing, Moscow (2013)
10. Strauss, W., Howe, N.: Generations: The History of America's Future, 1584 to 2069. Morrow, New York (1991)
11. Tapscott, D.: Grown up Digital: How the Net Generation is Changing Your World. McGraw-Hill, New York (2008)
12. Prensky, M.: Digital Natives, Digital Immigrants. From On the Horizon, vol. 9(5), MCB University Press. Bingley. (2001). http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf. Accessed 10 Jan 2020

13. Bauerlein, M.: The Dumbest Generation: How the Digital Age Stupefies Young Americans and Jeopardizes Our Future (Or, Don't Trust Anyone Under 30), 1st edn. Tarcher, New York (2009)
14. Carr, N.: Is Google Making Us Stupid? What the Internet is doing to our brains, www.theatlantic.com/magazine/archive/2008/07/is-google-making-us-stupid/306868. Accessed 12 Jan 2020
15. Carr, N.: The Shallows: What the Internet is Doing to Our Brains. W.W. Norton and Co., New York (2010)
16. Small, G., Vorgan, G.: iBrain: Surviving the Technological Alteration of the Modern Mind. HarperCollins Publishers, New York (2008). www.harpercollins.com/browseinside/index.aspx?isbn13=9780061340338. Accessed 13 Jan 2020
17. Stillman, D.: Pokolenie Z na rabote. Kak ego ponyat' i najti s nim obshhij yazy'k [Generation Z at work. How to understand him and find a common language with him]. Mann, Ivanov and Ferber, Moscow (2018)
18. Palfrey, J., Gasser, U.: Born Digital: Understanding the First Generation of Digital Natives. Basic Books, New York (2008)
19. Howe, N., Strauss, W.: Millennials Rising: The Next Great Generation. Knopf Doubleday Publishing Group, New York (2000)
20. Dolot, A.: The characteristic of Generation Z, "e-mentor", pp. 44–50 (2018). https://doi.org/10.15219/em74.1351
21. Mamina, R.I., Tolstikova, I.I.: Phygital generation in free global communication. Int. J. Open Inf. Technol. **8**(1), 34–41 (2020)
22. Naselenie Rossii po polu i vozrastu: statistika, raspredelenie [Russian population by gender and age: statistics, distribution]. http://www.statdata.ru/nasel_pol_vozr. Accessed 05 Jan 2020
23. The Screen Age. https://www.washingtonpost.com/sf/style/2016/05/25/13-right-now-this-is-what-its-like-to-grow-up-in-the-age-of-likes-lols-and-longing/?utm_term=.f7f060c89a1b. Accessed 20 Dec 2019
24. Gen-Z: Today's 'Identity Shifters, Tomorrow's Buying Power. https://www.mediapost.com/publications/article/328794/gen-z-todays-identity-shifters-tomorrows-buy.html. Accessed 24 Dec 2019

Young Citizens Attitudes Towards CCTV and Online Surveillance in Russia

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Abstract. The digitalization of governance is meant to increase public satisfaction with state service and facilitate citizen involvement in safety provisions. Due to the digitalization trend, one can expect expansion of digital technologies in policing. Those technologies can be used for surveillance but they can also create a platform for cooperation between various actors in security production. Therefore, citizen's perceptions of technologies are of critical importance. Russia cannot be considered a pioneer in the use of police technologies. However, the number of closed circuit television (CCTV) cameras in public places is steadily growing. Police surveillance extends to virtual spaces as well such as social networks and public messengers. Based on a 570 sample of university students St. Petersburg, Russia we explore views related to CCTV and online monitoring. Results show that young people are willing to accept surveillance in public places, but are unsupportive of online surveillance tools and regulations. Citizens views are ambivalent regarding effectiveness of police technologies in crime prevention, enhancing security, and increasing police accountability. However, they express concerns regarding possible infringement of their privacy due to the use of technology. The study was funded by the Russian Foundation for Basic Research (grant 18–011-00756 A "The study of citizens involvement in public governance under conditions of the formation of a digital government").

Keywords: Police technologies · Digital surveillance · Privacy and security

1 Introduction

Economic growth, the competitiveness of the country, and improving the quality of life of citizens, as noted in the government program titled "Digital economy of the Russian Federation", to a significant extent depend on the digitalization of the economy. The goals of the digital economy are not only to improve the availability and quality of public services for citizens, but also to increase domestic and international security. Currently, digitalization covers all spheres of public policy and management in Russia. Governance of security management is also not immune to these trends. The leading end-to-end technologies that are used in all areas within the framework of the digital economy development according to the Digital economy program are Big Data, neurotechnology and artificial intelligence, new production technologies, robotics, and

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sensor components, wireless communication technologies, virtual and augmented reality. The introduction of new digital and facial recognition technologies and algorithms in the field of crime control policy is designed to make citizens' lives safer through the use of systems that provide notification of life risks, control public order with the help of video monitoring systems, video analytics, photo-recording of violations, providing access control to public spaces. The use of technologies is not limited to public space. The virtual space government also uses hard- and software that allows monitoring users' activities on regular websites and in social networks for crime prevention purposes, introduces digital platforms that allow citizens to communicate and retrieve information about emergencies.

This study focuses on citizens and their perceptions of street surveillance cameras and technologies used for monitoring citizens' data in social networks. These two areas were chosen because both technologies are relatively recent additions to the repertoire of policing in Russia, and their expansion is surrounded by avid public discussion. The use of CCTV cameras is no longer limited to order monitoring in public spaces and traffic violations control. In St. Petersburg (the cite for this study) they are being installed on the entrances of the residential buildings' entrances, accompanied by the emergency buttons linked to the centralized public emergency centers. Online surveillance is based on the use of hard- and software that monitoring users' activity online, and regulations that prescribe the platform owners to retain users' data for a certain amount of time as well as provide law enforcement agencies access to it under the circumstances specified in legal provisions.

2 Literature Review

An optimistic view of the digitalization processes is not shared by everyone. Skepticism about digital technologies is associated with the perception of them as a means of strengthening political control, dominance, and subordination. Modern critical political and legal studies argue that citizens become much more transparent objects for state control in the context of digitalization, losing at the same time opportunities for exerting control over agencies involved in policing. One example is the introduction of algorithms into law enforcement [1]. Its mechanism of functioning often appears to be opaque, constituting a commercial secret of the developer. Another example is policing based on behavior monitoring technologies and Big Data analysis. Critics perceive it as a part of a single system of "surveillance assemblage", the existence of which calls into question the very possibility of exercising the right to privacy and protection of information [2]. Scholars express concerns that the security of the "smart" city may turn this city into a kind of prison cell, where the resident becomes a 'prisoner' whose behavior is continuously watched by the eye of the camera [3].

Criticism of digital surveillance practices also stems from the idea that new security technologies are not inclusive [4], contributing to the creation of safe spaces that provide protection only for the rich and 'trustworthy.' Those citizens who cannot 'buy' security, and are unable to prove to society that they are not a danger, are largely excluded from these spaces. Gated communities, protected communal spaces (shopping and amusement centers) create enclaves of security displacing the new 'dangerous class' in urban ghettos.

Unequal distribution of security benefits strengthens "negative" solidarity based on a common desire of people to protect themselves from sources of risk by erecting additional barriers. The question remains whether new technologies of "safe" and "smart" cities can distribute security in a just and fairway.

However, the hope of technology optimists is that citizens and communities in the new digital age will become active creators and participants of the new digital space. The main concern of new digital governance is not limited to increasing efficiency of the public services delivery. It should also be aimed at ensuring governability through involving citizens in the process of governance, increasing their participation, empowering them to become active participants of governance activities. Engaging citizens in security governance is becoming one of the most important tasks that can be achieved through platform technologies. Combating crime only through the activities of the criminal justice system is extremely expensive and ineffective. Effective crime control and security provision are impossible without participation of citizens, be it in the form of community policing, strengthening the social cohesion of local communities, or other forms of the participation of citizens in the protection of public order.

Digital technologies should not be designed only to make citizens' lives more permeable for crime prevention purposes and to make the activities of the police and law enforcement agencies more transparent to citizens. They can be a way to ensure effective interaction between citizens and the police: citizens should be able to report the incident to the relevant emergency services and receive information about the activities of law enforcement agencies aimed at ensuring their safety.

However, increasing citizens' participation in security governance and enhancing police-citizens relationships through digital technologies is impossible without citizen's approval and acceptance of their use. Scholars in several countries have explored the issue of accepting such technologies as closed-circuit television (CCTV) and body-worn cameras, crewless aerial vehicles, and face-recognition systems [5–12]. However, little is known about the extent to which citizens in Russia are optimistic about the digitalization of policing and their views on the system of surveillance that is being created to police public and cyberspaces. This information is vital as it was suggested that the expansion of the informal and formal surveillance practices of the police might challenge the legitimacy of criminal justice agencies [13].

Our research aims to look at the general question of whether citizens accept the use of cameras and online surveillance. We are also looking at perceptions relating to the risks and benefits of these technologies, namely citizens' views regarding technologies' potential in increasing safety, crime prevention, and police accountability. In addition, we assess citizens' concerns about possible privacy violations due to the use of cameras and online monitoring.

3 Methods

3.1 Survey Construction and Sample

A survey questionnaire was constructed in Russian, partly drawing from prior research conducted to explore citizens' attitudes towards various technologies used for of surveillance and crime control [8,9] as well as from literature on citizens' concerns about privacy

and security [14]. Some original questions were included in the survey to fit it to the local context of surveillance practices. Survey questions were designed to collect citizens' responses on a wide range of issues relating to their attitudes towards introduction of different kinds of video monitoring in public places (cameras in public places, traffic cameras, 'smart residence' cameras) as well as cyber-surveillance (users' data collection, retention, and access for crime control purposes). We have also included questions measuring attitudes towards benefits of using technology (separately for cameras and online surveillance): potential for providing safety, effectively controlling crime, and enhancing police accountability and transparency. Several questions assessed citizens' fears regarding the possibility of violations of their privacy due to law enforcement agencies. The survey was administered to 15 students to test the validity and reliability of scales that were developed and to test the translation of some adopted questions from the English language literature. Respondents' answers were coded on a 7-point Likert Scale, where 1 represented "strongly disagree" and 7 represented "strongly agree" on various constructs drawn from the prior literature as well as designed by the researchers.

Questions that were used to assess different dimensions of citizens' attitudes towards cameras and online monitoring are presented below.

In order to evaluate the level of citizens' technology acceptance we described six of the most commonly used technologies and regulations used by crime control agencies. While the list is not exhaustive, these six categories were chosen as they are more widely used and familiar for the people of St. Petersburg. We asked respondents to rate the level of their approval of their use. Following six surveillance technologies were presented:

1. *Today there are 30000 surveillance cameras in 18 districts of St. Petersburg. They monitor highways, streets, intersections, city parks, residential areas, and residential hallways*
2. *St. Petersburg uses mobile and stationary cameras that monitor traffic violations (speeding, illegal parking, etc.). They identify license plates numbers and transfer the visual information about violations to the traffic police.*
3. *Government of St. Petersburg introduced a program "Smart residence". Local government installs access control systems on the entry doors of residential buildings equipped with electronic keys, surveillance cameras and an emergency button.*
4. *Russian police purchased equipment that allows it to monitor users' public activity in social networks (postings, membership in groups, likes, public comments, etc.)*
5. *Government requires all telecommunication providers to retain telephone calls and messages made and received for a period of 6 months. This information can be retrieved by the police.*
6. *Government requires messengers, social networks, mail clients and websites to assist special services in getting access to any private message that law enforcement agents might need*

Questions relating to perceptions of technologies' effectiveness in various domains of policing and crime governance, and as privacy concerns are presented in the Results section in Tables 2, 3, 4 and 5.

The survey was administered during the Spring and Fall semesters of 2019 academic year in two large top-ranked public universities in St. Petersburg, the city in the North-West of Russia with about 5 million people. The two universities have approximately 27,000 students each drawing students a range of educational and social backgrounds giving access for diversity of students. In each of them, 2–3 departments were chosen to collect data from students specializing in different areas of study (law, political science, liberal arts, economics, and art and design). In each department agreement of 3 to 6 professors' was obtained to administer surveys in their classroom either at the beginning of the class, during the class break or, after the final exam. Data came from survey administration in a total of 18 classrooms. The number of students in each class ranged from 12 to 50. A total of 600 surveys were distributed. In addition, the survey was distributed among 50 students in the cafeteria and Wi-Fi zones in 2 departments, after confirming with them if they had taken a survey in one of their classes. Of the 650 surveys that were distributed, 597 people agreed to participate in the study, representing a response rate of approximately 92%. Out of these, 570 surveys were usable, yielding a final response rate of 88%.

There were 321 females (56.3%) and 240 males (42.1%) in the sample. Of all the respondents, 203 (35.6%) were freshmen and sophomore students, 268 (47.0%) were junior and senior, and the remaining 88 (15.4%) were MA or Ph.D. students. A majority of the respondents (239/49.2%) were from families with an above-average monthly income (the average monthly salary in St. Petersburg in 2018 was 59,000 Rubles), and 197 (40.5%) reported average income. Only 50 respondents (10.3%) were from families with below-average income.

4 Results

Approval of Surveillance Technologies. Respondents' approval of technology by way of cameras and social networks in assisting police with crime prevention activities are listed in Table 1, which contains the mean scores and standard deviations for various questions posed to them in the survey. Mean scores range from 1 (strongly disagree) to 7 (strongly agree). Findings suggest that respondents strongly support and approve the use of cameras in public spaces (mean = 5.63), for monitoring traffic (mean = 5.77), and introduced as part of access control devices connected with 'smart residence' programs (mean = 5.60). In contrast, however, respondents are less supportive of use and access to technology related to access and surveillance of social networks that aid in police work. For example, respondents were reluctant to approve police use of technology for monitoring social networks (mean = 2.36), or retrieval of telephone calls and messages for police work (mean = 2.74), and technology associated with websites providing access and assistance to the police (mean = 2.47).

Table 1. Respondents approval of technology use in police activities (N = 570).

	Mean*	Std. Dev.**
Approve cameras for monitoring public areas	5.63	1.54
Approve Cameras for monitoring traffic	5.77	1.62
Approve cameras for 'smart residence' access control programs	5.60	1.60
Approve technology for monitoring social networks	2.36	1.73
Approve regulations that require storage of users' data for up to 6 months and grant police access to this data	2.74	1.90
Approve regulations that require messengers and social networks aid security services in getting access to users' data	2.47	1.84

* Responses on a Likert Scale of 1 (Strongly disagree) and 7 (Strongly Agree).
** Standard deviation.

Technology Use and Safety. In Table 2, young citizens' perceptions regarding the sense of safety derived from technology applications and use are presented. Nearly two-thirds of all respondents believe the use of cameras in society is directly tied to enhancing security relative to the deployment of social networks for the same purposes (16.5%). However, in contrast, only a third (36.2%) expressed a sense of personal safety that can come from the deployment of security technology through cameras, and even a lesser number of respondents (11.9%) feel the sense of security through surveillance of social networks. A little over half of all the respondents (58.1%) and less than a quarter (22.3%) reported having confidence in security technologies' ability through cameras and social networks, respectively. Finally, a vast majority of the respondents had a strong belief in the ability of deployment of new technologies such as cameras (61%) and monitoring of social networks (72.2) on deterring criminals from engaging in crime.

Table 2. Respondents perceptions (%)* of technology use and safety (N = 570).

	Cameras			Online Surveillance		
	SD/D**	Neutral	SA/A***	SD/D**	Neutral	SA/A***
Security of society is dependent on security technologies *(Security is dependent on new technologies)*	17.5	17.9	63.6	68.2	14.3	16.5
New security technologies make me feel safe *(Technologies will make me feel safe)*	43.3	19.9	36.2	75.3	11.3	11.9

(*continued*)

Table 2. (*continued*)

	Cameras			Online Surveillance		
	SD/D**	Neutral	SA/A***	SD/D**	Neutral	SA/A***
New security technologies will prevent more crimes *(Benefits for crime prevention)*	24.7	16.7	58.1	61.8	14.9	22.3
More people will stay away from crime as they know that they are being watched (*Deterrent effect)*	27.8	10.9	61.0	18.1	8.7	72.2

* Percentage distributions of responses on a Likert Scale where 1 = Strongly disagree and 7 = Strongly Agree. Percentages may not add up to 100% due to missing cases.
** SD/D Strongly disagree/disagree.
*** SA/A Strongly agree/agree.

Technology use and privacy concerns. Table 3 presents respondents' concerns about possible privacy infringements due to the use of surveillance technologies. People in our sample believe that both cameras and online surveillance can be used not to ensure safety but for monitoring citizens' private lives. However, those perceptions are more robust in the case of social networks monitoring (72.2%) than in the case of public cameras (61%). Similarly, respondents are much more concerned about possible privacy infringement online (76.3%) in public spaces (46.9%). About half of the respondents are afraid that government security cameras technology has the potential for its abuse by the government – they strongly believe that the government may use their personal information against them. An even more significant proportion of respondents share similar concerns relating to online surveillance.

Table 3. Respondents perceptions (%)* of technology use and privacy (N = 570).

	Cameras			Online Surveillance		
	SD/D**	Neutral	SA/A***	SD/D**	Neutral	SA/A***
Security technologies do not really help to prevent serious crime, but for monitoring ordinary citizens' private life *(Not used for crime prevention)*	27.8	10.9	61.0	18.1	8.7	72.2

(*continued*)

Table 3. (*continued*)

	Cameras			Online Surveillance		
	SD/D**	Neutral	SA/A***	SD/D**	Neutral	SA/A***
Use of new technology infringes my privacy *(Infringement on privacy)*	35.2	16.9	46.9	14.1	8.7	76.3
I am afraid technology will allow government to use my personal information against me *(Use not to prevent crime)*	31.6	16.1	51.3	15.3	8.5	75.1

* Percentage distributions of responses on a Likert Scale where 1 = Strongly disagree and 7 = Strongly Agree. Percentages may not add up to 100% due to missing cases.
** SD/D Strongly disagree/disagree.
*** SA/A Strongly agree/agree.

Technology Use and Crime Control Effectiveness. Table 4 presents beliefs that relate to perceptions of the effectiveness of technologies in crime prevention and apprehension of criminals. About two-thirds of the respondents believe that cameras are useful for identifying and arresting offenders, but about a half disagree that the evidence gathered through cameras is useful for prosecution and punishment. More than 70% agree that cameras effectively prevent and fight crime and allow to cut down on the number of police officers. However, only 20% think that cameras will help to save money allocated to crime control. Respondents appeared to be more skeptical about the crime control potential of online surveillance. Half of them doubt that surveillance is useful

Table 4. Respondents perceptions (%)* of technology use and crime prevention and control (N = 570).

	Cameras			Online Surveillance		
	SD/D**	Neutral	SA/A***	SD/D**	Neutral	SA/A***
New security technologies will help identify and arrest offenders *(Offender identification & Arrest)*	15.5	16.3	68.2	55.1	15.5	28.2

(*continued*)

Table 4. (*continued*)

	Cameras			Online Surveillance		
	SD/D**	Neutral	SA/A***	SD/D**	Neutral	SA/A***
Evidence gathered through the use of new technologies will allow to prosecute and punish those who violate the law *(Evidence gathering)*	52.3	16.3	29.6	72.6	13.7	10.9
If we use new security technologies less manpower will be needed to prevent and fight crime *(Manpower efficiency)*	13.9	13.1	71.8	48.5	18.1	32.0
With the use of technology more crime can be prevented with less money *(Cost efficiency)*	60.8	17.1	21.3	35.2	16.9	46.9

* Percentage distributions of responses on a Likert Scale where 1 = Strongly disagree and 7 = Strongly Agree. Percentages may not add up to 100% due to missing cases.
** SD/D Strongly disagree/disagree.
*** SA/A Strongly agree/agree.

for offenders' identification, and 72.6% do not believe that evidence obtained through online surveillance will be useful for prosecution purposes. Respondents disagreed that the use of new technologies can lead to a decrease in the workforce (48.5%), but almost half (46.9%) believed it would decrease crime prevention costs.

Technology Use and Police Accountability. Results about respondents' perceptions about the impact of technology use on police transparency and accountability are presented in Table 5. Data suggests that young people are much inclined to see this impact on the case of cameras use. Forty-one percent believe that cameras can decrease the possibility of police abuse of power, 32.6% agreed that cameras make police more accountable, while 36.2% make police work more transparent. In contrast, when asked about online surveillance, only 20.7% of the respondents supported the idea that online monitoring decreases the possibility of power abuse. Even less proportion of young people believe in the potential of online surveillance to make law enforcement professionals more accountable (15.5%) and transparent (17.5%).

Table 5. Respondents perceptions (%)* of technology use and police accountability (N = 570).

	Cameras			Online Surveillance		
	SD/D**	Neutral	SA/A***	SD/D**	Neutral	SA/A***
Technology decreases possibility for police abuse of power (*Reduction of power abuse)*	41.0	16.5	41.0	63.6	14.1	20.7
Technology makes police more accountable to the public *(Accountability)*	46.1	20.3	32.6	67.2	15.7	15.5
Technology makes police work more transparent to the public *(Transparency)*	44.5	18.3	36.2	67.8	13.3	17.5

* Percentage distributions of responses on a Likert Scale where 1 = Strongly disagree and 7 = Strongly Agree. Percentages may not add up to 100% due to missing cases.
** SD/D Strongly disagree/disagree.
*** SA/A Strongly agree/agree.

Summary of Attitudes Towards Risks and Benefits of Surveillance Technologies. Figure 1 represents a summary of the survey items' mean scores to measure citizen's attitudes towards risks and benefits associated with the introduction of surveillance cameras and monitoring of users' online activities. Respondents are much more willing to acknowledge cameras' potential to enhance police transparency and accountability (mean scores are above 3) than similar benefits of online monitoring (mean scores above 2 and below 3). Similarly, they see more advantages of cameras that of online surveillance when it comes to safety and police efficiency. Respondents believe that the security of the society is dependent on cameras (mean = 5.2) and they make crime prevention more effective (mean = 4.68). However, when asked about similar online monitoring, respondents were less likely to agree that it has an impact on the overall security of the society (mean = 2.87) or crime prevention (mean = 3.13). Young people are concerned about possible privacy infringements due to the introduction of technologies allowing online monitoring of social network activities (mean = 5.74). They are afraid that the information that the law enforcement agencies obtain through the use of this technology can be used against them (mean = 5.6) and do not trust that this information will be used to control crime and not against them (mean = 5.54). Concerns about the use of cameras in public places are less stronger (mean scores are in the range of 4.32–4.86).

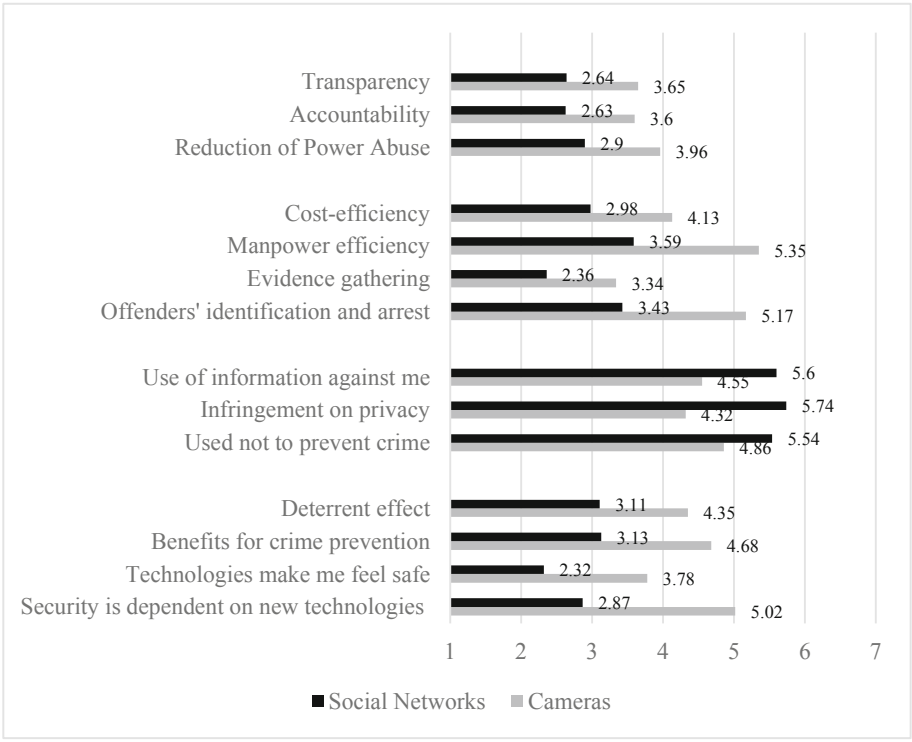

Fig. 1. Perceptions of Use of Technology on Safety, Privacy, Police Effectiveness, and Police Accountability (N = 570) Mean Scores (1 = Strongly disagree ~ 7 = Strongly Agree)

5 Discussion

Our findings suggest that citizens are more accepting of the older and more visible technologies, such as surveillance cameras. Specifically, traffic control cameras gain the most approval. As for online types of surveillance, as can be expected, citizens' level of support appears to be much lower given all the negative coverage these technologies have received in the media. Specifically, information about users' online activities resulting in controversial charges of extremism, terrorism and subsequent convictions may result in a more cautious attitude towards surveillance practices.

Young people in our study do not demonstrate strong views about the potential of technologies to ensure safety and increase crime control efficiency. This can be due to the lack of knowledge about technology's effect on crime and disorder. Studies conducted in other parts of the world demonstrate that the use of CCTV consistently decreases crime, particularly in car parks and residential areas [15]. However, studies of this kind were not conducted in Russia. Less evidence exists about the effectiveness of users' online activities monitoring. Without evidence of technologies' potential in bringing safety, we can expect ambivalent citizens' attitudes towards their use.

Much of the research on surveillance addresses the importance of citizens' concerns about privacy. The trade-off between privacy and security became part and parcel of discussions relating to introduction of new technologies aimed at crime and terrorism prevention [16]. Our findings suggest that young Russian young citizens are not an exception in being concerned with possible privacy infringements due to technology.

It is not surprising that young people believe in cameras' ability to turn the police in a much more transparent and accountable agencies but is skeptical when asked similar questions relating to online surveillance. The mechanism for enhancing accountability through cameras is much more apparent than for cyberspace monitoring as cameras directly observe interactions between citizens and the police. In the case of police abuse of power or other unlawful actions, footage obtained from security cameras can be used to provide evidence of law violations. Also, cameras can be an effective deterrent mechanism the potential civilian offenders and police officers. Research that followed the introduction of police body-worn cameras suggested that they can increase transparency and accountability and reduce the number of citizens' complaints about police behavior [17]. Being aware of the camera gaze, they may lead officers to desistance from violence or corruption. White [18] demonstrated that these cameras have a civilizing effect not only on citizens but also on the police and lead to a de-escalation of force. However, some studies found an increase in widespread violence after the introduction of cameras [19]. We are not aware whether a displacement effect of cameras specifically on police behavior was investigated. Police officers may will be likely to invent new places and methods to abuse their powers, avoiding camera surveillance. However, with other types of offending evidence regarding displacement effect has been mixed. Some studies found support for the diffusion of benefits effect rather than the crime displacement effect [20] while others provide evidence for both effects in different locations [21].

6 Conclusion

Our research finds that young citizens of St. Petersburg are generally supportive of police cameras for enhancing security and crime prevention though they had some privacy concerns. In contrast to support for cameras, their support for online surveillance was limited. Further, risks associated with online surveillance were perceived to be higher than the risks of cameras. Lastly, citizens believed in more significant benefits from cameras but not from police monitoring of social networks. These findings have implications for policy. While the decision to introduce technology is a government mandate, citizens' apprehension about the use of technology suggests the need to educate the public on benefits of technology in enhancing the overall safety and security of the citizens. If the government demonstrates the benefits of these technologies in the areas of crime prevention, transparency and accountability of police, citizens will become less suspicious of the new technologies and digital platforms, and more accepting of technology and digital platforms and increasing of the willingness to cooperate with police in crime prevention.

Despite these findings, we identify some limitations in this research. In this paper, we only examine citizens' views about surveillance but do not assess factors that shape those views. Future research could address whether approval of police technologies is

determined by citizens' attitudes towards their risks and benefits as well as by other factors such as the level of institutional trust, including trust in police, the overall level of optimism regarding technological progress, fear of crime and victimization. Understanding the determinants of public attitudes towards different dimensions of policing is of critical importance if we want to improve the image of crime control agencies in citizens' eyes. If state governance reforms relying on digital technologies are aimed at increasing citizens' participation in governance, then the role of positive citizens' views about state performance on various arenas, including security provision, cannot be underestimated.

A second limitation of our research was that it was limited to studying young peoples' attitudes who are students of large state universities. Also, most of them reported reasonably high levels of income. Therefore, results from this study are not generalizable to other population groups: adults, residents of smaller cities or rural areas, and disadvantaged citizens. The sampling strategy should be different to account for the attitudes of the general population in Russia.

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References

1. Wisser, L.: Pandora's Algorithmic Black Box: The Challenges of Using Algorithmic Risk Assessments in Sentencing, vol. 56. American Criminal Law Review (2019)
2. Haggerty, K.D., Ericson, R.V.: The surveillant assemblage. Br. J. Sociol. **51**(4), 605–622 (2000)
3. Zedner, L.: Security. Routledge, Abingdon (2009)
4. Eubanks, V.: Automating Inequality: How High-tech Tools Profile, Police, and Punish the Poor. St. Martin's Press, NY (2018)
5. Bennett, T., Gelsthorpe, L.: Public attitudes towards CCTV in public places. Stud. Crime Crime Prevent. **5**(1), 72–90 (1996)
6. Bradford, B., Yesberg, J., Jackson, J., Dawson, P.: Live facial recognition: trust and legitimacy as predictors of public support for police use of new technology (2020). SocArXiv, https://osf.io/preprints/socarxiv/n3pwa/. Accessed 20 Feb 2020
7. Gill, M., Bryan, J., Allen, J.: Public Perceptions of CCTV in Residential Areas: "It Is Not As Good As We Thought It Would Be. Int. Crim. Justice Rev. **17**(4), 304–324 (2007)
8. Heen, M.S., Lieberman, J.D., Miethe, T.D.: The thin blue line meets the big blue sky: Perceptions of police legitimacy and public attitudes towards aerial drones. Crimin. Justice Stud. **31**(1), 18–37 (2018)
9. Sakiyama, M., Miethe, T.D., Lieberman, J.D., Heen, M.S., Tuttle, O.: Big hover or big brother? Public attitudes about drone usage in domestic policing activities. Secur. J. **30**(4), 1027–1044 (2017)
10. Sousa, W.H., Madensen, T.D.: Citizen acceptance of police interventions: an example of CCTV surveillance in Las Vegas, Nevada. Crimin. Justice Stud. **29**(1), 40–56 (2016)
11. Taylor, E., Lee, M.: Points of view: arrestees' perspectives on police body-worn cameras and their perceived impact on police-citizen interactions. Br. J. Criminol. **59**(4), 958–978 (2019)

12. West, J.P., Klofstad, C.A., Uscinski, J.E., Connolly, J.M.: Citizen support for domestic drone use and regulation. Am. Politics Res. **47**(1), 119–151 (2019)
13. Kearon, T.: Surveillance technologies and the crises of confidence in regulatory agencies. Criminol. Crimin. Justice **13**(4), 415–430 (2013)
14. Pavone, V., Esposti, S.D.: Public assessment of new surveillance-oriented security technologies: beyond the trade-off between privacy and security. Public Underst. Sci. **21**(5), 556–572 (2012)
15. Piza, E.L., Welsh, B.C., Farrington, D.P., Thomas, A.L.: CCTV surveillance for crime prevention: a 40-year systematic review with meta-analysis. Criminol. Public Policy **18**(1), 135–159 (2019)
16. Davis, D.W., Silver, B.D.: Civil liberties vs security: public opinion in the context of the terrorist attacks on America. Am. J. Political Sci. **48**(1), 28–46 (2004)
17. White, M.D.: Police Officer Body-Worn Cameras: Assessing the Evidence. Office of Community Oriented Policing Services, Washington, DC (2014)
18. Hedberg, E.C., Katz, C.M., Choate, D.E.: Body-worn cameras and citizen interactions with police officers: Estimating plausible effects given varying compliance levels. Justice Q. **34**(4), 627–651 (2017)
19. Sivarajasingam, V., Shepherd, J.P., Matthews, K.: Effect of urban closed circuit television on assault injury and violence detection. Injury Prevent. **9**(4), 312–316 (2003)
20. McLean, S.J., Worden, R.E., Kim, M.: Here's looking at you: An evaluation of public CCTV cameras and their effects on crime and disorder. Crimin. Justice Rev. **38**(3), 303–334 (2013)
21. Ratcliffe, J.H., Taniguchi, T., Taylor, R.B.: The crime reduction effects of public CCTV cameras: a multi-method spatial approach. Justice Q. **26**(4), 746–770 (2009)

Environmental Agenda in Protest Campaigns: Components and Results

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Abstract. Online protest activity has become a trend of the last few years, attracting the attention of both theorists and practitioners of protest movements and social and political campaigns. The events of the last few years allow us to say that social media play a significant role in protest activity around the world. In 2019, one of the most visible and appealing forms of protest activity was environmental activism, which, however, increasingly had politicized features. In this paper, the authors define online protest as well as the role of social media in this process. The perspectives on environmental protest discussed in this paper are used to analyze three cases. Based on them, the main topics and directions that are used by environmental protest initiators to mobilize social media users are identified. Each of the selected topics of protest actions is analyzed in terms of the impact on the protest in general, as well as on users' activity and their desire to support a certain direction of protest.

Keywords: Social media · Protest activity · Protest · Environmental activism

1 Introduction

Modern civic involvement practices are increasingly using the products of information and communications technology development, combining both traditional forms of collective action and relatively new and evolving virtual actions to achieve their goals. Thus, one form of collective action - citizen protest activity - is increasingly moving to the Internet, where the real interests of citizens are expressed in the form of posts, discussions and reactions. They form protest agendas that are broadcast through the active work of actors who disseminate information about the problem. Such actors include both initiators of protest actions and campaigns, and active users of social media, who share information and develop the agenda, complementing it with information. However, the protest agenda often includes many topics, the manipulation of which is the key to drawing attention to the agenda. The combination of these topics provides the most complete picture of the protest, as well as an indication of what is its core and basis.

Social media are one of the main platforms for broadcasting the agenda. In this study, social media are understood as information and communication technology products that allow for personal, group and mass communication [1]. It is these platforms that provide

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space for communication between actors of protests and campaigns on the Internet, while the process of mobilizing users to participate in these actions takes place here as well. An important role in this process is played by the broadcasting of protest agendas, which reflect problems of concern to the community and allow the formation of public opinion.

In order to identify the specifics of agendas and mechanisms to involve people in protest movements through the use of social media, a study was carried out to analyze examples of protest actions on the Internet on the environmental agenda. In the agenda, the authors identified the topics used to involve users in protest activities and assessed the effectiveness of their use. The choice in favor of environmental protest analysis is justified by the relevance and prevalence of this topic in Russia in 2019 [2]. This study hypothesized that the protest actions under consideration were initially based on the same environmental agenda, but over time they were complemented by different themes that reflected the problems faced by the protesters. Thus, it is not the main (environmental) agenda that comes to the fore, but a different topic that emerged in the course of the protest, as it is the agenda that allows to reveal the content of the protest campaign and to identify its main and related objectives

2 Theoretical Approach

Study of online processes is one of the priority areas for researchers in the social and political field. This issue is particularly acute for Russia, where social media are at a crossroads due to the ongoing change in media consumption habits [3]. In addition, as Olessia Koltsova and Svetlana S. Bodrunova note, the content and structure of the Russian language online discourse has not been sufficiently studied yet [4]. There are many approaches to studying online protests and impact of information technology on civic engagement in the virtual space. For example, A.M. Ertugrul, Y. Lin and W. Chung adhere to the spatiotemporal approach to the studying protest activity on social media, examining the relationship between protest phenomena, their social and geographical features, and interpretation of events in the virtual space [5]. Aaron Franklin Brantly adheres to a similar approach, using the example of protests in Ukraine in 2013–2014, he notes that in addition to the geographical factor, protest activity is also influenced by the linguistic factor [6]. A different approach to studying online activity can be seen in the work of Jinhee Kim and Ki Deuk Hyun. They consider the mobilization role of political discourse in social media and come to the conclusion that political agreement or disagreement with an information resource can lead to both an increase and decrease in political activity [7].

Another approach is to analyze reactions to certain events on social media. For instance, Alexander Dunkel, Gennady Andrienko, Natalia Andrienko, Dirk Burghardt, Eva Hauthal and Ross Purves in their work point out that collective reactions [8].

Frédéric Volpi and Janine A. Clark describe the important role of social media in the process of mobilizing “bottom-up” political activity under the influence of social and political factors, using the Arab Spring as an example. They note that the political role of social media is not as significant as it is commonly assumed in a regime-centric political reading, but that despite this, the impact of social media on political mobilization is still

quite large [9]. A similar opinion is held by Delia Dumitrica and Mylynn Felt, who argue that activists often do not see the difference between high expectations from social media and actual experiences of their use [10]. Rasmus Rodineliussen, describing the role of Facebook in the framework of the military conflict in Syria, notes that it has become an element of mobilization infrastructure, as well as a means of effectively spreading revolutionary sentiments among users [11].

In addition, the role of social media in shaping group identity is significant, as noted in the work of Marie Merle, Gerhard Reese and Stefan Drews [12]. Andrew Dawson and Martin Innes consider the problem of the influence of social media on the social and political discourse through misinformation of population. They, like many other researchers, point out that information on social media has a greater influence on collective consciousness than on that of an individual [13]. This idea is also supported by the team of authors of the work "The role of social media in shaping solidarity and compassion fade: How the death of a child turned apathy into action but distress took it away". They point out that group consciousness can be supported by social media [14].

Another form of social media influence is motivating users to participate in various forms of online activity. For example, in "E-Petitioning and Online Media: The Case of #BringBackOurGirls", a group of researchers prove the influence of Twitter on signing an online petition. In particular, the authors note that the speed and ease with which tweets spread is the basis for the emergence of viral effects, i.e. they significantly increase the speed with which the link to the petition reaches users [15]. A study of online activity involvement conducted by Raffael Heiss, Desiree Schmuck and Jörg Matthes is interesting, as well. Through studying various formats of posts and materials, they were able to ascertain that emotionally coloured posts attract more attention from users, while mobilization posts have a negative effect on user involvement [16].

The interrelation between digital media and social movements is also one of the controversial issues of modern science. In this area, Elena Pavan and Andrea Felicetti note that activists critically assess social media on the basis of three factors: the relevance of the main digital platforms for informing citizens, the projected effectiveness of digital tools, and an attempt to distinguish themselves from the global network of transition period [17].

The development of the Internet as a communication channel in social and political relations has come a long way. The origin of those opportunities and tools, which are now integral parts of interaction in the virtual space, became possible in the development of the Web 2.0 environment. Tim O'Reilly stated that in the social aspect, the new generation of Internet technologies, technically based on high-speed connection to the network, is aimed at maximizing the use of interactive technologies to form online communities [18]. Talking about the ideas laid down by O'Reilly, another researcher, Paul Anderson, stated in 2007 that the new environment had allowed the development of many different Internet resources and tools, in particular: blogs, Wiki services, tags, multimedia distribution platforms, podcasts and RSS feeds, etc. [19]. Later, under the influence of technical progress, these resources began to be transformed into more familiar to the modern user social media, hashtags, and RSS replaced the news feed of social media. Over time, thanks to the development of the Internet, the possibilities of telecommunication networks and growing audience, social media began to occupy one of the key roles

in the life of modern people. Due to their functionality and impact on society, some researchers began to notice signs of social institutions in social media: communicative, regulatory, integrative, broadcasting, and other signs [20]. In contrast, some researchers are convinced that social media are a substitute for objective reality [21]. Nevertheless, their development marked a new era in social and political relations, when traditional forms of collective action began to acquire a virtual character: electronic petitions, online flash mobs, protests and campaigns, online protest activity began to appear.

Explaining the concept of online protest activity and collective action in an online environment, it is necessary to divide these terms into key components. The notion of online activity means a communication space derived from the Internet, in which mass values are disseminated with norms and values specific to the virtual space that are different from the real ones [22]. The notion of protest activity is most often mentioned in the context of collective ones, caused by public discontent with the existing social order, which is perceived as infringing or limiting their interests [23]. Thus, the joint use of the two above mentioned concepts allows us to define online protest activity as a form of collective actions of citizens aimed at changing the existing social order and conditions of life, implemented on the Internet using specific forms of communication and based on values unique to the virtual space

Such values are, in particular, the different reactions of social media users. Thus, the most popular types of reactions include likes, comments, reposts, views, as well as a special form of coparticipation which is subscription or adding as friends. Attention to this form of communication between users is justified primarily by the fact that reactions are some of the most accessible for both user and researcher forms of identification of involvement, complicity, and support. Some social media researchers point out that from a socio-psychological point of view, reactions such as reposts are a statement that the user shares the views of the author and is willing to tell others about them [24]. This very aspect of reactions in social media is one of the main studied features of social media as a communication channel. Another important issue is the degree of support for authors, an idea embedded in their material or an initiative put forward on social media. In its consideration, a special role is given to comments as one of the tools of self-representation of the user, where facts and opinions with subjective meaning are reflected, interpreted and evaluated [25]. Such subjectivity of comments allows for the possibility to take into account the attitude of users, determining the tone of comments of single users, and the average tone of all subscribers, as a whole, if we are talking about large actions and campaigns. Such actions can also be considered environmental, which, as noted above, became one of the most discussed in Russia in 2019. Environmental protest is defined as a protest in the field of environmental problems, the purpose of which is the harmonious coexistence of nature and humankind in the living environment [26]. However, most researchers note the radicalization of environmental protests and their politicization. In particular, the researchers draw attention to the fact that modern environmental protests aim to counteract the implementation of major infrastructure projects by applying a wide range of political and legal technologies [27]. In this study, the authors adhere to both positions, noting both the environmental foundations of protest and its broad politicization and radicalization, which will be proved or disproved in the future.

3 Research Methodology

In order to identify the specifics of the agendas and mechanisms for involving the population in protest movements through the use of social media, a study of three major Russian protest campaigns in 2019 was conducted: 1) protest against the construction of a junkyard in the Lensky district of the Arkhangelsk Oblast near the Shiyes railway station; 2) protest against the construction of a water bottling plant on the Lake Baikal; 3) protest against the construction of a pulp and paper plant at the Rybinsk Reservoir. A number of factors have contributed to the selection of these cases: 1) as mentioned above, in 2019, one of the main topics in Russia and widely discussed in the world was the environment and ecology, to which these cases belonged; 2) the environmental issues under consideration were widely discussed in the mass media, which led to high public awareness of the events; 3) these protests were highly supported on social media; 4) the protests were characterized by a wide geographical coverage, i.e. residents of several regions of Russia were involved in active actions.

Thus, all of the protests considered were environmentally oriented and related to the prevention of implementation of decisions made by the authorities or lobbied by groups seeking the construction of ecologically unsafe facilities.

Policy analysis methods such as event analysis and index analysis were used to analyze the content of the agendas and mechanisms for mobilizing users of Vkontakte social media website. This study does not cover the population in general, but the users of social media who are members of the groups under consideration or have signed up for their updates.

The largest groups in the Vkontakte social media website for each of the identified protests were used as the empirical basis for the research: “STOP TsBK | Yaroslavl Oblast” (“STOP PULP AND PAPER PLANT| Yaroslavl Oblast”) [28], “Sudsky TsBK – ugroza Rybinskomu vdkhr. i r.Volga” (Sudsky Pulp and Power Plant – a threat to the Rybinsk Reservoir and Volga River) [29], “Protiv zavoda na Baikale” (Against the Baikal Plant) [30], “MY PROTIV SVALKI NA SHIYESE” (WE ARE AGAINST THE SHIYES JUNKYARD) [31], “SHIYES” [32].

Quantitative analysis included counting of posts in Vkontakte communities, which are dedicated to the protest under consideration and reveal the content of the key environmental topic, as well as the number of public reactions to them, including possible user actions in the Vkontakte social media website. These include viewing the publication placed in the group; liking as an expression of approval to the content of a certain publication in the social media through the use of evaluation or “Likes”; repost which is placement in the group of the publication from the page of other users of the social media; comments which are messages/posts of the user in the social media as a reaction to previously proposed content in the group. Comments were classified by the following types: 1) expressing support for the publication placed in the community and 2) not supporting the shared information. Data collection was carried out using the “Popsters” software which is a service of analytics of posts and accounts in social media. It allowed collecting an array of data necessary for further analysis. The obtained data were entered into the table developed by the authors, thanks to which it became possible to visualize the dynamics of the use of various topics in the main protest agenda. In addition, positive

and negative comments were counted manually to determine the tone of comments on each of the topics.

All publications were classified according to the main agendas singled out by the authors depending on their mentioning in the groups of protest actions under consideration:

1) ecology/environment include posts containing information on environmental and geological problems, statistical data on assessment of human impact on environment, etc.
2) citizens' health include posts on the impact of ecology on public health;
3) legal sphere includes such aspects as publication of final administrative or judicial documents, disputes between the authorities and the protest society regarding the holding and approval of public actions, violation of citizens' rights (to hold public events, to a favorable environment, etc.);
4) politics includes publication of information related to the activities of public officials on the problem under consideration, disputes between the authorities and the population regarding the coordination/non coordination of public protest actions, expression of public dissatisfaction with the authorities' work on the protest agenda;
5) mobilization of citizens includes information about the upcoming and past protest actions, posts include calls for participation in public events, for collecting signatures.

The marked categories are listed in the table for the purpose of calculation (Table 1).

Table 1. Event analysis of social media

Date of publication			01/01/01	02/01/01	03/01/01
Name of the protest campaign	Mobilization				
	Environmental				
	Health				
	Politics				
	legal				
Subscribers' actions on social media	Likes				
	Reposts				
	Comments	Support			
		Lack of support			
	Views				

Each of the selected agendas was also analyzed using the event analysis method, which made it possible to determine both the total number of reactions from the population to it (likes, reposts, comments, views) and identify the most frequently used method of informing population about the protest issue. In this study, the method of informing

population is understood as a specific type of information on a social media website that enables conveying of the message of a post: 1) text which is a post which contains mainly textual type of conveying information; 2) photo which is a post which contains images, illustrations of actions, events on the topic that are taking place; 3) video which is a post which contains audiovisual content aiding comprehension of the agenda under consideration; 4) interactive type of conveying information which is a post which contains links to external, for example, news resources, links to petitions, as well as "public surveys" and "public polls".

On the basis of the quantitative data obtained, the index of social media users' involvement in protest activity was calculated for the protests under consideration as a whole and for the separate protest agendas. Involvement should be understood as the level of social media users' participation in the protest Internet activity under consideration determined by counting the number of user actions.

The involvement index (W) is calculated by the formula (1):

$$W = \frac{L * 0.48 + C * 0.73 + R * 0.73 + V * 0.37}{P + F * 0,63} / t / 100, \quad (1)$$

where

L is the product of the total number of likes (L) on official pages of protest activity and the weighting coefficient assigned according to the results of the expert survey.
C is the product of the total number of comments (C) on official pages of protest activity and the weighting coefficient assigned according to the results of the expert survey.
F is a derivative of the total number of subscribers (F) on official pages of protest activity and the weighting coefficient assigned according to the results of the expert survey.
R is the product of the total number of reposts (R) on official pages of protest activity and the weighting coefficient assigned according to the results of the expert survey.
V is the product of the total number of views (V) on social media websites and the weighting coefficient assigned according to the results of the expert survey.
P is the total number of posts for the studied period. This variable shows the activity of the protest campaign initiator on social media websites.
t is the number of months in the studied period [33].

Weighting coefficients of reactions on social media websites used in the framework of this study were obtained as a result of a survey of experts on the significance of a particular form of reaction (from among those included in the index) on assessing the involvement of a social media user in online activity. It was suggested that the assessment should be made on a 10-point scale, after which an average value was taken, which was also divided by 100 for ease of calculation. A total of 10 experts (2 media representatives, 2 representatives of scientific community, 2 representatives of state authorities, 4 representatives and organizers of social movements, actions and campaigns) were interviewed.

Thus, the methods of political analysis chosen by the authors will make it possible to develop the subject matter of the study and achieve set goals. Insert the piece about similar studies conducted using the same methods and this will make it possible to obtain representative data.

During quantitative calculations, conclusions will be drawn about the presence or absence of protest agendas related to the main protest topic, the prevailing agendas in each of the environmental conflicts under consideration will be identified, and the level of user involvement in a particular protest field will be determined. Consideration of ways to inform users about the problem will make it possible to identify the most frequently used methods of involving social media users in Internet protest for each of the identified fields.

4 Protest Against the Construction of a Plant on Lake Baikal

The community "Against the Baikal plant" which unites users who oppose the construction of a plant for bottling Baikal water in the village of Kultuk, became the smallest in terms of the number of participants and posts for the period of 2019, which is probably due to the specific character of the problem, i.e. its locality and a narrow circle of interested individuals. Active efforts to inform users about the problem in this community on the Vkontakte social media website were carried out from March to September 2019, but the beginning of the protest itself dates back to the first half of 2017. Over the seven months of functioning of the community "Against the Baikal plant" 21 publications on the topic were posted with the total number of 640 likes, 57 reposts, 9 supporting comments, and 23,546 views.

A distinctive feature of the community presented for analysis is restriction of users' actions regarding posting comments under the posts, which is related to the main goal of the community – to draw attention to the problem and inform rather than discuss it.

The largest number of posts in the community was concerned with the topics of mobilization (15 posts) and legal field (5 posts), while the topics of health and politics were not addressed at all. At the same time, involvement was higher when it came to informing users about the protest movement, calls for offline protests (0.0185) and about environmental situation of the region (0.0044).

The most popular way to attract users' attention to the information posted was through photos and images. Posts with such content accounted for more than 90% of all posts in the community. The largest number of photos posted is found in fields such as mobilization (80%) and environment (100%), where this type of content makes it possible to clearly show the problem. When users were encouraged to participate in various forms of protest, photos with media persons expressing support for the protest movement were often posted.

Interactive forms of involving the community's subscribers proved to be peculiar to the legal field and contained links to external news publications and links to petitions posted on the Internet. This field is also characterized by textual expression of news, due to the specific character of legal information on the issue.

Thus, during the protest campaign in the community on the social media website created to unite citizens in order to prevent the construction of water bottling facilities on Lake Baikal, key issues for discussion were the ones associated with the mobilization and legal fields. The main type of information posted in the community was text and photos, the overall level of user involvement was 0.028, which indicates low interest of citizens in participation and support of the Internet protest.

5 The Protest Against the Construction of a Junkyard at the Shiyes Station Area

The protest against the construction of a landfill near the Shiyes railway station was one of the most discussed in 2019. It is, in fact, a continuation of the protests against the importation of garbage from Moscow into Russian regions. The protest agenda on social media websites is supported not only by individual users and public opinion leaders, but also in numerous communities, which are platforms for communication, coordination and mobilization of users. The largest and most active communities are "WE ARE AGAINST THE SHIYES JUNKYARD" and "SHIYES". An interesting detail is worth noting: while the first community was purposefully created to support the protest in May 2019, the second community was reformatted from the community with advertisements for sale, purchase of various goods and services in mid-2019. Thus, the activity of these communities can be reduced to eight months: from May, when the protesters began to actively oppose the regional authorities and the construction management, to November, when the protest entered a phase of lull, which can be attributed to the onset of cold weather and suspension of construction. Over the analyzed period of time 296 posts on the main agenda were published which received 29,830 likes, 6,102 reposts, 2,368 positive and approving comments, 212 comments not related to the agenda or criticizing it, and 1,452,824 views. The total number of subscribers of the 2 communities amounted to 17,380 people. Based on these indicators, total user involvement was calculated, it is 0.071, which is a very low indicator and demonstrates an actual lack of users' interest in participation and coverage of this action, despite the high level of support, based on the tone of comments, where the ratio of positive and negative comments is 11.16. A positive indicator demonstrates that social media users share the positions of the authors of posts; however, if we consider this indicator together with the involvement, we can conclude that users only share the attitude of the protest action initiators, but are not ready for active manifestations of protest.

If we consider this protest action from the point of view of further development of the main agenda, we can ascertain that it was further developed, to a greater extent, due to the mobilization activity of the authors who urged users to attend the rallies, impede the construction of the landfill, as well as help the protesters in Shies. In addition, the analysis of the posts suggests a high level of politicization of the protest: almost half of the posts in one way or another touched upon the illegality of the government's actions, criticized it, abuse of power by it and the law enforcement agencies, as well as the lack of attention from the government to the protesters. The topic of civil rights protection also has a high indicator of mentioning, which was seen in the story about illegal detention of protesters, infliction of bodily injuries, unsuccessful attempts to coordinate rallies and referendums, as well as unfair, in the authors' opinion, court decisions. At the same time, the environmental topic was the least mentioned, although it was initially the starting point for the protest: the first posts were on this very topic. The topic of the impact of the construction on human health, as well as the public health issues were not addressed in the action under consideration. The distribution of publications by topics is given in Fig. 1.

It is also worth noting that each of the topics, in addition to obvious differences in the level of mentioning, had different indicators of users' activity and their involvement

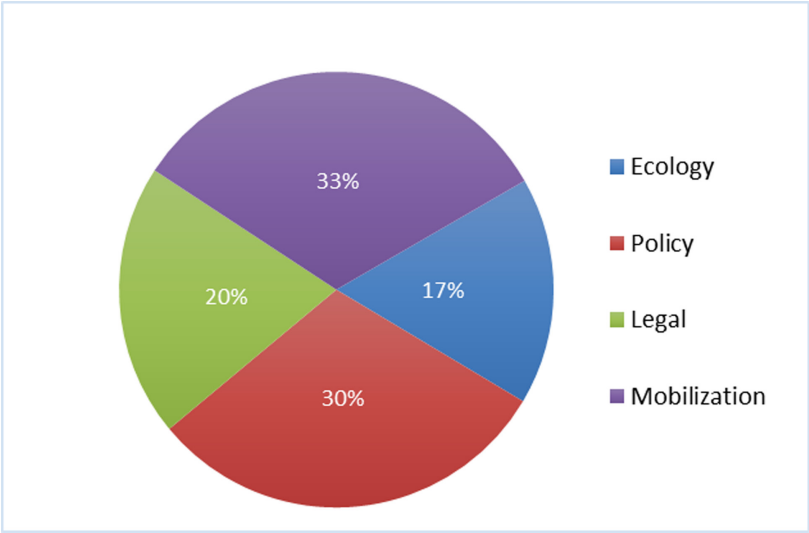

Fig. 1. The distribution of publications‘ topic

in each of the topics. What is interesting is that despite the considerable support for the topic of citizens' rights protection (which is clear from the high indicator of average comment tone of 32.2), the involvement in this topic, on the contrary, is the lowest. From this, we can conclude that the users are ready to show empathy due to unfair decisions, but are not ready to actively defend the rights of others. The distribution of the level of activity, support and involvement by topics is presented in Table 2.

Table 2. Activity, support and engagement levels by topics.

	Ecology/nature protection	Health	Political	Defense of rights	Mobilization
Number of posts	50	0	90	60	96
Likes	4187	0	13137	4055	17445
Reposts	692	0	2547	568	4020
Views	162360	0	651092	259031	873869
Total number of comments	263	0	1184	396	1350
The tone of comments	10,52	0	13,26506	32,21429	18,37288
Involvement	0,008248774	0	0,032696	0,012888	0,043882

Thus, in this action we can observe the process of unsuccessful attempts to mobilize social media users, which, despite the high publication activity, caused only indirect support and empathy of the citizens.

6 The Protest Against the Construction of a Pulp and Paper Plant at the Rybinsk Reservoir

The decision taken by interested groups to build a pulp and paper mill directly affects the interests of residents of several Russian regions, in particular the Yaroslavl, Vologda and Kostroma oblasts. In order to quickly inform citizens about the decisions taken by the government and legal authorities, as well as to consolidate the population opposed to the construction of the plant, a number of communities on the Vkontakte social media website were created, two of which have the largest number of subscribers were chosen to conduct the study: "STOP Pulp and Paper Plant" | YAROSLAVL OBLAST [28], "Sudsk Pulp and Paper Plant – a threat to the Rybinsk Reservoir and Volga River" [29].

The period of active posting in the communities was from November to December 2019, which can be attributed to offline protests in Russian regions. Throughout 2019, in both communities the total of 174 publications on the topic were posted, 90 of which belonged to the mobilization field, 51 – to the political field, 30 – to the environmental field, 21 – to the legal field and 1 publication – to the topic of health.

This protest campaign also confirms the trend that it is other agendas that prevail in protest communities, rather than the environmental topic that thematically unites them. For example, in the Internet protest against the construction of a pulp and paper mill, the leading fields were the mobilization and political ones, which also testifies to the politicization of the protest. The topic of health was not relevant for the Vkontakte users.

In connection with public events held in the form of pickets and rallies, it can be said that communities on the social media websites have become a peculiar tool for mobilizing citizens to participate in protest movements. This fact is confirmed through the largest number of likes (10,890), reposts (2,820) and views (374,881) in the field of mobilization. The main type of information in posts aimed at informing the population about the upcoming rallies and collecting signatures against the construction of the pulp and paper mill was photos (70%) and text (56.6%).

The topic of environment and environmental protection was most often supported by posts including videos and photos, which is explained by the simplicity of perception, visibility and colorfulness of the information presented.

To cover the political topic the most frequently used information formats were: text (60.7%) and interactive formats (66%), often containing external links to regional news resources, related to unsuccessful attempts to coordinate a public event with authorities, relocation of the protest event venue.

Speaking about the ratio of comments supporting the information posted on the community to those not supporting it, it can be concluded that there is the greatest solidarity in the legal field (18.2), at the same time users expressed the least concord in comments in the field of health (4.6) and political field (8.7).

Against the background of the low overall involvement in the Internet protest activity (0.026), the posts in the mobilization field aroused greater interest among citizens (0.0156).

Thus, the specificities of the Internet protest against the construction of a pulp and paper mill on the Rybinsk reservoir were: 1) the dominance of political and mobilization fields in the general theme; 2) the active use of interactive forms of informing the population about the problem, mainly in the political aspect, by posting links to external news sites; 3) as in the campaigns already considered, the main type of information posted on the environmental topics were photos and videos. The involvement of social media users was at a low level, with the prevalence of involvement in the mobilization field. At the same time, the posts on the legal field received the most support in the comments, which indicates the importance of the topic of personal and public rights protection for users.

7 Discussion

The data obtained in the framework of the study demonstrates the ambiguity of protest activity in the online space. On the one hand, even in local protests we can observe a high level of user activity, and on the other hand, there is a rather low level of user involvement. Based on these results, several assumptions can be made which may serve as a basis for further studies:

- Existence of interrelation between online activities and real ones can be manifested in users' assessment of real situation and its correlations with the agenda on social media websites. For example, users actively expressed support for "victims" of unlawful actions by law enforcement officials and authorities, but when assessing the risks of participating in an open confrontation, they were not very active in protecting their interests both online and offline.
- Radicalization and politicization of protest is possible not only as a result of the development of central agenda, but also as a basis for protest, prepared for and used to mobilize users.
- The interrelation between online and offline activity has not been fully understood. Despite the evident impact of external factors on the activity of the protest campaign on social media websites (the beginning of the confrontation and its end, key events, etc.), during other periods the activity is spasmodic in its nature, which may not be connected with real events. This leads to the assumption that only a few online actions are reflections of the offline space.

Thus, the above assumptions remain unresolved within the framework of this paper, however, they require further elaboration, since their study will make it possible to greater understand the nature of virtual social and political relations, as well as the role of ICT products in real processes. The issue concerning effectiveness of various methods for mobilizing social media users remains unresolved as well. Thus, despite the prevalence of textual materials, it is video and photo posts that receive the greatest number of reactions, which may indicate different effectiveness of materials, but does not indicate the level of influence on involvement.

The object under study also requires clarification and concretization in further studies. In the framework of this study, the object under study was selected based on the

common agenda but at different levels, which may explain different levels of involvement and support from users. Concretization of the object by the level of protest into federal, regional and local levels may become necessary for comparative analysis of protest actions with greater reliability of the results obtained, which was not the purpose of this study.

8 Conclusions

In conclusion, one should note the major role of the substantive and supporting agenda in disseminating information about protest campaign, as well as in mobilizing users to participate in it. Consideration of major environmental protests of 2019, in particular their coverage on the Vkontakte social media website, suggests the following patterns of online protest:

1) Despite the fact that environmental issue was the key protest topic in all the actions considered, there was a relatively low number of posts on this topic, which is explained by such factors as: the decrease in interest in the main topic and the activists' attempt to keep users' attention; the implementation of the protest required the addressing of emerging (current) issues;
2) The protest campaign was mostly based on the posting of information of mobilization or political orientation, the involvement in which on the part of users was usually higher than in other fields. Social media served as a platform for broadcasting real events to the users, and as a result, the online reaction on mobilization issues was at a predominantly high level. At the same time, the topicality of the political topic can be explained by the fact that these problems were discussed at the level of federal and regional authorities, therefore, we can talk about high involvement of government representatives in the process of environmental decision-making. Frequent discussion of problems at the level of authorities has contributed to the emergence of a great number of news opportunities in the media and social media.

It should also be noted that the obtained results confirmed the hypothesis set forth before the beginning of the study: despite the fact that the initial agenda for all actions was the environmental issue, it was not supported on a permanent basis, and preference was given to mobilization materials and posts on political topics. They were the main ones throughout the protest campaign and also attracted more attention from users. It could therefore be concluded that the politicization of the protest is now coming to the fore along with the attempts of the campaign initiators to maximize the number of participants through mobilization of users. Based on the analysis of the materials posted, it can be concluded that the most commonly used are textual materials and photos, rather than various video or interactive forms that social media websites currently offer: tests, surveys, polls, etc. This suggests that the initiators of protest campaigns do not take into account the development trends of popular forms of content presentation, since they use textual materials to a greater extent, although the study has proved that posting of video materials and interactive forms of content contributes to the greatest involvement of users.

To sum up, the study suggests that online protest has become widespread in contemporary collective action practices. An easier form of communication, a variety of forms of user interaction and various forms of user mobilization make social media attractive for both large protest campaigns, such as the protest against the construction of a landfill in the Shies station area, and more local ones, such as the construction of a plant on Lake Baikal. Due to the public availability of social media and their spread, even local protests can grow into federal ones, which happened with Shies, and also attract the attention of authorities and media, that use communities and pages of protest campaign on social media websites as a source of relevant information. However, such activity on social media, despite its attractiveness for conducting social and political campaigns, has a number of significant drawbacks, one of which is the difficulty in determining the results of the campaign, as well as its effectiveness and impact on real events. The study has proved the high role of social media in broadcasting protest agendas and public opinion. Competent use of social media websites increases the information coverage of the agenda, by increasing the number of recipients and their involvement in online and offline protest. Thus, among users the most popular are mobilization posts, which, in addition to their information function, encourage users to take part in various activities within the protest action.

The results of the study can be extrapolated to protest actions and campaigns with other agendas. In addition, the author's methodology is unique and can be used to analyze existing campaigns, in order to demobilize protesters and for settlement of the protest situation as well.

In conclusion, it should be noted that the most comprehensive analysis of online protest activity will be possible only after the complete institutionalization of social media and the emergence of methods that allow to determine more accurately the explicit and indirect interrelation between online and offline space.

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References

1. Voyskunskiy, A.E.: Social perception in social network sites. MSU Vestnik. Series 14. Psychology **2**, 90–103 (2014)
2. Ezhov, D.A.: Environmental protest in the political and technological dimension: systematization of methods. Power **5**, 34–37 (2019)
3. Lehtisaari, K., Miazhevich, G.: Introduction: the Russian media system at a crossroads. Russ. J. Commun. **11**(1), 1–5 (2019)
4. Koltsova, O., Bodrunova, S.: Public discussion in Russian social media: an introduction. Media Commun. **7**(3), 114–118 (2019)
5. Ertugrul, A.M., Lin, Y., Chung, W., et al.: Activism via attention: interpretable spatiotemporal learning to forecast protest activities. EPJ Data Sci. **8** (2019). https://epjds.epj.org/articles/epjdata/abs/2019/01/13688_2019_Article_183/13688_2019_Article_183.html. Accessed 15 Jan 2020

6. Brantly, A.F.: From cyberspace to independence square: understanding the impact of social media on physical protest mobilization during Ukraine's Euromaidan revolution. J. Inf. Technol. Polit. **16**(4), 360–378 (2019)
7. Kim, J., Hyun, K.D.: Political disagreement and ambivalence in new information environment: exploring conditional indirect effects of partisan news use and heterogeneous discussion networks on SNSs on political participation. Telemat. Inform. **34**(8), 1586–1596 (2017)
8. Dunkel, A., Andrienko, G., Andrienko, N., Burghardt, D., Hauthal, E., Purves, R.: A conceptual framework for studying collective reactions to events in location-based social media. Int. J. Geogr. Inf. Sci. **33**(4), 780–804 (2019)
9. Volpi, F., Clark, J.A.: Activism in the Middle East and North Africa in times of upheaval: social networks' actions and interactions. Soc. Mov. Stud. **18**(1), 1–16 (2019)
10. Dumitrica, D., Felt, M.: Mediated grassroots collective action: negotiating barriers of digital activism. Inf. Commun. Soc. (2019). https://www.researchgate.net/publication/333302161_Mediated_grassroots_collective_action_negotiating_barriers_of_digital_activism/link/5ce6031ca6fdccc9ddc7009b/download. Accessed 15 Jan 2020
11. Rodineliussen, R.: Organising the Syrian revolution—student activism through Facebook. Vis. Stud. **34**(3), 239–251 (2019)
12. Merle, M., Reese, G., Drews, S.: #Globalcitizen: an explorative twitter analysis of global identity and sustainability communication. Sustainability **11**, 1–10 (2019). https://doi.org/10.3390/su11123472
13. Dawson, A., Innes, M.: How Russia's internet research agency built its disinformation campaign. Polit. Q. **90**(2), 245–256 (2019)
14. Thomas, E.F., Cary, N., Smith, L.G.E., Spears, R., McGarty, C.: The role of social media in shaping solidarity and compassion fade: how the death of a child turned apathy into action but distress took it away. New Media Soc. **20**(10), 3778–3798 (2018)
15. Harrison, T., et al.: E-petitioning and online media: the case of #BringBackOurGirls. In: Proceedings of the 18th International Conference of the Digital Government Society, Staten Island, NY, June 2017, 10 p. (2017)
16. Heiss, R., Schmuck, D., Matthes, J.: What drives interaction in political actors' Facebook posts? Profile and content predictors of user engagement and political actors' reactions. Inf. Commun. Soc. **22**(10), 1497–1513 (2019)
17. Pavan, E., Felicetti, A.: Digital media and knowledge production within social movements: insights from the transition movement in Italy. Soc. Media Soc. 1–12 (2019). https://journals.sagepub.com/doi/pdf/10.1177/2056305119889671. Accessed 15 Jan 2020
18. What Is Web 2.0. https://www.oreilly.com/pub/a/web2/archive/what-is-web-20.html. Accessed 15 Jan 2020
19. What is Web 2.0? Ideas, technologies and implications for education. http://www.ictliteracy.info/rf.pdf/Web2.0_research.pdf. Accessed 15 Jan 2020
20. Sherbakova, I.A.: Institutionalization of social network sites. Commun. Electron. Sci. Mag. **3** (2018). https://cyberleninka.ru/article/n/institutsializatsiya-sotsialnyh-setey. Accessed 15 Jan 2020
21. Cherepanova, T.V.: Online social network sites as a phenomenon of modern culture. Mariupol State Univ. J. Ser. Philos. Cult. Sci. Soc. Sci. **4**, 123–128 (2012)
22. Shakirova, E.Y.: Consciousness vs virtuality. Moscow University for the Humanities Scientific Papers **3** (2018). http://journals.mosgu.ru/trudy/article/view/745. Accessed 15 Jan 2020
23. Konevskaya, O.Y.: Methodological approaches to the study of protest activity of the population. Issues Mod. Jurisprud. **12**(51), 85–93 (2015)
24. Bezbogova, M.S., Iontseva, M.V.: Social and psychological aspects of users' interaction in online social network sites. World Sci. Pedagogy Psychol. **5**, 1–6 (2016)

25. Karpoian, S.M.: Comment functions on various social media communication platforms. Humanit. Soc.-Econ. Soc. Sci. **11**(2) (2015). https://cyberleninka.ru/article/n/funktsii-kommentariya-na-razlichnyh-kommunikativnyh-platformah-sotsialnyh-setey. Accessed 15 Jan 2020
26. Galustov, K.A.: Spatiotemporal models of the impact of environmental and ecocultural protest on the use of urban space on the example of Leningrad-Saint Petersburg. Vestnik of Saint Petersburg Univ. Earth Sci. **3**, 163–179 (2016)
27. Ezhov, D.A.: Environmental protests: reconstruction of the problem field. Power **6**, 157–160 (2019)
28. STOP the pulp and paper mill: Yaroslavl Oblast. https://vk.com/stopcbk_volga. Accessed 13 Jan 2020
29. Sudsky pulp and paper mill is a threat to the Rybinsk reservoir and the Volga river. https://vk.com/stop_cbk. Accessed 13 Jan 2020
30. Against the plant on Lake Baikal. https://vk.com/public166386670. Accessed 13 Jan 2020
31. We Are Against The Dump On Shiyes. https://vk.com/great__food. Accessed 13 Jan 2020
32. SHIYES. https://vk.com/ob_kotlas. Accessed 13 Jan 2020
33. Sokolov, A.V., Belyakov, A.A.: Engagement index: a measure of protest activity. In: Sokolov, A.V., Vlasova, A.A. (eds.) Opportunities and Threats of a Digital Society 2019, pp. 12–17. Digital Printing House LLC (2019)

Factors of Temporal Behavior in Online Media: What Shapes Time on Internet?

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Abstract. The Internet forms not only new cyberspace but also has a significant impact on the perception of time and its organization. Focusing on the phenomenon of temporal behavior in social media, the current study aims to identify factors that can determine the dynamics of communication in the comments of the popular Russian social network Vkontakte. The research is based on data from six major online media: "Meduza," "Lenta.ru," "Rossiyskaya Gazeta," "Novaya Gazeta," "Mayak," and "Russia Today." We examine the frequency of publications, the dynamics of communication, the temporal distribution of comments, and the post response rate. The identified four temporal behavior models described as "Discussion media," "Stimulus is a response," "From call to call," "Timeless or Silence is gold," provoke assumptions about the possible causes of differences in the dynamics of communication between Russian Internet users.

Keywords: Social networks · Cybertime · Temporal behavior · Social media · Comments

1 Introduction

Whereas *cyberspace* is one of the most popular metaphors used to describe all specifics of virtual reality, the concept of *cybertime* has not become widespread to a similar degree. So far, very little attention has been paid to the research into the temporal dimension, and its role in online relations. At least two lines of temporal network research can be distinguished. The first one is the theoretical analysis of modern society under the conditions of developing information technology [2, 5, 16]. The second one is empirical research, the important part of which is devoted to temporal behavior [4, 13, 15].

However, cybertime changes day-to-day life and established patterns by mixing and restructuring the relations between people. Cybertime offers new freedoms meaning the choice of strategy of temporal behavior, but at the same time, even stricter, it limits people who cannot hide from the new time dimension in habitual and safe physical places. Moreover, the view on the Internet is not that of a single cyberspace, but rather a multitude of cyberplaces which inevitably suggests the differentiated nature of the passing of time in these cyberplaces as well as various dynamics of communication. Such non-linearity of social time is reinforced due to the appearance of a great many groups and individual behavioral strategies [1].

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We suppose that media, the audience, and objective factors (incl. the size of the audience) can set temporal behavior. In particular, media can determine it through the particularity of news, formation of audience communication rules, moderation, etc. Alternatively, the causes in the differences of temporal behavior on the part of the media audience can be various strategies of temporal behavior determined by a set of factors [1].

This study aims to identify the characteristics of the temporal behavior of commentators of news public pages on the VKontakte social network, the most widely used networks among the Russian-speaking cyberspace community.

2 Theoretical Background

The theoretical research into online time has enriched the scientific vocabulary with such insufficiently worked-out constructs as *cybertime, virtual time, cybertemporal, electronic temporality*. Given this connection, discussions arise, calling into question the relevance of the noted phenomenon with the use of evanescent buzzword [9]. As a rule, these terms are necessary to highlight the difference between virtual and real time and to link a temporal dimension to social transformations characteristic of the network society.

Initially, research of time as a factor of social interaction in modern society has become a basis of the well-known concepts of *liquid modernity* of Bauman [2] and of *mobile society* of Urry [16]. The logic of the works on time varies from stating an actual decrease of the importance of time as a result of decreased space [18] to transforming time as the most crucial element of the new day-to-day culture.

A fundamental construct describing the transformations of the phenomenon of time is a *timeless time*. As Castelles states: 'Linear, irreversible, measurable, predictable time is being shattered in the network society' [5: 463]. Timeless time becomes a "dominant form of social time in the network society" [5: 465]. In terms of research into the Internet, Castelles's thesis "time is local" [5: 460] seems to be a key one; that is, in modern society, space organizes time. The specifics of timeless time consist in it being engendered by the space of flows, which is truly the dominant spatial form of the network society [5: 448]. The space of flows "dissolves time by disordering the sequence of events and making them simultaneous, thus installing society in eternal ephemerality. The multiple spaces of places, scattered, fragmented, and disconnected, displays diverse temporalities, from the most primitive domination of natural rhythms to the strictest tyranny of clock time." [5: 497]. Castelles's idea of the space of flows and place determining the time seems to be important in terms of research into specific online media that are able to determine their time parameters.

With the term *cybertime* Strate denotes a "type of metatime that can be structured as different experiences in whatever way the programmer desires" [14]. The use of the term cybertime is characteristic of an analysis of how time on the Internet becomes an important factor of globalization [10]. The concept cybertime has the same explanatory role as timeless time of Castelles, for research into blurring the boundaries between the working week and the weekend [9: 224].

Another significant aspect of theoretical constructs is their complete applicability to research on the influence of a network factor on time; in particular, to an analysis of

the influence of Internet communication on production. Nowadays, work time becomes a more flexible phenomenon requiring re-evaluation. Castelles notes that "the flexible management system of networked production relies on flexible temporality, on the ability to accelerate or slow down product and profit cycles, on the time-sharing of equipment and personnel, and on the control of time lags of available technology vis-a-vis the competition" [5: 468]. The research into negative or deviant forms of workplace behavior such as cyberloafing [6] implying escapism of workers who use the Internet during working hours for non-work purposes is relevant.

At the same time, works done on an empirical analysis of temporal factors are widespread as well. Research into Internet traffic done by Google Analytics shows that within the boundaries of nation-states, fluctuations in the Internet use are apparent. One can even talk about an online rush hour as an analog to TV prime time. The growing significance of streaming services as a substitute for conventional telecasting demonstrates the coincidence in time of the Internet rush hour with the TV prime time [17].

The term that describes temporal specifics of behavior on the Internet is temporal behavior. As a rule, researchers in temporal behavior are engaged in analyzing network traffic over 24 h and seven days' time scales [4, 13, 15]. Besides, a great deal of previous research into temporal behavior has focused on content sharing in social networks [8], comparison of social bots and regular users [7], clustering Web users [12]. Though Castelles differentiates space of flows of which timeless time is characteristic, and "places" that are time-bounded, we can view separate flows as specific cyberplaces, whereas "any site on the Web has a temporal dimension" [11].

3 Methods

As the aim of this study is to identify the characteristics of the temporal behavior of commentators, empirical data was based on posts and comments on public pages of the large Russian mass media on Vkontakte. They were selected under the following principle: pure online media ("Meduza" and "Lenta.ru"), print media (two newspapers opposite in their ideological bent, state-linked "Rossiyskaya Gazeta" and opposition "Novaya Gazeta"), a radio station ("Mayak") and a news TV channel ("Russia Today"). Besides, these public pages are the most popular ones among the users, on the one hand, and oriented toward various target audiences, on the other hand (Table 1).

During the first stage, using "TargetHunter" service, all posts of the indicated public pages were downloaded for period February, March, April, May 2019 to identify the frequency of publication. During the second stage, the ten most commented posts in each of them were chosen for further analysis (total 60 items). Criteria for selecting were as follows: time frames (February, March, April, May 2019) and the frequency of posts (about 2–3 posts per month). In each community, the selected posts were not to represent a series of publications on the same event. In the first place, we were interested not in the feedback of a specific event, but in the temporal responses of the audience of these public pages to any publications on subjects initially disputable or relating to day-to-day practices. Moreover, we focused attention on a post's life cycle as a period between the first and the last comment of the users.

Table 1. Age and gender of subscribers (according to service "Popsters")

Age (%) Gender (%)	Russia Today	Lenta.ru	Mayak	Meduza	Novaya Gazeta	Rossiyskaya Gazeta
Under 17	1,43	2,4	0,78	1,6	0,7	0,54
18–20	2,49	4,49	1,03	5,6	2,26	1,4
21–23	2,81	4,04	1,19	7,55	3,37	2,91
24–26	3,37	4	1,73	5,96	3,3	4,34
27–29	4,01	4,1	3,1	4,14	3,53	4,58
30–34	6,58	5,66	8,49	3,84	5,63	6,48
35–44	7,44	6,05	12,79	2,21	6,12	6,55
Over 45	7,91	7,88	7,55	2,76	8	6,3
Not indicated	63,96	61,38	63,34	66,34	67,09	66,9
Male	67,69	56,48	60,58	51,16	61,55	44,53
Female	32,08	43,38	39,32	48,78	38,32	55,42
Not indicated	0,23	0,14	0,1	0,06	0,13	0,05

One of the methods of research was a statistical analysis of time series, particularly visual studying of the graphic presentations of the time series as a succession of time-ordered values characterizing the level of the state and change of the phenomenon. We used the dot plot chart, where each dot represents one comment from one user, written at a particular time under the post. From this sample, we selected the most demonstrative trends characteristic of all posts of this public page. In our understanding, the time series include such characteristic as temporal behavior of the users: the period within which they respond to a message with comments. In this vein, it can be suggested that the media can intervene in this process using moderation, building of communicative strategies with their users, and posting of news materials.

All dates and hours in the text of the research are given in Moscow time.

4 Results

4.1 Frequency of Publications

To identify information updates of the public pages, we calculated the average number of posts in them in each month (Table 2).

As can be seen from the table above, the highest publication activity is characteristic of the "Russia Today" ("RT") public page (the average number of publications per day is 148.9). It touches upon the highest number of newsworthy events, which makes it different not only from "Rossiyskaya Gazeta" (90.3 publications per day) but also from such large information agency as "Lenta.ru" (80.7). A possible explanation for this might be related to the original bent of this resource on the absolute inclusivity of materials and exposure to an international audience. At that, the lowest indices of "Novaya Gazeta"

Table 2. Frequency of publications

	Russia Today			Lenta.ru			Meduza		
	Like	Comment	Repost	Like	Comment	Repost	Like	Comment	Repost
Mean	46,9	72,9	2,6	44,4	47,5	3	174,6	51,2	7,7
Standard error	0,4	0,5	0,02	0,5	0,5	0,04	2,3	0,7	0,2
Median	31	56	2	30	34	2	127	37	4
Mode	21	0	1	16	15	1	67	20	2
Standard deviation	56	65,2	3,2	54,7	48,8	4,5	158,8	51,3	11,5
Min	4	0	0	0	0	0	14	0	0
Max	2074	1039	102	1581	1735	134	1656	730	225
Sum	838684	1302314	47229	430571	460439	28876	810807	237678	35932
Number of posts	17871			9686			4644		
Av. number of posts per day	148,9			80,7			38,7		
	Rossiyskaya Gazeta			Novaya Gazeta			Mayak		
	Like	Comment	Repost	Like	Comment	Repost	Like	Comment	Repost
Mean	16,3	6,1	2,2	46,8	11,6	5,7	16	9,3	1,4
Standard error	0,2	0,08	0,05	1	0,3	0,2	0,3	0,3	0,1
Median	12	4	1	30	7	3	10	3	1
Mode	9	0	0	14	2	0	7	0	0
Standard deviation	21,9	8,3	5,05	57,4	15,4	9,2	21	18,2	4,5
Min	0	0	0	4	0	0	1	0	0
Max	702	198	118	1190	340	147	409	305	163
Sum	176698	65601	23949	142689	35238	17309	78245	45849	6718
Number of posts	10839			3046			4901		
Av. number of posts per day	90,3			25,4			40,8		

(25.4) and "Meduza" (38.7) are probably explained by the ideological bent of the media and their focus on some public issues linked not as much to the actual event, as to its nature and possibility of critical re-evaluation. Radio "Mayak" (40.8) is distinguished with a specific mix of the most significant popular news and purely entertaining content, which brings it to average values.

It can be suggested that the more messages are posted on the public page, the less is the post's life cycle. Vice versa, the fewer posts there are per day, the livelier they are discussed, disparate statements on the text growing into entire discussion threads.

An essential point in evaluating comments and the rate of response to a post can be the lead time of a first comment: a huge flow of information in the users' news feeds does not allow them, at the moment of scrolling, to focus on "long-reads," and most often an opinion is given on the heading, not on the laid-down material. Here an important point is the communicative thrust of the heading, not even the event itself (indeed, we do not mean sensational or scandalous occurrences). It is for this reason that we touch upon the time of discussions – in terms of social networks, all news is initially equal to each other, their hierarchy is arranged to suit each specific user. For instance, in VKontakte there is a function of displaying posts both by time and by significance. This reason can be used to explain a relatively modest frequency of publications on the public page of "Meduza" or "Novaya Gazeta" as well. These mass media are oriented not toward inclusivity, but toward the specific target audience that is ready to spend their time on prompted discussions, and when necessary not just to note in their feed a new message but also to purposefully open the public page.

4.2 Life Cycles of the Most Discussed Posts

On each of the public pages, we selected the ten most discussed posts within the stated period. Based on this, the median values of continuation of discussing the posts (from the date and time of the first comment to the last) in each public page were calculated (Table 3).

Table 3. Time of discussing the posts

	Russia Today			Lenta.ru			Meduza		
	LC (min)	LC (h)	LC (d)	LC (min)	LC (h)	LC (d)	LC (min)	LC (h)	LC (d)
Median	2768	46,1	1,9	1679	28	1,2	1125	18,8	0,8
Min	728	12,1	0,5	615	10,2	0,4	581	9,7	0,4
Max	32447	540,8	22,5	16126	268,8	11,2	48340	805,7	33,6
	Rossiyskaya Gazeta			Novaya Gazeta			Mayak		
	LC (min)	LC (h)	LC (d)	LC (min)	LC (h)	LC (d)	LC (min)	LC (h)	LC (d)
Median	761,5	12,7	0,5	1342,5	22,4	0,9	1484	24,7	1
Min	90	1,5	0,1	175	2,9	0,1	332	5,5	0,2
Max	3886	64,8	2,7	6778	113	4,7	4808	80,1	3,3

The public page of "Rossiyskaya Gazeta" has a median temporal value of 12.7 h. It is assumed that its audience is more inclined to learn information from its printed version or on the official website. Initially, this media is oriented toward a more senior age group than the average "VKontakte" user.

The median value of "Meduza" is 18.8 h. Such paradoxical indices of the resource so much in demand of modern young people can be related to the specifics of the consumers of this content. With all the discussing nature of the materials, in part, they are limited by certain subjects which are repeated with any variations, which allows an assumption the administration itself sets the frameworks, including time ones, for discussions.

The public page of "Novaya Gazeta" has the median value of 22.4. Despite the initial discussing nature of the subjects under discussion its audience gravitates in terms of demography to a more senior age cohort and becomes, although in terms of a different ideological position, comparable in this vein to the audience of "Rossiyskaya Gazeta".

The median value of the radio "Mayak" is within 24.7 h, which may provide evidence of the special nature of the mutual relations arising between the media and the users. It can be exemplified by a relation between the subject of the post and the subject of the show on air. The media itself sets the format of the temporal mutual relations: discussions under the poll take place simultaneously with the broadcast and do not lose their relevance until the next broadcast.

The public page of "Lenta.ru" has an index of 28.0, which exceeds the number of hours in a day. This value can be related to posting news, both having general informative nature and that beyond the limits of restrained provision of information, inviting "holy wars" or a heated debate among adherents of rival ideologies, paradigms by headings only.

"Russia Today" has an index of 46.1 h. Despite a great amount of news published here, the users find the subjects most relevant to them to which they are ready to respond within several days. It can be suggested that here an effect of a fusion menu operates: out of the wide range, everybody is sure to find something to his/her liking.

Overall, the assumption that the number of discussion hours is reversely proportionate to the frequency of publications is not confirmed.

4.3 Distribution of Comments by Time

The visual presentation of the time series (dot plot) allows the quality, structure of commenting on posts to be assessed, and possible peaks, deviations identified. The first comments in all public pages were made with an interval up to 60 s after publication. We built graphs for each of the selected posts most commented on in the communities (the total of 60). Let us refer to the most illustrative of them.

In Fig. 1 of the publication of the *radio "Mayak"* on the subject "Who is Your Favorite Actor", the discussion is haphazard, proceeding mostly within the showtime on air. Nevertheless, due to the subject being sufficiently simple, debatable, and enjoyable to many, we can observe referrals to it within several days. It is instead a typical temporal behavior of the audience of this mass media. The number of threads in a discussion is, as a rule, the lowest, which reflects atomized opinions of the users who vocalize their point of view, but do not strive to take part in the discussion.

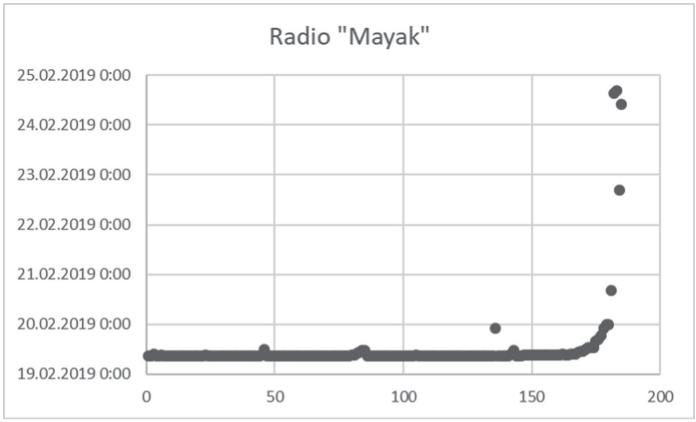

Fig. 1. Distribution of comments by time (radio "Mayak"). Post: https://vk.com/wall-35744422_754675

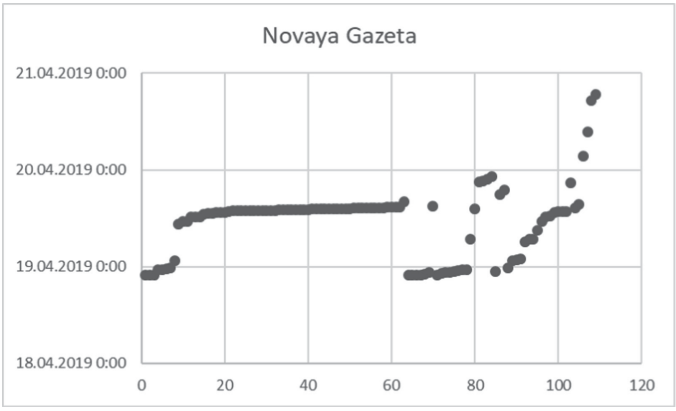

Fig. 2. Distribution of comments by time ("Novaya Gazeta"). Post: https://m.vk.com/wall-67266778_1458895

Novaya Gazeta. One of the most indicative posts related to the temporal behavior of the users of "Novaya Gazeta" is a post on selective abortion (Fig. 2). The discussion began at 09:53 pm and became a short-term discussion within one thread that prompted discussion on the next day from morning till evening. Also, on the evening of the publication of the post another discussion thread was formed, which rapidly depleted itself. An hour after the publication, the third thread appeared, which lasted until late in the evening of the next day. Apart from this, occasional opinions on the published problem can be observed.

Rossiyskaya Gazeta. A post of Rossiyskaya Gazeta is related to a suggestion of one of the deputies that children registered in groups formally be excluded from day-care centers. In Fig. 3, one can observe a significant number of peaks, and irregular commenting generally. For instance, some users switched on to the discussion after days-off. Most

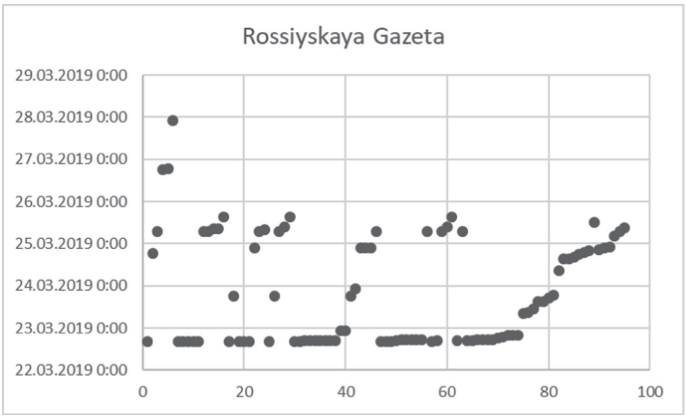

Fig. 3. Distribution of comments by time ("Rossiyskaya Gazeta")

threads were formed only due to later comments after several days. This signals that isolated statements of the users are more characteristic of the public page of "Rossiyskaya Gazeta", not interaction with other users within specific discussions.

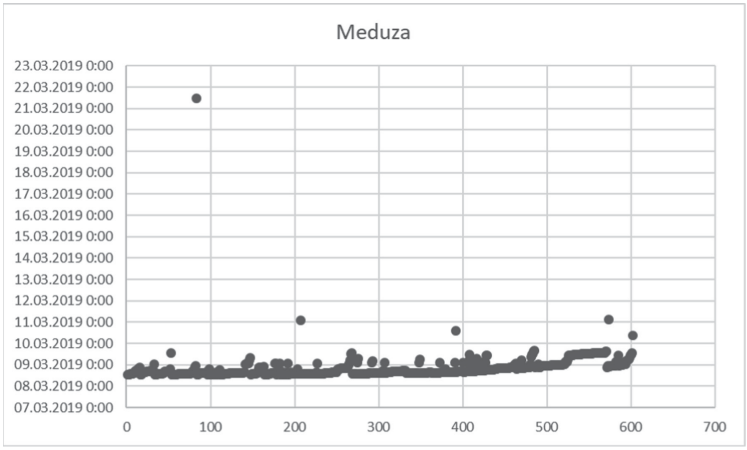

Fig. 4. Distribution of comments by time ("Meduza"). Post: https://vk.com/wall-76982440_2718647

Meduza. The subject of the most characteristic post on the "Meduza" public page is "An Event in a Feminist Café". Here we can see an active discussion of the subjects arising immediately after the publication and lasting 24 h (Fig. 4). Dense commenting develops in various threads, which provides evidences that it is the discussion that the audience is tuned into, not just a simple utterance of a position (it finds its confirmation in the figure in the "tails" of the discussion threads gradually going upward, and pin-point comments).

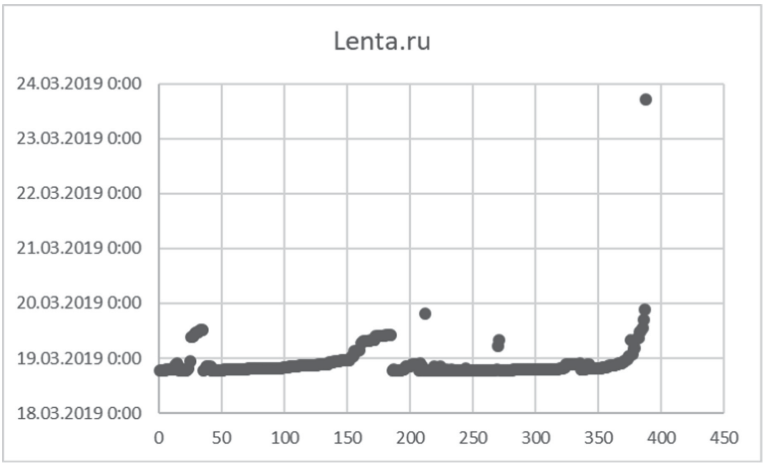

Fig. 5. Distribution of comments by time ("Lenta.ru"). Post: https://vk.com/wall-67991642_3225940

Lenta.ru. On the public page of "Lenta.ru" we chose a post "Putin Signed Law on Insulting Authorities". Here we can observe three discussion threads appearing almost immediately after the discussion began, the second one lasting till the following morning (Fig. 5). The third thread developed to 141 comments. After that, we can observe a series of short threads and standalone opinions. Interestingly, the peculiar feature of temporal commenting in this public page consists of the first comments developing into threads, and ten-fifteen minutes after the post is published, one can already observe standalone comments, which mostly remain unanswered. Thus, the users are inclined to have extremely quick interaction, not lengthy discussion.

Russia Today. The subject of a post in the "Russia Today" public page is "Resignation of Nursultan Nazarbayev" (Fig. 6). The first comment was deleted but prompted a long discussion thread of 127 comments proceeding until the morning of the next day. The second thread of 50 comments started similarly. Then a small thread of 5 comments and a dense thread of 135 comments appeared, that, though with breaks, lasted till the next morning (100 comments of them appeared from 05:45 am to 07:19 am, Moscow time). Then a series of short statements and several isolated threads proceeding till the next day. In the afternoon, one can observe only an aggregation of standalone opinions.

4.4 Post Response Rate

Let us now turn to the presented median values of the time differences between the commentators' responses to each other in minutes (Table 4). A quick response to the course of the discussion and generation of new statements is characteristic of "Mayak", "Lenta.ru" and "Russia Today". "Meduza" and "Novaya Gazeta", proceeding from the discourse, imply response after the users take time. The audience of "Rossiyskaya Gazeta", being less active, demonstrates the most significant gaps between the commentators' responses (20 min).

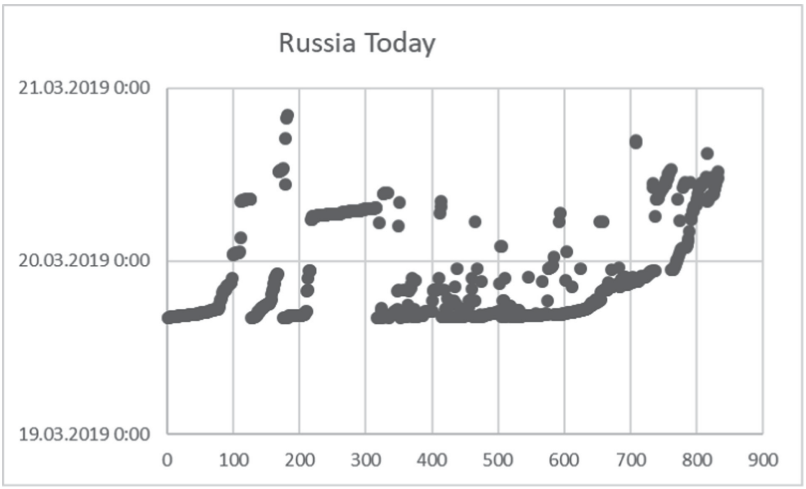

Fig. 6. Distribution of comments by time ("Russia Today"). Post: https://vk.com/wall-40316705_30326092

Table 4. A difference in a response to a previous commentator

	Russia Today	Lenta.ru	Mayak	Meduza	Novaya Gazeta	Rossiyskaya Gazeta
Median	1	1	0	4	3,5	20
Mode	0	0	0	1	0	1
Min (min.)	0	0	0	0	0	0
Max (min.)	1156	5522	5712	18043	1148	3757
Total	840	391	186	603	110	95

5 Conclusion and Discussion

The main goal of the current study was to determine the characteristics of temporal behavior of the commentators of the six news public pages in VKontakte social network. We assume that the passing of time in different cyberplaces will vary and influence on dynamics of communication. In particular, media can determine temporal behavior through the particularity of news, formation of audience communication rules, moderation, etc., while the media audience can choose various strategies of temporal behavior determined by a set of factors: gender, age, ideological values, etc.

This study has found that the response rate of the users to the emerging news was equally high (less than a minute) for each of the communities. The degree of activity was, however, different. Based on our data and the specifics of temporal behavior of the users, we can divide the media into the following subgroups:

"Discussion media ("Novaya Gazeta", "Meduza")" distinguished with the least number of published materials, but in addition to that, numerous discussion threads can be

observed in the grid of long-time comments. Commentators are inclined not just to create lengthy discussions, but issue considered, studied, in their view, opinions, turning everything into a kind of "special interest club". Remarkably, both these publications have an analytical rather than mass media nature and are distinguished by liberal views. The similarity of the temporal behavior of users of "Meduza" and "Novaya Gazeta" contrasts with different age indicators of the audience. Although the data on the full composition of the audience is extremely incomplete, according to the distribution of people who have indicated their age (Table 1), it can be concluded that the audience of "Novaya Gazeta" is much older than that of "Meduza". Nevertheless, the age factor seems to be not crucial in determining temporal behavior. This result is consistent with other studies showing that value orientations and some other factors are more relevant for explaining user behavior [3].

"Stimulus is response ("Lenta.ru" and "Russia Today")" is characterized with a quick response of the users to numerous posts, discussions which do not often result in active discussion threads. At that, of these media a great number of atomized comments are characteristic which are reduced to a simple statement of isolated opinions of authors independent from each other. This is somewhat logical, considering that both public pages are virtual "affiliates" of information agencies and directed at the aggregation of new information.

"From call to call ("Mayak")" despite splurges of active discussions, the entertaining nature of the public page latently organizes the rules for its participants. The discussions most active in time last at any time within the frameworks of entertainment shows and proceed, as a rule, until the next issue.

"Timeless or Silence is gold ("Rossiyskaya Gazeta")" is temporal behavior of the "Rossiyskaya Gazeta" audience, characterized by the least interest in virtual discussions. This is evidenced by a big-time gap between comments, their irregularity, and low life cycle indices, despite a great many messages per day. Such type of behavior might be related, on the one hand, to the discourse of this public page not implying active debate and having an information and enlightening nature, and on another, a more senior age group who do not seek to express their opinion, to prove something to someone, but only take official information into account. Besides, it seems possible that quite a large part of its audience is, to a higher degree inclined to receive information not through a link from "VKontakte", but immediately from the official virtual or printed version.

The most surprising result is that with all the differences in the temporal behavior of the users, the life cycle of posts of these information public pages still is, in most cases, a little more than 24 h. These similarities can be explained in part by the modern lifestyle of the users of social networks who are involved in a great number of interactions at various online platforms, and a large volume of information which is daily scrolled in each news feed.

The results of this study support the idea that even in a single social network, comparable-sized audiences can demonstrate different patterns of temporal behavior. Further studies need to be carried out in the quest for the many factors that form such models. A detailed research of the causes of temporal behavior will help to understand how time management occurs.

Finally, a number of potential limitations points need to be considered. First, the social network "VKontakte" itself is oriented to a higher degree toward the youth audience, which significantly restricts presentations on the temporal behavior of other social groups. Further studies, which take the behavior of the users in other social networks into account, will need to be undertaken. Secondly, a crucial problem to resolve for future studies is a comparative analysis between temporal activity of the audience of the public pages of the same publications, but in various social networks and on official websites of the publications. However, difficulties may arise; more specifically, people who access the Internet once a day or less will help to expand the discussion, but this factor is difficult to determine. Thirdly, time span and the list of public pages can be extended to check the possible influence of seasonality on the temporal activity. Fourthly, further research might explore the specifics of temporal behavior of the commentators in different hour zones.

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References

1. Ambarova, P.A.: The concept and typology of social communities temporal behavior strategies. Izvestia Ural Fed. Univ. J. Ser. 1 Issues Educ. Sci. Cult. 1 **123**, 123–139 (2014). (in Russian)
2. Bauman, Z.: Liquid Modernity. Polity, Cambridge (2000)
3. Bodrunova, S., Litvinenko, 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). https://jsps.hse.ru/en/2016-14-1/178312074.html
4. Caceres, R.: Measurements of Wide Area Internet Traffic. UCB/CSD. University of California, Berkley (1989)
5. Castells, M.: The Rise of the Network Society, 2nd edn. Wiley-Blackwell, Malden (2010)
6. Kasap, Y.: Cyberloafing behavior in the workplaces and management practices. A thesis submitted to the institute of social sciences of Ankara Yildirim Beyazit University. Partial fulfillment of the requirements for the degree of master of science in the department of management and organization (2019). http://afyonluoglu.org/PublicWebFiles/Reports-TR/Akademi/2019_Yasemin%20Kasap_İşyerlerindeki%20siber%20aylaklık%20davranışı.pdf
7. Duh, A., Slak Rupnik, M., Korosak, D.: Collective behavior of social bots is encoded in their temporal twitter activity. Big Data **6**(2), 113–123 (2018). https://doi.org/10.1089/big.2017.0041
8. Niu, G., Long, Y., Li., V.O.K.: Temporal behavior of social network users in information diffusion. In: Proceedings of the 2014 IEEE/WIC/ACM International Joint Conferences on Web Intelligence (WI) and Intelligent Agent Technologies (IAT) (WI-IAT 2014), vol. 02, pp. 150–157. IEEE Computer Society (2014). https://doi.org/10.1109/wi-iat.2014.92
9. Laguerre, M.: Virtual time. Inf. Commun. Soc. **7**(2), 223–247 (2004). https://doi.org/10.1080/1369118042000232666
10. Lee, H., Whitley, E.A.: Time and information technology: temporal impacts on individuals, organizations, and society. Inf. Soc. **18**, 235–240 (2002)

11. Milahache, A.: The cyber space-time continuum: meaning and metaphor. Inf. Soc. **18**, 293–301 (2002)
12. Petridou, S., Koutsonikola, V., Vakali, A., Papadimitriou, G.I.: Time-aware web users' clustering. IEEE Trans. Knowl. Data Eng. **20**(5), 653–667 (2008)
13. Salihu, A., Shefkiu, M., Maraj, A.: Characteristics and temporal behavior of internet backbone traffic. Int. J. Bus. Technol. **6**(3) (2018). Article 3 https://doi.org/10.33107/ijbte.2018.6.3.03
14. Strate, L.: Cybertime. In: Strate, L., Jacobson, R., Gibson, B. (eds.) Communication and Cyberspace: Social Interaction in an Electronic Environment, pp. 351–377. Hampton, Cresskill (1996)
15. Thompson, K., Miller, G.J., Wilder, R.: Wide-area internet traffic patterns and characteristics. IEEE Netw. **11**(6), 10–23 (1997)
16. Urry, J.: Mobilities. Polity, Cambridge (2007)
17. Wong, J.I.: The internet has developed its own prime time, and it's coming for TV (2016). https://qz.com/701016/the-internet-has-developed-its-own-prime-time-and-its-coming-for-tv/
18. Zalot, M.: Buying "time" on eBay: cybertime, nostalgia, and currency in online auctions. Atlantic J. Commun. **21**(1), 17–28 (2013). https://doi.org/10.1080/15456870.2013.743317

E-Society: Computational Social Science

Machine Learning Models Interpretations: User Demands Exploration

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Abstract. Automated decision making is becoming more and more popular in various domains and demonstrates high performance capabilities. The growing model complexity has limited the opportunities for understanding and justifying the model behaviour. Explainable Artificial Intelligence (XAI) has emerged to make complex models more transparent and provide insights of model behaviour. There are numerous XAI tools for implementing different types of explanations, but the majority of these tools' outputs are quite complex and can be misused. Therefore, this research aims to make explanations more comprehensible. We plan to review existing approaches to explanation, study user needs for interpretation tools and propose the design of the tool, selecting the appropriate approach and returning explanation in a simple form.

Keywords: Explainable AI · Machine learning · Prediction biases · User-studies

1 Introduction

Artificial Intelligence (AI) algorithms have taken over the majority of decision-making processes over the recent years. As AI performance keeps improving its usage spreads over new domains, including those that affect people's lives every day (social sphere, medicine, transport [20]), even if decisions are coupled with high risks.

The performance improvement is usually achieved by the complication of the predictive models, using "black-box" approaches, which only return the result and the inner logic remains unknown. Moreover, the structure and the logic of many machine learning algorithms leads to the models that "possess a degree of unavoidable complexity" [3]. That means that even if the decision-maker (e.g. researcher or user) knows in details how the algorithm works it can be impossible to explain what particular factors and their values influence the model prediction. One of the important consequences is the difficulty of detecting biases: it is impossible to check on all possible biases in advance, since a relatively easy access to the data and availability of computational resources increase the use of highly-dimensional datasets in many areas [19,24]. Complex algorithms failed to

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provide insights into the decision-making process which boosted the development of Explainable Artificial Intelligence (XAI).

XAI introduces some transparency in complex AI systems. There are several approaches to model explainability [17]: the extraction of the inner model structure, the introduction of a simpler proxy model, which simulates the behaviour of the original model, but is more interpretable by design, and a post hoc interpretation, using model probing for the extraction of the inner logic. Though such methods provide valuable insights into model behaviour, the explanations they provide are often difficult to comprehend for a regular user, not specialising on working with data.

However, not only data scientists are interested in explainable AI, there are people, who use AI as a decision support system, such as physicians, managers, loan officers. Regulatory bodies are also concerned with AI solutions' inner logic to make sure the decisions are fair and unbiased. End consumers of products with automated decision making are eager to know, what affected the final decision and how it can be changed. These user groups have different thresholds for explanation complexity and domain knowledge, but all of them can come across the situation when the motivations behind certain decisions are essential.

There is a great variety of XAI tools and extensions, implementing diverse techniques, but the majority of them return results in the form of metrics, which are unintelligible by an average user or require special training to comprehend. Several solutions, adapted for use in a special domain field or a certain case (for example, diagnostics of some disease), have an interface and return a set of indicators, which are understandable by a target user. Though, there are very few instruments able to use any provided model and return user-friendly interpretations, which cover the needs of different user groups and provide all the desired insights.

Even data scientists may fail to interpret XAI tools' output, which highlights the value of user-studies in XAI [9]. The authors also emphasise the importance of collaboration of ML (Machine Learning) and HCI (Human-Computer Interaction) communities, with HCI methods used while justifying the need of user-studies, designing comprehensible instruments and validating all stages of development through user-studies.

The goal of this study is the extensive review of the existing approaches of XAI and identification of user demands for an instrument that simplifies the selection of the most appropriate XAI methods for the given task. The overview of existing XAI methods will allow us to compare the existing approaches and choose the most relevant and efficient ones. The features of the instrument will be chosen according to the user needs and demands, aligned with the recent research results in the field of AI and HCI. The developed tool will have a user-friendly interface in a query form, allowing users without a technical background explore the results of machine learning modelling to understand the underlying decision-making process.

2 Related Work

2.1 Key Concepts

What does the term "interpretable model" mean? Interpretability can be defined as "the degree to which a human can understand the cause of a decision" [15]. It is also stated that interpretations are contrastive and people are interested not only in the prediction P, but why is P predicted instead of Q.

The goal of interpretability is the description of the system internals in an understandable to humans way [7]. The degree of interpretability depends on the user's knowledge and background, to be meaningful it should operate the vocabulary, meaningful to the user. The goal of completeness is the description of the inner logic of the system, the fully complete explanation is the set of mathematical operations and parameters. There is always a tradeoff between interpretability and completeness in all XAI methods.

Explainable outputs are essential for the implementation of machine learning solutions for problems with the high costs of misclassification such as the majority of problems in healthcare. However, sometimes interpretation is unnecessary if it is known that the prediction accuracy is quite high or the problem under consideration is well studied [17]. For example, while the number of patients expected to arrive in the emergency department does not require explanations unless it is accurate, the explanations of the length of hospital stay predicted for each patient may be useful in decision making. For some prediction tasks associated with high risks and the necessity to take an immediate action the performance may be sacrificed for interpretability [1,2].

The possibility of exploring the reasoning behind decisions makes it possible to reveal biases and spurious correlations and exclude them from the model. An illustration of the model with high accuracy, but wrong causation patterns is the pneumonia risk prediction case study [5]. In this study, one of the most significant predictors of not dying from pneumonia was having asthma. An opposite is true, but patients with asthma are provided more timely care, which increases the chances of survival. The detailed investigation of the reasons behind the predictions provided the researchers with insights needed to rectify the model.

Interpretations give the end-users reasons to accept recommendations. That is why the possibility of model verification and its debuggability (the possibility to identify and remove errors or biases) are as important as accuracy. The knowledge of how often the model is right might be less valuable than the insights of cases when the model is always wrong. If the model makes mistakes in the most obvious cases it won't be trusted and maintained without supervision [12].

The presence of the explanation can increase the acceptance and therefore trust in recommendations [14,18]. In the absence of understanding why the model recommended the certain item users fail to invoke trust to it. The most popular examples of the explanations of recommendations systems' behaviour are "frequently bought together" items and "users who liked this item also liked", which are adopted by the majority of large online shops and media-services providers.

Another challenge for the adoption of AI systems is the "right to explanation" introduced by European Union's General Data Protection Regulation (GDPR) [10,11]. GDPR requires transparency of decisions, such as credit scoring and other predictions based on personal data. Such regulation obliges companies to provide on-demand explanations of their decisions. Under the circumstances of GDPR the interpretability of algorithms can become not only a desirable feature but a necessity. The transparency of decisions, in its turn, requires algorithms to conform to ethical standards and avoid discrimination.

A controversial feature of interpretable ML is the possibility to manipulate the result. For example, credit-seeker can open or close accounts, affect dept-ratio requesting increases to credit lines, therefore, game the rating system invalidating its predictive power [12]. On the contrary, such transparency can persuade clients that there are no manipulations with the scores and anyone, who satisfies the conditions can get a credit.

2.2 XAI Design

The key to the adoption of explainable AI (XAI) systems is answering the question "What types of explanation might users need in the course of using AI systems?" and leveraging the possible scenarios of system usage on the early stages of development [23]. The author outlines that such measures as accuracy and other performance metrics are often unable to capture the system complexity. Even the definition of the "user" of the system brings the specificity of actors, backgrounds, goals and actions which can sometimes be conflicting. The author recommends using scenario-based design approaches, working with real problems and real people. Thinking who will use the system and what they might need can bring up more XAI design alternatives, which will be aligned with users' needs.

Another study explored how model explanations affect user trust and what information is the most helpful for users to understand the system's decisions [4]. The user study of the clinical decision support system showed that revealing comprehensive details of the facts used in the model's decision making led to users' over-reliance. On the contrary, giving more selective explanations caused the lack of trust in the model, which promoted self-reliance. This study proved that the balance between the completeness and intelligibility of the reasoning behind the ML model's decisions is essential. Moreover, according to the feedback of the system's users the ability to follow the system's reasoning and explore decision's alternatives is more helpful than giving the system's confidence (accuracy) of the given decision.

There are attempts to develop guidelines for designing transparent intelligent systems [6]. The authors emphasise that in the real-world applications the needs of several stakeholders should be taken into consideration: users want to understand what is behind the system's reasoning, companies want to meet the regulations on transparency (such as GDPR) without revealing the inner working of the system. Their design approach is based on users' mental models – "conceptualizations of the objects, systems or processes around us that allow

us to explain and predict their workings". If mental models do not reflect the system complexity users may fail to explain the behaviour of the system, which may lead to usability problems.

The authors state that the usefulness of the explanation highly depends on its design. The two decisions to be made is "what to explain" and "how to explain". The subject of explanation can be controversial as there is the ongoing discussion on the full system transparency and comprehensibility of explanations. Having reviewed numerous researches authors concluded that the necessary amount of information provided should be determined for each specific case, as some cases require all system logic details, some are satisfied with a short explanation.

The explanations' best presentation format remains specific for each case. The researchers have only agreed that explanation should reduce users' cognitive effort, be more simple and appealing [6].

2.3 Approaches to Explainability

In this section we briefly introduce several most popular methods and techniques for explaining black-box model s to illustrate the general ideas and concepts.

LIME. The goal of LIME (Local Interpretable Model-agnostic Explanations) is the identification of an interpretable model over the interpretable representation that is locally faithful to the initial model [18]. According to LIME explanation is a model with low complexity (transparent model) which uses interpretable representations instead of original model features. It samples instances around the instance being explained, gets prediction using the original function, weighs them by proximity to the instance and learns a locally faithful explanation. In other words, it builds the simple model that the user can easily explain (usually it is linear regression or decision tree) and for the examples that are very similar to the one the user explores the answers (*predictions*) of this new model are close to the ones of the original complex model.

LIME primarily addresses the problem of explaining individual predictions and allows to assess trust even when the prediction is correct, though, the reasoning behind it is wrong (like [5]). This tool is model-agnostic and explains the predictions of any model in a manner understandable to a non-expert user and improves overall trustworthy to a model [18].

SHAP. A unified measure of feature importance SHAP (SHapley Additive exPlanation) is based on the computation of Shapley values of a conditional expectation function of the original model [13].

Shapley regression values are the feature importance values for linear models with feature collinearity. Its calculation implies training the model on all feature subsets, firstly with the feature present and then with the same feature withheld. Then the differences are computed for every subset of features and the weighted difference is assigned to each feature as the importance value. So the algorithm measures how the predictions differ with and without every feature, taking

into account possible interactions between features. [13] underline that while SHAP aligns with the Shapley regression and sampling it allows for connections with LIME and other methods. Authors introduce various SHAP approximates model-agnostic kernel SHAP, incorporating linear LIME and model-specific linear, low-order, max and deep SHAP approximations.

The comparison of SHAP and LIME on various decision tree models showed that their values can differ significantly, which authors relate with the local accuracy and consistency of SHAP values.

Counterfactual Explanations. While "explanation" generally refers to an attempt to represent the internal logic of the system, counterfactuals only depend on the facts leading to the certain decision. The main idea of counterfactual analysis is to explore how the model prediction changes if we change the value of the feature for one selected observation (e.g. "Does the model make the opposite job offer decision if we change the sex in this particular resume?"). Hence, a counterfactual explanation is the smallest change to the feature values that changes the prediction to a predefined output. Counterfactuals can provide evidence of discrimination as this approach can reveal the effect of any variable [21]. Mathematically, the counterfactual is computed as finding the point closest to the original, solving an optimisation task of finding a local minimum (valid for classifications with an underlying optimisation algorithm, e.g. DNN, SVM). However, counterfactuals assume variable independence. There is an opinion that it allows to check for data inaccuracies and simplifies model because capturing all interdependencies can be challenging [21]. The main benefit of such explanation approach is its independence of the domain knowledge, therefore such explanations can be presented in a simple and comprehensible form.

Interactive Tools. Along with the various XAI approaches several ready-to-use applications such as What-If tool have appeared recently [22]. The tool is destined for ML practitioners to explore and probe trained models. Its features include simple visual analysis, datapoint editing, finding nearest counterfactual (the most similar datapoint with a different label), partial dependence plots, general performance metrics. It also allows for models comparison and has fairness metrics (metrics comparison across subsets of data). The tool is model-agnostic, provides local and global model understanding, counterfactual reasoning, intersectional analysis. The app was shaped by the usability studies, defining user needs in the early stages of development. There is a web version of the application available, as well as an extension in Jupyter or Colab notebook.

Another interactive tool RuleMatrix [16] extracts simple rules from the original model and visualises them. The tool was designed for domain experts, who lack the knowledge of ML. The authors have developed a rule induction algorithm, which extracts a rule list approximating the original classifier. The tool is available as a Python library and provides both a visual interface and the extracted rule set.

3 Research Design and Methods

The goal of our study is prototyping the instrument, simplifying the selection of interpretability method for the given task. As there are numerous tools for interpretability we aim to overview the available instruments and select the most efficient and effective for specific types of tasks.

To address the problem of the variety of users' needs and goals and, therefore, various expectations of XAI models we propose a questionnaire aimed to reveal general expectations of XAI interface. The questionnaire is not related to any specific ML model and contains general questions and concerns about XAI. The target user groups for the questionnaire are decision-makers – people, who use ML model results to make a decision (managers, recruiting specialists, product owners) and end consumers – people, who are impacted by ML system's decisions such as product users or job applicants [8].

The purpose of the user study is to reveal the types of explanations which users mark as enhancing user experience. The method of conjoint analysis was chosen to gather preferences as it allows to collect data without direct questions, reducing possible bias. Cards (situations) for CA were constructed on the base of the literature review (possible questions and methods).

The study will also allow to measure the level of trust in prediction results with and without results' interpretations. The questionnaire contains several examples of the XAI approaches and the participants will be asked to assess the level of usefulness of such approaches. The general questions about background and previous experience with machine learning and XAI will allow to separate different user groups and develop various cases for each group. Each case will represent the real-life task (e.g. request for credit line), the decision made by the system ("approve/reject") together with additional details about the decision (one of the follows: probability distributions, algorithms used, LIME explanations, SHAP values) with or without visualisations. Also, the post-task part of the questionnaire is focused on the exploring additional requests from potential users, revealing what information is useless, what helps to make a decision, what is missing and should be added to the output, what types of questions they try to answer while making a decision.

The respondents of the questionnaire will be recruited at the large Russian IT companies and among undergraduate and graduate students of the large Russian university. The questionnaire will be distributed via mailing lists and the participation will be voluntary. Therefore, the method of convenience sample will be used with the questionnaire addressing people, willing to participate. The questionnaire will be distributed in two steps. The first step will validate the developed approach of user-study and will be focused on Product Managers and HR-managers in IT-companies. A small group of respondents (10–15) will be selected and user feedback will be collected on completion. This will allow to check for the understanding of research objectives and question definitions. During the second step the questionnaire will be distributed to larger groups of people. The expected sample size is around 50–60 participants.

Based on the analysis of the questionnaire results we plan to select several interpretation approaches that users find the most helpful in interpreting the prediction results. For each of the selected approaches we fill find the most relevant tools building upon the review of the available XAI technologies. Further, we will create a Python library, which will contain methods wrapping existing XAI tools and providing more user-friendly outputs, compared with the original outputs. Therefore, we aim to change the format of presenting results to the user, as existing tools often seem too confusing even for ML practitioners [9].

4 Preliminary Suppositions and Implications

The proposed research addresses the lack of intelligibility of the majority of XAI techniques, which causes XAI misuse and the lack of trust to such approaches. We aim to develop a potential new way of presenting model interpretations so that people without a special training were able to understand them.

The developed instrument may be helpful for decision-makers for decisions improvement and enhanced understanding of models' behaviour; for product owners, as they could integrate such solution into their systems and use it to interpret AI predictions to product consumers to gain their trust. It can also be used by data scientists to validate the assumptions about model behaviour, gain additional insights and avoid misusing more complex tools and making wrong conclusions.

However, to prove the enhancement of usability due to the developed prototype additional user study is needed.

5 Conclusion

The proposed study aims to assess the existing approaches to XAI. As there is little study of interpretability instruments, we will design a user-study to reveal the comprehensibility levels of different XAI methods and the main user needs. Such study will contribute to the existing knowledge of application and evaluation of the XAI tools in different contexts.

Based on the results of the user study we will attempt to design an instrument, which can be used by people with different backgrounds. This tool will not implement any new XAI methods, instead will wrap several existing approaches and select the most appropriate one depending on the context. Such a tool will try to combine both efficiency and user-friendliness aiming at the large user groups with different backgrounds.

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References

1. Ahmad, M.A., Eckert, C., McKelvey, G., Zolfaghar, K., Zahid, A., Teredesai, A.: Death vs. data science: predicting end of life. In: The Thirtieth AAAI Conference on Innovative Applications of Artificial Intelligence, pp. 7719–7726 (2018). www.aaai.org
2. Ahmad, M.A., Eckert, C., Teredesai, A., McKelvey, G.: Interpretable machine learning in healthcare. IEEE Intell. Inform. Bull. **19**(1), 1–7 (2017). http://arxiv.org/abs/1705.10301
3. Burrell, J.: How the machine 'thinks': understanding opacity in machine learning algorithms. Big Data Soc. **3**(1) (2016). https://doi.org/10.1177/2053951715622512
4. Bussone, A., Stumpf, S., O'Sullivan, D.: The role of explanations on trust and reliance in clinical decision support systems. In: 2015 International Conference on Healthcare Informatics, pp. 160–169. IEEE (2015)
5. Caruana, R., Lou, Y., Gehrke, J., Koch, P., Sturm, M., Elhadad, N.: Intelligible models for healthcare. In: Proceedings of the 21th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining - KDD 2015, pp. 1721–1730. ACM Press, New York (2015). https://doi.org/10.1145/2783258.2788613. http://dl.acm.org/citation.cfm?doid=2783258.2788613
6. Eiband, M., Schneider, H., Bilandzic, M., Fazekas-Con, J., Haug, M., Hussmann, H.: Bringing transparency design into practice. In: 23rd International Conference on Intelligent User Interfaces, pp. 211–223 (2018)
7. Gilpin, L.H., Bau, D., Yuan, B.Z., Bajwa, A., Specter, M., Kagal, L.: Explaining explanations: an overview of interpretability of machine learning. In: 2018 IEEE 5th International Conference on Data Science and Advanced Analytics (DSAA), pp. 80–89. IEEE (2018)
8. Hind, M.: Explaining explainable AI. XRDS: Crossroads ACM Mag. Stud. **25**(3), 16–19 (2019)
9. Kaur, H., Nori, H., Jenkins, S., Caruana, R., Wallach, H., Vaughan, J.W.: Interpreting interpretability: understanding data scientists' use of interpretability tools for machine learning. Technical report, working paper (2019)
10. Khaitzin, E., Shlomo, R., Anderson, M.: Privacy enforcement at a large scale for GDPR compliance. In: Proceedings of the 11th ACM International Systems and Storage Conference, p. 124. Association for Computing Machinery (ACM), June 2018. https://doi.org/10.1145/3211890.3211913
11. Krebs, L.M., et al.: Tell me what you know. In: Conference on Human Factors in Computing Systems - CHI 2019, pp. 1–6. ACM Press, New York (2019). https://doi.org/10.1145/3290607.3312808. http://dl.acm.org/citation.cfm?doid=3290607.3312808
12. Lipton, Z.C.: The mythos of model interpretability. Queue **16**(3), 30:31–30:57 (2018). https://doi.org/10.1145/3236386.3241340. http://arxiv.org/abs/1606.03490
13. Lundberg, S., Lee, S.I.: A unified approach to interpreting model predictions. In: Advances in Neural Information Processing Systems, pp. 4765–4774, May 2017. http://arxiv.org/abs/1705.07874
14. McInerney, J., et al.: Explore, exploit, and explain. In: Proceedings of the 12th ACM Conference on Recommender Systems - RecSys 2018, pp. 31–39. ACM Press, New York (2018). https://doi.org/10.1145/3240323.3240354. http://dl.acm.org/citation.cfm?doid=3240323.3240354

15. Miller, T.: Explanation in artificial intelligence: insights from the social sciences. Artif. Intell. **267**, 1–38 (2019). https://doi.org/10.1016/j.artint.2018.07.007
16. Ming, Y., Qu, H., Bertini, E.: RuleMatrix: visualizing and understanding classifiers with rules. IEEE Trans. Vis. Comput. Graph. **25**(1), 342–352 (2019). https://doi.org/10.1109/TVCG.2018.2864812
17. Molnar, C.: Interpretable machine learning (2019)
18. Ribeiro, M.T., Singh, S., Guestrin, C.: "Why should i trust you?" In: Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining - KDD 2016, pp. 1135–1144. ACM Press, New York (2016). https://doi.org/10.1145/2939672.2939778. http://dl.acm.org/citation.cfm?doid=2939672.2939778
19. Roski, J., Bo-Linn, G.W., Andrews, T.A.: Creating value in health care through big data: opportunities and policy implications. Health Aff. **33**(7), 1115–1122 (2014)
20. Rudin, C., Wagstaff, K.L.: Machine learning for science and society. Mach. Learn. **95**, 1–9 (2014). https://doi.org/10.1007/s10994-013-5425-9
21. Wachter, S., Mittelstadt, B., Russell, C.: Counterfactual explanations without opening the black box: automated decisions and the GDPR. Harv. JL & Tech. **31**, 841 (2017)
22. Wexler, J., Pushkarna, M., Bolukbasi, T., Wattenberg, M., Viégas, F., Wilson, J.: The what-if tool: interactive probing of machine learning models. IEEE Trans. Vis. Comput. Graph. **26**(1), 56–65 (2019)
23. Wolf, C.T.: Explainability scenarios: towards scenario-based XAI design. In: Proceedings of the 24th International Conference on Intelligent User Interfaces, pp. 252–257 (2019)
24. Zhou, L., Pan, S., Wang, J., Vasilakos, A.V.: Machine learning on big data: opportunities and challenges. Neurocomputing **237**, 350–361 (2017)

Game Experience Evaluation. A Study of Game Reviews on the Steam Platform

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Abstract. Player experience is often difficult to understand, and it is not always clear to game developers which game features should be eliminated or maintained. By analyzing reviews of particular games, it is possible to create high-quality games and understand player psychology and game preferences. Our pilot study aimed to find out how people evaluate their game experience based on reviews on the Steam platform and to extract its main dimensions. By utilizing the Structural Topic Model (STM), we extended previous research on main components of game experience and found topics which were not discussed in previous works. Using the community detection method, we divided our topics into seven main dimensions that connect with different strength. Our research contributes more knowledge about the processes of evaluation as a whole and game evaluation in particular.

Keywords: Game reviews · User-generated content · Experience evaluation

1 Introduction

Player experience has multiple dimensions, which complicates finding out the game qualities most appreciated by players. Games are experience goods whose quality can be revealed through direct consumption but hard to predict in advance. Moreover, games can be understood as singularities of value – they are incomparable, unique things that have a multidimensional, incommensurable, and indefinite quality. It is hard to develop a universal scale of quality related to game experience.

The solution to this problem can be found through studying player practices and their opinions. This will enable us to comprehend the meaning behind players' choice of games and their tastes. Untangling such experiences helps us to better understand the experience of players in general and to make new substantiated requirements for games or eliminate existing deficiencies.

In our paper, we try to understand the important features of game experience using quantitative textual analysis of game reviews on the Steam platform. By using the Structural Topic Model (STM), we extracted seven clusters of topics

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that represent the main dimensions of player experience and how they are interrelated. We illustrated each dimension by examples from reviews, which enabled us to understand the process of game evaluation in depth.

This work contributes to understanding consumer retention mechanisms and supports the idea that reviews can help to improve a product. Reviews can be used efficiently to increase sales as electronic word-of-mouth has a more positive effect on purchases than face-to-face word-of-mouth [2]. Usage of topic modelling can reveal key dimensions of service satisfaction and consumer expectations, as was shown in previous studies of hotel reviews [7].

2 Background

Steam is a digital gaming distribution service developed in 2003 by Valve Corporation, a game development company that allows developers to distribute their games to millions of users. At the moment, the Steam catalog includes about 30,000 games and occupies more than half of the global market share of computer games sales. Service statistics report 18 million active Steam users on average[1]. In addition to its digital distribution service, Steam provides users features to write reviews about all games and recommend (or not recommend) them to other players.

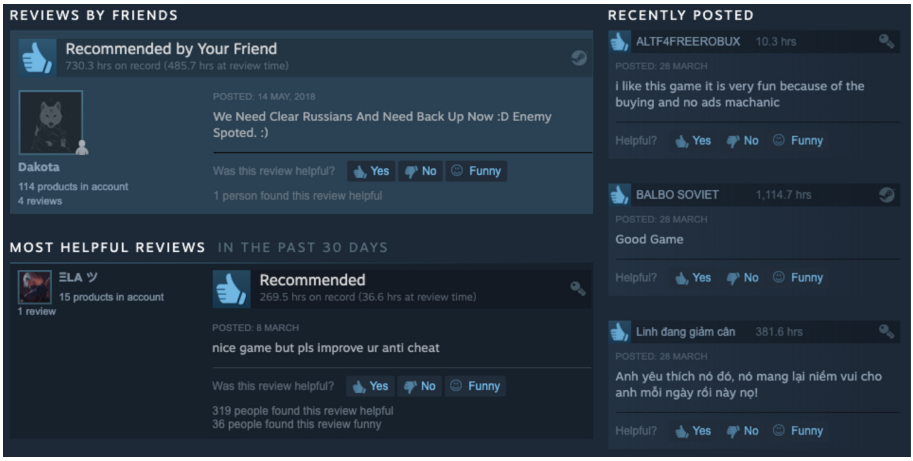

Fig. 1. Example of steam reviews on counter-strike: global offensive (28.03.2020).

Under the description of each game, there is a section with reviews by users who have already played this game (Fig. 1). At the top of the section are the reviews by the user's friend. These reviews provide ample opportunities for "peer

[1] Steam Game and Player Statistics Web Page: https://store.steampowered.com/stats/.

marketing." On the basis of their personal network connections, users make decisions about the genre of the game to play and the purchase. After the reviews of friends, the reviews deemed most useful by users are displayed.

3 Related Works

3.1 Motivations and Game Preferences

Player game preferences and motivations help identify player tastes and reasons behind topics they discuss in reviews. Game design sustaining interaction between players and self-perception is the topic of authors studying motivation to play video games. The most essential in the field is the work of N. Yee [3], who discussed dimensions of gamer motivation, which are social, achievement, and immersion with their subcomponents. These dimensions are discussed by major authors writing about the influence of game mechanics on player behavior and interaction, mainly in the game *World of Warcraft*. They discovered social networks leading to real-life relationships [4], the appearance of stratification and control system inside games [5], and broader topics like the influence of game content on player affiliation to game and gamer interactions [6].

Recent studies have classified game preferences by player type. One classification by G. F. Tondello et al. [7] divide gamers by "action," "goal," and "esthetic" orientations based on preferred playing styles and game mechanics. So, it was proven these player types along with gender affect game attitudes and define their tastes. Another categorization is based on 5 preference categories ("manage," "journey," "assault," "coordinate," and "care") [8]. These categories were created by the analysis of player behavioral strategies inside games and the way players manipulate game elements. The final classification considers two dimensions of player preferences: game elements and playing styles [9]. These approaches are applicable to players reviewing game storylines and visuals, interactions with other players, and game bugs. From game reviews, we can understand why some games are more popular than others and look at video games from a gamer perspective.

3.2 Game Reviews

Aforementioned topics, along with the pros and cons and teamwork aspect, are discussed by players in game reviews. So, in reviews, players express their attitudes towards games through their own performance and progress. Even though researchers can use reviews as the main source of knowledge about user preferences, there is a lack of studies on game reviews. Works devoted to the textual analysis of reviews focus mostly on the descriptive level of their content. There is no consensus among researchers as to which of the generated measurements best reflect the quality of the gaming experience and players' preferences.

For example, Pielka et al. [10] analyzed 36,621 online game reviews posted on the German gaming network between October 2010 and December 2016.

The authors were interested in extracting latent and influential topics, which were found to be elaborate descriptions of gameplay, technical, and gameplay issues.

Lin et al. [11] compared the characteristics of reviews on Steam and in mobile apps and found them to be different. Their findings showed that reviews are longer for early access, indie, and non-free-to-play games and other results. The Steam reviews were grouped into six categories: "pro." "con," "bug," "video," "suggestion," and "not helpful". Furthermore, there were more complaints about game design rather than bugs, and reviews for major free-to-play games were written only after an hour of play.

Sirbu [12] also analyzed 9,500 reviews of video games extracted from Amazon to identify opinions and latent linguistic dimensions. Implementing Principal Component Analysis on word frequency, the authors found eight dimensions of how players evaluate their experience in terms of communication and perception: negative and positive emotions, relations between players and their game roles, actions and skills, motivations, and communication language.

The latest and the most comprehensive work on this field is presented by Wang and Goh [13]. They conducted a research on game components associated with players' satisfaction on 10,000 reviews from Amazon. Using LDA topic modelling, they found 7 meta-topics, which included main components of game experience that gamers found the most important in reviews: Achievement, Narrative, Social interaction, Social influence, Visual/Value, Accessories, General experience. Narrative and Achievement are found to be the main components that affect players' satisfaction with the video games.

3.3 Research Question

The paper of Wahng and Goh [13] described more general model of existing mechanisms of assessing video games by players, but our work is focused on specification of these mechanisms through studying player experiences and game attitudes reflected in reviews on the Steam platform. In our work, we want to find, **by which criterion do people evaluate game experience**?

4 Methodology, Data and Method

4.1 Methodology

Netnography was chosen as the research methodology. It is a mixed approach to studying digital documents and practices of online communities using digital means and methods [14]. Online communities produce large amounts of digital data, which is difficult to analyze only by qualitative methods, as it is time-consuming for the researcher. Quantitative methods of analysis, in turn, erase the contextual features of the community. Netnography, being a mixed approach, implies that a researcher uses quantitative analysis to extract the most interesting materials from an array of data, which can then be analyzed manually.

In our study, using a computational text analysis model, we identified the most important patterns in gamers' reviews from Steam to characterize the main features of gaming experience. We used qualitative analysis to interpret obtained patterns in the context of the gaming community on Steam. We highlighted the most important texts of reviews as examples confirming existing patterns.

All data retrieved from reviews and user profiles on the Steam is in the public domain of the service – users agree to provide their opinion, and their comments to be viewed by other people.

4.2 Data

Games Sample. The games dataset consisted of 335 unique game titles from two different Steam Community thematic groups[2]: Dota X2 and 2K publisher. Groups on Steam are communities of interest relating to specific games, game publishers, and game journalists.

Text Corpus. To obtain the reviews, Steamworks was used. It is the open tool offered by the Steam platform, which provides game developers and publishers with data extraction to further study user behavior. For each game, a limit was set to the 2,000 most helpful reviews because several games have less than that number of reviews.

The raw text dataset included 613,195 reviews in English only. After filtering reviews less than 13 words (too short and uninformative) and more than 690 words (mostly spam and ads messages), **291 970** reviews remained. The dataset included the review's ID, text, and game ID. Before the analysis, the data were cleaned using a standard preprocessing procedure, which consisted of removing stop-words and specific frequent words for this text, and also stemming the text corpus.

4.3 Method

The analysis of reviews using topic modeling methods is actively used in social sciences and marketing to obtain the dimensions of user experience [15]. For example, using Latent Dirichlet Allocation (LDA), researchers identified the main dimensions of discussions concerning the opinion of Twitter users about the Destiny game [16]. To assess review text content and obtain components of user experience, Santos et al. used subgroup discovery and LDA [17]. Using a newer Structural Topic Model (STM) method compared with LDA, the researchers identified the main aspects of the experience of students who studied abroad and linked them to metadata associated with the context of their learning [18].

In our work, STM was chosen to analyze review text [19]. It allowed us to extract topics from discussion arrays without manually processing text. Topic modeling helps to identify documents that enable the researcher to interpret the results obtained directly through examples.

[2] Steam Community Official Web Page. Retrieved from https://steamcommunity.com.

A topic model produces the probability of word distribution in each topic, so each topic can be characterized by several high probable words, while the probability of other words occurring is close to zero. Each text consists of some of the most probable topics. STM allows researchers to make covariates with document metadata, which can be helpful with finding a connection between topics and metadata. This method also can be useful with finding topic correlation to observe connections amid discussion.

During the analysis, 120 topics were extracted. We chose this number of topics after the model diagnostics using the searchK function built into the STM R package[3]. There are four basic metrics to estimate the model quality: the held-out likelihood is highest between 120 and 140 topics, and the residuals are lowest around 120 topics. Semantic coherence is maximized between 100 and 120 topics and exclusivity is peaked at 130 topics. So, the optimal number of topics was set at 120 topics[4].

5 Analysis and Results

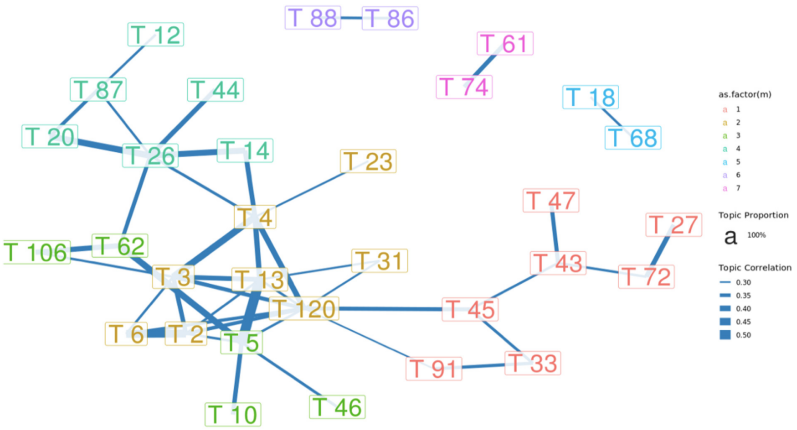

Fig. 2. Example of steam reviews on counter-strike: global offensive (28.03.2020).

The topics reflect different dimensions of game experiences. Table 1 presents the example of the topic with a high prevalence in the text corpus (2.8%). All topics were interpreted based on the most probable words (highest prob) and verified by example reviews. The highest prob contained 7 words with the highest probability in the topic. FREX means that these 7 words have not only a high probability but also a high exclusivity score for a particular topic.

To reveal the most important relations among topics in text corpus, we found that most interconnected with each other. To do so, we built a topic correlation network, sorted nodes by degree > 1 and correlation coefficient > 0.3, and

[3] STM R package: https://www.structuraltopicmodel.com.
[4] https://juliasilge.com/blog/evaluating-stm/.

Table 1. Example of the most occurring topic with the example of a review.

Topic ID 62	Highest prob.: voice, act, beautiful, detail, excellent, sound, plot FREX: excellent, act, brilliant, compel, storyline, stanley, impressive
Many people will agree that this game is the face of valve. The gameplay is awesome, combat is phenomenal, and the **voice acting** is perfect. My favorite part of the game is when you get the crowbar (duh) and get to beat the crud out of aliens. I would highly recommend this game to anyone who wants a game with a good **story** and gameplay	

applied a fast greedy modularity optimization algorithm for finding communities of topics (see Fig. 2).

We found 7 clusters of topics: Social interactions (blue), Battle and Achievements (purple), Value (pink) – separate clusters, Game performance/Visuals (red), Experience (orange), Social influence (green), and Gaming progress (mint) – main component (Table 2).

Table 2. Clusters and corresponding topics.

Clusters	Topics
Battle and achievements	T88 (attachment), T86 (shooting)
Value	T61 (microtransactions), T74 (in-game payment)
Social interactions	T68 (teamwork and matchmaking), T18 (team balance)
Game performance/visuals	T47 (updates), T43 (game bugs), T72 (optimization), T27 (devices), T45 (time), T33 (decision making), T91 (reaction)
Experience	T120 (playing process), T31 (positive/negative sides), T13 (game enjoyment), T2 (game perception), T6 (difficulty level), T3 (impressions from game), T4 (expectations), T23 (playtime)
Social influence	T62 (appreciated game features), T106 (game type), T5 (recommendations), T10 (persuasion to buy), T46 (nostalgia)
Gaming progress	T12 (skills), T87 (abilities), T20 (offered possibilities), T26 (consequences), T44 (game actions), T14 (usefulness)

The **Battle and Achievements** cluster represents two topics about attachment in games (T88, *most probable words: gun, disassembly, hey*) and shooting or weapons use (T86, *shoot, bullet, sniper*). As battles are a significant component of many video games, the users' satisfaction with the shooting experience

influences both their decision to stay in a game and to recommend it. For example, one of the reviewers says that the game *Blacklight: Retribution* was more popular when there was a greater variety of guns and attachments:

> "used to be good, now servers are always empty, 2014? it was all full, you could add any **attachments** you wanted on any gun, you could buy any **gun** you wanted, now? sucks..." (player id 76561198102548479)

The **Value** cluster shows discussions about microtransaction (T61, *treyarch, mw, pay*) and in-game payments (T74, *cash, spend, cost*). Microtransactions are micropayments to buy in-game things. Users were concerned about the cost of the game components, which may worsen the impression from the game. For instance, one of the gamers was annoyed by the costs of the downloadable content in the game *Hunter Classic*, which was advertised as free-to-play:

> "a free2play game that has 171,93 worth of dlcs and on top of that you need to buy a **membership** to hunt animals." (player id 76561198074012171)

In the **Social Interaction** cluster gamers discuss teamwork and matchmaking (T68, *team, teamwork, match*) as important elements of the game experience. Matchmaking is a process of matching two or more players in one game session. In particular, players share their impressions about the balance of the team (T18, *balance, paladins, unbalance*). So, the optimization of matchmaking determines a gamer's desire to continue a game and recommend it to other players. This statement can be confirmed by one of the players who wrote that they would not recommend a game because of poor matching:

> "recommended - just barely. don't get me wrong, it's a great game, but it has a fatal flaw. the **matchmaking** puts people who are playing their first **match** against those who have 4000 under their belt..." (player id 76561198025681784)

The updates (T47, *update, developer, release*), game bugs (T43, *fix, issue, load*) and optimization (T72, *frame, optimize, performance*) are reflected in the **Game Performance/Visuals** cluster showing the major game aspects that usually concern players. They expect improvements and elimination of bugs in game design from game developers. Based on these improvements, players decide whether to continue playing a game and recommend it to others. For instance, one author states that despite bugs, the game *Toribash* is worth recommending but asks its developers to resolve the problems:

> "hey guys can u please **fix** the **update** i can never open the game and then it just quits and i do **recamend** this game becouse its a great fighting game and there are cool **stuff** you can do in it too so just saying can u guys please **fix** rhe unexpected quiting plz". (player id 76561198098304103)

The cluster **Experience** describes playtime (T23, *achievement, extreme, playtime*), game enjoyment (T13, *perfect, enjoy, enjoyable*) and overall player perception of a game (T6, *hard, huge, deserve*; T4, *bore, expect, opinion*). This helps us understand player opinions of a game derived from their playing practices and divide them between positive, negative, or neutral. In the example below, a player describes their impressions from the game *Trine 2* that causes them to recommend this game to others:

> "... the game is quite **easy** but there are challenges (such as **achievements**) so that even if the puzzles are **easy**, they "suggest" what to do to make them **harder** ... i **enjoyed** every hour i spent on this. i strongly suggest you to buy it." (player id 76561198142377217)

Recommendations (T5, *amaze, highly, absolutely*) and nostalgia (T46, *remember, gaming, curve*) are well illustrated by the **Social Influence**. This influence broadens our comprehension of the game features, like music or storyline, appreciated by players and making them give recommendations to other gamers. For example, one player expresses their excitement about the game *Hitman* through a review:

> "... the graphics are **amazing** and the game is well optimized, also there is a ton of content with an interesting **storyline** and the attention on the little details is just phenomenal. Very **recommended**, especially if it's on sale." (player id 76561198168690505)

The **Gaming Progress** cluster describes skills (T12, *diablo, torchlight, arpg, skill*) and abilities (T87, *ability, increase, require*). They are used by players to improve their performance and gain achievements. This cluster gives us understanding of the effective and ineffective tools and strategies gamers use to cope with difficulties and advance in games. Such understanding can be seen through a player review on the game *Mark of the Ninja*:

> "... different enemies that require different approaches to take down, ... test your puzzle **skills**. ... You possess multiple **abilities** that aid you ... the second strongest factor of this game and only **increases** the replayability of the different playstyles introduced. ... the ability to do stealth kills along with two tools; ... give you tokens which are used to **gain** upgrades to make the main character stronger...." (player id 76561198055976611)

6 Discussion and Conclusion

In our pilot study, we extended the discussion by showing a broader range of player experience aspects and the way they interrelate. This analysis is essential because it narrows broad topics to specific aspects that are worth studying to uncover players' game experience and attitudes towards video games.

Clusters of topics that we obtained in our research go along with the previously found seven dimensions (i.e., Achievement, Narrative, Social interaction,

Social influence, Visual/Value, Accessories, General experience) [13]. Still, the results make these categories more detailed due to discovering new topics not mentioned previously. Our topic model shows that the aforementioned meta-topics can be disentangled in more experience dimensions that are connected to each other with different strength. For example, the social interaction dimension can be divided into matchmaking and teamwork discussions. This can generate more knowledge of the evaluation processes as a whole and game evaluation in particular.

Furthermore, our study contributes to the exploration of patterns then united in topics that are mostly valued by players in game reviews. The results of the work extend comprehension of consumer retention mechanisms and supports an idea that reviews can serve product improvements. That can be useful for game design, as our research provides a better understanding of users' motives and the criteria by which they compare games.

During our analysis we faced several limitations. All reviews were obtained from the Steam distribution platform and reflect discussion on games only from this source. Moreover, games have different numbers of reviews written on them by years and by the review length.

One of the possible direction of the future study is to explore how players discuss different games. To conduct this research, each game from the sample has to be analyzed separately and the most common topics for every game have to be extracted. The results would indicate how the discussion of games differs from one game to another and the main reasons for these differences.

References

1. Bounie, D., Bourreau, M., Gensollen, M., Waelbroeck, P.: The effect of online customer reviews on purchasing decisions: the case of video games 21 (2005)
2. Mankad, S., Han, H., Goh, J., Gavirneni, S.: Understanding online hotel reviews through automated text analysis. Serv. Sci. **8**(2), 97–248 (2016)
3. Yee, N.: Motivations for play in online games. Cyberpsychol. Behav. **9**(6), 772–775 (2006)
4. Williams, D., Ducheneaut, N., Xiong, L., Zhang, Y., Yee, N., Nickell, E.: From tree house to barracks: the social life of guilds in World of Warcraft. Games Cult. **1**(4), 338–361 (2016)
5. Taylor, T.L.: Does WoW change everything? How a PvP server, multinational player base, and surveillance mod scene caused me pause. Games Cult. **1**(4), 318–337 (2016)
6. Ducheneaut, N., Yee, N., Nickell, E., Moore, R.J.: Building an MMO with mass appeal: a look at gameplay in World of Warcraft. Games Cult. **1**(4), 281–317 (2016)
7. Tondello, G.F., Valtchanov, D., Reetz, A., Wehbe, R.R., Orji, R., Nacke, L.E.: Towards a trait model of video game preferences. Int. J. Hum.-Comput. Interact. **34**(8), 732–748 (2018)
8. Vahlo, J., Kaakinen, J.K., Holm, S.K., Koponen, A.: Digital game dynamics preferences and player types. J. Comput.-Mediat. Commun. **22**(2), 88–103 (2017)

9. Tondello, G.F., Wehbe, R.R., Orji, R., Ribeiro, G., Nacke, L.E.: A framework and taxonomy of videogame playing preferences. In: Proceedings of the Annual Symposium on Computer-Human Interaction in Play, Amsterdam, The Netherlands, pp. 329–340 (2017). https://doi.org/10.1145/3116595.3116629
10. Pielka, M., Sifa, R., Ramamurthy, R., Ojeda, C., Bauckhage, C.: A community detection based approach for exploring patterns in player reviews. In: Bi, Y., Bhatia, R., Kapoor, S. (eds.) IntelliSys 2019. AISC, vol. 1037, pp. 553–565. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-29516-5_43
11. Li, K., Nguyen, H.V., Cheng, T.C.E.: How do avatar characteristics affect avatar friendliness and online gamer loyalty? Perspective of the theory of embodied cognition. Emerald Insight (2018). https://doi.org/10.1108/IntR-06-2017-0246
12. Sirbu, D., Secui, A., Dascalu, M., Crossley, S.A., Ruseti, S., Trausan-Matu, S.: Extracting gamers' opinions from reviews. In: 2016 18th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing (SYNASC), pp. 227–232. IEEE (2016). https://doi.org/10.1109/SYNASC.2016.044
13. Wang, X., Goh, D.H.-L.: Components of game experience: an automatic text analysis of online reviews. Entertain. Comput. **33**, 100338 (2020)
14. Kozinets, R.V.: Netnography. In: The International Encyclopedia of Digital Communication and Society, pp. 1–8. American Cancer Society, Seattle (2015)
15. Hu, M., Liu, B.: Mining and summarizing customer reviews. In: Proceedings of the Tenth ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, Seattle, WA, USA, pp. 168–177 (2004)
16. Wallner, G., Kriglstein, S., Drachen, A.: Tweeting your destiny: profiling users in the Twitter landscape around an online game. ArXiv:1905.12694 Cs (2019)
17. dos Santos, T.F.T., Lemmerich, F., Strohmaier, M., Helic, D.: What's in a review: discrepancies between expert and amateur reviews of video games on metacritic. In: Proceedings of the ACM Human-Computer Interaction (CSCW), vol. 3, pp. 1–22 (2019)
18. Grajzl, P., Irby, C.: Reflections on study abroad: a computational linguistics approach. Soc. Sci. Res. Netw. (2018) https://doi.org/10.2139/ssrn.3235551. SSRN Scholarly Paper ID 3235551. Rochester, NY
19. Roberts, M.E., Stewart, B.M., Airoldi, E.M.: A model of text for experimentation in the social sciences. J. Am. Stat. Assoc. **111**(515), 988–1003 (2016)

Value Dimensions in the Reviews of the MOOCs Students

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Abstract. Massive Open Online Courses (MOOCs) are a popular educational format. However, it is not clear how to assess students' experience in MOOCs. This pilot study aims to determine how the discussion of essential aspects of online education differs for students taking online courses from four different categories of education. Moreover, this study is an attempt to explore the value dimensions of the students of MOOCs – the attributes of online education experience that online learners deem most important. Using texts of student feedback it is possible to identify underlying aspects of courses students value and the difference of features and their frequency of mentioned across four fields of education.

We collected 8558 sets of feedback from students taking 37 courses on Coursera. Text mining methods – frequency analysis, keyword extraction, and dictionary construction – were used to identify the MOOCs features to which students pay the most attention.

This study identifies the dimension values of MOOCs students and distinct trends in the discussion of online learning experiences that are strictly specific to different areas.

Conducting a value analysis of MOOCs using feedback allows us to look at the features of the courses that are important for students.

Keywords: MOOCs · Reviews · Students' satisfaction

1 Introduction

Massive Open Online Courses (MOOCs) are online courses that do not have formal requirements for entering, do not impose limits on enrollment of students, are free of charge, do not earn students credit, and may offer certification for completion [1]. In our work we decided to focus on feedback from Coursera and chose four categories of courses: Mathematics, History, Chemistry, and Design. The chosen courses are quite different from each other, as they relate to different disciplines. The novelty of our idea is that we evaluate several thematically different courses simultaneously. The problem we seek to address with our research is to try to identify value dimensions for students of MOOCs and different trends in the discussion of online courses in the students' reviews. Currently, many studies investigate one or more online courses on similar topics solely at one university [1–3].

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This study looks at the MOOC platform, where courses from different universities are gathered and where anyone can study courses. Our research is designed to help determine what is important for students taking online courses from different categories of education. To collect feedback from the Coursera website, we used the text mining approach. Reviews were selected as a unit of analysis. We think our solution is suitable for the identified problem, as we attempt to define value dimensions and compare the discussion of these dimensions in the reviews on thematically different courses using a quantitative method. Moreover, such analysis is not time-consuming and is free of charge, as we did not seek volunteers to conduct surveys or interviews.

Our work should close the gap that exists in research on online education. Many papers focus on a single thematic course. We make a comparison between different categories of courses simultaneously, while also exploring value dimensions. Our work allows us to identify both similar and different values that guide students in different course categories. However, it must be noted that this research is a work in progress.

2 Literature Review

2.1 Value Dimensions

Marketing studies and consumer behavior research define client satisfaction as a client's subjective opinion of a product based on expectations and performance. Clients evaluate their level of satisfaction according to the perceptions of the attributes of a service that they consider to be the most essential. These aspects represent value dimensions. Several studies have proposed that client satisfaction plays an essential role in customers' loyalty, and as a result it leads to positive reviews [4]. The value dimensions extracted from the data provide a set of client wants and needs that are expressed in their language, organized according to the way in which a product is used. These dimensions demonstrate clients' current satisfaction with all the available MOOCs [4]. Identifying value dimensions of MOOCs students is one of the aims of this study.

2.2 Evaluating Feedback on Online Courses

Since the launch of the first official truly online course in 1981, there have been many differences from live teaching, which marked the beginning of improving online courses and studying student involvement [5]. To avoid and correct errors as effectively as possible, a feedback evaluation system was introduced in many courses [6]. Of course, it was initially and partially used to evaluate professors' teaching and allowed university administrations to control their staff [7–10]. However, the main challenge is still to identify student needs and key trends in online education [10–12]. Most existing studies used quantitative analysis. Surveys were initially used as a data collection method. Almost all surveys were based on the Likert scale, the scores varying from study to study [13–15]. Unfortunately, teachers were not always happy with this way of analyzing feedback, as it is impossible to understand from surveys what is valuable for students and what is worth improving. Among other things, the authors of that paper noted that the assessment of a course through a survey is interpreted by students as another formality and they fill it out without proper attention, which affects the results, especially of open questions [16].

Later there were attempts to introduce qualitative feedback analysis from students [16–18]. The main advantage of the qualitative analysis was that it allowed for the identification of additional topics of concern to students. However, this method lost out to quantitative analysis because it required more effort and resources from course organizers or teachers in terms of analysis [19, 20].

Therefore, most studies continue to be conducted using quantitative analysis. Of course, some studies have used surveys that also had open-ended questions where students could provide an additional opinion. However, their effectiveness was quite low because of the low response rate [10].

The development of quantitative analysis methods did not stagnate and researchers continued to examine ways to improve them. Thus, the idea of automated text-based course evaluation was accepted, which would allow for the quantitative evaluation of qualitative data without requiring significant time and human resources. Active development of automated text summarization in online course feedback took place from 2017 and is ongoing. Researchers use different methods, such as identifying keywords and their frequency, identifying key phrases, topic modeling, and content analysis [21]. Some researchers use integer linear programming (ILP), latent semantic analysis (LSA), or latent Dirichlet allocation (LDA) [16, 21, 22]. Researchers also use targeted sentimental analysis of students' comments to assess not only the meaning of the comment, but also its emotional coloration [23]. All these approaches show good results of qualitative research analysis. However, most researchers pay attention to one course or several courses from a similar education area; few have compared reviews from thematically different courses.

Furthermore, an important area in the study of student satisfaction in online courses is the study of the online course interface and design solutions, which should be taken into account when designing a course to keep students until the end of the course [24].

Despite the improvement in the methods of quantitative and qualitative evaluation of data and the introduction of an automatic part in them, there is still a gap in the topic under study. Most papers focus on the evaluation of feedback from one course or several courses in one area: for example, students could choose which of four modules they wanted to take as part of a medical course [2]. However, the results between groups of respondents from different modules were not studied further.

There are differences in the structure and content of courses dedicated to distinct subjects. These differences affect the preferences of those who take the courses. Therefore, we aim to reveal the aspects of online education that are important for the students of distinct categories of courses. We anticipate that people from different courses will have slightly different values. Also, the unit of our analysis is the feedback from Coursera, which allows us to explore the needs of students in a real environment, without creating an experimental environment.

3 Research Problem and Research Question

Among the existing studies, there is a clear gap in the study of courses on different topics. In particular, of the works that were reviewed, no attention was paid to the definition of value dimensions in the industry of online education and the differences in the discussions

between course categories. To address this research problem, we decided to study student feedback on different categories of courses. Most papers present a qualitative analysis of the feedback received, while this study, because of the large amount of data, aims to solve this problem through quantitative analysis.

Therefore, our research questions are the following: 1) How do MOOC features on Coursera discussed in students' reviews differ in terms of the frequency with which they are mentioned across four different categories of courses? 2) What are the value dimensions of the students who take online courses?

4 Methodology

4.1 Data

The unit of analysis of the research was student reviews of online courses from Coursera. Reviews can help identify some new features of courses that may have been overlooked. It was decided that feedback would be taken from four categories of courses: Chemistry, Mathematics, History, and Design. The choice was based on the fact that all four categories considered are part of more global directions such as Physics and Mathematics, Humanities, Chemistry and Biology, and Arts.

All the evaluated reviews were collected from 37 Coursera courses. The number of courses in each category is presented below in Table 1. The total number of reviews was 8558. The average length (mean = 14.0617 words) of reviews and the median (median = 9 words) were calculated, and reviews that were longer than 9 words were left in the dataset, because reviews with fewer words were irrelevant to the study. The size of the final analyzed dataset was 5385 reviews. In Table 2 the final numbers of reviews in the four categories are presented. Additionally, English stop words were deleted from the reviews. Then it was decided to find out the frequency of each word in the whole dataset and each category. The most frequent words in all categories were "courses", "good", "thank", "great", "much", "really", and "learn". We decided to delete these during keyword analysis, because these words are quite common and of little value.

Table 1. Number of courses across four categories

Chemistry	Mathematics	History	Design
7	8	11	11

Table 2. Number of reviews across four courses

Chemistry	Mathematics	History	Design
242[a]	1657	1258	2228

[a]The number of reviews is relatively small due to the limited number of chemistry-related MOOCs on Coursera.

4.2 Analysis

Three text mining methods were applied: frequency analysis, keyword extraction, and dictionary construction.

The frequency analysis technique was used to find the most commonly used terms in text data. This technique revealed the general trends of discussions in the reviews of the MOOCs.

The most common phrases were derived by keyword extraction. This is a text mining technique that is used to explore frequently occurring phrases/n-grams by applying dependency parsing that explores dependency relations between parts of speech, thereby narrowing down the context of extracted data. Given that, words with the dependency relation "nominal subject" and the adjectives of these words were left in the dataset. Therefore, entities discussed in the reviews were combined with adjectives used to describe the entities.

Using the extracted phrases, we obtained frequently used words and essential features of online education that are discussed by users of the MOOCs. Given these features, we constructed six topic dictionaries that reflect value dimensions of the MOOCs students to define the value dimensions in question and understand the differences in the discussions in the reviews of the distinct MOOCs categories. The value dimensions present six distinct aspects of online education: formats that are used in the courses to convey content, content, course structure, instruction, assessment, and assignments.

5 Results

Frequency analysis demonstrated general trends in students' discussions of the MOOCs. Despite this fact, the terms were extracted without links to the context of the use of a particular term. Additionally, the extracted terms mostly referred to the content of the courses. Given that this study aims to uncover the differences in discussion between the MOOCs categories, the keyword extraction technique was used. This allowed for the narrowing down of the context of phrases to be extracted and for a focus on specific entities discussed in the reviews. In this case, phrases that contained nouns and adjectives that described these nouns were extracted to observe entities that are frequently discussed in the reviews. The dictionaries enabled the construction of the value dimensions that reflect the essential aspects of online learning.

5.1 Frequency Analysis and Keyword Extraction

Frequency Analysis. To define the most frequent keywords in each category the lists of the most frequent words for each category and all the categories were constructed (Table 3).

Chemistry. For chemistry students, the most important aspects were explaining, understanding, gaining new knowledge, and quizzing, which seemed to act as a small test to consolidate the material. This category had more students who mentioned words such as "problem" and "answer".

Table 3. Top 10 words distributed by the frequency of occurrence in each category

All	Chemistry	History	Mathematics	Design
Course	Chemistry	Interest	Algebra	Design
Good	Quiz	History	Concept	Think
Much	Lecture	Professor	Understand	Really
Learn	Really	Lecture	Linear	Graphic
Great	Explain	Really	Really	Assignment
Design	Take	Ancient	Math	Lot
Really	Understand	Lot	Probability	Can
Think	Can	Take	Machine	Make
Thank	Knowledge	Enjoy	Take	Interest
Interest	Interest	Understand	Example	Understand

History. Courses related to history were dominated by the words "lecture" and "understand". In the other categories of courses, there is no such attention to the professor.

Mathematics. For mathematics courses, students mentioned mathematical terms more often than others: "algebra", "linear", "concept", "probability", and "math". At the same time, students also paid much attention to understanding the material and its explanation. The word "example" was relatively common.

Design. In Design courses, students paid more attention to "assignments" than other courses and mentioned words such as "work" and "make". Also, in reviews of design courses, the word "think" was common.

Frequency analysis demonstrated the content of these four distinct categories of courses. However, one of the aims of the study is to reveal the features of online education that are essential for the students who take MOOCs. For this reason, the keyword extraction technique was used to focus on the specific types of phrases that are used by the reviewers to write about courses.

Keywords Extraction. The most common phrases were illustrated by the word cloud (see Fig. 1).

History. Students of history courses often discussed the quality of lectures, videos, and instruction, for instance, "knowledgeable instructor", "excellent lecture", "interesting video". In the other categories (except mathematics, e.g. "clear lecture" or "easy lecture"), phrases containing "instructor" and "lecture" were mentioned less frequently.

Mathematics. The students who took mathematics courses usually commented on the structure of the course and its difficulty, using keywords such as "challenging week" and "fast pace". They also discussed the difficulty of tests, for instance, "hard quiz", and "challenging quizze". These aspects were discussed much less frequently in other categories.

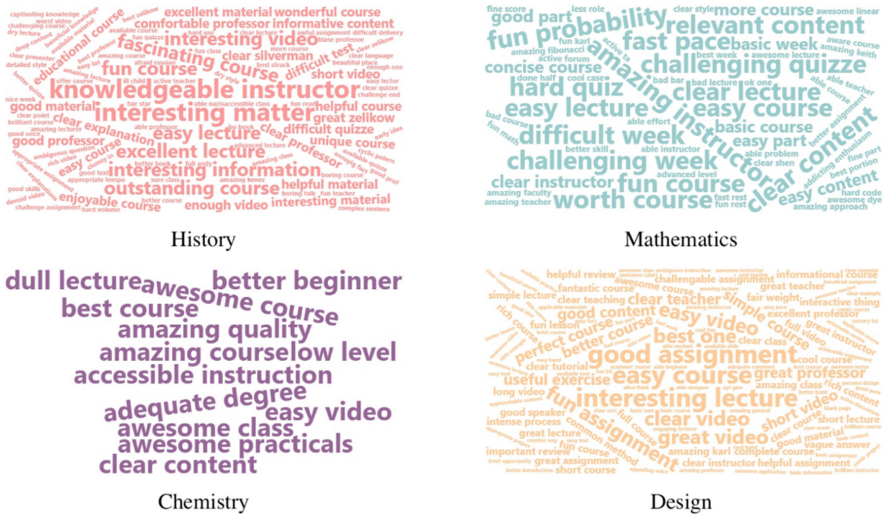

Fig. 1. Word clouds with the extracted most commonly used phrases for each course category.

Chemistry. Chemistry students discussed the quality of instruction, practical tasks, and videos with equal frequency, for example, "awesome practicals", "accessible instruction", and "easy video". The equal frequency of the entities' occurrence might be a consequence of a lower number of reviews of chemistry-related courses.

Design. The students who studied design on Coursera mostly discussed assignments, videos, and lectures, using keywords such as "good assignment", "interesting lecture", and "great video". Assignments, lectures, and videos were also discussed by students of the other categories of courses.

Keyword extraction revealed new insights concerning course structure, formats that are being used in the MOOCs, and other aspects of online education. All these aspects are reflected by the value dimensions that are explored in the next section.

5.2 Value Dimensions

The distribution of words by categories of courses in terms of percentage in each dictionary is demonstrated (see Fig. 2).

"Assessment" Dimension. Design students discussed assessment more than other students: all five words from the "Assessment" dictionary were mostly used by the student who took design courses. It also should be noted that the words "mark" and "assessment" were used by all students with approximately equal frequency.

"Assignments" Dimension. History students discussed reading and writing assignments more than other students, whereas students of design courses mentioned projects and their requirements much more frequently than other students. In the reviews of mathematics courses, quizzes and problems were discussed more frequently than in the

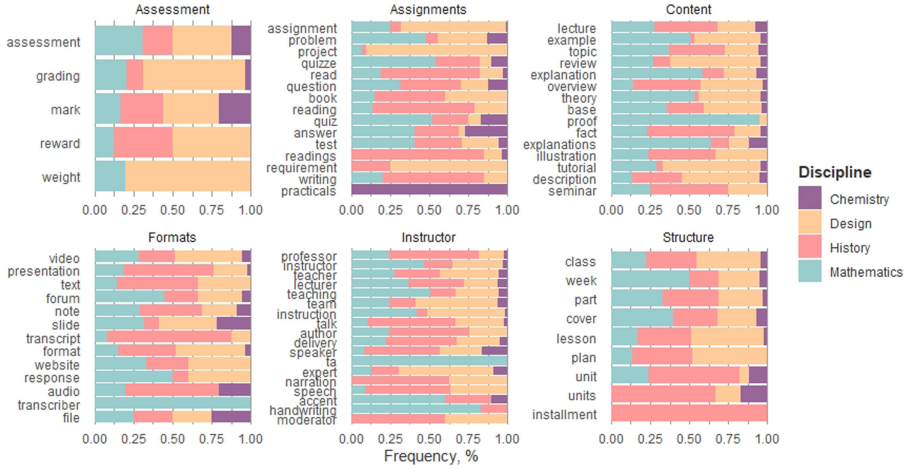

Fig. 2. Word frequency for dictionaries and disciplines.

reviews of other categories of courses. The term "practicals" was used by chemistry students only. However, some entities were mentioned with almost equal frequency among several different categories of courses, such as the words "question" and "answer" in reviews of chemistry, history, and mathematics courses.

"Content" Dimension. Students who took mathematics courses discussed explanation in general and explanation-related details much more often than the students of other categories of courses, whereas design students mentioned the terms "review", "tutorial", and "description" more frequently than students of other categories of courses. Two words that were used by history students more than students of other disciplines were "fact" and "seminar". Some entities were discussed by the students from chemistry, history, and mathematics courses with nearly equal frequency: "topic", "lecture", and "illustration".

"Formats" Dimension. The most frequently discussed entities in the reviews of history courses in comparison with those of other categories of courses were "presentation", "transcript", "audio", and "text". Only mathematics students mentioned the entity "transcriber". Some terms were used by the students of mathematics, history, and design courses with approximately equal frequency: "website" and "note".

"Instructor" Dimension. History students mentioned the words "professor", "talk", "author", "narration", "moderator", and "speaker" much more frequently than students of other categories of courses. The terms "ta", "handwriting", "accent", and "teaching" were more frequently mentioned by mathematics students. Design students used the terms "expert", "instruction", and "team" more frequently than other students. The words "teacher" and "lecturer" were used by the students of history, mathematics, and design courses with nearly equal frequency.

"Structure" Dimension. Mathematics students used the term "week" more frequently than students of other categories of courses. History students mentioned the entities "units", "unit", and "installment" much more frequently than the students of other categories of courses. The students of design courses used the terms "lesson" and "plan" more frequently than students of other courses. As in the previous dictionaries, there were terms that were used by the students of mathematics, design, and history courses with almost equal frequency: "class", "part", and "cover".

6 Discussion and Conclusions

Collecting feedback on online courses is an integral part of all online education. With the help of feedback from students, the creators and developers of online courses can understand what features of the course satisfy or dissatisfy students. Such analysis allows courses to retain and attract new students.

Despite the progress in the field under study, there were still no studies that compared courses in different specialties. For this reason, our research focused on several categories of courses at the same time: chemistry, mathematics, history, and design. Additionally, the analysis of student comments and feedback avoids students disrespecting course evaluations, because they write these comments in person.

Our preliminary research led to the following conclusions. First, for students studying courses in history, chemistry, and design, the level of interest in the subject was important, unlike for students studying mathematics. For students in design, mathematics, and chemistry, the practical part of the course was important. For design and history students, the way in which the course material was communicated was important. Such differences can be justified by the specifics of the subjects themselves: in some subjects, more practical knowledge and skills are needed, while in others, students just need to learn and retain new knowledge.

A common feature of all the subjects analyzed was words such as "professor" or "teacher", as well as "lecture" or "class". In all reviews, students noted course characteristics such as good structure, material, and content. Also, students noted how familiar they were with the topic and whether it is suitable for beginners.

The observed value dimensions are the following: Assessment, Assignments, Content, Formats, Instructor, Structure.

This study has several limitations. First, since this was our first experience in research on this topic, we might have missed some important details, despite the analysis of existing work. Second, in some categories, we did not use all the courses presented on Coursera, and could have missed some important details of the courses. Third, most of the reviews in our dataset (70–80% in each category) were rated at 5 stars, which did not allow us to identify all course attributes that may not suit students. Fourth, most of the courses under the study were in English, but reviews were sometimes also found in other languages and were not analyzed.

In further research, we expect to conduct a deeper analysis of feedback using metrics such as TD-IDF and LDA. Some authors have already used such technology of feedback analysis, and the results could have increased knowledge in this area [22]. Also, we

believe that it is necessary to pay attention to the semantic analysis of reviews and try to identify with it the stars from the reviews that indicate the satisfaction or dissatisfaction of students with a certain element of the online course. Our results could expand on and enable a comparison with the data obtained in previous work where the authors also used semantic analysis [23].

References

1. Annaraud, K., Singh, D.: Perceptions of hospitality faculty and students of massive open online courses (MOOCs). J. Hosp. Tour. Educ. **29**, 82–90 (2017). https://doi.org/10.1080/10963758.2017.1297714
2. May, L., Acquaviva, K.D., Dorfman, A., Posey, L.: Medical student perceptions of self-paced, web-based electives: a descriptive study. Am. J. Distance Educ. **23**, 212–223 (2009). https://doi.org/10.1080/08923640903332120
3. Okech, D., Barner, J., Segoshi, M., Carney, M.: MSW student experiences in online vs. face-to-face teaching formats? Soc. Work. Educ. **33**, 121–134 (2014). https://doi.org/10.1080/02615479.2012.738661
4. Guo, Y., Barnes, S.J., Jia, Q.: Mining meaning from online ratings and reviews: tourist satisfaction analysis using latent dirichlet allocation. Tour. Manag. **59**, 467–483 (2017). https://doi.org/10.1016/j.tourman.2016.09.009
5. Harasim, L.: Shift happens: online education as a new paradigm in learning. Internet High. Educ. **3**, 41–61 (2000). https://doi.org/10.1016/S1096-7516(00)00032-4
6. Williams, J.: Student feedback on the experience of higher education. In: Menon, M.E., Terkla, D.G., Gibbs, P. (eds.) Using Data to Improve Higher Education: Research, Policy and Practice, pp. 67–80. SensePublishers, Rotterdam (2014). https://doi.org/10.1007/978-94-6209-794-0_5
7. Kember, D., Leung, D.Y.P., Kwan, K.P.: Does the use of student feedback questionnaires improve the overall quality of teaching? Assess. Eval. High. Educ. **27**, 411–425 (2002). https://doi.org/10.1080/0260293022000009294
8. Brinko, K.T.: The practice of giving feedback to improve teaching. J. High. Educ. **64**, 574–593 (1993). https://doi.org/10.1080/00221546.1993.11778449
9. Harvey, L.: Student Feedback [1]. Qual. High. Educ. **9**, 3–20 (2003). https://doi.org/10.1080/13538320308164
10. Spooren, P., Brockx, B., Mortelmans, D.: On the validity of student evaluation of teaching: the state of the art. Rev. Educ. Res. **83**, 598–642 (2013). https://doi.org/10.3102/0034654313496870
11. Grebennikov, L., Shah, M.: Commencing student experience: new insights and implications for action. Eur. J. High. Educ. **2**, 267–289 (2012). https://doi.org/10.1080/21568235.2012.683663
12. Smithson, J., Birks, M., Harrison, G., et al.: Benchmarking for the effective use of student evaluation data. Qual. Assur. Educ. **23**, 20–29 (2015). https://doi.org/10.1108/QAE-12-2013-0049
13. Ferguson, J.M., DeFelice, A.E.: Length of online course and student satisfaction, perceived learning, and academic performance. IRRODL **11**, 73–84 (2010)
14. Gaebel, M.: MOOCs: Massive Open Online Courses. An Update of EUA's First Paper (January 2013). EUA Occasional Papers (2014)
15. Sanford, D., Ross, D., Rosenbloom, A., Singer, D.: Course convenience, perceived learning, and course satisfaction across course formats. e-JBEST **11**, 69–84 (2017)

16. Steyn, C., Davies, C., Sambo, A.: Eliciting student feedback for course development: the application of a qualitative course evaluation tool among business research students. Assess. Eval. High. Educ. **44**, 11–24 (2019). https://doi.org/10.1080/02602938.2018.1466266
17. Grebennikov, L., Shah, M.: Student voice: using qualitative feedback from students to enhance their university experience. Teach. High. Educ. **18**, 606–618 (2013). https://doi.org/10.1080/13562517.2013.774353
18. Brockx, B., Van Roy, K., Mortelmans, D.: The student as a commentator: students' comments in student evaluations of teaching. Procedia Soc. Behav. Sci. **69**, 1122–1133 (2012). https://doi.org/10.1016/j.sbspro.2012.12.042
19. Huxham, M., Laybourn, P., Cairncross, S., et al.: Collecting student feedback: a comparison of questionnaire and other methods. Assess. Eval. High. Educ. **33**, 675–686 (2008). https://doi.org/10.1080/02602930701773000
20. Richardson, J.T.E.: Instruments for obtaining student feedback: a review of the literature. Assess. Eval. High. Educ. **30**, 387–415 (2005). https://doi.org/10.1080/02602930500099193
21. Unankard, S., Nadee, W.: Topic detection for online course feedback using LDA. In: Popescu, E., Hao, T., Hsu, T.-C., Xie, H., Temperini, M., Chen, W. (eds.) SETE 2019. LNCS, vol. 11984, pp. 133–142. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-38778-5_16
22. Luo, W., Liu, F., Liu, Z., Litman, D.: Automatic summarization of student course feedback. In: Proceedings of the 2016 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, pp. 80–85. Association for Computational Linguistics, San Diego (2016). http://dx.doi.org/10.18653/v1/N16-1010
23. Welch, C., Mihalcea, R.: Targeted sentiment to understand student comments. In: Proceedings of COLING 2016, the 26th International Conference on Computational Linguistics: Technical Papers, pp. 2471–2481. The COLING 2016 Organizing Committee, Osaka (2016)
24. Korableva, O., Durand, T., Kalimullina, O., Stepanova, I.: Studying user satisfaction with the MOOC platform interfaces using the example of coursera and open education platforms. In: Proceedings of the 2019 International Conference on Big Data and Education, pp. 26–30. Association for Computing Machinery, London (2019). https://doi.org/10.1145/3322134.3322139

Hybrid Method of Multiple Factor Data Clusterization

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Abstract. The urgent scientific problem of multifactor clustering using various methods of normalization and averaging is investigated. Metric calculation values to improve the quality of clustering. A literary review of scientific publications on the topic of clustering social graphs and identifying communities has been carried out. The shortcomings of modern research in the field of analysis of social networks are identified. The list of network analysis metrics recommended as basic for data pre-processing is presented. The algorithm of the hybrid method of multifactorial clustering is presented, which allows reducing the computational costs of data clustering. An algorithm execution procedure is described for selecting several centrality metrics. Various methods of averaging centrality metrics are presented. This approach can significantly increase the assessment of the quality of clustering. The developed hybrid method based on averaging and the Louvain multi-factor clustering algorithm allows us to reduce computational resources. The clusterization application problem in the online community ITMO.EXPERT of the VKontakte social network is considered.

Keywords: Multivariable clusterization · Social network · Graph methods · Centrality metric · Hybrid method · Louvain algorithm

1 Introduction

Social network analysis (SNA) attracts attention enormous amount of researchers from around the world. Daily co-operating in a network the Internet with other users makes basis of life of modern man. Cooperation comes true by means of communication by e-mail, communications in messengers or social networks. A requirement grows in the improvement of existent methods of SNA because constantly the volumes of data grow in social networks. Users community detection is one of basic tasks of SNA. Researches are conducted already in this subject area during many years. However, modern researchers test a sharp requirement in development of effective graph methods for large-scale network structures. Each of existent methods has individual features, dignities and defects. And each of them can be a component in the development of the so-called hybrid method for analysing the graph model in social networks.

Social networks differentiate on the method of model of social cooperation of entering into them users. It is generally known, users of social networks, as a rule, form

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related subgroups. Users in subgroups are in a greater degree constrained within the framework of one subgroup than with other users of social network. Most modern authorial researches, as a rule, are sanctified to the analysis of behaviour of users in various subgroups and cooperation of various subgroups (clusters) among themselves. The study of behaviour of cluster groups helps to understand the paths of distribution of data flows between users. Principle of understanding of general network structure is the key to understanding of principles of distribution of data flows in a network. Network structures differ from each other based on combination of basic network metrics.

The main purpose of this work is to develop a hybrid multiple factor data clustering method.

In this work, the following scientific tasks are solved:

1. Research of methods of normalize metric calculation and averaging values calculation to improve the quality of clustering.
2. Development of a hybrid clustering algorithm.
3. Approbation of an offer methodology on the collected set of the applied data.

It is worth noting, the special attention is paid to classification of users on key positions in researches of social networks. However, in research [1] general network structures on the basis of dataflow models are used with the purpose of classification of dialogues in a social network Twitter. The authors presented concepts and methods for classifying the structures of social networks based on common network metrics. As a result of this research, the authors proposed six patterns of information flow. A result is shown on the example by segmenting 60 thematic sets of data of social network Twitter in the different templates of collective connections. The authors described the term homophily. Homophily is the main organizational principle of building the structure of a social network. According to this principle, users more often form new network social connections with users most look like them. Structural characteristics are identified and analysed as density, modularity and presence of isolates from the point of view cooperation of users. A key influence on the distribution of information flow is also the degree of hierarchy of the network structure. In the SNA, this fact corresponds to the concept of centralization of the network Authors are mentioned a fact that social networks consist of a few different structures of connection. For example, the relationship of the "Friend" between users has no direction due to joint adoption. Leaving comments implies the existence of a one-way communication. One of the key results of this work can be considered an universal typology of network structures based on variations of the main network metrics.

Possibilities of SNA can be applied in area of e-learning at education of students. Research authors [2] suggest to use the SNA for the estimation of participation of students in the courses of e-learning. They suggest using SNA techniques to detect network structures generated by user interactions. The authors developed a special analysis toolkit called Meerkat-ED, which uses mining community techniques. Possibility of determination of explorers of knowledge (students with the maximal degrees of centralization) is a characteristic advantage of using graph methods. Assessment of student participation can be given at each stage of training. Assessment of student participation can be given

by a systematic study of the degree of centrality of the node in the general graph of the group.

The principles of building social networks allow the use of probabilistic thematic models to analyse the graph of relationships between users. Research authors [3] use given an opportunity with the purpose of grouping and marking of subgroups based on their thematic similarities in a graph. The variant of improvement of work of model of the Latent Dirichlet allocation (LDA) offers with popular network nodes by nodes with many incoming edges. Offer solutions can be used for the grant of more actual recommendations. For example, at the search of possible friends on the certain area of similar interests of users.

The main problem in SNA remains the detection of cohesive user groups (clusters). The publication of the authors [4] was an important event on the way to solving this problem. It presented some graphic patterns of network structures in large social communities. The paper classifies typical approaches to the analysis of user graphs. The construction and interaction of large network structures allows us to identify common features among them. A similar analysis can be difficult at research of small network structures. The authors believe that "the most well-known characteristics are: scale-free distribution, small world effect, and strong community structure". The clustering coefficient was proposed as a measure of transitivity, that is, estimates of the probability of the existence of relations between neighbouring vertices in the friendship graph. The detection of cluster in a social network can be carried out by maximum click search algorithm. Another way to discover a cohesive community can be to build a hierarchical network structure based on topology. This study contains objective merit: the description of identified community assessment strategies to facilitate comparison of different community detection methods. One of key problems at finding out associations is a problem of scalability, since most existing methods require combinatorial optimization for graph analysis. Authors predict speed-up development of appearance of new methods of analysis because of general conformities to law of development of social networks and necessities of decision of new tasks. Community detection is an important in terms of classifying nodes conducted with the purpose of search homogeneous subgroups or leaders of subgroups.

The authors of the publication [5] made a successful attempt at a theoretical description of the basics of graph analysis of social networks. In their work, they proposed analysis metrics that can be used both at the level of small agents of social networks and at the level of the whole network. The first method explores the network in terms of the concept of centrality. The second method allows to evaluate the overall structure of the network. It is separately needed to extract such area affected by authors, as a hierarchical clusterization. Hierarchical clustering algorithms create a flexible inlaid cluster structure. As a rule, the structure is presented in the form of a multi-level network structure. The basic going is presented near a hierarchical clusterization: separation methods and agglomeration methods. One of the most famous and widely used community search algorithms is described in detail - the Hirvan and Newman algorithm. According to the authors, an important research task is the development of effective, scalable and automated methods to analyse the dynamic development of social networks.

The authors of [6] solve the problem of creating a small representative sample while maintaining the properties of the original graph from a massive graph with millions of nodes. The authors analyse modern sampling algorithms and evaluate their performance on oriented graphs based on large-scale data. The work deserves attention, since the evaluation is carried out not only with the help of the distribution of the degree of the node usually used in such cases. The work also uses the clustering coefficient, which quantitatively determines how well the neighbours are connected in the graph.

As mentioned earlier, one of the main SNA problems is the large-scale volumes of data that are subject to various kinds of studies. Researchers are trying to propose various solutions to problems of this kind. The authors of the study [7] reasonably argue that most of the existing works use a selective subgraph of the network structure as datasets. Similar approach can result in serious inaccuracies or even loss of major indexes. The authors of this study analyse a social network with tens of millions of users based on distributed approach, performing of social interactions analysis between users. Data analysis was performed using popular breadth-first search algorithms such as BFS algorithm and the MHRW algorithm (Metropolis-Hastings Random Walk). "The MHRW algorithm is an adaptation of the MCMC (Markov Chain Monte-Carlo) algorithm, which receives a random sample of nodes according to the degree of their distribution" [7]. The results of this analysis allowed to confirm a hypothesis about the predictability of behaviour of users on the basis of research of data about their registration.

The authors of [8] studied the classification methods that were proposed to solve the Node Classification Problem. Sociologists consider that one of the simplest variants of decision of problem is bringing in of experts for realization of the quality marking of nodes. However, this approach is undesirable from the enormous scales of analysable data. As an alternative they suggest to use the methods, built on the basis of the information already coded before in a partly mark graph. This information will help in the prediction of mark. Simply speaking, iterative classifier training takes place based on examples of previously labelled network nodes. It must be remembered that the classification problem is different from the traditional tasks of classifying machine learning. In such tasks, classification objects are considered independent. The study proposes to introduce additional functions based on adjacency or proximity in the graph. Analysing the results of the study, the authors state the problem of modern literature in this subject area. Often, the proposed methods are not scaled in terms of computing huge amounts of data.

The authors of [9] consider methods of analysing social networks from the point of view of graph visualization and comparison of user vertex graphs. As a result of this work the method based on the construction of cluster count offered. A method has a row of fundamental structural limitations. Additionally, a method was proposed for calculating similarity estimates between the vertices of two graphs by expanding the previously presented methods.

Existent methods and algorithms of SNA must be rethought. They must be processed as it applies to run-time development of social networks. The same opinion is shared by the authors of [10], who presented a theoretical overview of the methods, techniques, and visualization features of dynamic social networks. There are various methods of network analysis depending on network scale. In service methods, it is desirable to

support the results of a data mining process. Classification and clustering are examples of similar methods. In analytical methods desirably directly in number to estimate changes happening in a base network model for a certain temporal interval.

Research of the method of k-Path centrality underlay work of authors [11]. This method is considered one of the most effective in the area. The authors note that "centrality measurement is used to measure the ability of a node to transmit information". From the point of view of disseminating information in a social network, the shortest path between two nodes is not always the way of disseminating information between them. The collision can be solved by applying the k-Path method of centrality with the addition of its random algorithm. "The algorithm would look for all possible combinations of information transfer (not just the shortest paths)". The experiment conducted by authors was sent to the search of the most grade influential users in a social network Twitter. The results showed that the ranking indicator is key in solving the research problem. The ranking indicator is worked out by an experimental path. In addition, the position of the user as the link of the group has a serious impact on the final rank of the user.

The authors of article [12] consider the application of methods of SNA to determine interpersonal relationships and identify network communities. This work presents theoretical descriptions of various network metrics and community search algorithms. The article also presents the results of a study using Clauset & Newman and Blondel et al. algorithms. Arbitrary datasets from the social networks Facebook and Twitter acted as a data source. The problem of identifying user cliques arises when identifying users behaving similarly in different subgroups. Defining appropriate indicators or functions to carry out the selection procedure is essential to solve this problem.

Research of procedure of clusterization of attributive graphs found the reflection in-process authors [13]. According to the authors, "graph clustering and community detection have traditionally focused on graphs without attributes". This approach is an obvious drawback of this kind of research. This article presents a qualitative literature review of studies on the solution of the problem. It is proposed to use an algorithm to expand the graph model and obtain additional information. The algorithm supports various kinds of edges between nodes (users). For example, such relations may be friendly relations and relations with colleagues. The authors indicate that the task of finding a quasi-clique in a graph is NP-hard. Accordingly, no algorithm can solve this problem within a reasonable time, even with small amounts of data. The researchers presented the hypothesis, the clusters may occur when a specific combination of graphs and disappear when the model added new graphs.

A research of such topics can also be found in the authors' work [14], in which the authors presented a joint model for using information. The model uses both structural and semantic information to search for related groups of nodes and subsequent layout for cluster graphs. The authors note that "the layout algorithm divides the nodes into two types. One type for nodes with edges connecting other communities. Another type for edges connecting nodes within a particular community". The results of the algorithm are constructed cluster graphs. They contain the structure of the original graph and the configuration of the partition, i.e. the relations between the clusters. The advantage of this approach is the simplification of visualization of the graph of a social network

by focusing on the connections between groups. The experimental results showed an improved detection result compared to traditional structural clustering.

The authors' work [15] is also devoted to solving the problem of community detection in a network structure. The goal of the work is to develop a detailed procedure for solving this problem. In opinion of authors, the most acceptable definition of proximity between users is based on the topology of the network edges. In this case, community detection may be to establish the difference between density of bonds in different parts of the network. They believe that the research community needs a new approach to systematize the body of knowledge in solving the problem of community detection. The approach should not be an arbitrary search for any communities, but the search for communities that would be of particular interest to us. The authors believe that the key problem is the lack of certainty and some duplication in the definition of the concept of community. This drawback leads to confusion among different researchers in solving various problems. The authors propose using the multidimensional function of the network community to solve this problem.

The authors of [16] proposed their own algorithms designed to detect communities. Their algorithms interact with both structural and attributed information. Their methods break a graph with attributes into communities so that homogeneous nodes are tightly connected in one community. The research concept is devoted to studying the relationship between the semantic similarity of users and the topology of social networks (homophile concept). Data is extracted using six different methods. As a result of the experiment, a more balanced distribution of the sizes of the detected communities was obtained. The author's methods are parameterized, as a result of which a strategy for determining the approximation weight coefficient is proposed for the work.

The authors of the research [17] adhere to the same point of view. The results of their study demonstrated the existing difference between structural communities and metadata groups. The authors "compare the structure of communities discovered by various popular discovery algorithms over a collection of network datasets". The following algorithms were used in the work: Louvain, Infomap, InfomapSingle, LinkCommunities, CliquePerc, Conclude, COPRA, Demon, Ganxis, GreedyCliqueExp. Algorithms were applied to undirected and unweighted versions of datasets. This approach allowed us to increase the range of use of various methods, since not all of them are able to process the directions and weights of the edges.

In [18], the authors presented the CESNA algorithm (Communities from Edge Structure and Node Attributes). "CESNA is an accurate and scalable algorithm for detecting community overlap in attributed network nodes". He has a list of objective advantages. This method developed the existing approaches to the analysis of social networks. The authors assure that their algorithm achieves a 47% improvement in community detection accuracy compared to other algorithms. The algorithm is based on a probabilistic model combining user membership in a community, network topology and node attributes. Community detection accuracy is enhanced by adding site attributes to the model. This approach also provides clues for interpreting detected communities.

The authors' work [19] attracted attention "from the point of view of the data source selection format for conducting the study". As a data source has been selected collection of articles on static modelling and, directly, the analysis of social articles. Books and

voluminous dissertations were deliberately avoided because of the sheer volume of references they encountered. According to the authors, the disadvantage of the proposed method that the situation where some relevant articles may be skipped because they were not cited in other sources.

The authors of [20] proposed a rough cluster approach that identifies similar users with high speed. Then it creates the structure of a joint user model that can significantly reduce computational time costs without loss of accuracy. The obvious advantage of this model is its scalability, and, consequently, the ability to interact with large-scale social networks.

The authors of [21] devoted their work to the topic of data clustering, as a result of which they presented "a hybrid clustering algorithm based on GSA and DPC algorithms (GSA-DPC)". The choice of these algorithms is due to the desire to use their ability to measure distance and the nearest neighbour method. The authors prove the effectiveness of the presented algorithm by comparing it with four related clustering algorithms.

Authors of the article [22] proposed a Gaussian pigeon-oriented graph clustering algorithm for social networks cluster. After building the graph model, the K-medoid algorithm is launched to determine the central user in the subgroups. The Gaussian pigeon algorithm searches for similarities between the central user in a group and each user in this group. To solve the problem of sparse data, the developed mechanism functions by combining them using Pearson similarity and various social interactions. At the clustering stage, to improve accuracy, the algorithm searches for the user with the maximum similarity with respect to the previously discovered central user.

As previously stated, one of the problems in the SNA is the lack of a single, rigorous terminology base. The authors of the article [23] attempted to solve this problem, "which developed a solid repertoire of basic concepts and analytical measures, which takes into account the general structure of multidimensional networks". Modern networks are multidimensional, so it is necessary to distinguish between different types of interactions between users. The stated and described metrics (proposed by the authors as the main characteristics) were experimentally calculated based on the created random network. The quality of their work merits authors identify that "measures also appear to be able to capture real, non random, phenomena, and allow for interesting result interpretation".

According to the authors of [24], "a promising approach to graph clustering is based on the intuitive concept of intracluster density with respect to intercluster sparsity". The authors proposed their own approach and combined proven methods of graph partitioning and geometric clustering. Several formalizations have already been proposed to separate sparse subgraphs from each other. The results of an experimental research confirmed the presence of various shortcomings in all four selected algorithms for clusterization. For example, the Markov Clustering Algorithm (MCL) revealed such objective shortcomings as generating clusters of inappropriate size and excessive time costs. Realizing the need to improve the performance of existing algorithms, the authors propose using the GMC algorithm as a basis. It has a clear additional potential, taking into account its flexibility in relation to the principles of geometric clustering and objective function.

A fundamental contribution to solving the problem of detecting communities in graphs was made by [25]. This article is a thorough analysis of the thematic area of the basic definitions and the formulation of the main problems. With a subsequent description

of most of the developed methods and their comparative analysis. The problem of graph clustering, intuitive at first sight, is actually not well defined. There is a huge amount of research in modern literature, in each of which researchers differently interpret the tasks facing them and their results. According to the author, this is due to the imperfection of the terminological base of the basic definitions. Area of research clustering graphs formed quite chaotic, without a common handle-duction or indications. Each researcher has his own opinion about what can be considered a community in social networks, so there are still certain disagreements in the research environment. As a result, it remains impossible to unambiguously determine which of the many already developed algorithms works better than others. Clustering algorithms should be developed in accordance with generally accepted definitions.

A common drawback of the studied authors' works is the fact that the algorithms and procedures for clustering that they proposed are developed exclusively for narrowly specialized tasks. In our work, we attempted to propose a procedure that allows multifactorial clustering for a wide range of possible tasks.

Thus, the conclusion of the analysis of publications can be recognized that most authors recognize the need to create scalable and effective methods for analysing social networks. The methods should be adapted to the dynamics of the development of networks in terms of constantly increasing volumes of information. Standard methods from graph theory can not be applied due to the high degrees of clustering and power correlations of social networks. In modern social networks, there are various correlations, which are an interesting subject to study during various research.

2 Description of the Hybrid Clustering Algorithm

First of all, let us define the concept of "social graph" and formulate a formal statement of the clustering problem.

A social graph is a graph whose nodes are user accounts on a social network, and the edges are the connections between these users.

The cluster analysis of the graph model (as well as the cluster analysis as a whole), as a rule, has a list of objective difficulties:

1. There is no unambiguously objective criterion for the quality of clustering. But there are many algorithms that can implement a "reasonable" clustering and provide different results.
2. The number of clusters before the start of the study is an unknown parameter and is set subjectively by an expert.
3. One of the key values in clustering is the choice of metric, which is also set by an expert in a subjective way.

Thus, one of the tasks in the development of cluster analysis can be considered the development of such a clustering procedure that could qualitatively adapt the huge variety of existing metrics and clustering algorithms. This approach would maximize the quality assessment of cluster analysis.

A significant effect on the result of clustering is played by the parameter of the number of clusters. Therefore, clustering algorithms, as a rule, are based on some sorting of the

possible range of the number of clusters and determining some optimal value of this parameter.

There are many ways to improve the results of the quality of clustering for solving one or another highly specialized problem. As a rule, researchers focus on choosing the subjectively most appropriate metric, on the basis of which the cluster analysis procedure is subsequently carried out. In this paper, we tried to focus on the possibility of a significant improvement in the results of clustering. This can be achieved by using the totality of existing centrality metrics at various stages of averaging calculations. We proposed our own algorithm for clusterization, which includes several different methods of averaging values.

The need to average the results of several metrics is explained by the desire to obtain a more representative picture than when using a single metric. Most work in the field of graph clustering involves either the initial use of a single one or the choice of a metric based on an empirical study based on a range of metrics previously selected by an expert.

2.1 Calculation of Network Analysis Metrics

One of the first steps of any research is the pre-processing and description of the source data. In the case of clustering of social graphs, we consider it necessary to calculate the following basic metrics of network analysis:

1. Connected Users Share – the proportion of users within the social graph having at least one connection with other graph users.
2. Connected Components – the number of related components in the graph. A related component is a subset of graph nodes in which for any pair of nodes there is a path connecting them.
3. Density – the ratio of existing graph relationships to all possible for a graph with an equal number of vertices.
4. Density Without Isolates – graph density only among related users.
5. Modularity – modularity value, showing how pronounced the cluster structure is in the graph and how easily the graph can be divided into subgroups of vertices.
6. Mean Geodesics – average geodesic distance (average shortest path between any pair of nodes).
7. Diameter – maximum geodesic distance in a graph.
8. Max Degree – maximum degree of centrality of a vertex in a graph.
9. Mean Degree – average value of the degree of centrality for the vertices of the graph.

Calculation of the above metrics allows not only to evaluate the cluster structure of the initial graph, but also to compare the clustering results with respect to the original dataset.

2.2 Centrality Metric Selection

The proposed approach to clustering graph models of a social network is based on the concept of the simultaneous use of several graph metrics.

The following is one of the possible sets of metrics used in this study. We offer it as one of the possible clusters of this research.

1. Closeness Centrality (average distance from node v_i to neighboring nodes)

$$\sum\nolimits_j d_{i,j}/k, \tag{1}$$

d - distance matrix between graph vertices, k - the number of vertices associated with v_i.

2. Betweenness Centrality

$$\sum\nolimits_{N_s \neq V_i} \sum\nolimits_{N_i \neq V_i} \frac{1}{2} \frac{\sigma_{v_s v_t}(v_i)}{\sigma_{v_s v_t}}, \tag{2}$$

$\sigma_{v_s v_t}$ – the number of shortest paths between v_s и v_t, $\sigma_{v_s v_t}(v_i)$ – the number of shortest paths passing through v_i. Normalized by dividing by the maximum possible value.

3. Eigen Centrality

$$X_\upsilon = \frac{1}{\lambda} \sum\nolimits_{t \in M(\upsilon)} x(t) = \frac{1}{\lambda} \sum\nolimits_{t \in G} a_{\upsilon,t} x_t, \tag{3}$$

$M(\upsilon)$ – number of neighbours υ, a λ - const.

We opted for centrality metrics, because they have the advantage not only of reflecting the potential activity of an object in a social graph, but also as an assessment of the ability to control the transmission of information.

2.3 Hybrid Multi-factor Clustering Algorithm

Let us consider a hybrid method of multifactor clustering based on normalization and averaging of the results of calculating various metrics.

The First Method (Sequential Averaging). The first option of averaging the results involves sequential averaging based on the results of calculating a specific metric. After averaging the results of the first metric, the next step is to calculate the weights of the nodes using the following metric. Metrics are determined by the researcher for this study with their subsequent averaging, etc. The number of metrics used is not limited, but we recommend correlating their number with computing resources.

The Second Method (Total Averaging). The second option for averaging the results involves the final averaging at the end of the calculations of all metrics selected by the expert for this analysis.

The Third Method (Adapting the Algorithm to Work with Multi-factor Weights). The third option involves the refinement of the clustering algorithm selected by the expert for this study in order to enable it to work with multi-factor weights.

It is worth noting that directly the procedure of averaging the results can also be performed in various ways. This can be a method by calculating a typical value of the arithmetic mean or a method by normalizing the value of the vertex weight and then calculating the root mean square value.

Below is the proposed hybrid data clustering algorithm with averaging metric calculation values by calculating the root mean square value:

1. Building a list of vertex weights using the consistent application of centrality metrics of a connected social graph.
2. Normalization of the maximum value of the vertex weight from the resulting list by dividing the weight value of each vertex by the maximum weight.
3. Calculation of the root-mean-square value of the vertex weight of the graph from the list of normalized vertex weights obtained in the previous step.
4. Converting a list of vertices by sorting the original list by increasing the weights of the vertices.
5. Clustering the final list into fixed-size clusters.

The assessment of the quality of clustering of a social graph may consist in the analysis of the intersection of clustered graphs obtained by the previously proposed methods. The criterion for assessing the quality of detection of communities is determined based on the density of connections within the community compared with the relations between communities.

Modification of the Louvain Algorithm. This subsection describes the principle of operation of the Louvain algorithm, adapted for solving multidimensional problems.

Part of the algorithm efficiency results from the fact that the gain in modularity ΔQ obtained by moving an isolated node i, into a community C can easily be computed by [26]:

$$\Delta Q = \left[\frac{\sum_{in} + k_{i,in}}{2m} - \left(\frac{\sum_{tot} + k_i}{2m}\right)^2\right] - \left[\frac{\sum in}{2m} - \left(\frac{\sum tot}{2m}\right)^2 - \left(\frac{k_i}{2m}\right)^2\right], \quad (4)$$

where "$\sum_{in}$ – is the sum of the weights of the links inside C, $\sum_{tot}$ – is the sum of the weights of the links incident to nodes in C, k_i is the sum of the weights of the links incident to node i, $k_{i,in}$ is the sum of the weights of the links from i to nodes in C and m is the sum of the weights of all the links in the network" [26].

The principle of operation of the Louvain algorithm can be formulated as "greedy optimization of modularity values". The operation of the algorithm consists of several stages. At the first stage, a search is made for small communities by optimizing modularity at the local level. Secondly, community nodes aggregate, thus forming a larger network. These stages are repeated until the maximum value of the degree of modularity is obtained [26].

The result of the Louvain algorithm depends on the order of sorting the vertices at the first stage of execution. The modified algorithm allows, at the first stage, to determine the order of sorting, depending on the averaged multifactor weights.

At the first stage of execution, the modified Louvain algorithm suggests starting the graph clustering not from a random vertex, but from a vertex with the maximum degree of centrality. This node for increasing the quality assessment can also be determined by using various degrees of centrality with subsequent normalization and averaging of values.

3 Algorithm Approbation

The programming language R was chosen as the software tool used in this study. It specializes in statistical data processing and graphics. The iGraph software package (Csardi, Nepusz 2006) was also used in the R environment. The CINNA package was used to calculate centrality metrics.

The initial graph consists of vertices and edges, which correspond to users and connections that are members of the ITMO.EXPERT ITMO online community of the social network VKontakte. Data collection was carried out using the vkR software package of environment R. The number of nodes is 180 and the number of edges is 687.

Table 1 shows the results of calculating metrics network analysis of the original graph.

Table 1. Results of calculating metrics network analysis the initial graph.

Metric	Metric value
Connected users share	0.603
Connected components	2
Density	0.026
Density without isolates	0.073
Modularity	0.0029
Mean geodesics	3.276
Diameter	8
Max degree	66
Mean degree	9.957

The next stage of the study included the calculation of centrality metrics. Table 2 presents the averaged results of the metric centrality values (the values are averaged by calculating the arithmetic mean).

Table 2. Averaged results of calculating metrics centrality.

Metric	Metric value
Closeness centrality	0.121
Betweenness centrality	0.296
Eigen centrality	0.874

In Fig. 1, the only connected component is distinguished, including a pair of vertices.

Figure 2 shows a graph of the online community clustered by the Louvain algorithm (the number of clusters is 10, modularity 0.47).

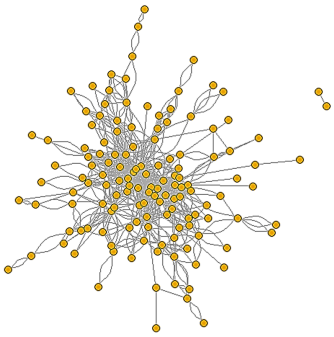

Fig. 1. Non-clustered social graph online community.

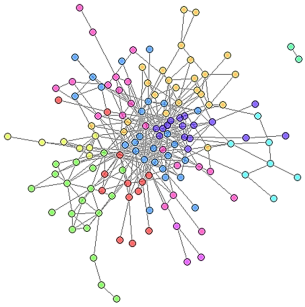

Fig. 2. Clustered algorithm Louvain social graph online community.

Figure 3 shows a graph of an online community clustered by a hybrid algorithm (the number of clusters is 8, modularity 0.48).

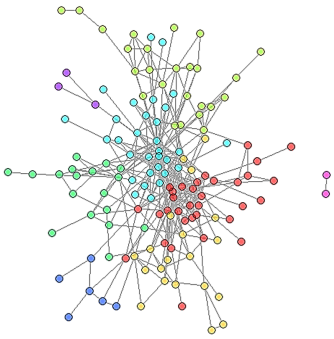

Fig. 3. Clustered hybrid algorithm social graph online community.

Thus, the hybrid multivariate clustering algorithm showed a slight increase in modularity with a reduced number of clusters.

4 Conclusion

All existing cluster analysis algorithms are classified as NP-hard. Therefore, solving the clustering problem using such algorithms involves enumerating all possible combinations of objects that require grouping. Clustering algorithms require significant computing resources. With a large number of objects, the clustering problem becomes difficult to solve.

It is also impossible to unambiguously determine the clustering algorithm that will work best with source datasets. Under these conditions of the existence of many algorithms, we consider it of paramount importance not to develop the next clustering algorithm, which objectively has its advantages and disadvantages. The most important task is the adaptation of existing algorithms in order to maximize assessment of the quality of clustering.

In this work, several methods were proposed for averaging the results of clustering: sequential averaging and total averaging. It also describes the application of the hybrid data clustering algorithm and provides an example of practical implementation in comparison with the use of the standard Louvain algorithm.

The results of the work can be applied as a methodological basis for conducting cluster analysis of social networks in order to increase assessment of the quality of clustering of existing algorithms.

The principle of hybrid multi-factor clustering can be used to adapt other existing algorithms.

References

1. Himelboim, I., Smith, M., Rainie, L., Shneiderman, B., Espina, C.: Classifying twitter topic-networks using social network analysis. J. Soc. Media + Soc. **3**, 1–13 (2017). https://doi.org/10.1177/2056305117691545
2. Reihaneh, K., Takaffoli, M., Zaïane, O.: Analyzing participation of students in online courses using social network analysis techniques. In: 4th International Conference on Educational Data Mining, Netherlands, pp. 21–30. EDM Press (2011)
3. Cha, Y., Cho, J.: Social-network analysis using topic models. In: Proceedings of the 35th International ACM SIGIR Conference on Research and Development in Information Retrieval, New York, pp. 565–574. Association for Computing Machinery (2012)
4. Lei, T., Huan, L.: Graph mining applications to social network analysis. In: Aggarwal, C.C., Wang, H. (eds.) Managing and Mining Graph Data, pp. 487–513. Springer, Boston (2010). https://doi.org/10.1007/978-1-4419-6045-0_16
5. Oliveira, M., Gama, J.: An overview of social network analysis. WIREs Data Mining Knowl. Discov. **2**, 99–115 (2012)
6. Wang, T., et al.: Understanding graph sampling algorithms for social network analysis. In: 31st International Conference on Distributed Computing Systems Workshops, Minneapolis, pp. 123–128. IEEE Press (2011)
7. Chen, Y., Hu, J., Zhao, H., Xiao, Y., Hui, P.: Measurement and analysis of the swarm social network with tens of millions of nodes. IEEE Access **6**, 4547–4559 (2018)
8. Bhagat, S., Cormode, G., Muthukrishnan, S.: Node classification in social networks. In: Aggarwal, C. (ed.) Social Network Data Analytics, pp. 115–148. Springer, Boston (2011). https://doi.org/10.1007/978-1-4419-8462-3_5

9. Truong, Q.D., Truong, Q.B., Dkaki, T.: Graph methods for social network analysis. In: Vinh, P.C., Barolli, L. (eds.) ICTCC 2016. LNICSSITE, vol. 168, pp. 276–286. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-46909-6_25
10. Cordeiro, M., Sarmento, R., Brazdil, P., Gama J.: Evolving networks and social network analysis methods and techniques. In: Višňovský, J., Radošinská, J. (eds.) Social Media and Journalism - Trends, Connections, Implications, London, pp. 101–134. IntechOpen (2018)
11. Taniarza, N., Adiwijaya, Maharani, W.: Social network analysis using k-Path centrality method. J. Phys.: Conf. Ser. **971**, 1–9 (2018). https://doi.org/10.1088/1742-6596/971/1/012015
12. Niewiadomska-Szynkiewicz, E.: Application of social network analysis to the investigation of interpersonal connections. J. Telecommun. Inf. Technol. **2**, 81–89 (2012)
13. Bothorel, C., Cruz, J., Magnani, M., Micenkova, B.: Clustering attributed graphs: models, measures and methods. Netw. Sci. **3**, 408–444 (2015)
14. Cruz, J., Bothorel, C., Poulet, F.: Community detection and visualization in social networks: integrating structural and semantic information. ACM Trans. Intell. Syst. Technol. **5**, 11:1–11:26 (2014)
15. Coscia, M., Giannotti, F., Pedreschi, D.: A classification for community discovery methods in complex networks. Stat. Anal. Data Mining **4**, 512–546 (2011). https://doi.org/10.1002/sam.10133
16. Dang, A., Viennet, E.: Community detection based on structural and attribute similarities. In: 6th International Conference on Digital Society, Valencia, pp. 7–14. IARIA XPS Press (2012)
17. Hric, D., Darst, R., Fortunato, S.: Community detection in networks: structural clusters versus ground truth. Phys. Rev. E **90**, 062805 (2014). https://doi.org/10.1103/PhysRevE.90.062805
18. Yang, J., McAuley, J., Leskovec, J.: Community detection in networks with node attributes. In: 13th IEEE International Conference on Data Mining, Dallas, pp. 1151–1156. IEEE Press (2013)
19. A Social Network Analysis of Articles on Social Network Analysis. https://arxiv.org/pdf/1810.09781.pdf/. Accessed 10 Jan 2020
20. Zhao, Y., Cai, S., Tang, M., Shang, M.: Coarse cluster enhancing collaborative recommendation for social network systems. Physica A: Stat. Mech. Appl. **483**, 209–218 (2017)
21. Sun, L., Tao, T., Chen, F., Luo, Y.: An optimized clustering method with improved cluster center for social network based on gravitational search algorithm. In: Chen, F., Luo, Y. (eds.) Industrial IoT 2017. LNICST, vol. 202, pp. 61–71. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-60753-5_7
22. Sun, Y., Yin, S., Li, H., Teng, L., Karim, S.: GPOGC: gaussian pigeon-oriented graph clustering algorithm for social networks cluster. IEEE Access **7**, 99254–99262 (2019)
23. Berlingerio, M., Coscia, M., Giannotti, F., Monreale, A., Pedreschi, D.: Foundations of multi-dimensional network analysis. In: International Conference on Advances in Social Networks Analysis and Mining, New York, pp. 485–489. IEEE Press (2011)
24. Brandes, U., Gaertler, M., Wagner, D.: Engineering graph clustering: models and experimental evaluation. J. Exp. Algorithmics **12**, 1–26 (2008)
25. Fortunato, S.: Community detection in graphs. Phys. Rep. **486**, 75–174 (2010)
26. Blondel, V., Guillaume, J., Lambiotte, R., Lefebvre, E.: Fast unfolding of communities in large networks. J. Stat. Mech.: Theory Exp. (2008)

Non-discrete Sentiment Dataset Annotation: Case Study for Lövheim Cube Emotional Model

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Abstract. The research project we are conducting is devoted to text emotional analysis. In this paper, we report the preliminary results of the non-discrete data assessment method, which uses an original interface developed to annotate texts according to emotion model known as Lövheim Cube. Swedish neurophysiologist H. Lövheim put eight basic emotions in the cube vertices according to the particular combination of three monoamines triggers each of them. We took four supporting diagonals of the cube and mapped them onto assessment scales: Distress/Enjoyment, Rage/Disgust, Shame/Excitement, Fear/Surprise. 172 human assessors were asked to adjust the pointer of a slider between two opposite emotions on the scales after having been read each of 48 text fragments retrieved from Russian social network VKontakte. By converting labeled scalars into spatial coordinates in the cube space, we obtained a set of comparable evaluations. The effectiveness of the approach has been validated using the Intra-class correlation metric. The proposed method offers noticeable benefits when compared to the discrete assessment procedure, giving to each text a multidimensional evaluation, which is closer to the natural text perception while reading.

Keywords: Emotion · Emotion analysis · Lövheim Cube · Non-discrete emotion assessment

1 Introduction

The article discusses the results of applying a new procedure of the text emotion assessment procedure which is specially designed for annotating the data set of Internet texts in Russian.

The striking growth of social media platforms explains the increasing researchers' interest to emotional and sentiment analysis of Internet texts. The conducted study seeks to elaborate a classifier able to perform a multiclass emotion analysis of texts. The emotion analysis engine is expected to assign an emotional evaluation to each text passing onto it. To choose a list of basic emotions we used a typology proposed by Silvan Tomkins [1] and justified on the neurophysiological level by Swedish scientist Hugo Lövheim [2].

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For achieving our research goal our first objective was to collect a dataset – a collection of texts expressing different emotions used to learn the model in order to perform the classification of unseen data. To obtain such a training sample we need a group of respondents to assess the emotion of each text suspected to be included in the sample. Though the procedure of emotion annotation has already become a routine research practice, in the frame of our research it turns out to be a problem.

Since we do not deal with the dichotomy positive/negative attitude proper to text polarity classification, but with eight emotional classes of texts, the traditional procedure of manual annotating texts with few discrete classes executed by respondents did not meet our research purpose. Our major difficulties were the following:

1) emotion is not homogenous; it rather represents a graduate scale and should be assessed as such;
2) the ensemble of emotions forms a sort of continuum where most of them are deeply meshed – what is felt by the assessor after the text reading may be the mix of two or three emotional states, while one of them being more or less intensive. For instance, while reading a text a human assessor could feel a strong disgust and some fear expressed in it.

In other words, a new project task required a new way to assess emotions in text – a non-discrete way. Thus, in the present paper we propose to discuss the results obtained while using a new, non-discrete, assessment interface in the framework of text emotional analysis and to describe its challenges.

The rest of the paper is structured as follows: Sect. 2 gives an overview of previous works on the field of sentiment analysis and sentiment assessment; Sect. 3 contains the description of proposed procedure of non-discrete sentiment dataset annotation backed by Lövheim Cube model of emotions; the obtained results and their validation through different statistically based methods are given in Sect. 4, 5, and Sect. 6 summarizes the difficulties we have met and our suggestions for the further work.

2 Related Works

There are many research papers for sentiment analysis problem. Most of them focus on the polarity detection task [3–5]. As the analysis of literature has shown, the discrete annotation dominates such research practices. In the frame of texts polarity evaluation, the assessors are usually asked to specify sentiment using four-point scale: positive, negative, neutral and both [6]. To make the annotation more sensible to the degree of negative/positive attitude expression, researchers propose to the annotators to put the score 1, 3, 5 to each retrieved attitudinal content [7]. The first attempts to deal with the polarity continuum we find in image sentiment analysis presented in [8] where, while labeling the image according to the emotion it represents, each image emotion coloring was rated on 0–10 scale: 0 means ‘very negative’ and 10 – ‘very positive’. When applying a score scale for assessment, the researchers use the vector of scores representing each emotion to label the evaluation object – text, sentence or image.

The same tendency to prefer the discrete annotation we observe in works dealing with the multiclass emotion evaluation. For example, in [9] the annotators were invited

to put the evaluated instances in one of the six categories: anger, disgust, fear, joy, sadness and surprise. The researchers refused a vector of score method for labeling and considered only sentences on which two annotators or more completely agreed on the emotion category.

Another research group faced the problem we did – how to differentiate the emotions if they are more than one to be present in the text. The annotators were working in pairs on the same textual subcorpus and, even before performing the annotation task, they had been trained separately and then while annotating they worked independently. As the researchers note [10:581] "after having marked the sentence level with one of eight primary emotions, which were targets, the annotators also marked the text for other affective contents, i.e. background mood, and secondary emotions via intensity, feeler, and textual cues". Finally, the first annotator was charged to resolve the disagreements between different estimations and to choose one of the competing labels [10].

The overview enlightens the gap existing in current researches in the emotional analysis domain, the gap that we expect to bridge. The evidence is that the text emotional analysis within a multiclass classification framework demands a more complex assessment process than in a polarity task. There is a number of works modifying the procedure in the way to make it more sensitive to the emotion graduality, there are researches, which pay more attention to the complex and meshed character of emotional content searching to detect primary and secondary emotion in it. We propose an approach synthetizing both.

To summarize, we agree with C.O. Alm, D. Roth and R. Sproat that the emotion assessment task has a very subjective nature, but we should seek to find tools and techniques to catch and to formalize it despite its elusiveness. The detailed description of our attempt to address the problem is proposed in the next sections.

3 Lövheim Cube as a Model Used for Non-discrete Emotions Assessment

The model name is due to the geometric figure of the cube used by Swedish neurobiologist Hugo Lövheim to visualize his conception of emotion activators. He postulated that the different levels of the three monoamines – dopamine, noradrenaline and serotonin – cause the emotional states lived by humans. Furthermore, he represented the correlations existing between emotions and monoamines by orthogonal monoamines axes whose assemblage form a cube. In eight vertices of the cube, he placed eight emotions (Fig. 1).

Thus, on the first, vertical, axis, depending on the level of noradrenaline, he puts the emotions of Shame/Humiliation, Fear/Terror, Enjoyment/Joy, Contempt/Disgust (each emotion is doubly named because its former nomination indicates the weakest degree of its manifestation, while the latter – the strongest) on the bottom (minimal level of the noradrenaline) and the emotion of Distress/Anguish, Anger/Rage, Interest/Excitement and Surprise (or Startle) – on the axis top. According to the level of serotonin, the same emotions were placed differently on another "left to right" axis: Shame/Humiliation, Fear/Terror, Distress/Anguish, Anger/Rage – at the beginning because of the minimal monoamine's level, and Contempt/Disgust, Enjoyment/Joy, Surprise and Interest/Excitement by the end of the axis. Finally, the third "front to

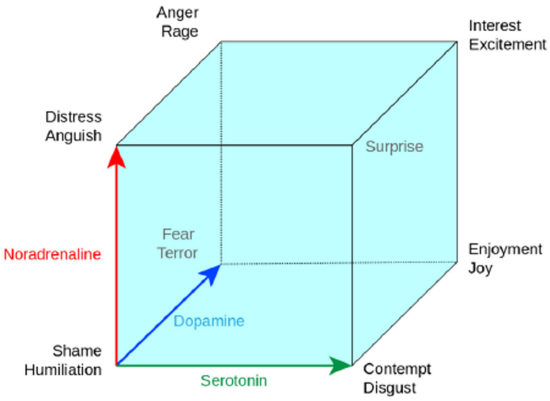

Fig. 1. Lövheim Cube model.

back" axis showing the level of the dopamine starts from the low-dopaminergic emotions of Shame/Humiliation, Distress/Anguish, Contempt/Disgust, Surprise and goes to the high-dopaminergic emotions of Fear/Terror, Anger/Rage, Enjoyment/Joy and Interest/Excitement.

Localized in this way, the emotions form four oppositions, which correspond with the supporting diagonals inside the cube (see Fig. 2):

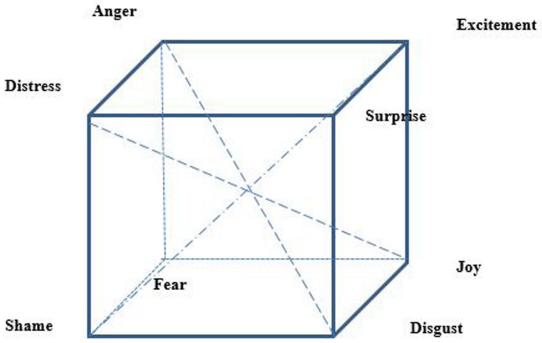

Fig. 2. Supporting diagonals of Lövheim Cube.

1) Distress – Enjoyment ("−" serotonin; "+" noradrenaline; "−" dopamine/"+" serotonin; "−" noradrenaline; "+" dopamine);
2) Rage – Disgust ("−" serotonin; "+" noradrenaline; "+" dopamine/"+" serotonin; "−" noradrenaline; "−" dopamine);
3) Shame – Excitement ("−" serotonin; "−" noradrenaline; "−" dopamine/"+" serotonin; "+" noradrenaline; "+" dopamine);
4) Fear – Surprise ("−" serotonin; "−" noradrenaline; "+" dopamine/"+" serotonin; "+" noradrenaline; "−" dopamine).

Thus, such dichotomies allow us to conceptualize paired emotions as antipodes: fear, for example, is a negative form of surprise; rage is aggressive antonym of disgust, etc.

As the terms of "opposite" or "antonym" more familiar for assessors, than "monoamines", we decided to elaborate a slider giving to the assessors the opportunity to scale the emotional expression differentiating, for example, "very aggressive" text from "moderately aggressive" one [11] or to point out other emotions they feel mixed with the primary one.

The design of slider for the non-discrete assessment is shown on the Fig. 3. The ends of the scale mean the strongest expression of the named emotions; the middle point correlates with zero emotion assessment – the less emotion the assessor feels, the nearer to the scale middle he puts the slider.

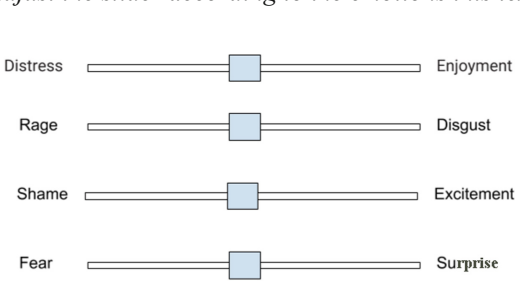

Fig. 3. Slider for the non-discrete assessment.

The main advantages of the above mentioned assessment tool design are: 1) the assessor can point not only the primary emotion, but also to indicate a secondary one if, for example, the text sample is mostly about fear sentiment, but an assessor wants to mention slight impact of rage; 2) it allows us to treat each opposition as $(-1, 1)$ period and to map a slide-bar position to a vector which angle coincides with corresponding diagonal and the magnitude of this vectors that is equal to the value chosen for given emotional oppositions; 3) the assessors are enabled to measure the degree of expression of an emotion by putting the slider relative to the middle point.

4 Selection of Test Samples for Annotation

The model was applied to a real emotion assessment procedure. The large dataset was extracted from a public group of Russian social network VKontakte known under the hashtag Overheard. 15000 text fragments of 80–100 words were retrieved according to the semantics of hashtags they were put under. Thus, we have mapped a range of hashtags and 8 correlating emotions from Lövheim model: #Overhead_ stydno – emotion of shame, #Overhead_ fu – emotion of disgust, #Overhead_ strashno – emotion of fear, etc. Then 5000 tests from this preselection were chosen by the first group of 34 assessors as the best exemplars of height emotions according to Lövheim's Cube.

The second group of annotators included 172 persons, 34 males and 138 females, aged from 15 to 48, the average age of the assessors was 22.06 years. All of them indicated in the online questionnaire that they were native Russian speakers. From 5000 text fragments belonging to 8 emotional classes we built up a little corpus of 48 texts – 6 from each emotional class in our large dataset. We proposed this subcorpus to the informants to mark up the emotions. The rationale for choosing a small corpus is that this survey is a pilot one, and we wanted to estimate the degree of agreement between annotators and the whole validity of this approach on a small number of texts.

The assessment was executed online via a web platform designed for this experimental task. We invited the pool of annotators by publishing an announcement in social networks. Each of them was, firstly, asked to fill in the questionnaire containing questions about age and sex of the informant. After, they passed to the evaluation procedure: the text, preceded by the instruction and followed by the slider (as shown on the Fig. 4) appears on the screen. When the task is completed, the respondent goes to the next text assessment by pressing the button “Continue”.

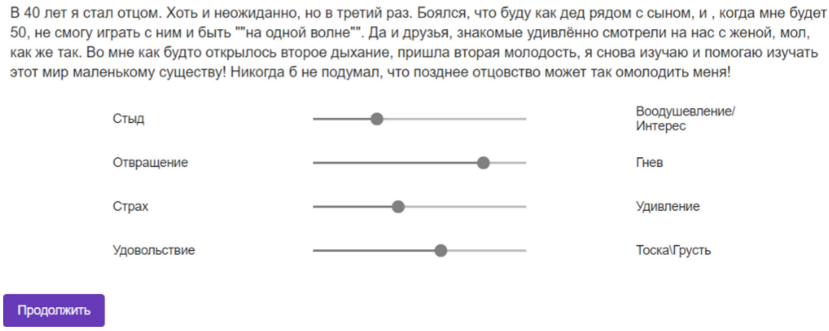

Fig. 4. Assessment interface in form of web-application.

5 Mapping Diagonal Positions Values into Cube’s Coordinates

In Sect. 3 we suggested an approach for collecting users’ data, but in order to get the resulting emotion point in Cube’s space we need a transformation and pooling strategy, as collected data are scalars, but the needed data we can process is of spatial 3-d nature. Thus, the general task is to convert labeled scalars into spatial coordinates.

Raw values taken from survey are scalars from -5 to 5. We define 0-position as neutral position and it corresponds with a center of Cube. This scalar value is a magnitude of a vector. The label matching a scalar corresponds with a diagonal and is translated into angle.

To define a translation into 3-d space we posed the following assumptions about ‘axes-to-monoamine’ correspondence: x axis is for serotonin, y axis is for noradrenaline and z – for dopamine. We have four diagonals that connect opposing vertices of the Cube with respected raw labels names.

The label consists of two parts separated by underscore ("_" symbol). The first component of diagonal denotes the "bottom" vertex and the second the "top" vertex. If a scalar in raw value is less than 0, it means that the vector is approaching the "bottom" vertex, if the value is more than 0 – the vector is approaching the top vertex. To get the coordinate of a given diagonal vector we need to multiply the slider value to the direction unit vector. Here are mapping unit vectors for estimated diagonals (x, y, z format):

'shame_excitement': (1, 1, 1) – all coordinates (monoamine values) are increasing in that direction;
'disgust_rage': (−1, 1, 1) – dopamine and noradrenaline are growing, serotonin is decreasing;
'fear_surprise': (1, 1, −1) – dopamine is decreasing, noradrenaline and serotonin are increasing;
'enjoyment_distress': (−1, 1, −1) – only noradrenaline is increasing, others are decreasing.

This mapping can be applied for vectors going towards upper vertices. To apply transformation for "bottom" vertices we need to invert it, i.e. to multiply by −1, which is already done in raw estimation. To convert the diagonal values to vector we multiply the value by mapping and add 5 to shift the beginning of axis to the center of cube. In order to aggregate the estimations from all four paragraphs we do averaging the vectors from all 4 diagonals.

Here is a pseudo-code for procedure of converting raw scalars and their respected values into cube coordinates:

```
for estimation in estimations_list
  # Co-ords are kept in format (x, y, z) where x - ser, y - nor, z- dop
    mapped_directions_vecs = {
       'shame_excitement': [1,1,1],
       'disgust_rage': [-1,1,1],
       'fear_surprise': [1,1,-1],
       'enjoyment_distress': [-1,1,-1]
    }

    result_vec = [0,0,0]

    # keys are the same as in mapping.
    for key in estimation.keys():
      # Shift starting point from center to cube's 0 and calc point.
      diag_vec = (mapped_directions_vecs[key] * survey_values[key]) + 5
      result_vec = result_vec + diag_vec

    return result_vec / 4
```

We also do rescaling of the coordinates in an interval of from 0 to 1. After rescaling the center of the cube has coordinates of (0.5, 0.5, 0.5). The detailed code and dataset are available at [12, 13].

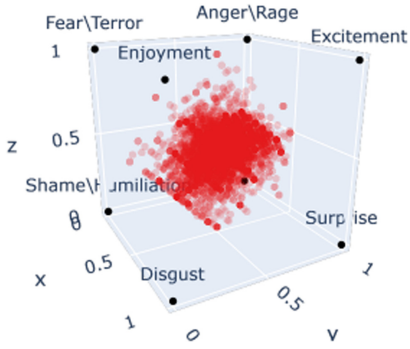

Fig. 5. Visualization of translated and pooled text annotations.

In the Fig. 5 a visualization of transformations applied to raw estimations of text is demonstrated. As it is shown, the estimation forms some kind of irregular sphere being dense near the center of the cube. It must be explained by the fact that extreme emotion evaluations are quite seldom and the magnitude of emotions in estimated texts is normally distributed.

5.1 Validation of the Approach with Intra-class Correlation for Continuous Values

To estimate the validity of the approach described above we used Intra-class correlation metric proposed in [14]. This metric allows to see how continuous values from different subjects correspond with each other. The range is defined in period from 0 to 1, where 0 means no correlation at all – all subjects give different results – to 1 when all subjects give the same estimations for the same item or the same period of time.

The number of subjects is equal to the number of participants. The number of estimated units is equal to 48 (6 text for each of 8 emotions). The Intra-class correlation is being calculated along those 48 estimations for all participants who annotated these texts. Thus, the value for the metric for current dataset appears to be 0.6325, which can be interpreted in the following way: the annotators values generally agree for the most part of data.

5.2 Accuracy Test with Discretized Values

Initially, before the continuous annotation with sliders, all text samples were collected by experts to represent certain emotions from our inventory of eight cube emotions. Hence each text has some kind of "golden" label. We want to estimate how continuous non-discrete annotation agree with discrete labeling. To make the resulting continuous vector a discrete value we used searching for the nearest cube vertex and defined this nearest vertex label as a label derived from coordinates.

The resulting accuracy appeared to be 34% which is quite a moderate result considering we have 8 discrete classes. The confusion matrix for "golden" label and the label derived from resulting vector coordinates is presented in the Fig. 6.

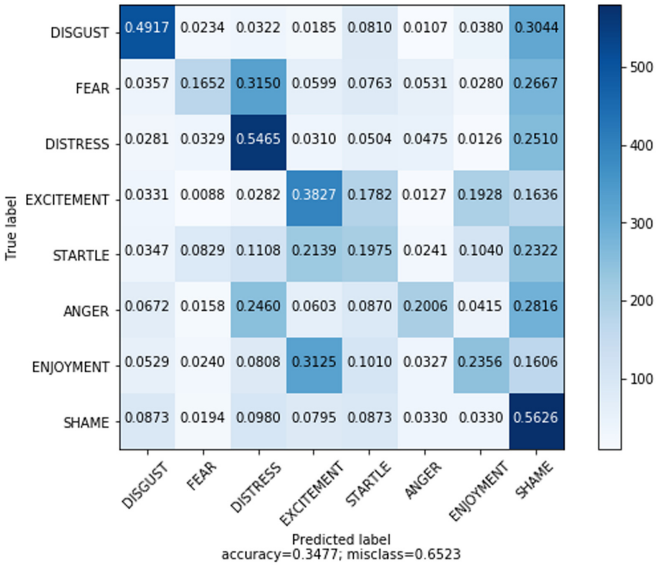

Fig. 6. Confusion matrix of the "true" label and predicted label.

As it can be seen Disgust, Distress, Excitement and Shame are very distinguishable with such an approach, however others are not so probable. Anger is mistaken with Distress and Shame, while Enjoyment and Excitement are mutually mistaken.

The shift towards Shame can be described by the absence of a neutral class (where coordinates are (0.5, 0.5, 0.5)), that is the reason all neutral cases were taken to the closest Shame vertex.

Another cause of rather moderate accuracy of annotation results could be the faulty combination of the chosen length of texts proposed to assessors (each text was of 4–5 sentences) and of the particular assessment scales design. Texts were quite voluminous and rich in heterogeneous emotions, even "opposite" ones. However, our scales, having been metaphorically transferred from the neuroscience field to emotion analysis domain, allow the assessors to mark up only one of the emotions considered on the neural level as opposite (e.g. Anger – Disgust) because they involve incompatible combinations of hormones. In other words, despite our main intention to make the annotation procedure more natural and ecological, in some way, our assessors were forced to choose between the opposites we have formed. We suppose that if the assessors were asked to evaluate not the whole text but each sentence of it, even using the same scales, the accuracy would be higher.

Finally, it is worth saying that the confusion of emotion assessment given by experts and our annotators could be due to the discrepancies in the personal level of empathy in the majorities of two groups. We didn't measure the level of personal empathy in group of experts, but before to proceed to the annotation all our assessors answered a questionnaire intended to assess their empathetic tendency score. Later, while analyzing the results we found some correlation between the level of empathy of an assessor and his text evaluation.

6 Conclusion and Further Steps

As shown in the present paper, such new approach allows more granular estimation of text sentiment with wider range of emotional inventory. Major assessors' agreement and a small deviation among assessors' opinion upon certain texts show that such approach is valid and promises to be efficient if applied in further work.

However, a certain number of problems has been also identified: 1) strategies for pooling diagonal vectors to resulting vector should be revised and the information can be lost during simple averaging; 2) discretizing continuous vector estimations can be misleading since small change in continuous scale can change the discrete label of the text; 3) in current survey annotators used one estimation for the whole text sample, but there may be spans with different emotions within different sentences of the text, so the procedure may be adjusted to capture this phenomenon as well; 4) one main drawback is the size of the text samples in the survey – current dataset was done with only 48 samples of distinct texts, though we are going to scale this number to several thousand using crowdsourcing method.

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References

1. Tomkins, S.S.: Affect theory. In: Ekman, P. (ed.) Emotions in the Human Face, pp. 353–395. Cambridge University Press, Cambridge (1982)
2. Lövheim, H.: A new three-dimensional model for emotions and monoamine neurotransmitters. Med. Hypotheses **78**, 341–348 (2012). https://doi.org/10.1016/j.mehy.2011.11.016
3. Nakov, P., Ritter, A., Rosenthal, S., Sebastiani, F., Stoyanov, V.: SemEval-2016 task 4: sentiment analysis in twitter. In: Bethard, S., Carpuat, M., Cer, D., Jurgens, D., Nakov, P., Zesch, T. (eds.) Proceeding of the 10th International Workshop on Semantic Evaluation (SemEval–2016), San Diego, pp. 1–18. Association for Computational Linguistics (2016). https://doi.org/10.18653/v1/S16-1001
4. Yang, G., He, H., Chen, Q.: Emotion-semantic-enhanced neural network. IEEE/ACM Trans. Audio Speech Lang. Process. **27**(3), 531–543 (2019). https://doi.org/10.1109/TASLP.2018.2885775
5. Yousefpour, A., Ibraim, R., Abdel Hamed, H.N.: Ordinal-based and frequency-based integration of feature selection methods for sentiment analysis. Expert Syst. Appl. **75**, 80–93 (2017). https://doi.org/10.1016/j.eswa.2017.01.009
6. Blinov, P.D., Kotelnikov, E.V.: Semantic similarity for aspect-based sentiment analysis. Russian Digit. Libr. J. **18**(3–4), 120–137 (2015)
7. Chetviorkin, I.I., Loukachevitch, N.V.: Sentiment analysis track at ROMIP-2012. Computational Linguistics and Intellectual Technologies, vol. 2, pp. 40–50 (2013)
8. Rakovsky, A., Moskvichev, A., Filchenkov, A.: Data augmentation method for the image sentiment analysis. In: Proceeding of the AINL FRUCT 2016 Conference, Saint Petersburg, pp. 106–109. IEEE (2016)
9. Chaffar, S., Inkpen, D.: Using a heterogeneous dataset for emotion analysis in text. In: Butz, C., Lingras, P. (eds.) AI 2011. LNCS (LNAI), vol. 6657, pp. 62–67. Springer, Heidelberg (2011). https://doi.org/10.1007/978-3-642-21043-3_8

10. Alm, C.O., Rot, D., Sproat, R.: Emotions from text: machine learning for text-based emotion prediction. In: Raymond, J. (ed.) Proceedings of Human Language Technology Conference and Conference on Empirical Methods in Natural Language Processing, Vancouver, pp. 579–586. Association for Computational Linguistics (2005)
11. Kalinin, A., Kolmogorova, A., Nikolaeva, G., Malikova, A.: Mapping texts to multidimensional emotional space: challenges for dataset acquisition in sentiment analysis. In: Alexandrov, D.A., Boukhanovsky, A.V., Chugunov, A.V., Kabanov, Y., Koltsova, O. (eds.) DTGS 2018. CCIS, vol. 859, pp. 361–367. Springer, Cham (2018). https://doi.org/10.1007/978-3-030-02846-6_29
12. Kalinin, A., Kolmogorova, A., Malikova, A.: A Sentiment Analysis with Lövheim Cube of Emotion. GitHub Repository (2020). https://github.com/AlexDel/levheimcube
13. Kalinin, A., Kolmogorova, A., Malikova, A.: Non-Discrete Sentiment Annotation for Lövheim Cube. Google Colab Notebook (2020). https://colab.research.google.com/drive/15_0q1ff7_2fuldHoC1qzh4U7av16qM1V
14. Bland, J.M., Altman, D.G.: Measurement error and correlation coefficients. Br. Med. J. **313**(7048), 41–24 (1996). https://doi.org/10.1136/bmj.313.7048.41

Mass Media Evaluation Using Topic Modelling

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Abstract. Automatic evaluation of public opinion is an actual problem in many areas, including both governmental and private sectors. There is number of scientific schools and corporations which work on to solve the problem of automatic evaluation of publications in media, social networks and other internet resources, in order to solve such problems as evaluating public image of a company, product or persona, evaluating work of PR departments and agencies, analyzing the most socially significant and resonant newsmakers and issues. The problems involve area of natural language processing and understanding, which is considered to be technologically and mathematically complex, and is nowadays being solved using deep learning models, which require a large marked dataset with texts of similar domain, which is hard and expensive to obtain. Another problem of such systems is performance issues. In this work an informational system is described, which attempts to solve the outlined problems. In the paper an approach is proposed, which allows to classify the most important/positive/negative/resonant topics and publications, and to analyze their dynamic characteristics. The proposed approach is not based on manual creation of keyword dictionary, or labelling of big amounts of documents and allows to evaluate documents according to arbitrary criterion. The approach was verified on one criterion by comparing it's results to a dictionary-based system.

Keywords: Media evaluation · Topic modelling · Sentiment analysis · Natural language processing · Information system

1 Introduction

Evaluation of contents of mass media is a focus for many researchers and developers due to its practical applicability for news agencies, PR departments and governmental structures. For example, predicting popularity and resonance of news articles and planning of PR-strategy for promoting certain products and services can be performed based on content analysis [1, 2]. Governmental organization apply such tools for promoting and explanation of their work and innovations, classifying critique and overall sentiment of

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the publications about certain topic, and attempting to distinguish fake news and illegal content.

When audience does not possess reliable knowledge and experience in relation to some topic or event, they are especially dependent on information from mass media [3]. In order to form public opinion or to focus audience's attention on certain topics or events, mass media may use various manipulative mechanisms [4, 5]. Hence, it is necessary to classify which news sources use their influence in order to be able to mitigate negative effects, while attempting to produce positive (desirable) effect no public opinion [6].

Existing media analysis products primarily solve problem of reputation management. We need systems that could perform a comparative analysis of the media, evaluate the thematic characteristics of news materials, evaluate the dynamics of topics in the media, etc. In this paper, we describe a system that solves the above problems on the basis of topic models of corpora of news documents.

The work consists of the following sections:

- Section 2 briefly describes existing media monitoring tools
- Section 3 describes the method underlying the developed system
- Section 4 describes system architecture
- Section 5 describes the results

In conclusion, we describe the possible applications of the system and the challenges of future research.

2 Current Solutions in Field of Mass Media Monitoring

There are a significant number of products that monitor the media and social media, some of which are listed in Table 1 [7–9].

Media monitoring tools are an important part of reputation management. The most frequently implemented functions: brand mentions (with or without direct tagging), relevant hashtags (branded and unbranded), mentions of competitors, general trends applicable to some industry.

The main question that can be answered with the help of such tools: "Do you know what they say about your company or brand in the media?"

However, these tools do not solve the issues of evaluating the media themselves. As a rule, they are limited in query semantics. At the same time, a tool is needed that would allow us to ask more diverse questions and perform a comparative analysis of the media.

The main goal of such tool is to provide experts, researchers, managers and supervisors with a comprehensive and powerful set of analytical tools to obtain up-to-date relevant reports, visualizations and evaluations of public mass media publication in certain given area of interest.

The method we proposed is based on topic modeling, which reduces the cost of labeling up the corpus of documents. At the same time, the method shows results comparable to more labor-intensive approaches based on supervised learning.

Table 1. Some examples of media monitoring tools.

System	Social media (remarks)	Links
Awario	Twitter, Facebook, Instagram, Google+, YouTube, Reddit, news/blogs, the web	awario.com
Google Alerts	Web, news, blogs, videos, and discussions	google.com/alerts
Keyhole	Twitter, Instagram, YouTube, Facebook, news, and blogs	keyhole.co
Agorapulse	Facebook, Twitter, Instagram, and YouTube	agorapulse.com
TweetDeck	Twitter. (The app is 100% free)	tweetdeck.twitter.com
Sprout Social	Twitter, Instagram, Reddit, YouTube, Tumblr, the web	
System	Social media (remarks)	Links
Social Mention	Twitter, Facebook, YouTube, Reddit, Google+, etc. (The platform is free)	socialmention.com
Hootsuite	Twitter	hootsuite.com
Crimson Hexagon, Brandwatch	Facebook, Twitter, Instagram, YouTube, Google+, Pinterest, Sina Weibo, VK, QQ, news and blogs, the web	brandwatch.com
SentiOne	Facebook, Instagram, Twitter, LinkedIn, VK, and others	sentione.com
Signal AI	Real-time unlimited information and insights for media monitoring, reputation management and market intelligence	signal-ai.com
Talkwalker	Flickr, Foursquare, SoundCloud, Twitch, Pinterest, and others	https://www.talkwalker.com/

3 Method. Document Evaluation Model Based on Topic Modeling

3.1 Media Analytic Tools

Modern methods of data mining allow processing of large corpora of text documents in order to identify both certain properties of individual documents included in the corpus, as well as patterns characterizing their combination. Since these algorithms involve extracting a wide range of diverse characteristics from texts, which is often a complex task in itself, the solution of which involves the use of complex and by no means always high-speed algorithms, it becomes necessary to store the extracted characteristics (along

with the documents themselves) in high-performance distributed databases and storages. In this case, the information model of the document repository and their characteristics will largely depend on the type of text corpus being studied and the nature of the tasks to be solved, for example, news processing systems to identify destructive information [10] significantly differ from scientific information processing systems [11] and, moreover, literary texts, both prosaic and poetic [12].

Currently, in the field of software systems development, text processing is an actively developing industry of information technology. A review of works in this area is available, for example, in [13–16]. Note that in the last decade, the main direction of the development of algorithms for processing text document bodies is the use of machine learning methods (see, for example, [17–19]). In the general case, for automatic text analysis, the following approaches can be distinguished [20]:

1. Based on rules using patterns - uses tools such as Part-of-Speech-taggers and parsers.
2. Supervised machine learning. The training sample is manually marked up by experts or dataset engineers. Then, the marked-up corpus of texts is used to train various classifiers.
3. Unsupervised machine learning. The main difference from supervised machine learning is the lack of manual markup for model training. Unsupervised learning approach presumes using hidden patterns, hidden latent distribution and structures in order to extract information from big volumes of unlabeled data.
4. The hybrid approach can combine machine learning methods, and use rule templates.
5. Pre-trained models based on deep neural networks (transfer learning), when a pre-trained model is fine tuned to solve specific problems, for example BERT [21], which achieved state-of-the art results in multiple NLP tasks.

The proposed model uses hybrid approach, but instead of using complex deep-learning models pretrained on a large corpus in order to train it to distinguish important features, it uses topic modelling for extracting these hidden latent structures, which are used as model features. The main advantages of the proposed model are:

- Minimal amount of necessary manual labelling (due to topic-level labelling, instead of document-level labelling)
- It allows to use very simple, trivial models for obtaining object classification, while presenting results, comparable to more complex models

3.2 Topic Modelling

Topic modeling is a family of algorithms and models which allow to automatically find coherent topics in an unstructured set of textual data. Fundamentally, topic modelling solves the problem of clustering, simultaneously combining words of the corpus into clusters/topics (φ_{wt} matrix) and combining texts of the corpus into clusters/topics (θ_{tm} matrix). Essentially topic modeling is an approach to solving clustering problems on textual corpora, which allows simple and comprehensive interpretation of the model results in the form of weighted list of words which constitutes the topic [22].

The cluster approach allows to process millions of documents without the use of time-consuming and lengthy expert labelling.

The following approaches can be used to build a topic model of the document corpora: Probable latent-semantic analysis (PLSA), ARTM (Additive regularization of topic models) [23] and, very popular, latent Dirichlet placement (LDA) [24, 25]. LDA can be expressed by the following equality:

$$p(w, m) = \sum_{t \in T} p(w|t, m)p(t|m) = \sum_{t \in T} p(w|t)p(t|m) = \sum_{t \in T} \varphi_{wt}\theta_{tm} \quad (1)$$

which is a sum of mixed conditional distributions across all topics of T, where $p(w|t)$ is a conditional distribution of words in topics, and $p(t|m)$ is a conditional distribution of topics by documents (news). Transition from $p(w|t, m)$ to $p(w|t)$ is performed using hypothesis of conditional independence, according to which appearance of words w in document m on topic t is dependent on topic, but not on document m, and is common for all news. This relation is just, due to assumption of independence from words order in documents (news), order of documents in the corpus, and moreover LDA method assumes that components φ_{wt} and θ_{tm} are generated by continuous multidimensional Dirichlet probability distribution. The goal of the LDA algorithm is to optimize φ_{wt} and θ_{tm} to maximize likelihood function according to regularization:

$$\sum_{m \in M} \sum_{w \in m} n_{mw} ln \sum_{t \in T} \varphi_{wt}\theta_{tm} + R(\varphi, \theta) \rightarrow \max \quad (2)$$

n_{mw} – number of appearances of word w in document m, $R(\varphi, \theta)$ – logarithmic regularizer.

In this system an extension of LDA model called BigARTM is used. BigARTM is a topic model, built on top of LDA with addition of a pool of different configurable regularizes, which allow to flexibly tune the desired output of the model. Let us consider some of the regularizers implemented in the system [26]:

- Smooth sparse phi regularizer – penalizes number of elements in each row of phi matrix proportional to parameter tau.
- Smooth theta regularizes – acts in a similar manner to previous one, but on theta matrix. High value of tau leads to binary strict membership of each news to a small number of topics.
- Decorrelator phi regularizer – penalizes inclusion of the same word to several topics, i.e. decorrelates phi matrix.

In total, 13 different regularizers are implemented in BigARTM, and it is a separate optimization problem to tune them in a way that maximizes defined quality metric.

3.3 Evaluation Model

The main feature of the system is the document evaluation model, which attempts to use hidden latent information of the given corpus in order to minimize the necessary amount

of manual expert labelling and allow usage of simple trained or untrained models to aggregate the expert labelling into evaluation of each document in the corpora according to any arbitrary evaluation criterion, such as sentiment, innovation, social significance for different social layers, etc. Hence, the main contribution of the developed model is decreasing the volume of manual expert labelling and increasing evaluation performance in order to provide high-performance algorithm for evaluation of big amount of textual data, including streaming and real-time access with moderate computing powers.

The process of analyzing media text is summarized as follows [26]:

- Compilation of a list of parameters that determine how high is the value of the given criterion;
- Evaluation of the comparative significance of the parameters;
- Calculation of the parameter estimates for each text;
- Aggregation of the parameter estimates and their comparative significance to obtain a decision on the class the text can be assigned to;
- Evaluation of the media based on the classifications of the texts obtained.

The process is implemented in the form of algorithm of multimodal evaluation, the main idea of multi-criterion evaluation and aggregation of objective and subjective indicators is adopted from [27].

To implement the described process, we defined the text parameters and their weighted significance for the task of evaluating the documents and developed an algorithm for calculating parameter estimates based on the topic model of the text corpora.

Application of topic model generated through cluster analysis (unsupervised learning) in conjunction with classes and attributes defined by experts is note-worthy about the proposed approach. This way, the semantics of the distribution is determined by the user (expert), and the initial topic modeling depends on the corpora of documents.

Application of the Bayesian approach allows assessing the probability of a hypothesis based on incomplete information with a part of the text corpora. In other words, it allows obtaining evaluation estimates for a media for the mentioned modalities by processing only a part of the text corpora, albeit with reduced accuracy.

According to this process, document weighted parameters and their relation to each text is calculated, and the last step of the process is evaluation aggregation, which can be performed using several different approaches:

1. Simple weighted average – this approach was used to obtain results described in the next section.
2. Bayesian approach – this approach considers subjective probability of a document to correspond to the given criterion. Its advantages were described in [27, 28].
3. Semi-supervised approach. It is possible to pre-train supervised model on results obtained by approaches a, b or some other unsupervised approach, and then to use document labelling in order to fine-tune the model, thus improving its performance.

The results presented in this article are obtained using the first approach (simple weighted average). The other approaches are planned for further development and

research, and are expected to provide quality gain, since they allow more refined analysis of the provided features.

4 System Architecture

4.1 Overview

The information system that solves the problem of automatic media evaluation has to be developed with a number of technical requirements considered, which include:

- Modularity
- Horizontally scalability
- Ability to perform idempotent data transformations
- Real-time visualization, filtering and full-text searching

In order to meet the requirements, a three-layer system architecture was proposed (Fig. 1):

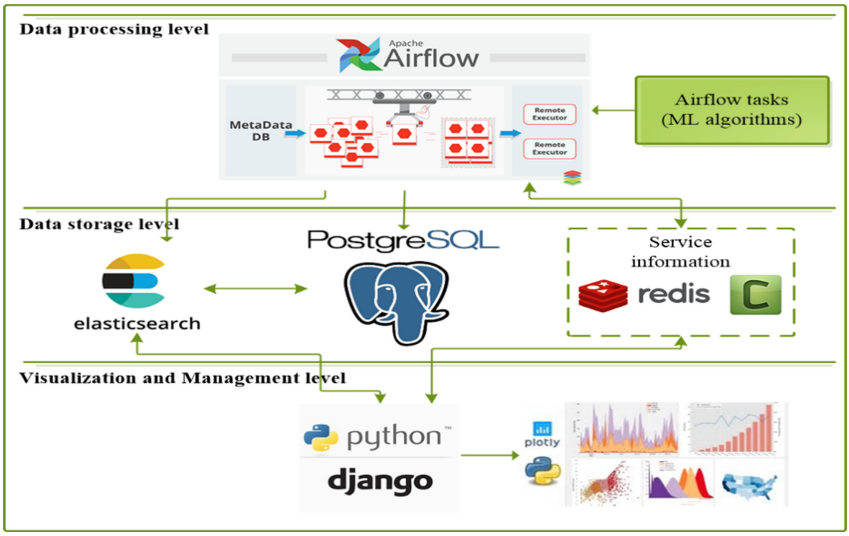

Fig. 1. Three-layer architecture of the system.

1. Data processing layer (ETL – Extract-> Transform-> Load)
2. Storage layer
3. Visualization and management layer

Each layer is described in detail in further sections.

The system is deployed using Docker-containers, since they support modularity and relatively simple horizontal scalability. Currently in production it is deployed using

Docker stack, however it is planned to migrate the system to Kubernetes cluster, since it would allow to automatically load balance between different nodes and auto scale, i.e. dynamically adjust number of each type of containers.

Conceptually the system is a Big Data analytical tool, which allows to perform a number of data transformation tasks, including stream processing, save the results in distributed storage and then provide access to analytical queries and visualization through web interface.

The data is obtained in the process of scraping publicly available news web sites using open source Python library Scrapy, which supports parallel robust web scraping. On the top of Scrapy a tool for parsing HTML documents was developed, which allows to obtain structured documents representation with meta information, based on a number of rules, described by CSS selectors and/or regular expressions. The parsed documents are first stored in PostgreSQL persistent storage, and then sent to Elastic Search, followed by ETL (Airflow) transformation, up to the point when the new results are ready to be visualized and queried.

The architecture is described in more details in [29].

5 Experiments and Obtained Results

5.1 Results and Visualization Overview

The system provides a web-interface for different roles of users – administrators, experts (users who perform labelling of data), developers and simple viewers. Web interface layout is implemented using HTML + CSS, mainly based on Boot-strap 4 CSS framework. Visualization is done using Plotly.js visualization library.

Figure 2 illustrates the interface of the system – menu on the left allows navigation through three main modules of the system:

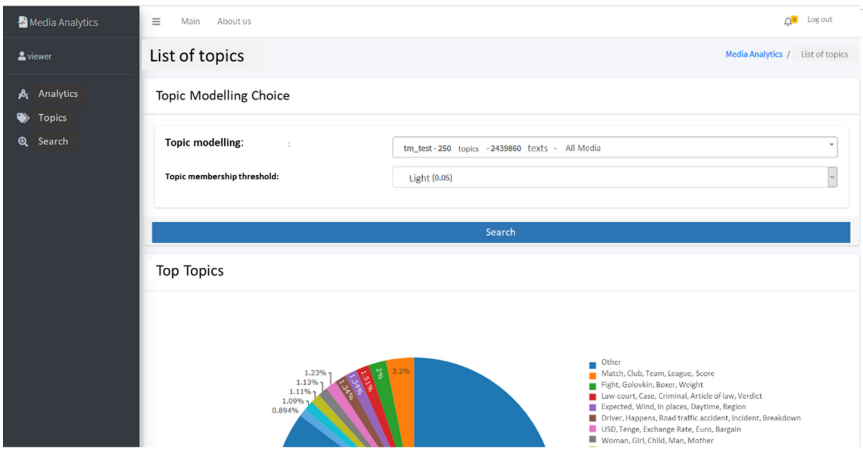

Fig. 2. Web interface of the system.

- Search
- Topics
- Analytics

Search module allows to perform full-text search, including fuzzy search, as well as simple filtering by date, author, source, title, etc. The module provides dynamic representation of the dynamics of queried documents in several forms (absolute, relative) and a list of most relevant documents. Document list can also provide document evaluations for certain defined criterion, for example sentiment as shown in Fig. 3. The module provides information that can be used for different types of sociological, polyetiological and other types of humanitarian research, as both source of insights and source of numerical data to support promoted claims. However, it provides very simple basic filtration, without taking any hidden latent structures into account.

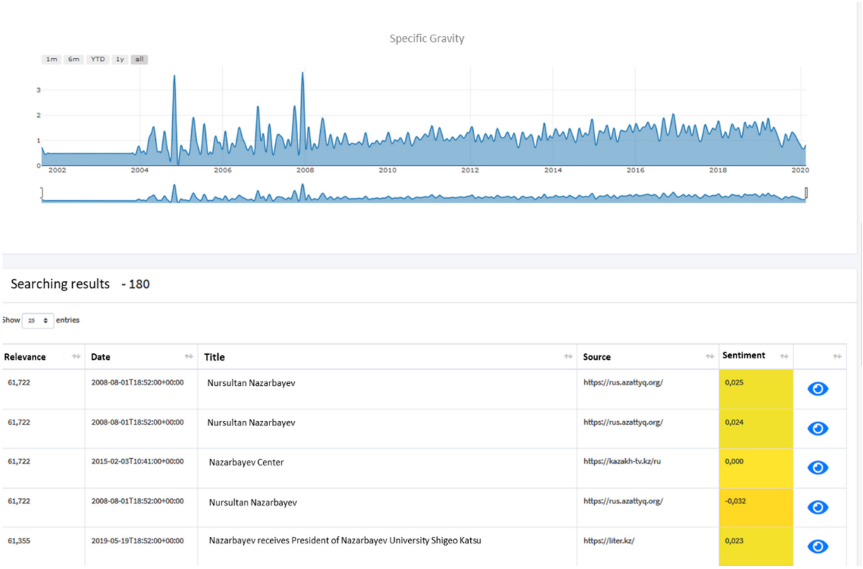

Fig. 3. Search results page

The next interface module is Topics – it provides access to different topic models, allows searching, sorting and filtering of topics, representing their volume, weight and weighted keywords. The topics can be filtered and queried one by one or in groups, which allows to perform a higher-level analysis based on hidden latent structures in the corpus. As an example, it can provide researcher with insights by presenting topics which in fact exist in corpora, but were not initially in scope of researcher's assessment. For example, if researcher is concerned with analysis of reputation of education system of Kazakhstan, he might not be aware of certain public event, which is directly connected to the topic of the research, but doesn't come up in simple keyword query, and that expert is not initially aware of.

The most detailed view on the results of the work of the system is provided by Analytics interface. Its main goal is to provide visualization for results of evaluation of documents in relation to different arbitrary criteria described using model described in the Sect. 3.2 of the paper. It has a number of visualizers and reports which allow in depth analysis by whole topic models, topics and topic groups, keywords, sources, etc.:

- Overall criteria distribution histogram.
- Criteria dynamics plots – overall and positive/negative separately (Fig. 4).

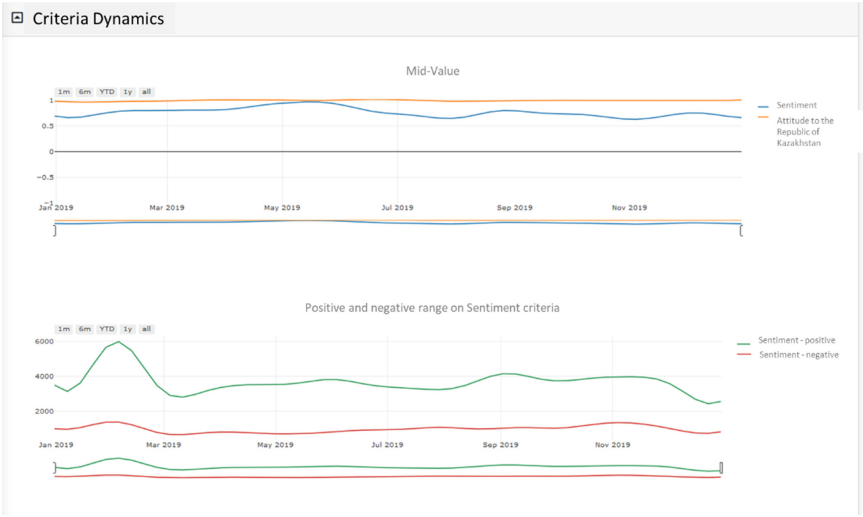

Fig. 4. Analytics page – criteria dynamics.

- Source (media) distribution – volume or positive/negative distribution according to given query.
- Crucial topics – topics with highest positive/negative impact on queried criteria.
- Crucial documents – list of documents with the biggest impact (negative of positive) on the queried criteria.
- Low-volume positive – list of topics which were assessed by experts to be positive, but have low volume for the given period of time.

Overall, the interface of the system attempts to provide analytical tools from many different perspectives, from simple keyword queries and dynamic analysis to in-depth topic-based criteria visualization with support of complex analytical queries. In the next section a quantitative approach to validating the system and the model is discussed.

5.2 Model Verification and Comparasement

In order to verify that the developed model and its implementation yield reasonable quality of results, both qualitative (described in the previous section) and quantitative

approaches are necessary. The developed model was compared on a random sample of about 42 thousand news from Kazakhstan web sited with a similar dictionary-based supervised model developed for the similar task of Kazakhstan news sentiment analysis. The model was developed by Information-Analytical Center of Ministry of Education and Science of the Republic of Kazakhstan with a very similar task statement [30]. There are two reasons why other available models were not used for the comparison:

- Models trained for the task of sentiment analysis of news articles are pretty uncommon – currently researcher are mostly concerned with sentiment analysis of short social media posts, reviews, comments, etc.
- In this case the problem statement differs from classical sentiment analysis – it is not required to assess author's attitude towards some objects or event, but to assess how positively or negatively the described event or object impacts overall human and social development of the country.

The same 42 thousand documents sample was evaluated by both algorithms in order to verify the developed model. They were compared on binary classification task (positive or negative), since the two models have significantly discrepant result value distribution (Table 2).

Table 2. Results of model validation using Scikit-learn scoring function.

Class	Precision	Recall	F1-score	Support
−1	0.49	0.61	0.54	8133
1	0.9	0.85	0.87	33924
Parameters				
Accuracy			0.8	42057
Macro avg	0.69	0.73	0.71	42057
Weighted avg	0.82	0.8	0.81	42057

The results were compared using classification scoring function provided by Sckit-Learn python library. As illustrated by Table 2, the accuracy metric for the comparison is 0.8, and f1 score varies from 0.54 for negative class to 0.87 for positive. The metrics seem to indicate, that the results of the two models are highly correlated, which is assumed to support the verification of the developed model and its implementation.

The quality of classification for negative sentiment is significantly lower, than for positive, and it can be observed that the recall of the model is much better than the precision. This is a limitation of the approach in general, since it by-design a tool for coarse, high-level analysis. Currently it is planned to improve the model by introduction new features, such a topics combination, and training more complex models, fine tuning them using a limited amount of per-document manual labelling.

6 Conclusion

In the work the developed system for mass media evaluation using topic modeling and original evaluation model is described. The system was developed based on principles of computation and storage distribution and modularity, in order to provide big data storage and processing and real-time complex analytical querying and visualization.

The main advantages of the developed hybrid evaluation method are significant reduction of necessary expert labeling and possibility to use simple and high-performance aggregation methods, including both machine-learning approaches, and unparametrized approaches, such as weighted average described in the work. The algorithm also allows to perform labeling and evaluation of corpus for arbitrary set of criteria, since the volume of manual labeling is low. Another factor to support arbitrary criterion evaluation is that labelling is performed on the high level of analysis, which allows to use hidden latent structures to describe high-order dependences inside the corpora.

Interface and results obtained by the system were described, and qualitative and quantitative verification was performed and analyzed.

The developed system could be applied for:

- Sociological and other humanitarian research. The system can be used to get high-level generalized reports on any given topics/event/object for analysis, as well as quantitative indicators to support their research.
- As a KPI-management system for PR-department. It may be hard to evaluate work of PR department in absence of quantitative indicators to support the conclusions, and the system can provide tools for KPI evaluation on several levels, including simple media coverage volume estimation, sentiment evaluation of the coverage, and in-depth thematical analysis is also possible.
- Extracting the most socially significant topics and trends for different demographical groups can be a powerful tool for local administrations and governmental agencies, since the system is able to extract hidden latent structures of the corpora in order to detect trends and events that could be left out of scope of the organizations.
- Regular reporting. The system can be used to regularly extract reports on up-to-date state according to some analytical query, in order to get both generalized analytics and visualization, and actual list of the most resonant published documents, or the most negative documents, etc.

The system and developed algorithms and models can also be applied to other types of textual corpora, such as scientific literature, document workflow of big corporations and governmental structures, comments and reviews, etc.

In future studies, we plan to implement the Bayesian approach to aggregating estimates of the parameters of documents and the media. We also plan to use semi-supervised methods for more accurate markup of documents.

References

1. Tatar, A., Antoniadis, P., De Amorim, M.D., Fdida, S.: Ranking news articles based on popularity prediction. In: 2012 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining, pp. 106–110. IEEE (2012)

2. Bandari, R., Asur, S., Huberman, B.A.: The pulse of news in social media Forecasting popularity. In: Sixth International AAAI Conference on Weblogs and Social Media (2012)
3. Miller, D.: Promotional strategies and media power. In: The Media: An Introduction, pp. 65–80 (1998)
4. Bushman, B.J., Whitaker, J.: Media influence on behavior. In: Encyclopedia of Human Behavior, vol. 2, pp. 571–575. Elsevier (2012)
5. Stacks, D., Li, Z.C., Spaulding, C.: Media effects. In: International Encyclopedia of the Social & Behavioral Sciences, vol. 2, pp. 29–34. Elsevier (2015)
6. Bushman, B.J., Whitaker, J.: Media influence on behavior. Reference Module in Neuroscience and Biobehavioral Psychology. Elsevier (2017)
7. Top of the best social media monitoring tools. https://www.socialmediatoday.com/news/20-of-the-best-social-media-monitoring-tools-to-consider/545036/. Accessed 19 May 2020
8. Media monitoring ultimate guide. https://www.agilitypr.com/media-monitoring-ultimate-guide/. Accessed 19 May 2020
9. Social media monitoring tools. https://blog.hootsuite.com/social-media-monitoring-tools. Accessed 19 May 2020
10. Barakhnin, V.B., Kuchin, Y.I., Mukhamediev, R.I.: On the problem of identification of fake news and of the algorithms for monitoring them. In: Proceedings of the III International Conference on Informatics and Applied Mathematics, pp. 113–118. The Institute of Information and Computational Technologies, Almaty, Kazakhstan (2018)
11. Shokin, Y.I., Fedotov, A.M., Barakhnin, V.B.: Tehnologija sozdanija programmnyh sistem informacionnogo obespechenija nauchnoj dejatel'nosti, rabotajushhih so slabostrukturirovannymi dokumentami. Comput. Technol. **15**(6), 111–125 (2010)
12. Barakhnin, V.B., Kozhemyakina, O.Y., Borzilova, Y.: Proektirovanie in-formacionnoj sistemy predstavlenija rezul'tatov kompleksnogo analiza pojeticheskih tekstov. Vestnik NSU **17**(1), 5–17 (2019). https://doi.org/10.25205/1818-7900-2019-17-1-5-17
13. Pang, B., Lee, L., Vaithyanathan, S.: Thumbs up? Sentiment classification using machine learning techniques. In: Proceedings of the ACL-02 Conference on Empirical Methods in Natural Language Processing, vol. 10, pp. 79–86. Association for Computational Linguistics (2002)
14. Choi, Y., Cardie, C., Riloff, E., Patwardhan, S.: Identifying sources of opinions with conditional random fields and extraction patterns. In: Proceedings of the Conference on Human Language Technology and Empirical Methods in Natural Language Processing, pp. 355–362. Association for Computational Linguistics (2005)
15. Manning, C.D.: Part-of-speech tagging from 97% to 100%: is it time for some linguistics? In: Gelbukh, A.F. (ed.) CICLing 2011. LNCS, vol. 6608, pp. 171–189. Springer, Heidelberg (2011). https://doi.org/10.1007/978-3-642-19400-9_14
16. Mukhamedyev, R.I., Kuchin, Y., Denis, K., Murzakhmetov, S., Symagulov, A., Yakunin, K.: Assessment of the dynamics of publication activity in the field of natural language processing and deep learning. In: Alexandrov, D.A., Boukhanovsky, A.V., Chugunov, A.V., Kabanov, Y., Koltsova, O., Musabirov, I. (eds.) DTGS 2019. CCIS, vol. 1038, pp. 744–753. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-37858-5_63
17. Tarasov, D.S.: Deep recurrent neural networks for multiple language aspect-based sentiment analysis. in: Proceedings of the International Conference "Dialogue-2015", Moscow, Russia, pp. 65–74. Computational Linguistics and Intellectual Technologies (2015)
18. Garcia-Moya, L., Anaya-Sánchez, H., Berlanga-Llavori, R.: Retrieving product features and opinions from customer reviews. IEEE Intell. Syst. **28**(3), 19–27 (2013)
19. Mavljutov, R.R., Ostapuk, N.A.: Using basic syntactic relations for sentiment analysis. In: Proceedings of the International Conference "Dialogue-2013", Bekasovo, Russia, pp. 101–110. Russian State University for the Humanities Press (2013)

20. Prabowo, R., Thelwall, M.: Sentiment analysis: a combined approach. J. Informetrics **3**(2), 143–157 (2009)
21. Devlin, J., Chang, M.W., Lee, K., Toutanova, K.: Bert: pre-training of deep bidirectional transformers for language understanding. arXiv preprint arXiv:1810.04805 (2018)
22. Uys, J.W., Du Preez, N.D., Uys, E.W.: Leveraging unstructured information using topic modelling. In: PICMET'08-2008 Portland International Conference on Management of Engineering and Technology, pp. 955–961. IEEE (2008)
23. Vorontsov, K., Frei, O., Apishev, M., Romov, P., Dudarenko, M.: BigARTM: open source library for regularized multimodal topic modeling of large collections. In: Khachay, M.Y., Konstantinova, N., Panchenko, A., Ignatov, D.I., Labunets, V.G. (eds.) AIST 2015. CCIS, vol. 542, pp. 370–381. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-26123-2_36
24. Blei, D.M., Ng, A.Y., Jordan, M.I.: Latent dirichlet allocation. J. Mach. Learn. Res. **3**, 993–1022 (2003)
25. Jelodar, H., et al.: Latent dirichlet allocation (LDA) and topic modeling: models, applications, a survey. Multimedia Tools Appl. **78**(11), 15169–15211 (2018)
26. Vorontsov, K., Frei, O., Apishev, M., Romov, P., Dudarenko, M.: BigARTM: open source library for regularized multimodal topic modeling of large collections. In: Khachay, M.Y., Konstantinova, N., Panchenko, A., Ignatov, D.I., Labunets, V.G. (eds.) AIST 2015. CCIS, vol. 542, pp. 370–381. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-26123-2_36
27. Barakhnin, V.B., et al.: Methods to identify the destructive information. J. Phys. **1405**(1), 012004 (2019)
28. Mukhamediev, R.I., Mustakayev, R., Yakunin, K., Kiseleva, S., Gopejenko, V.: Multi-criteria spatial decision making support system for renewable energy development in Kazakhstan. IEEE Access **7**, 122275–122288 (2019)
29. Barakhnin, V.B., Kozhemyakina, O.Y., Mukhamediev, R.I., Borzilova, Y.S., Yakunin, K.O.: The design of the structure of the software system for processing text document corpus. Bus. Informatics **13**(4), 60–72 (2019). https://doi.org/10.17323/1998-0663.2019.4.60.72
30. Nurumov, K., Baimakhanbetov, M., Buldybayev, T., Akoyeva, I., Ospanova, U.: An approach for detecting sentiments in mass media publications using content specific informative features. In: Proceedings of the scientific conference "Modern Problems of Informatics and Computing Technologies", Almaty, Kazakhstan, pp. 21–31. The Institute of Information and Computational Technologies (2019)

Problems of Designing Polylingual Ontology OntoMath^{Edu}

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Abstract. We present the polylingual problems encountered in the design of the educational ontology OntoMathEdu and describe the developed solutions. Some of these problems and their solutions became the basis for the development of new solutions in the design of the entire ontology. The content of mathematical education, approaches to the definition of a number of mathematical concepts both in general and at different levels of instruction are different. Therefore, there are differences between the sets of concepts of ontology as a whole and its educational projections for use in Russian-language, English-language, and Tatar-language learning environments. It is planned to use the OntoMathEdu ontology with projections for various language learning environments in teaching digital systems. In particular, for teaching mathematics in English to foreign students, helping Russian schoolchildren and students to learn English.

Keywords: Polylingual education · Mathematical terms · Educational ontology · OntoMathEdu · Plane geometry

1 Introduction

Modern educational platforms offer many different MOOC courses in school and university disciplines for different language audiences. At the same time, most of the courses are tied to one language of instruction, and translation into the student's language occurs automatically (literally) using a browser. For example, on the Russian version of the Khan Academy website, there is only one course in mathematics, and the terms have an unusual translation into Russian. The English version of the site contains several dozen courses for various levels of education. The mission of the developers is to provide free education around the world. However, it is important to understand that the terms of various scientific fields require special translation; the terms of education must correspond to the curricula and traditions of the countries. Therefore, the problem of correct translation is especially relevant for MOOC, SPOC courses to expand the audience. The time has come when it is necessary to create polylingual courses that will look adequate in different languages, the terminology in them will correspond to the language of the student.

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Nevertheless, the problem of the effectiveness of these resources remains urgent due to the lack of general didactic principles for their organization and application in the educational process at different stages of education. A modern electronic course requires the availability of intelligent databases based on subject ontologies, the introduction of recommendation systems that can build individual learning paths and offer additional educational information based on the educational levels of students.

For the first time, the educational mathematical ontology OntoMathEdu is created at the Kazan Federal University by the team of mathematicians, specialists in the field of ontologies and mathematical education in three languages: English, Russian and Tatar [1]. Ontology was designed on the basis of concepts used in Russian and English-language school textbooks of geometry, and OntoMathEdu is presented in three languages: Russian, English [2] and Tatar [3]. Textbooks in the Tatar language are translated from Russian. The Tatar language is the national language of the Republic of Tatarstan and is used in teaching schoolchildren. The choice of English is also due to the compulsory study of a foreign language in Russian schools. The projection of an ontology in English is capable of performing a double function: to teach mathematics foreign students in English and to help Russian schoolchildren and students in learning a foreign language, to deepen knowledge of the subject in accordance with the distinctive features of educational systems.

The feature of the created ontology is the requirements for its content. On the one hand, ontology projections in all three languages must interact with each other. On the other hand, each of them should be a complete product, thanks to which one can teach mathematics. As a result of this approach, problems arise in translating certain terms and terminological structures due to the difference between Russian and foreign (English) educational programs, and the dependence of the methods for defining terms on existing cultural realities. Subsequently, the identified translation problems affect the design of the ontology as a whole.

2 Overview of Existing Ontologies in the Educational Field

At the moment, formalization of subject areas is an urgent problem of digitalization of education. In world scientific practice, there are various types of ontologies; the most extensive area is represented by upper-level ontologies (metaontologies), which describe concepts and relations that are independent of a specific subject area. Examples of such ontologies are DC (Dublin Core), BIBO (The Bibliographic Ontology), AIISO (the Academic Institution Internal Structure Ontology), SKOS (Simple Knowledge Organization System) and etc. [4].

Subject ontologies contain dictionaries of terms used in metaontologies and describe the concepts of a particular subject area and the tasks it solves. In the field of mathematics, ontologies such as Mocassin, ScienceWISE, OntoMathPro [5]. Ontologies in the field of education informatization are also developing: ontology “E-learning” [4], ontology of educational standards [6], ontology of university courses [7], ontology of training programs and automatic testing of knowledge in business informatics [8].

Among the ontologies that have been developed to date, there are no mathematical high school ontologies containing a full range of terms and theorems, the task of which is their further use in digital learning environments for schoolchildren. In particular, the use of markup of educational materials, test generation, automatic recommendation of educational materials in accordance with the curriculum [5]. The developed ontology performs not only a reference function, but also a teaching one – the primary task of the OntoMathEdu ontology is to use the ontology in educational electronic resources.

3 Polylingual Problems of Designing Ontology OntoMathEdu

The main problems of OntoMathEdu ontology design are related to the formalization of geometric concepts, the relations between them, the construction of full-fledged language projections of educational ontologies. To do this, the following steps are required:

1. Development of general requirements for ontology: the formation of a base of materials, sources, textbooks, the definition of the form, content and characteristics of the concepts presented in three languages.
2. Selection of the maximum number of geometric concepts covering educational subjects in three languages.
3. The construction of selected geometric concepts in a joint hierarchy.
4. Creating different kinds of relationships between concepts.
5. Filling the content of the selected concepts and relationships (definitions, images, links to external resources, etc.).
6. Ensuring the relationship between ontology projections in different languages, without violating their educational essence, integrity and independence.

When implementing the above steps, design problems arose with the ontology polylingualism. Two levels of problems are highlighted. The first level is associated with a different understanding and the presence of mathematical terms and an ambiguous approach to their definition in various educational systems. The second level has problems of a linguistic nature (ways of translating terms and definitions), since it is impossible to carry out literal translation, while preserving the systematic educational nature of the ontology in Russian or English.

3.1 Development of General Requirements for Ontology

At this stage of the development of the OntoMathEdu ontology, the following categories are allocated for each mathematical concept (Table 1):

Table 1. Categories of mathematical concepts in ontology OntoMathEdu

Ontology projection Category of mathematical concept	Russian	English	Tatar
Ontological term	✓	✓	✓
School term	✓	✓	✓
Wiki article link	✓	✓	
Link to an educational resource	✓	✓	
Educational level	✓	✓	

At the same time, ontological terms perform the function of structuring the ontology, they may coincide with the school term, have a school analogue, or the school term may be absent for a given ontological term (Table 2).

Table 2. Examples of mathematical term in ontology OntoMathEdu

	Ontological term	School term
Ontological and school terms coincide	Треугольник (Treugol'nik)	Треугольник (Treugol'nik)
Ontological term has school analogue	Теорема о площади треугольника по сторонам (Teorema o ploshchadi treugol'nika po storonam)	Формула Герона для треугольника (Formula Gerona dlya treugol'nika)
School term is absent	Теорема о пересечении чевиан треугольника (Teorema o peresechenii chevian treugol'nika)	–

Links to Wiki articles, it was decided to introduce as additional educational content. However, their main function is the integration of the OntoMathEdu ontology into the cloud of open connected data, which can also be connected with other ontologies. The content of the article may differ in Russian and English. In particular, for the term *Теорема Фалеса* (*Teorema Falesa*) literal translation will be *Thales's theorem.* The Russian-language article corresponds to the article *Intercept theorem*, where the content indicates that the *Thales's theorem* option is also possible, which suggests a different theorem – *Theorem about the angle based on the diameter of a circle.* To eliminate the problem of translation and substantial difference between articles, links to educational resources are introduced in two languages: in Russian – *Russian educational resource* and in English – *English educational resource.*

The selection of educational resources is based on the educational level. For example, the concept *Triangle* on an educational resource may contain extensive or analytical definitions. An extensive definition in school literature is used in the early stages of

studying a concept, and an analytical definition in later ones. In the analytical definition of the concept, theorems and consequences from them are added to ensure a higher level of training for students. As a rule, Wiki articles contain analytical definitions. Links to educational resources are added based on extensive definitions. The presence of such links will be an important factor in the formation of recommendation systems in accordance with the individual trajectories of students.

3.2 Selection of Geometric Concepts for OntoMathEdu Ontology Using Russian and English Educational Literature

In the selection of geometric concepts, Russian textbooks on geometry, approved by the Ministry of Education of the Russian Federation, were used [9–13]. The ontology was filled with terms of planimetry in English by searching for terms in English-language textbooks on geometry [14–18], using of Russian-English dictionaries ABBY Lingvo, Multitran, translation of terms in complex terminological structures and the search for terms on foreign educational sites such as Encyclopedia of Mathematics, Lexico.com, MathIsFun etc.

An analysis of foreign textbooks made it possible to determine the substantive and methodological differences of geometry courses.

The following items were highlighted:

- concepts of the designed ontology that are absent in English-language textbooks: ломаная (lomanaya), самопересекающийся многоугольник (samoperesekayushchiysya mnogougol'nik), равносоставленные фигуры (ravnosostavlennyye figury), равновеликие фигуры (ravnovelikiye figury) and etc.
- concepts that are absent in Russian textbooks: kite, dart, alternate interior angles, alternate exterior angles, complementary angles, supplementary angles.
- the ambiguity of approaches to the definition of certain terms and the designation of figures. In English geometry textbooks, the designation of the ray coincides with the designation of the vector, the concept of opposite rays is introduced, in Russian textbooks there is the concept of opposite vectors. The concept of vector itself is not presented in most analyzed English-language textbooks to study. Nevertheless, the notion of parallelism is applied to vectors, and the notion of collinearity is applied to straight lines and points, in Russian textbooks, on the contrary, lines are parallel, vectors are collinear.

As a result, terms that were not found in English-language textbooks were translated using Multitran, ABBY Lingvo online dictionaries, and literal translation. Terms translated from Russian that do not have an equivalent in English-language textbooks are indicated with a special label in the ontology. For example, the concept *Дельтоид* (*Del'toid*) has been added to the ontology in Russian, and the label *Additional program* has been introduced for this concept. For the term *Накрест лежащие углы* (*Nakrest lezhashchiye ugly*) the literal translation *Alternate angles* is added, but there is a label corresponding to the Russian school. In the ontology projection in English, there are two terms *Alternate interior angles* and *Alternate exterior angles*, which in the projection in Russian also have a literal translation.

3.3 The Influence of Linguistic Features on the Construction of Selected Geometric Concepts in a Joint Hierarchy

The need to build selected geometric concepts into a joint hierarchy, to distinguish generic relationships led immediately to the problem of the absence of terms in the language of school mathematics and the problem of using the singular or plural of individual terms in the names of classes, subclasses, and instances.

The Problem of Translating Terms into English

Introduction of Missing Terms for Ontology Design. For the intellectual formalization of the subject area, it was necessary to add ontological terms that are not used explicitly or implicitly in the course of school geometry. So, to combine all the geometric figures, the areas of which can be found in the course of school mathematics, two subclasses *Неограниченная часть плоскости* (*Neogranichennaya chast' ploskosti*) and *Ограниченная часть плоскости* (*Ogranichennaya chast' ploskosti*) were added in the class *Часть плоскости* (*Chast' ploskosti*). Such terms are not used in school mathematics and there are no terms close to them. There are terms that are used in the course of school mathematics, but in an implicit form. For example, the concept *Взаимное расположение окружности и многоугольника* (*Vzaimnoye raspolozheniye okruzhnosti i mnogougol'nika*) does not occur in such a formulation in teaching, but is implied when we teach inscribed and described circles of polygons or encounter other arrangements of a polygon and a circle in geometric problems. The inclusion of these terms creates a good framework for subject ontology. Due to the absence of such terms, the problem of their translation into English arose. It should be noted once again that these terms will not be present in the projections of educational otology in Russian and English. Examples of added ontological terms and their literal translation into English are presented in the Table 3.

Table 3. Examples of added terms

Ontological term in Russian	Literal translation into English
Ограниченная часть плоскости (Ogranichennaya chast' ploskosti)	Bounded part of a Plane
Теорема о соотношении углов и сторон в равных треугольниках (Teorema o sootnoshenii uglov i storon v ravnykh treugol'nikakh)	Theorem about the ratio of angles and sides in equal triangles
Свойство четырехугольника (Svoystvo chetyrekhugol'nika)	Quadrilateral property

Disagreement with Literal Translation. Most of the terms are complex terminological structures. For example, in the geometry course of a Russian high school there is a theorem *Первый признак подобия* (*Pervyy priznak podobiya*). Literal translation of this term is *First criteria of triangles similarity*. In English-language textbooks, this theorem is called *Angle-Angle (AA) similarity theorem*. On the one hand, both names (Russian and English) correspond to the same theorem, on the other hand, the question arises of the appropriateness of using a literal translation from Russian into English. Since the developed ontology is not only informative, but also educational in nature, it was decided to use several use cases in both languages, if any, to provide a better understanding of Plane geometry by foreign students and to adapt to the content of Russian textbooks.

The Problem of Using the Singular or Plural

In ontology, the inclusion of concepts only in the singular or only in the plural is fundamentally important.

At the initial stage of ontology design, it was decided to use geometric concepts in the names of classes and instances singularly. When developing an ontology projection in English, the problem of distinguishing between the use of the singular or plural of some terms was revealed. As a rule, it is customary to use the singular in dictionaries and subject indexes, however there are a number of terms that have the plural.

In Russian textbooks and mathematical dictionaries there are a number of terms expressing paired concepts in geometry and presented in the plural. For example, вертикальные (смежные, односторонние, соответственные, накрест-лежащие) углы; коллинеарные (сонаправленные, противоположно направленные) векторы; равновеликие (равносоставленные) многоугольники; параллельные (перпендикулярные) прямые; пропорциональные отрезки, касающиеся окружности и др. These concepts can be found in the singular in the framework of a specific context: прямая, параллельная прямой, угол, смежный с углом, etc. It was found that some of these paired terms are found in Russian and English textbooks and dictionaries, both in the plural and in the singular.

Due to the problem of translating such concepts into English, where the plural concepts are mainly used for paired concepts, it was decided not to use the singular. As a result of this approach, a new hierarchy *Mutual arrangement of geometric figures on a plane* was added to the ontology. For example, the concept *Vertical angles* is included in the hierarchy of materialized relations of the subclass *Angles mutual arrangement* (Fig. 1). Initially, it was planned to make this concept a subclass of the *Angle* class in the type hierarchy (Fig. 2). Similar pair concepts were also included in the *Mutual arrangement of geometric figures on a plane* hierarchy.

3.4 Creating Different Kinds of Relationships Between Concepts

Ambiguity of Terms. The translation of mathematical terms in the design of ontology requires uniqueness of meaning. However, V.N. Shevchuk notes that even within a specific terminology, a technical term can be ambiguous, from which it concludes that

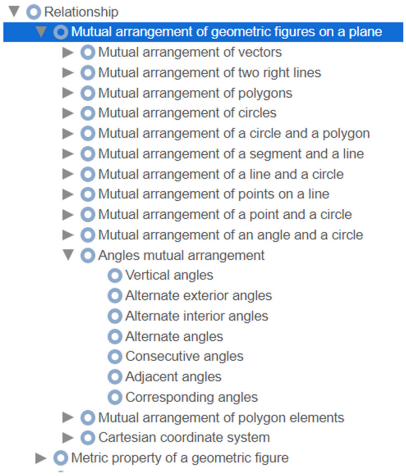

Fig. 1. Mutual arrangement of geometric figures on a plane hierarchy

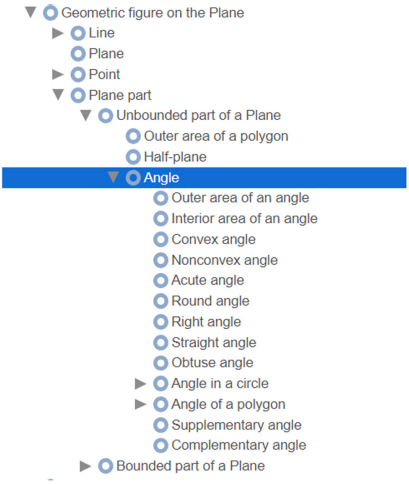

Fig. 2. Angle hierarchy

unambiguity is not a property of the term, but only a requirement that is presented to it [19].

Consider approaches to defining terms Circle, Circumference и Disk (Disc) in the following resources: Lexico.com (by Dictionary.com and Oxford University Press), Encyclopedia of Mathematics, Wikipedia (Table 4).

The table shows that in English there is a problem of substitution of concepts: *Круг* (*Krug*) is defined as a curve and as a limited part of the plane, *Окружность* (*Okruzhnost'*) is a plane curve and distance, *Диск* (*Disk*) is considered a limited part of the

Table 4. Examples of differences in definition of terms

Term Source	Circle	Circumference	Disk (Disc)
Lexico.com	A round *plane figure* whose boundary (the circumference) consists of points equidistant from a fixed point (the centre)[a]	The enclosing *boundary* of a curved geometric figure, especially a circle[b]	–
Encyclopedia of Mathematics	A closed *plane curve* all points of which are at the same distance from a given point (the centre of the circle) and lie in the same plane as the curve[c]	–	The *part of the plane* bounded by a circle and containing its centre[d]
Wikipedia	A circle is a *plane figure* bounded by one line, and such that all right lines drawn from a certain point within it to the bounding line, are equal. The bounding line is called its circumference and the point, its centre[e]	The circumference of a circle is the *distance* around it[f]	The *region in a plane* bounded by a circle[g]

[a] https://www.lexico.com/definition/circle
[b] https://www.lexico.com/definition/circumference
[c] https://encyclopediaofmath.org/wiki/Circle
[d] https://encyclopediaofmath.org/wiki/Disc
[e] https://en.wikipedia.org/wiki/Circle
[f] https://en.wikipedia.org/wiki/Circumference#Circle
[g] https://en.wikipedia.org/wiki/Disk_(mathematics)

plane. In Russian, *Окружность* is uniquely expressed by a plane curve, *Круг* is a part of a plane.

In addition, it was revealed in geometry textbooks [14–18] that both the perimeter (circumference) and area are found for the term *Circle*. Obviously, finding the area is possible only for planar figures of dimension 2. If we take *Круг* as a *Circle*, then using the same term for different concepts entails the problem of designing ontological dependencies.

As a second example, the terms *Линия* (*Liniya*) and *Прямая* (*Pryamaya*) can be used to denote various objects. In English, the term *Line* means both *Прямая* and *Линия*, therefore, it is possible to understand the meaning of the term only in a specific context, which contradicts the property of accuracy and independence of the term from

the context within the framework of specific terminology [20]. It is also impossible to refuse the use of the term *Линия* in ontology, since it is a generic concept of the *Geometric figure on a Plane* class.

Since in the future the ontology will be used in recommendation systems of electronic courses, it is important that the "address" of the object in the ontology is unique. The presence of terms with the same name and different meanings will not allow using the name of the object as this "address". Therefore, to solve the problem of the ambiguity of terms, special labels are introduced into the ontology that will perform the function of structuring and unambiguous definition of an object.

Synonyms of Terms. The presence of several versions of translations of the same term also complicates the process of filling the ontology with terms and establishing links between concepts. For example: Катет – leg of right triangle, catheter, leg, side; Кривая второго порядка – point conic, quadratic curve, second-order curve, curve of the second order [2]. For such terms in the ontology, several translation options are presented.

4 Conclusions

The problem of translation of professional terms is urgent. In the article [21] describes the problem of translation of educational terms. The importance of mastering special terminology in several languages is noted in view of the transition from the national education system to the global one in the process of internationalization. At the same time, the expansion of international communication in the educational space requires a transition to a polylingual basis. The initiative to create a network of polylingual educational complexes in the Republic of Tatarstan by 2022 was supported by President of the Russian Federation V.V. Putin[1]

In this article, we described the problems of translating the terms of the OntoMathEdu ontology, which contains more than 600 concepts of the school course of Plane geometry. Thanks to translation problems, a new concept of ontology construction has emerged by combining three language projections, which may have a different set of terms for the respective languages. The ontology is filling by new terms in Russian and English thanks to the continuous analysis of textbooks and dictionaries.

In the future, the developed ontology will be expanded to other sections of the school mathematics course in three languages. OntoMathEdu is preparing to be introduced into the electronic course of Plane geometry for schoolchildren engaged in advanced mathematics and preparing for final exams. The ontology will be used as a database for searching information in an electronic course and marking up educational material.

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[1] https://sntat.ru/news/science/03-04-2019/polilingvalnye-shkoly-shaymieva-obuchenie-na-treh-yazykah-internat-dlya-vunderkindov-i-filosofiya-soglasiya-5646642.

References

1. Shakirova, L.R., Falileeva, M.V., Kirillovich, A.V., Lipachev, E.K.: The design of educational mathematical ontology: problems and solution methods using the example of a planimetry course. In: XV International Conference on Computer and Cognitive Linguistics TEL 2018, Kazan, Russia, vol. 1, pp. 393–405. Publishing House of the Academy of Sciences of the Republic of Tatarstan (2018)
2. Dyupina, A.E.: Features of translation the terms from ontology of planimetry in English. In: XV International Conference on Computer and Cognitive Linguistics TEL 2018, Kazan, Russia, vol. 1, pp. 137–146. Publishing House of the Academy of Sciences of the Republic of Tatarstan (2018)
3. Galiaskarova, K.R., Mukhamedvalieva, S.R.: Features and problems of translation of the mathematical terms into Tatar language in the establishment of the taxonomy In: XV International Conference on Computer and Cognitive Linguistics TEL 2018, Kazan, Russia, vol. 1, pp. 61–71. Publishing House of the Academy of Sciences of the Republic of Tatarstan (2018)
4. Balashova, I.Y.: Ontologic models in system of informatization of education. Models Syst. Netw. Econ. Technol. Nat. Soc. 3, 15 (2015). https://www.elibrary.ru/item.asp?id=25057608
5. Shakirova, L.R., Falileeva, M.V., Kirillovich, A.V., Lipachev, E.K.: Problems and solutions in the design of formal taxonomy of concepts of geometry In: Proceedings of the 13th International Technology, Education and Development Conference (INTED2019), 11th–13th March 2019, Valencia, Spain, pp. 6793–6801 (2019)
6. Metkewar, P., Mapari, S.: Conceptual model of ontology in education era. Int. J. Latest Trends Eng. Technol. **3**(3), 150–155 (2014)
7. Ameen, A., Khan, K., Rani, B.P.: Creation of ontology in education domain. In: Technology for Education (T4E), 2012 IEEE Fourth International Conference, pp. 237–238 (2012). https://ieeexplore.ieee.org/document/6305981
8. Vas, R.: Educational ontology and knowledge testing. Electron. J. Knowl. Manag. **5**(1), 123–130. (2007). https://www.researchgate.net/publication/228361979_Educational_Ontology_and_Knowledge_Testing
9. Atanasyan, L.S., Butuzov, V.F., Kadomcev, S.B. i dr.: Geometriya, 7–9 klassy: uchebnik dlya obshcheobrazovat. organizacij. Moscow, Prosveshcheniye (2018)
10. Pogorelov, A.V.: Geometriya, 7–9 klassy: uchebnik dlya obshcheobrazovat. organizacij. Moscow, Prosveshcheniye (2018)
11. Smirnova, I.M.: Geometriya, 7–9 klassy: uchebnik dlya obshcheobrazovat. organizacij. Moscow, Prosveshcheniye (2015)
12. Sharygin, I.F.: Geometriya, 7–9 klassy: uchebnik dlya obshcheobrazovat. organizacij. Moscow, Prosveshcheniye (2018)
13. Atanasyan, L.S., Butuzov, V.F., Kadomcev, S.B. i dr.: Geometriya. Dopolnitel'nye glavy k uchebniku 9 kl.: ucheb. posobie dlya uchashchihsya shkol i klassov s uglubl. izuch. matematiki. Moscow, Prosveshcheniye (2005)
14. Africk, H.: Elementary college geometry. CUNY Academic Works (2013). https://academicworks.cuny.edu/ny_oers/6
15. Alexander, D.C., Koeberlein, G.M.: Elementary geometry for college students. Cengage Learning 628 p. (2016)
16. Cummins, J., Carter, J.A., Cuevas, G.J., Day, R, Malloy, C.: Glencoe Geometry, Virginia Student Edition. McGraw-Hill/Glencoe 810 p (2012)
17. Gantert, A.X.: Amsco's Geometry. AMSCO School Publications 643 p (2008). Incorporated
18. Larson, R.E., Boswell, L., Stiff, L.: Heath geometry an integrared approach. Teacher's Edition 876 p. (1998)

19. Shevchuk, V.N.: Derived military terms in English: [affixed word production]. Military Publishing, Moscow 231 p (1983)
20. Lotte, D.S.: Fundamentals of building scientific and technical terminology. Questions of theory and methodology. Publishing House of the Academy of Sciences of the USSR 160 p (1961)
21. Şimon, S., Kriston, A., Dejica-Carțiș, A., Stoian, C.: Challenges in translating educational terminology. In: 10th International Conference on Education and New Learning Technologies, pp. 5327–5335 (2018). https://doi.org/10.21125/edulearn.2018.1290. https://www.researchgate.net/publication/326716636_challenges_in_translating_educational_terminology

E-Polity: Governance and Politics on the Internet

Identifying Duplication in Statistical Indicators: Methodic Approach

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Abstract. Data-based and data-driven decisions are at the core of digital government transformation. However, the more the data is to be used to guide policy development, the higher are the requirements to the data accuracy and readiness. Larger reliance on data to inform policy decisions should not lead to increased reporting requirements and hence excessive administrative burden on businesses. Therefore, identifying and reducing duplication in statistical data should be performed at the early stages of the government digital transformation. Given the constantly increasing number of strategic documents and continuous amendments to the list of statistic indicators measured, there is a need for an instrument allowing for timely identification and elimination of possible duplication in statistical and other indicators.

In this paper we propose a methodic approach to identifying and evaluating possible duplication in statistical and other administrative indicators which is based on a partially automatable algorithm complemented by expert evaluation. The results of piloting this approach on a set of about 6,000 statistical indicators suggest that it could become a useful tool for data management that would allow to improve the quality of aggregated data, on the one hand, and reduce administrative reporting burden on businesses – on the other. The proposed approach could also be applied in a broader context, i.e., for the analysis of strategic planning documents, and may be of interest to practitioners from other countries where the quality of statistical data and duplication of administrative information is considered a barrier for further government digitalization.

Keywords: Data management · Digital government · Duplication · Statistical indicator · Strategic planning

1 Introduction

Digital transformation in public administration calls for implementation of data-based and data-driven decisions. As highlighted by the UN, "data are the lifeblood of decision-making and the raw material for accountability" [33]. High quality data should be based on cooperation of traditional and new data producers and international ethical, legal,

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and statistical standards protecting personal data and ensuring reliability of information used for decision-making. The ability to collect, correctly interpret and use data for management decisions becomes a critical administrative competence and an important competitive advantage at the global level [37]. The importance of the data used for governance decisions has become so high that the World Bank picked the issue of data for development as a topic for its annual World Development Report in 2021[1].

Noteworthy, use of government data spans far beyond the limits of public authorities. As a part of digital transformation efforts, many countries throughout the globe embarked on open government data (OGD) initiatives stimulating use and re-use of government data sets for creating new business opportunities and public value [27]. However, the success of these initiatives significantly depends on the data quality [20]: complexity and vast amount of data may hinder rather than promote better accountability and OGD re-use [12]. To maximize the positive effects of OGD initiatives both technical metadata standards and accuracy of the data itself should be addressed.

Better use of data for informing policy decisions as well as for other purposes calls for greater data timeliness and accuracy. To date, the Russian state statistical system does not meet the data requirements of public authorities and businesses in terms of providing the data needed in real time regime [6]. Neither Federal law *On official statistics* nor Federal Plan of Statistical Works provide for collection, processing, and publication of statistical data in real time manner. Often the data is processed and published with a significant time lag which makes it impossible to use statistics to guide policy decisions. Timeliness and relevance of statistical data is also an issue in other countries [7, 32] and international organizations [26, 36].

Lack of timely available accurate statistical information makes federal and regional authorities create their own data systems based on additional reporting forms. As a result, part of the data provided to various authorities in different reporting forms duplicate each other, the administrative costs of reporting increase [5], while the aggregate data is prone to discrepancies due to differences in scope of respondents and some methodic approaches to constructing statistical indicators. The problem of duplicative statistical forms and indicators has been highlighted by several studies conducted at the national level [4, 9] and in some specific sectors, such as legal enforcement [30], healthcare [18], culture [17], and environment protection statistics [25]. For instance, the analysis of over 13 thousand statistical indicators included in statistical and other reporting forms suggested that about 20% of statistical indicators duplicated the data collected in other reporting forms [4].

The need to improve quality of statistical data and reduce duplication in statistical indicators was acknowledged in the recently approved *Strategy for Developing Federal Statistic Service and the System of State Statistics till 2024*[2]. The strategy aims at eliminating duplication in statistical indicators and reducing the level of reporting burden on businesses at least by 50%. The current annual administrative costs related to statistical reporting estimated in the strategy account for 1500 billion RUR or 1.4% of GDP. Such

[1] See: https://blogs.worldbank.org/developmenttalk/world-development-report-2021-data-development.

[2] Approved on September 6, 2019. See: https://www.gks.ru/storage/mediabank/Strategy.pdf (in Russian).

estimate appears high but is possible, based on international experience. In Germany for example administrative costs of businesses related to data reporting to government authorities were estimated by National Statistics Service in 2014 at 49,3 billion euro [31] or 1.3% of GDP.

The situation with duplicative indicators in Russia is exacerbated by the increasing government needs in data to inform policy decisions, monitor and evaluate the implementation of various strategic documents. For instance, the existing Register of Strategic Planning Documents contains over 63 thousand of such documents developed at the federal, regional, and municipal levels[3]. State programs approved at the federal level contain over 2,500 indicators. Unless there is a way to meaningfully process and analyze all this data, the efforts on strategic planning and policy development may be wasted.

Frequent changes in strategic documents also entail changes to the contents of statistical works. During the past 5 years (2015–2019), the Federal plan of statistic works was amended 50 times. These amendments resulted in changes both in contents and scope of statistical indicators, including statistical reporting forms.

Overall, administrative burden related to reporting appears to be an issue and reducing duplication in statistical indicators is one of important options to solve it. However, given the constantly increasing number of strategic documents and continuous amendments to the list of statistic activities and indicators measured, there is a need for an instrument that would allow for timely identification and elimination of possible duplication in statistical and other indicators used to inform policy decisions. This paper aims at developing and testing a methodic approach to designing such instrument.

2 Objective

The objective of this paper is to develop methodic approaches and test an instrument for identifying and eliminating possible duplication in statistical and other indicators.

To achieve this objective, we need to:

1. review the existing methods which may be used for identifying possible duplication in statistical and other indicators;
2. develop a methodic approach for identifying possible duplication in statistical and other indicators and supporting decisions on eliminating such duplication;
3. test the proposed approach on a database containing statistical and other indicators.

The database used for testing includes a list of statistical indicators (extracted from all current official statistics reporting forms) and indicators used to monitor strategic documents (from the state automated information system GAS *Upravlenie*).

3 Methodology

3.1 Literature Review

Identifying possible duplication in statistical and other indicators calls for application of semantic methods which help to compare texts (as indicators names are text strings)

[3] See: http://gasu.gov.ru/stratplanning.

and estimate the difference (or similarity) between such texts. Such methods include the following:

- Levenshtein distance [19] applied in various contexts, including patent analysis [23];
- phonetic algorithms such as Metaphone [28] broadly used in linguistics analysis not only for English [16] but also for other languages, such as Bangla [34];
- Jaro [13] and Jaro-Winkler [35] string distances used for identifying similar text strings in various contexts [1, 15, 29].

To select the optimal method for this paper, the existing limitations of the above approaches should be accounted for given the context of our analysis.

Thus, Levenshtein method is based on comparison of the order of symbols in pairs of strings. Hence, the change of word order in one string leads to significant increase in Levenshtein distance measure. This is an important limitation as the names of indicators in various systems may contain identical (or highly similar) words with variations in word order.

Metaphone method is based on comparing phonetic characteristics of strings which makes this method effective when a risk of spelling mistakes in the text is high. For instance, this method is efficiently applied for Internet search [21] or with audio data [22]. However, in statistical and other indicators databases the propensity of spelling mistakes is relatively low (the databases are supported by public administration authorities), hence, the advantages of this method cannot be fully used.

Recent reviews suggest that Jaro-Winkler method outperforms other algorithms in record duplication detection [2, 15]. However, it should be noted that this method finds pairs of strings identical at the beginning more similar than those which have slight differences at the beginning but are identical otherwise. This feature of the algorithm may limit the prospects of automatic identification of partially similar indicators. On the positive side, both Jaro and Jaro-Winkler methods account for possible misprints such as changes in neighboring symbols which may be useful for analyzing large datasets of indicators included in Strategic Planning Register and other similar systems.

Overall, the brief literature review presented in this section of the paper concludes that while there are a number of methods used for estimating text similarity, the specific context of the task should be accounted for. Initial review of statistical indicators and indicators used in strategic planning document revealed the following characteristics important for developing correct methodic approaches for defining and eliminating possible duplication.

First, there are numerous cases when synonyms are used for denoting similar objects. For instance, the same indicator characterizing innovation is called ‘a share of innovatively active organizations in total number of organizations’ in a government state program Economic Development and Innovative Economy and ‘a percentage of innovatively active organizations in total number of organizations’ in statistics. Such differences cannot be detected automatically and calls for specific instruments to be applied.

Second, the attributes of indicators (such as units of measure) should be considered. For instance, production volumes may be measured in natural units and in monetary terms – in this case there is no duplication while the names of indicators may be identical or very

similar. Hence, identifying duplicative indicators cannot be limited only to comparisons of indicator names as text strings; indicator attributes should be part of the analysis.

Third, the scope of reporting subjects may differ. Identical indicators (such as firm turnover or average number of staff) may be reported by different reporting subjects (for instance, by commercial and non-commercial organizations) in different forms and this date is not duplicative. In some cases, the difference of reporting subjects scope may result in partial duplication (when some respondents submit the same information twice, and some – only once).

Fourth, the methodology of indicator estimation may vary in various statistical forms – in this case the decision to eliminate the duplication should include the decision on implementing uniform methodology.

Therefore, the objective of this paper calls for developing a context-specific methodic approach to identifying possible duplication in statistical and other indicators.

3.2 Methodic Approach

The procedure we propose for identifying and eliminating duplication in statistical and other indicators accounts for the characteristics of the databased discussed in Subsect. 3.1 and allows for possible integration of internationally accepted methods for detecting text similarity. In addition to the names of indicators, the following indicator attributes and characteristics are also subject of the analysis:

- units of measure;
- data aggregation types and levels (i.e. aggregation by territory, types of economic activity, etc.);
- respondents submitting the initial data (subjects of reporting);
- statistical methods (general sample or sub-sample);
- reporting periods (frequency);
- methodology for indicator computing;
- data sources (for calculated indicators).

The proposed methodic approach includes two main stages. At the first stage, semantic analysis methods are used to identify full or partial duplication in statistic and other indicators. Since the subject of our analysis are statistical indicators (formulated based on official terminology and scientific language), we deal with denotative meanings and, hence, may formalize the analysis. This method would not be applied if natural language text strings containing words with connotative meaning were to be processed (i.e., posts in social media, messages, etc.).

At the second stage, expert analysis is carried out to confirm (or reject) duplication for pairs of indicators with partial duplication. While the first stage of the procedure may be automated, the second stage calls for expert analysis. The algorithm of the method is presented in Fig. 1.

At the first stage semantic analysis of indicator names and their attributes is conducted. To identify duplication based on semantic analysis, the following steps are used:

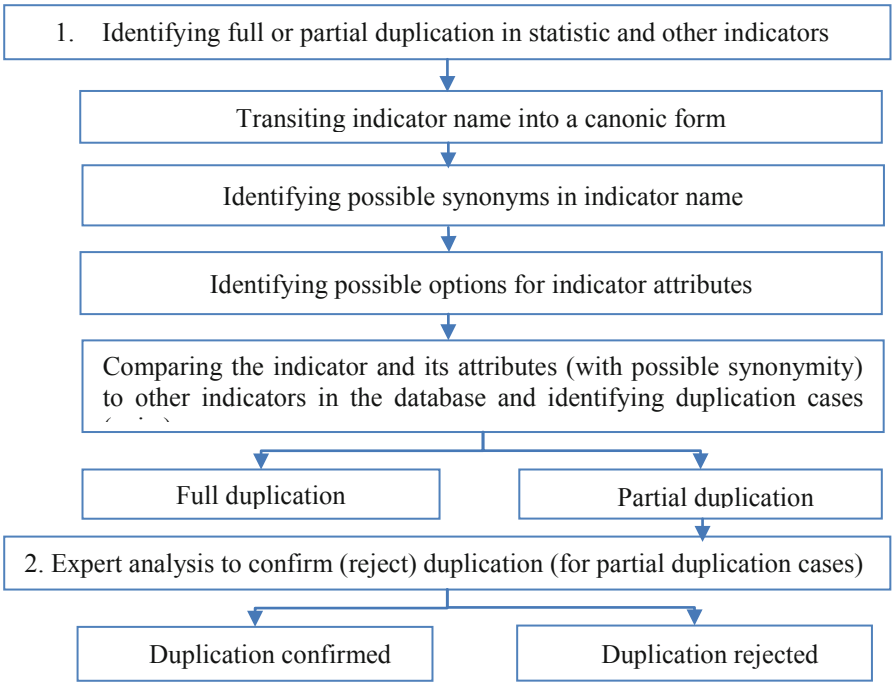

Fig. 1. The Proposed Procedure for Identifying and Eliminating Duplication in Statistical and Other Indicators

1. transiting indicator name into a canonic form,
2. identifying possible synonyms in indicator name,
3. identifying possible options for indicator attributes, and
4. comparing the indicator and its attributes (with possible synonymity included) to other indicators in the database and identifying duplication cases, including full and partial duplication of indicators.

Transiting indicator name into a canonic form is important in the context of Russian texts as similar meanings may be achieved by using prepositions or changing cases of nouns and adjectives. There are also some practical examples when similar indicators use singular or plural noun forms.

At this stage, the following operations are performed:

- all 'stop words' such as prepositions, demonstrative pronouns, and some others are excluded from indicator names, and
- all words in indicator names are presented in nominative form (nominative, singular for nouns; nominative muscular singular for adjectives, nominative for numerals, infinitive for verbs and so on).

To identify synonyms in the indicator name, the words (word combinations) included in the name of the indicator are compared to the words (word combinations) included

in the vocabulary of synonyms. This vocabulary includes acronyms (so that GDP is denoted the same as 'gross domestic product'; 'share' denotes the same as 'percentage'; etc.) and some words frequently used in statistical indicator names.

To develop the vocabulary of synonyms, we conducted frequency analysis of words included in indicators and our sample and found over a 100 of possible synonyms. In the future in case this approach is applied, a broader vocabulary of synonyms can be constructed.

To identify possible options for indicator attributes, two attributes are analyzed: units of measure and data aggregation.

Units of measure may also contain synonyms. For instance, the same indicator can be recalculated in rubles, thousand rubles, million rubles, or in other currency (using a conversion rate) but it cannot be recalculated in natural units.

Similarly, an indicator aggregated by territory may be recalculated based on other territory classifications but cannot be presented by the type of economic activity if the initial data is not collected this way.

At the stage of comparing the indicator and its attributes (with possible synonymity included) to other indicators in the database and identifying duplication cases the following operations are performed.

To identify the cases of full duplication the indicator is compared to the indicators in the database which satisfy the following requirements:

- contain all words included in canonic indicator name (or synonyms of such words or word combinations in accordance with the vocabulary of synonyms), and
- do not contain any other words (excluding 'stop words'), and
- have the same attributes (or synonyms of these attributes).

To identify the cases of partial duplication the indicator is compared to the indicators in the database which satisfy the following requirements:

- contain all words included in canonic indicator name (or synonyms of such words or word combinations in accordance with the vocabulary of synonyms) AND
- contain other words (excluding stop words or synonyms) OR
- contain other attributes (excluding synonyms).

For instance, indicators 'capital investment per capita' partially duplicates the indicator 'capital investment volume': the latter is used for calculating the former. To reduce possible variation of partial duplication, the algorithms of semantic analysis discussed in Sect. 3.1 may be used. Given the limitations of these methods discussed above, it is proposed to set a minimum requirement of achieving the level of 0.5 of Jaro similarity for the pair of indicators to confirm partial duplication (the requirement that the second indicator should contain all words included in the canonic form of the first indicator remains).

In case full duplication of statistical and other indicators is detected, it is recommended that duplicative indicators are excluded from statistical reporting forms. In case partial duplication is detected, an expert analysis should be carried out.

Expert analysis is conducted for each indicator for which one or more other partially duplicative indicators were detected. At this stage, all attributes of indicators are reviewed, and decisions to confirm duplication (i.e. to eliminate duplicative indicator) or reject duplication (i.e. preserve all indicators with partial duplication). The criteria used for the analysis and decisions based on these criteria are summarized in Table 1.

Table 1. Criteria and Decision Algorithms for Expert Analysis Aimed at Identifying and Eliminating Duplicative Indicators

No.	Criterion	Decisions based on criterion
1.	Different units of measure	In case indicators can be recalculated in other units of measure (i.e. units of measure are synonyms), duplicative indicators are eliminated. Otherwise, duplication is rejected
2.	Different aggregation (disaggregation) levels	Indicator with maximum disaggregation (presented by maximum number of classifications) is preserved, duplicative indicator is eliminated
3.	Differences in scope of respondents	In case there is partial duplication in scope of respondents, the indicator with lesser scope is eliminated, while the indicator with larger scope is preserved. In this case relevant disaggregation level (i.e. presentation of data by type of activity, type of reporting subject, etc.) is included to allow for data comparability. In case there is no duplication in scope, the indicators are merged (duplication rejected)
4.	Different statistical methods for data collection (general sample, other samples)	The indicator is preserved for the largest sample (i.e. when one indicator is based on general sample, and another – on sub-sample of respondents, the indicator based on general sample is preserved. The indicators characterizing sub-samples quality and representations are also preserved (for this type of indicators duplication is rejected)
5.	Different periodicity (frequency) of data collection	Indicators for which the data is collected less frequently are eliminated, indicators with maximum frequency are preserved
6.	Different methodology used for defining and calculating indicators	Where possible, methodology for defining and calculating similar indicators should be harmonized. In other cases, duplication is rejected

(*continued*)

Table 1. (*continued*)

No.	Criterion	Decisions based on criterion
7.	Partial duplication in indicator names	In case the indicator meaning is similar and no differences in methodology are detected, the duplicative indicators should be eliminated. Otherwise, duplication is rejected

Based on the expert analysis, for each partially duplicative indicator duplication is either confirmed (and the indicator is eliminated) or rejected (the indicator is retained). In some cases, merges of indicators and changes to methodology are introduced.

Since application of the proposed procedure is envisaged in the Federal Statistic Service of Russia which has sufficient in-house expertise in the field, the expert analysis may be organized within the organization as a part of the process of refining the Federal Plan of Statistical Works. However, in case the algorithm is applied in a broader context, special efforts for selecting and organizing the expert review stage using e-expertise approaches [10] would be needed.

4 Results

To test the proposed methodic approach, we used a sample of 5,923 statistical and other indicators included in statistical reporting forms and in state information systems aggregated in GAS Upravlenie.

At the first stage, a plain search of full duplication in indicator names was conducted. This search resulted in 126 cases of duplication which included 318 duplicative indicators (some cases include more than 2 duplicative indicators), or 5.4% of the sample. Some 62% of duplication cases was detected in state information systems, 38% – in statistical reporting.

After transition of indicators into canonic form 8 additional cases of full duplication were detected. Examples of such pairs (in transliteration and in translation) are presented in Table 2.

The examples in Table 2 illustrate that transiting indicators to canonic form is a useful tool for detecting full duplication. However, the results of such detection should be subject to expert analysis. While the first three examples present indicators with the same meaning, the fourth pair consists of different indicators: the first one estimates the number of births for women at a given age, the second one – at this age and earlier, thus, the data presented would be different.

The results of semantic analysis applied to indicators transited into canonic form allowed to identify partial duplication in 11.4% of the sample (in addition to the cases of full duplication described above). Use of synonyms allowed for better identification of potential duplication. Some examples of cases detected as a result of such analysis and recommendations made based on these cases in expert analysis are presented in Table 3.

Table 2. Examples of Fully Duplicative Indicators Identification in Canonic Form

First Indicator	Second Indicator
Nachislennye rabotnikam summy oplaty truda [Amounts paid to employees]	Nachisleno rabotnikam summ oplaty truda [Amount paid to employees]
Ostatki topliva [Fuel residues]	Ostatok topliva [Fuel residues]
Ocenka finansovogo polozhenija domohozjajstv [Evaluation of household financial status]	Ocenka finansovogo polozhenija domohozjajstva [Evaluation of household financial status]
Srednee chislo rozhdenij v dannom vozraste [Average number of births at a given age]	Srednee chislo rozhdenij k dannomu vozrastu [Average number of births to a given age]

Table 3 illustrates that indicators similar by meaning may be formulated in quite a different way. Therefore, the stage of expert analysis is needed to review the findings of semantic analysis and draw reasonable recommendations.

Table 3. Examples of Partially Duplicative Indicators Identification

First Indicator	Second Indicator	Decision based on criteria
Kolichestvo personal'nyh komp'juterov [number of personal computers]	Kolichestvo personal'nyh komp'juterov na 100 chelovek [number of personal computers per 100 persons]	The second indicator can be calculated based on the first indicator and other available data. Duplication confirmed
Nalichie osnovnyh stroitel'nyh mashin so srokom sluzhby, prevyshajushhim srok amortizacii [Number of construction vehicles with a service life exceeding the depreciation period]	Udel'nyj ves stroitel'nyh mashin so srokom sluzhby, prevyshajushhim srok amortizacii, v obshhem chisle mashin [The proportion of construction vehicles with a service life exceeding the depreciation period in the total number of machines]	The second indicator can be calculated based on the first indicator and other available data. Duplication confirmed
Ustanovlennaya elektricheskaya moshchnost' elektrostantsii [Installed electric power of a power plant]	Ustanovlennaya elektricheskaya moshchnost' teplovoy elektrostantsii [Installed electric power of a thermal power plant]	Duplication can be eliminated if the first indicator is presented with disaggregation by types of electric power plants

(*continued*)

Table 3. (*continued*)

First Indicator	Second Indicator	Decision based on criteria
Nachislennyy za god uchetnyy iznos osnovnykh fondov (amortizatsiya i iznos, otrazhayemyye v bukhgalterskom uchete i otchetnosti) [Accrued depreciation of fixed assets for the year (depreciation and depreciation reflected in accounting and reporting)]	Iznos osnovnykh fondov [Depreciation of fixed assets]	As formulated, the indicators present different notions (depreciation of fixed assets accrued in a specific year and total depreciation). However, the second indicator (in case the methodology is harmonized) may be calculated based on the first one. Hence, there is a possibility to minimize duplication

5 Discussion and Recommendations

Our findings suggest that the issue of duplication of statistical and other indicators in the Russian context is indeed significant. About 17% of indicators included in our sample were found fully or partially duplicative. Partial duplication is more widespread than full duplication, though it is also often the case. Broadening this sample by including sectoral statistics and other state information systems where additional reporting data is accumulated is likely to result in more cases of data requirements duplication and, hence, excessive reporting requirements to businesses.

The proposed methodic approach allowed to combine semantic analysis methods with expert analysis which considers the specific context of indicators and their attributes. The test results demonstrate that such combination of automated and manual analysis methods should be applied not only to the cases of partial duplication, as envisaged initially, but also to the cases of full duplication in case the names of indicators were found duplicative in canonic forms but were not found duplicative before transiting to canonic forms. This will eliminate the risk of false duplication cases.

The use of synonyms was found relevant, especially for cases when indicators are calculated based on raw data. Likewise, elimination of stop words simplified the search for fully and partially duplicative indicators.

The test results confirmed the need for expert refinement of the initial results obtained based on semantic analysis as examples of similar indicators formulated in very different ways were identified.

Noteworthy, the results of testing suggest that in many cases disaggregation of data and application of certain additional classifications at the data collection stage would help to resolve the issue of partial duplication in indicators. Often such duplication stems from the lack of access of sectoral authorities to disaggregated data collected by their peers. Thus, elimination of duplication in statistical and other indicators would

require granting all interested parties (especially government authorities) access to depersonified disaggregated data. Such change would call for amendments to the current legislation on statistics and reporting.

Overall, implementation of the proposed methodic approach would help to eliminate duplication in statistical and other indicators and hence reduce risks of data discrepancies and inaccuracy. If such tool is introduced as a part of the procedure for developing (reviewing) reporting requirements, it can generate significant reduction in administrative burden on reporting subjects (organizations and individual entrepreneurs), though such reduction is not likely to be twofold as envisaged in Rosstat's *Strategy for Developing Federal Statistic Service and the System of State Statistics till 2024.*

One of the options to further reduce such administrative burden is to broaden data sources used to inform government policy. In this case at the stage of an expert analysis a criterion based on the presence of alternative data sources which do not require reporting by reporting subjects (i.e. data from administrative information systems, data collected through Internet of Things, and the like) could be applied. In many cases the use of alternative data sources may radically improve timeliness of data; such sources are often less prone to manipulation and reduce excessive reporting burden on businesses [24]. However, this criterion should be applied not only to partially duplicative statistical and other indicators, but to all indicators included into official reporting. Hence, its application goes beyond the objective formulated for this paper, but it could be a useful direction of the future research.

Implementation of the proposed approach is not limited to the function of managing statistical works. For instance, it could also be also applied in a broader context, i.e., for the analysis of strategic planning documents which are currently developed, implemented, and evaluated at all three levels of state and municipal bodies in Russia. Currently, there are over 63 thousand of such documents and estimated number of indicators they use is over 200,000. While the existing Register of Strategic Planning Documents contains a list of indicators used for strategic planning in various sectors and at different levels of government, it lacks analytical instruments for aligning objectives and performance measures contained in strategic planning documents. Application of the proposed tool in the area of strategic planning could help aligning regional and local strategic documents with the federal ones and coordinate the systems of indicators used to measure progress across various sectors.

Finally, we believe that the proposed approach may be of interest to practitioners from other countries where the quality of statistical data and duplication of administrative information is considered a barrier for further government digitalization and digital transformation of economy and society at large. As demonstrated by this paper, overcoming this issue calls for a right combination of automated and expert analysis with due attention to indicator attributes, synonyms, and the issues of full and partial data duplication. For instance, the tool may be used for improving the quality of the OGD datasets (in terms of data consistency) and, hence, stimulate the use and re-use of the open data by the private sector and NGOs for creating new business opportunities and citizen-centered services. Another possible area where the proposed approach could be applied (with certain modification) is related to processing medical records data where duplication and inconsistencies create excessive administrative burden [11] and

limit health research [3]. Given the significant attention paid to digital transformation in public health, improving the quality and consistency of health records data based on removing duplication and identifying errors is an important task both for developed [8] and developing countries [14].

References

1. Agbehadji, I.E., Yang, H., Fong, S., Millham, R.: The comparative analysis of smith-waterman algorithm with Jaro-Winkler algorithm for the detection of duplicate health related records. In: Paper Presented at the 2018 International Conference on Advances in Big Data, Computing and Data Communication Systems, icABCD 2018 (2018). https://doi.org/10.1109/icabcd.2018.8465458
2. Alenazi, S.R., Ahmad, K., Olowolayemo, A.: A review of similarity measurement for record duplication detection. In: Proceedings of the 2017 6th International Conference on Electrical Engineering and Informatics: Sustainable Society Through Digital Innovation, ICEEI, 6 Jan 2017 (2018). https://doi.org/10.1109/iceei.2017.8312386
3. Blewett, L.A., Call, K.T., Turner, J., Hest, R.: Data resources for conducting health services and policy research. Ann. Rev. Public Health **39**, 437–452 (2018). https://doi.org/10.1146/annurev-publhealth-040617-013544
4. CEFC Group: Research on reporting forms inventory, including statistical data, developing new approaches to reporting (2018). http://sk.ru/foundation/legal/p/09.aspx. Accessed 15 Feb 2020. (in Russian)
5. Dmitrieva, N.E., Plaksin, S.M., Sinyatullina, L.H.: Ocenka izderzhek organizacij na sbor statisticheskoj otchetnosti, ili skol'ko stoit pokazatel' [The Main Approaches to the Assessment of Organizations' Costs in the Statistic Collection and Provision]. Public Administration Issues **2**, 71–93 (2018). (in Russian)
6. Dobrolyubova, E., Alexandrov, O., Yefremov, A.: Is Russia ready for digital transformation? In: Alexandrov, D., Boukhanovsky, A., Chugunov, A., Kabanov, Y., Koltsova, O. (eds.) DTGS. CCIS, 745, 431–444. Springer, Cham (2017)
7. Fitzgerald, G., FitzGibbon, M.: A comparative analysis of traditional and digital data collection methods in social research in LDCs - case studies exploring implications for participation. In: Empowerment, and (mis)Understandings (2014). http://www.validnutrition.org/wp-content/uploads/2015/03/A-Comparative-Analysis-of-Traditional-and-Digital-Data-Collection-Me.thods.pdf. Accessed 05 Feb 2020
8. Gabriel, R.A., Kuo, T.-T., McAuley, J., Hsu, C.-N.: Identifying and characterizing highly similar notes in big clinical note datasets. J. Biomed. Inform. **82**, 63–69 (2018). https://doi.org/10.1016/j.jbi.2018.04.009
9. Gokhberg, L.M.: Perspektivnaja model' gosudarstvennoj statistiki v cifrovuju jepohu [Prospective model of public statistics in digital era]. HSE, Moscow (2018). (in Russian)
10. Gubanov, D., Korgin, N., Novikov, D., Raikov, A.: E-Expertise: modern collective intelligence. Springer. Series: Studies in Computational Intelligence, vol. 558, XVIII (2014). https://doi.org/10.1007/978-3-319-06770-4
11. Hosseini, M., Faiola, A., Jones, J., Vreeman, D.J., Wu, H., Dixon, B.E.: Impact of document consolidation on healthcare providers' perceived workload and information reconciliation tasks: a mixed methods study. J. Am. Med. Inform. Assoc. **26**(2), 134–142 (2019). https://doi.org/10.1093/jamia/ocy158
12. Janssen, M., van den Hoven, J.: Big and Open Linked Data (BOLD) in government: a challenge to transparency and privacy? Government Inf. Q. **32**(4), 363–368 (2015)

13. Jaro, M.A.: Advances in record linkage methodology as applied to the 1985 census of Tampa Florida. J. Am. Stat. Assoc. **84**(406), 414–420 (1989). http://doi.org/10.1080/01621459.1989.10478785
14. Kabukye, J.K., de Keizer, N., Cornet, R.: Elicitation and prioritization of requirements for electronic health records for oncology in low resource settings: a concept mapping study. Int. J. Med. Inform. **135**, Article No. 104055 (2020). https://doi.org/10.1016/j.ijmedinf.2019.104055
15. Keil, J.M.: Efficient bounded Jaro-Winkler similarity based search. In: Grust, T., Naumann, F., Bohm, A., Lehner, W., Harder, T., Rahm, E., Heuer, A., Klettke, M., Meyer, H. (eds.) Lecture Notes in Informatics (LNI), Proceedings - Series of the Gesellschaft fur Informatik (GI), vol. 289, pp. 205–214 (2019)
16. Koneru, K., Pulla, V.S.V., Varol, C.: Performance evaluation of phonetic matching algorithms on english words and street names comparison and correlation. In: DATA 2016 - Proceedings of the 5th International Conference on Data Management Technologies and Applications, 57–64 (2016)
17. Kozlova, M.A.: Statistika kul"tury v formah statisticheskoj otchetnosti: tekushhee sostojanie i traektorii razvitija [Statistics of culture in statistical forms: current status and development trends]. Intellekt. Innovacii. Investicii **9**, 16–19 (2017). (in Russian)
18. Lazareva, M.L., Tyurina, I.V.: Finansovaja statisticheskaja otchetnost" medicinskih organizacij: sushhestvujushhie nedostatki i napravlenija optimizacii [Financial statistics of healthcare organizations: significant drawbacks and directions of optimization]. Farmakojekonomika. Sovremennaja farmakojekonomika i farmakojepidemiologija **11**(4), 61–66 (2018). (in Russian)
19. Levenshtein, V.I.: Binary codes capable of correcting deletions, insertions, and reversals. Soviet Phys. Doklady. **10**(8), 707–710 (1966)
20. Máchová, R., Lnénicka, M.: Evaluating the quality of open data portals on the national level. J. Theoretical Appl. Electron. Commerce Res. **12**(1), 21–41 (2017). https://doi.org/10.4067/S0718-18762017000100003
21. Mandal, A.K., Hossain, M.D., Nadim, M.: Developing an efficient search suggestion generator, ignoring spelling error for high speed data retrieval using double Metaphone algorithm. In: Proceedings of 2010 13th International Conference on Computer and Information Technology, ICCIT 2010, 317–320 (2010)
22. Mason-Blakley, F.: Information system hazard analysis and mitigation. In: Proceedings - 2015 IEEE International Conference on Healthcare Informatics, ICHI 2015, p. 472 (2015)
23. Mironenko, A.G., Kravets, A.G.: Automated methods of patent array analysis. In: IISA 2016 - 7th International Conference on Information, Intelligence, Systems and Applications (2016)
24. Morozov, A.N.: Al'ternativnye istochniki statisticheskoj informacii kak osnova prinjatija politicheskih reshenij [Alternative Sources of Statistical Information as the Basis for Political Decision Making]. Public Administration Issues **2**, 50–70 (2018). (in Russian)
25. Naiman, S.M.: Upravlenie othodami i problemy statisticheskogo ucheta [Waste management and statistical accounting issues]. Vestnik Permskogo nacional'nogo issledovatel'skogo politehnicheskogo universiteta. Prikladnaja jekologija. Urbanistika. **23**(3), 5–19 (2016). (in Russian)
26. OECD: Key Issues for Digital Transformation in the G20 (2017). http://www.oecd.org/G20/key-issues-for-digital-transformation-in-the-G20.pdf. Accessed on 05 Feb 2020
27. OECD: Open, Useful and Re-usable data (OURdata) Index: 2019, OECD Public Governance Policy Papers, No. 01, OECD Publishing, Paris (2020). https://doi.org/10.1787/45f6de2d-en
28. Philips, L.: Hanging on the Metaphone. Computer Language, **7**(12) (1990)
29. Santhosh Kumar, C.N., Pavan Kumar, V., Reddy, K.S.: Similarity matching of pairs of text using CACT algorithm. Int. J. Eng. Adv. Technol. **8**(6), 2296–2298 (2019)

30. Soboleva, O.V.: Cistematizacija pokazatelej vedomstvennoj statisticheskoj otchetnosti FSIN Rossii [Systematization of departmental reporting indicators in Federal Penitentiary Service]. In: VESTNIK FKU NIIIT FSIN ROSSII, pp. 135–142 (2018). (in Russian)
31. Statistisches Bundesamt. Die Bestandsmessung der Bürokratiekosten der deutschen Wirtschaft nach dem Standardkosten-Modell. Statistik und Wissenschaft, 14 (2014). https://www.destatis.de/GPStatistik/receive/DEMonografie_monografie_00000236. Accessed 05 Feb 2020. (in German)
32. UK Office of National Statistics. Data Collection Transformation Programme (2017). https://www.ons.gov.uk/aboutus/whatwedo/programmesandprojects/datacollectiontransformationprogrammedctp. Accessed 05 Feb 2020
33. United Nations. A World That Counts: Mobilising a Data Revolution for Sustainable Development (2014). https://www.undatarevolution.org/report/. Accessed 05 Feb 2020
34. UzZaman, N., Khan, M.: A Double Metaphone encoding for Bangla and its application in spelling checker. In: Proceedings of 2005 IEEE International Conference on Natural Language Processing and Knowledge Engineering, IEEE NLP-KE 2005, p. 705 (2005)
35. Winkler, W.E.: String comparator metrics and enhanced decision rules in the fellegi-sunter model of record linkage. In: Proceedings of the Section on Survey Research Methods. American Statistical Association, pp. 354–359 (1990)
36. World Bank. Digital Dividends. World Development Report. http://documents.worldbank.org/curated/en/896971468194972881/pdf/102725-PUBReplacement-PUBLIC.pdf. Accessed on 05 Feb 2020
37. World Bank. Russia Digital Economy Report. Competition in the Digital Age. Implications for the Russian Federation (2018) https://openknowledge.worldbank.org/bitstream/handle/10986/30584/AUS0000158-WP-REVISED-P160805-PUBLIC-Disclosed-10-15-2018.pdf?sequence=1&isAllowed=y. Accessed on 05 Feb 2020

So What's the Plan? Mining Strategic Planning Documents

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Abstract. In this paper we present a corpus of Russian strategic planning documents, RuREBus. This project is grounded both from language technology and e-government perspectives. Not only new language sources and tools are being developed, but also their applications to e-government research.

We demonstrate the pipeline for creating a text corpus from scratch. First, the annotation schema is designed. Next texts are marked up using human-in-the-loop strategy, so that preliminary annotations are derived from a machine learning model and are manually corrected.

The amount of annotated texts is large enough to showcase what insights can be gained from RuREBus.

Keywords: Named entity recognition · Relation extraction · Strategic planning documents

1 Introduction

Each Russian federal and municipal subject publishes several strategic planning documents per year, related to various directions of region development such as medicine, education, ecology, etc. The tasks, presented in the strategic planning documents, should meet several criteria, such as to fit into the budget and be economically sensible, be aligned with the state and local policy and satisfy the population's expectations. Modern language technology helps to assess strategic planning documents and to gain insights into the general directions of development.

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In this project, we intend to demonstrate the potential and the value of text-driven analysis when applied to strategic planning. Our approach exploits a common NLP pipeline, which involves annotation of large amount texts and training machine learning models. The most important steps of the pipeline are shown in Fig. 1. This pipeline is justified by recent success in other applications, such as processing of clinical stories [11] or statements of claim [7]. Not only we annotate a large amount of texts according to an in-house annotation scheme, but also we use a number of supervised techniques, which allow to extract high-quality information from the documents and convey a more specific and comprehensive picture of the strategic planning and its significance.

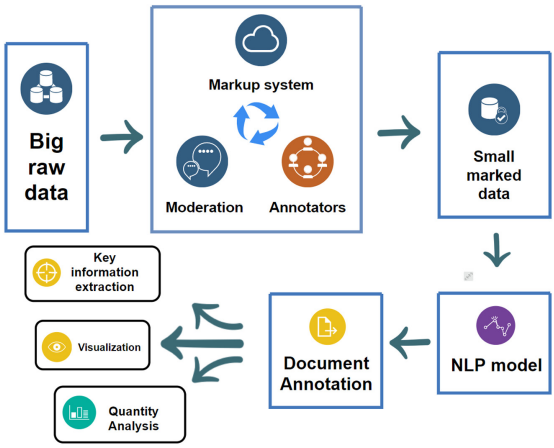

Fig. 1. Common NLP pipeline.

The government documents have not been widely subjected to processing and analysis. This means that we face a need to develop the whole domain-specific pipeline of annotation, information extraction and pre-training of language models. We showcase language technology capabilities. We present an annotation schema to markup named entities and relations, exploit active learning to annotate hundreds of documents and use state of the art methods for named entity recognition and relation extraction **to facilitate manual annotation**.

The contributions of the project are threefold. First, a new dataset is being developed, which can be used both by computer science and economics communities for further studies. Second, a number of tools for processing documents in Russian will be released. Third, the dataset will help to conduct detailed analysis of strategic documents, to compare federal subjects and administrative districts in terms of their goals and budget requirement.

2 Why We Build the Corpus

The annotation schema we have developed for this project provides a powerful tool for strategic document analysis. Indeed listing its possible applications for the domain is one of the main contributions of this paper (see Sects. 5 and 6 for details). However, what is arguably even more important from pure natural language processing perspective is that our dataset can be used as a more fitting case study for structuring unstructured information than other existing datasets. This is a rather bold claim that we intend to argue for in this section.

Structuring unstructured information or to be more specific converting data from text form into database-friendly (i.e. table) form is one of the most popular NLP business applications. Standard techniques used in order to solve this task are named entity recognition (or NER) and relation extraction (or RE). Both NER and RE are well-studied and there exist popular academic benchmarks for both tasks (CoNLL-2003 [27], ACE-2004 and ACE-2005 [8,19,28], SemEval-2010 Task 8 [10], FactRuEval-2016 [24]). There are, however, several important differences between any of aforementioned benchmarks and a typical business case dataset, the most important one being as follows.

Business case texts are usually domain-specific (e.g. legal) texts that can contain less than perfect language or other irregularities (ponderous sentences with complicated syntactic structure, slang etc.). Academic baselines, on the other hand, typically consist of well-written news or biography texts without any irregularities of this kind.

To sum up a popular perception that NER (and to lesser extent RE) is basically a solved task can potentially be to a large extent a product of existing academic benchmarks. While recent years have provided for several major breakthroughs in these tasks, results one can obtain on real-world client corpora are often much more modest than ones reported by scholars [15].

Given these considerations we decided to create a corpus closer to industrial NER and RE implementation than existing academic ones. Our corpus consists of unadopted domain-specific texts with many irregularities that can be found in practical applications. Hopefully, it can be a better benchmark for checking the suitability of a particular NER and RE model to business scenarios.

While this particular use of our corpus is not in the main focus of this paper, it was difficult for us to not provide one of our key motivations to create it.

3 Related Work

To the best of our knowledge, there are little NLP applications to the e-Government domain in general and strategic planning in particular. [3] present the only project of the unsupervised analysis of strategic planning documents. Other e-Goverment applications include processing country statements, governmental web-sites, e-petitions and other social media sources.

3.1 Processing e-government Documents

NLP methods allow to extract and structure information of governmental activity. Baturo and Dasandi [5] used topic modeling to analyze the agenda-setting process of the United Nations based on the UN General Debate corpus [18] consisting of over 7300 country statements from 1970 to 2014. In [22] Shen et al. explored Web data and government websites in Beijing, Shanghai, Wuhan, Guangzhou and Chengdu to conduct comparative analysis on the development of the five metropolia e-governments. Albarghothi et al. [2] introduced an Automatic Extraction Dataset System (AEDS) tool that constructs an ontology-based Semantic Web from Arabic web pages related to Dubai's e-government services. The system automatically extracts textual data from the website, detects keywords, and finally maps the page to ontology via Protégé tool.

3.2 Processing Petitions

NLP methods are widely used to aggregate and summarize public opinion, expressed in the form of electronic petitions. The concept of e-democracy implicates open communication between government and citizens, which in most cases involves the processing of a large amount of unstructured textual information [20]. Rao and Dey describe the scheme of citizens' and stakeholders' participation in Indian e-governance which allows the government to collect feedback from citizens and correct policies and acts according to it.

Evangelopoulos and Visinescu [9] analyze appeals to the U.S. government, in particular, SMS messages from Africans, sent during Barack Obama's visit to Ghana in July 2009 and data from SAVE Award - initiative, aiming to make the U.S. government more effective and efficient at spending taxpayers' money. For each of the corpus, authors extracted key topics with Latent Semantic Analysis (LSA) to explore trends in public opinion.

Suh et al. [26] applied keyword extraction algorithms based on $tf - idf$ and k-means clustering to detect and track petitions groups on Korean e-People petition portal. To forecast the future petition trends, radial basis function neural networks were us.

3.3 Processing Russian Documents

Metsker et al. [17] process almost 30 million of Russian court decisions to estimate the effectiveness of legislative change and to identify regional features of law enforcement. Alekseychuk et al. [3] use such unsupervised techniques as topic modelling and word embeddings to induce a taxonomy of regional strategic goals, extracted from strategic documents. This study motivated us to deep into the corpus of strategic documents. Our work extends this project, as we annotate the corpus with a detailed relation scheme. This allows of more detailed analysis.

4 Corpus Annotation Pipeline

4.1 Annotation Guidelines

We develop guidelines for entity and relation identification in order to maintain uniformity of annotation in our corpus [12]. Figure 2 presents annotation interface for assigning entities and relations.

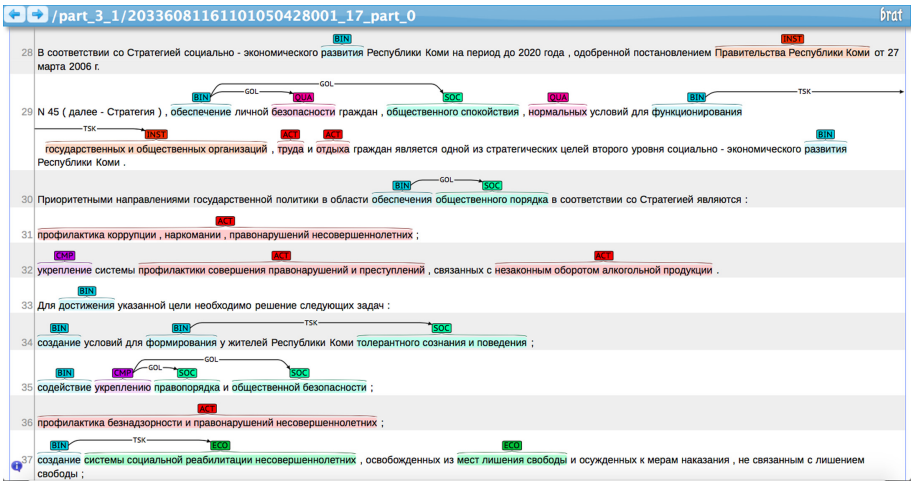

Fig. 2. Annotation interface for assigning entities and relations.

We define eight types of entities: 1. `MET` (metric) 2. `ECO` (economics) 3. `BIN` (binary) 4. `CMP` (compare) 5. `QUA` (qualitative) 6. `ACT` (activity) 7. `INST` (institutions) 8. `SOC` (social)

These entities associated with 11 semantic relations of 5 types: 1. Current situation: (a) Negative `NNG` (Now NeGative) (b) Neutral `NNT` (Now NeutTral) (c) Positive `NPS` (Now PoSitive) 2. Implemented changes/results (about the past): (a) Negative `PNG` (Past Negative) (b) Neutral `PNT` (Past NeutTral) (c) Positive `PPS` (Past PoSitive) 3. Forecasts: (a) Negative `FNG` (Future NeGative) (b) Neutral `FNT` (Future NeutTral) (c) Positive `FPS` (Future PoSitive) 4. `GOL` (abstract goals) 5. `TSK` (specific tasks).

All annotations were obtained using a Brat Rapid Annotation Tool (BRAT) [25]. Each document in the corpus was annotated by two annotators independently, while disagreements were resolved by a moderator. All annotation instructions are available at the GitHub repository[1]. Below we present description of entity types.

4.2 Entity Descriptions

`BIN` is a one-time action or binary characteristic. These entities represents one-time events such as construction, development, stimulation, formation, implementation, acquisition, involvement, absence, diversification, modernization, etc.

[1] https://github.com/dialogue-evaluation/RuREBus.

MET entity is a numerical indicator or object on which a comparison operation is defined. In particular, these entities often describe labor productivity, planned and actual values of indicators, seismicity of a territory, the probability of a violation, economic growth, the degree of deterioration of a building, etc.

QUA represents a quality characteristic. Annotators were asked to identify spans of texts such as *high*, *ineffective*, *limited*, *big*, *weak*, *safe* as QUA entities.

CMP represents a comparative characteristic. Annotators were asked to identify spans of texts as CMP entities, associated with increasing, saturation, increasing decrease, activation, exceeding indicators, positive dynamics, improvement, expansion.

SOC is an entity related to social rights or social amenities. SOC entities other describe country population, housing quality, social protection, leisure activities, historical heritage, folk art, terms related to social rights or social amenities, etc.

INST entities represent various institutions, structures and organizations. In particular, annotators were asked to mark cultural and leisure facilities, family and child support organizations, cultural center as INST.

ECO is defined as an economic entity or infrastructure object. Entities of this type are associated with biological resources, innovative potential, domestic market, regional economy, energy balance, budget financing, fishing fleet, roads, library and museum funds, etc.

ACT is an event or specific activity. These entities are often combined with BIN, e.g., *launched an educational project*, where *launched* is marked as BIN and an *educational project* as ACT. Entities of this type are associated with events like drug addiction prevention, orphan prevention, educational projects, psychological assistance.

4.3 Relations Descriptions

GOL represents aims and goals of program. It is used to describe changes and objective that are expected to be achieved as the results of actions, proposed by the program.

TSK denotes concrete actions planned by the program. Main difference between TSK and GOL is that the later one describe "what" the program aims to achieve and the first one state "how" it will be done.

The other nine relations are designed to describe perceptions of the present, past and future state of affairs. Past relations (PPS, PNG, PNT) describe the previous situation. Respectively present relations (NPS, NNG, NNT) present current situation. Last triplet (FPS, FNG, FNT) predicts trends, metrics or consequences of the program in a long-term perspective.

Table 1 presents examples of annotated relations.

Table 1. Examples of annotated relations.

Entity	Example (ENG)	Example (RU)
GOL	CMP improving SOC public health	CMP укрепление SOC здоровья населения
TSK	BIN halting ECO drug trafficking	BIN пресечение ECO нарко трафика
FPS	CMP reduction of MET mortality rate	CMP снижение MET уровня смертности

4.4 Active Learning

We also employ active learning technique [23]. Previously we obtained a subset of our corpus marked with this set of named entities and relations. Then we trained NER model and use it to markup unlabeled documents. Than documents were edited by annotators and verified by moderators. After that obtaining new part of final corpus model were retrained with this part added to training set.

In this work we employ NER model, namely char-CNN-BiLSTM-CRF (proposed by Lample et al. [14] and further developed by Ma and Hovy [16]). This architecture is widely used as a robust baseline in sequence tagging tasks. We use FastText [6] embeddings trained by RusVectores [13]. For relation extraction we also employ morphological, syntactical and semantical features, obtained from Compreno [4,29] and some hand-made features, such as capitalization templates and dependency tree distance between relation members.

5 How to Utilize Named Entities

In this and the following sections we provide an in-depth analysis of the annotated corpus and showcase applications of textual analysis, based on the proposed annotation schema. We start with the description of annotated entities and provide insights into strategic planning based on entity-level analysis. Than we take the analysis to the next level and explore relations between entities and the way the relations help to structure information from strategic documents.

5.1 Basic Statistics

Table 2. Statistics of annotated entities.

	Total	Mean len (std)
BIN	14236	1.05 (0.28)
MET	6377	4.23 (3.50)
QUA	3611	1.14 (0.52)
CMP	4149	1.16 (0.78)
SOC	5037	2.77 (2.31)
INST	3756	3.69 (2.81)
ECO	11422	2.78 (2.19)
ACT	5800	4.74 (4.57)

In this section we provide basic statistics based on annotated entities. There are 188 annotated documents in the training set, average number of named entities in document is 289, mean document length is 1787 tokens. All token-based statistics were obtained using razdel tokenizer.[2] (Table 2)

[2] https://github.com/natasha/razdel.

Named entity types are highly imbalanced, which may lead to significant problems when training classifier. However, we believe that proposed corpus design represents real-life situation well. These difficulties should inspire researches to invent more sophisticated solutions, rather than prevent them from approaching the task.

5.2 Named Entity Clustering

The main part of RuREBus are annotations of named entities. The types of the entities (such as 'activity' or 'institution') are quite broad to perform strategic analysis and planning. Clustering of entities into fine-grained subsets of entities that represent some concept, could be more useful in specific practical applications. Therefore, in this section we show how to use a simple technique to investigate find semantically related subgroups of named entities. For instance, a cluster of entities may represent a specific social-oriented measures (such as 'prevention of drug usage in youth'). We demonstrate how to use modern natural language processing methods to find semantic clusters of annotations.

The clustering procedure consists of the following steps. First, we preprocess texts: all textual representations of entities are lowercased and duplicates are removed. Then, we represent each entity with a vector, or embedding. Finally, we applied k-means algorithm to find clusters.

The steps above a applied to each entity type separately. In the second step we represent each named entity with a vector. The vector (embedding) for each named entity has 1024 numbers. The vector representations for named entities were calculated using a combination of the FastText model pre-trained on Russian Wikipedia, and a bidirectional LSTM model (both models are implemented in the Flair library [1]).

In the last step we use embeddings to find clusters. This step is performed by the k-means clustering algorithm. Number of clusters is a very important parameter; it varies dramatically from one type of entity to another. For example, entities of the `QUA` and `CMP` types have fewer subgroups variants. Hence, a reasonable number of clusters (N) for these types is smaller ($N = 10$) than for `ECO` or `MET` ($N = 50$). To select number of clusters we use classical silhouette analysis [21]; k-means clustering was performed by open-source library (scikit-learn).

In the rest of the section we briefly discuss the results of clustering. To represent results, we make use of a visualisation of a small fraction of the clusters (only 6 clusters are show in Fig. 3). One can see that entities have been clustered in different groups.

We analyzed in details clusters derived within the `SOC` type. These clusters have complex structures, e.g. they contain closely related entities ('youth', 'health of youth', 'patriotic education of youth'), hierarchies of entities ('family', 'youth family', 'single parent youth family') as well as subgroups of opposite entities ('unity of the Russian nation' and 'separatism'). This gives an interesting insight on how regions view the concept of youth and related entities in their strategic programs. Moreover, one can use the clusters to separate different

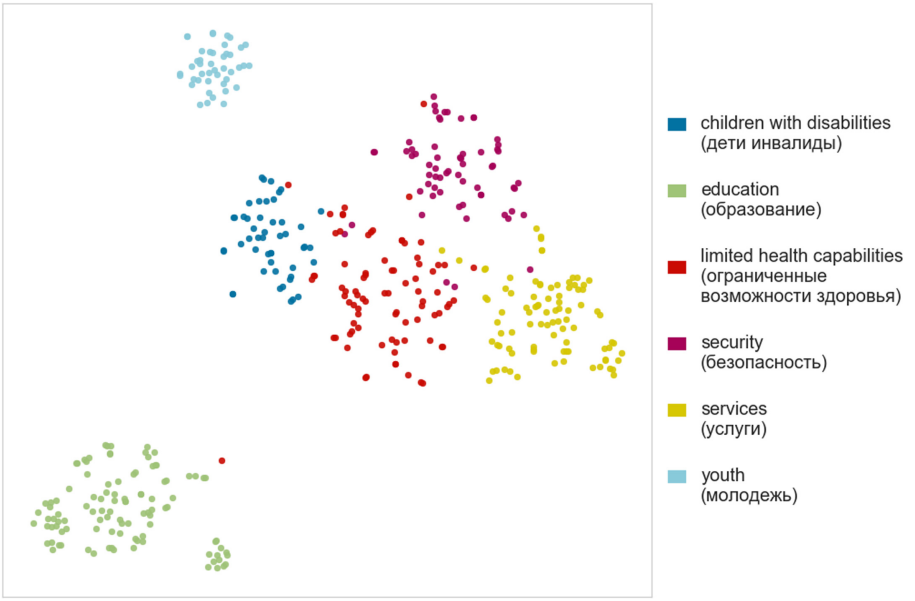

Fig. 3. Projection of 6 clusters obtained for the SOC type (each color represents a cluster of named entities).

subtypes of relations, e.g. goals (GOL) related to the 'Family' cluster in a specific region of Russia. The following list represents an example of top entities in a cluster related to 'Youth':

- *"patriotic education of children and youth"* (*патриотического воспитания детей и молодежи*);
- *"self-realization of children and youth"* (*самореализации детей и молодежи*);
- *"education of the younger generation and youth"* (*воспитания подрастающего поколения и молодежи*);
- *"self-realization of youth"* (*самореализации молодежи*).

Similar structures can be found in other typical clusters that make the whole corpus a very interesting resource for social, economic and geographic studies.

Finally, we list types of named entities along with clusters, which were found. The clusters clearly correspond to the intended meaning of the entity types (Table 1) and enable a detailed analysis of the annotated documents.

5.3 What actions are Being Taken?

ACT is an entity that describes what actions should be taken in order to complete the tasks and to reach the goals. We can think of two scenarios for action-based analysis. First, we presume that all actions are planned more or less in the

Table 3. Typical clusters for entity types.

Entity	Cluster names
BIN	Done, Impossible, Negotiation, Creation, Improvement, Change, Necessity, ...
ACT	Programs and Events, Management, Organization, Support, Repair, ...
MET	KPIs, Quantity, Effectiveness, Extent, Level, ...
QUA	Positive, Negative, Insufficient, Significant, Redundant, ...
CMP	Increasing, Decreasing, More than/Less then, Negative dynamics, ...
SOC	Demographic trends, Education, Science, Culture, Sport, Family, ...
INST	Enterprises, Departments, Regions, Executive authorities, ...
ECO	Industries, Innovations, Budgets, Taxes, Infrastructure, Energy, ...

same fashion by different regions, as there are a lot of common goals. However, there might be some unique actions, such as "creation of Cossack youth centers" (*создание казачьих молодежных центров*), which either reveal some specific needs of the region or unreasonable expenses. Second, we can estimate the cost of actions, based on data of previous years. This will enable on the fly evaluation of the strategic program budget (Table 3).

6 How to Utilize Relation

6.1 Basic Statistics

In Table 4, one can observe a number of relation occurrences based on the training set. Average amount of relations in document is 67. We also calculated a mean number of tokens between named entities spans participated in relation and the result is 0 for almost all relation types.

Table 4. Relation statistics.

RE	Total	RE	Total	RE	Total
GOL	3563	TSK	4613		
NPS	755	NNG	844	NNT	534
PPS	528	PNG	84	PNT	190
FPS	1167	FNG	229	FNT	141

6.2 Is Change Always Good?

Some types of relations allow us to evaluate ongoing changes. Positive assessments of changes are expressed by `NPS` and `PPS` relations. For example, `NPS(CMP, MET)`: "decrease" (*снижение*) – "gas prices" (*цен на бензин*) or `PPS(CMP, MET)`: "increased" (*увеличивались*) – "cash income of the population" (*денежные доходы населения*).

Negative assessments are expressed by `NNG` and `PNG` relations. For example, `NNG(MET, QUA)`: "the housing cost" (*стоимость жилья*) – "high" (*высокая*) or `PNG(MET, CMP)`: "the population size" (*численность населения*) – "decreased" (*сократилась*).

Neutral assessments of changes are expressed by `NNT` and `PNT` relations. For example, `NNT(SOC, QUA)`: "quality of life" (*качество жизни*) – "fair" (*удовле- творительное*) or `PNT(BIN, ECO)`: "the investment project" (*инвестиционный проект*) – "developed" (*разработан*).

The texts of the collection contain assessments of qualitative changes (i.e. a situation is compared between the past and the present) or assessments of the current state of affairs without comparison with the past. Therefore, entities involved in these relations are usually of `CMP` or `QUA` type.

An analysis of such relations could be useful for strategic planning of social and economic development of the country's regions. Such relations make it possible to judge how the implemented changes actually affect the life of society. However, it should be noted that assessments are subjective, and do not always coincide with the conventional wisdom.

6.3 Do the Tasks Meet the Goals?

Goals and tasks necessary to achieve the goals are expressed as relations between entities. We consider binary relations only, which allow to relate two entities. For example, a `goal` can be expressed as a relation between a `CMP` entity and a `MET` entity: "improvement" (*повышение*) – "accessibility of transport" (*доступность транспорта*). A `task` can be expressed as a relation between a `BIN` entity and an `ECO` entity: "commissioning" (*ввод*) – "new metro lines" (*новые линии метро*).

The presence of goals and tasks, expressed as fragments of text, allows us to measure the similarity between them. Different similarity types can be considered:

1. co-occurrence frequency: if a goal and a task are frequently used in the same documents, there is a strong association between them.
2. semantic similarity: if a goal and a task consists of words, that share similar meaning, such as "transport" (*транспорт*) and "metro lines" (*линии метро*), there is a semantic association between them.
3. topic similarity: if a goal and a task belong to the same topic, such as the goal "road development" (*развитие дорожной сети*) and the task "reduction in the number of road accidents" (*снижение числа дорожно-транспортных происшествий*) belong to the same topic, related to "transport".

Table 5. Analysis of done work to planned ratio analysis.

Republic, Region	Done work to plans ratio
Komi Republic, Pechora Municipal District	0.596
Ryazan Region, Mikhailovsky Municipal District	0.523
...	...
Voronezh Region, Khlebenskoe	0.06
Moscow Region, Dmitrovsky	0.02

Measuring similarity helps to reveal whether the goal was split into tasks reasonably. If a there no tasks, similar to the stated goal, the achievement of this goal in practice becomes unlikely. The opposite might be the case, too: the absence of similar tasks reflects unrealistic goals.

At the same time, being able to extract all tasks, may help to group them according to similarity measures, to find similar or even overlapping tasks and than to order them according to their complexity or urgency (Table 5).

We can employ the similarity measures mentioned above to align goals and tasks declared by federal and municipal subjects. The goal declared by a federal subject may be supported by smaller goal declared by its subdivisions, namely, municipal subjects. Although it is not necessary for all municipal subjects to share goals, the absence of common goals can reveal potential managerial and administrative weaknesses.

At the same time goals declared by municipal subjects should follow the main development direction. If the average similarity between the goals declared on different levels is low, it means that the region lacks coherent coordination of planning authorities.

To conclude with, the analysis of `goal` and `task` relations can be used in several ways. It can be applied both to a single strategic document and to multiple strategic documents, prepared in a region. In the first case, the relation analysis can help to structure goal setting along with goal decomposition and task prioritization. In the second case the relation analysis allows to discover coherence problems between different levels of subdivisions.

6.4 Temporal Analysis of `past` and `present` Relations

The time component of extracted relations (current state/implemented changes/forecasts) allows us to measure the proportion of the work done to the planned work, in other words, understand whether a document contains a report on the work done rather than a plan for future work. Such a simple metric can monitor whether there is any success in reaching goals within a region over years, or documents contain only plans.

Furthermore, we can match forecasts from previous years' plans with the descriptions of implemented changes of current year to check whether the plans were implemented or not.

Altogether, we can automatically calculate the percentage of goals stated in previous years and achieved this year. In addition, we could observe the tendencies in some key metrics over time and regions from current state relations, for example, how the youth crime level has changed in some region during the last 5 years.

7 Conclusion

The exponential growth in the volume of information overwhelms many domains of human activity, including state regulation and planning. As government documents exist in the form of written text, the role of language technology is increasingly important. In this paper we showcase two well-known tasks, named entity recognition (NER) and relation extraction (RE), formulated for the strategic planning domain.

In this on-going project we intend to carry out the full cycle of language technology development: we start from raw texts, elaborate an annotation schema, annotate hundreds of documents with the help of human-in-the-loop approach, train domain-specific models for the tasks under consideration. Finally, we design a few analytical applications, which demonstrate the relevance and validity of the designed language resource. Not only we managed to implement the whole NLP pipeline for a novel application, but also we have shown that governmental documents can be subjected to computational analysis. Future research of strategic planning and e-Goverment would be able to benefit from the developed methods and tools as we release all results and code in open access. These cab be used to extract knowledge and gain insights from strategic planning documents or can be applied to other domains.

The future work directions reflect the rapid development of language technology. A large language model may be trained on the strategic documents and enhance the quality of downstream tasks, NER and RE. The project may benefit from recent cross-lingual methods as this would allow to conduct comparison between strategic planning in different countries.

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References

1. Akbik, A., Blythe, D., Vollgraf, R.: Contextual string embeddings for sequence labeling. In: COLING 2018, 27th International Conference on Computational Linguistics, pp. 1638–1649 (2018)
2. Albarghothi, A., Saber, W., Shaalan, K.: Automatic construction of e-government services ontology from Arabic webpages. Procedia Comput. Sci. **142**, 104–113 (2018)

3. Alekseychuk, N., Sarkisyan, V., Emelyanov, A., Artemova, E.: Processing and analysis of Russian strategic planning programs. In: Alexandrov, D.A., Boukhanovsky, A.V., Chugunov, A.V., Kabanov, Y., Koltsova, O., Musabirov, I. (eds.) DTGS 2019. CCIS, vol. 1038, pp. 68–81. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-37858-5_6
4. Anisimovich, K., Druzhkin, K., Minlos, F., Petrova, M., Selegey, V., Zuev, K.: Syntactic and semantic parser based on abbyy compreno linguistic technologies. In: Computational Linguistics and Intellectual Technologies: Proceedings of the International Conference "Dialog" [Komp'iuternaia Lingvistika i Intellektual'nye Tehnologii: Trudy Mezhdunarodnoj Konferentsii "Dialog"], Bekasovo, Russia, vol. 2, pp. 90–103 (2012)
5. Baturo, A., Dasandi, N.: What drives the international development agenda? An NLP analysis of the united nations general debate 1970–2016. In: 2017 International Conference on the Frontiers and Advances in Data Science (FADS), pp. 171–176. IEEE (2017)
6. Bojanowski, P., Grave, E., Joulin, A., Mikolov, T.: Enriching word vectors with subword information. Trans. Assoc. Comput. Linguist. **5**, 135–146 (2017)
7. Dale, R.: Law and word order: NLP in legal tech. Nat. Lang. Eng. **25**(1), 211–217 (2019)
8. Doddington, G., Mitchell, A., Przybocki, M., Ramshaw, L., Strassel, S., Weischedel, R.: The automatic content extraction (ACE) program - tasks, data, and evaluation. In: Proceedings of the Fourth International Conference on Language Resources and Evaluation (LREC 2004), Lisbon, Portugal. European Language Resources Association (ELRA), May 2004. http://www.lrec-conf.org/proceedings/lrec2004/pdf/5.pdf
9. Evangelopoulos, N., Visinescu, L.: Text-mining the voice of the people. Commun. ACM **55**(2), 62–69 (2012)
10. Hendrickx, I., et al.: SemEval-2010 task 8: Multi-way classification of semantic relations between pairs of nominals. In: Proceedings of the 5th International Workshop on Semantic Evaluation, Uppsala, Sweden, pp. 33–38. Association for Computational Linguistics, July 2010. https://www.aclweb.org/anthology/S10-1006
11. Holderness, E., Yepes, A.J., Lavelli, A., Minard, A.L., Pustejovsky, J., Rinaldi, F.: Proceedings of the Tenth International Workshop on Health Text Mining and Information Analysis (LOUHI 2019). In: Proceedings of the Tenth International Workshop on Health Text Mining and Information Analysis (LOUHI 2019) (2019)
12. Ivanin, V., Artemova, E., Batura, T., Ivanov, V., Sarkisyan, V., Tutubalina, E., Smurov, I.: Rurebus-2020 shared task: Russian relation extraction for business. In: Computational Linguistics and Intellectual Technologies: Proceedings of the International Conference "Dialog" [Komp'iuternaia Lingvistika i Intellektual'nye Tehnologii: Trudy Mezhdunarodnoj Konferentsii "Dialog"], Moscow, Russia (2020)
13. Kutuzov, A., Kuzmenko, E.: WebVectors: a toolkit for building web interfaces for vector semantic models. In: Ignatov, D.I., et al. (eds.) AIST 2016. CCIS, vol. 661, pp. 155–161. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-52920-2_15
14. Lample, G., Ballesteros, M., Subramanian, S., Kawakami, K., Dyer, C.: Neural architectures for named entity recognition. In: Proceedings of the 2016 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, San Diego, California, pp. 260–270. Association for Computational Linguistics, June 2016. https://www.aclweb.org/anthology/N16-1030

15. Lin, Y., Liu, L., Ji, H., Yu, D., Han, J.: Reliability-aware dynamic feature composition for name tagging. In: Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics, Florence, Italy, pp. 165–174. Association for Computational Linguistics, July 2019. https://doi.org/10.18653/v1/P19-1016
16. Ma, X., Hovy, E.: End-to-end sequence labeling via bi-directional LSTM-CNNS-CRF (2016)
17. Metsker, O., Trofimov, E., Grechishcheva, S.: Natural language processing of Russian court decisions for digital indicators mapping for oversight process control efficiency: disobeying a police officer case. In: Chugunov, A., Khodachek, I., Misnikov, Y., Trutnev, D. (eds.) EGOSE 2019. CCIS, vol. 1135, pp. 295–307. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-39296-3_22
18. Mikhaylov, S., Baturo, A., Dasandi, N.: United nations general debate corpus (2017). https://doi.org/10.7910/DVN/0TJX8Y
19. Mitchell, A., Strassel, S., Huang, S., Zakhary, R.: ACE 2004 multilingual training corpus (2005). https://catalog.ldc.upenn.edu/LDC2005T09
20. Rao, G.K., Dey, S.: Decision support for e-governance: a text mining approach. arXiv preprint arXiv:1108.6198 (2011)
21. Rousseeuw, P.J.: Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. J. Comput. Appl. Math. **20**, 53–65 (1987)
22. Shen, Y., Liu, Z., Luo, S., Fu, H., Li, Y.: Empirical research on e-government based on content mining. In: International Conference on Management of e-Commerce and e-Government, 2009. ICMECG 2009, pp. 91–94. IEEE (2009)
23. Shen, Y., Yun, H., Lipton, Z.C., Kronrod, Y., Anandkumar, A.: Deep active learning for named entity recognition. CoRR abs/1707.05928 (2017). http://arxiv.org/abs/1707.05928
24. Starostin, A., et al.: Factrueval 2016: Evaluation of named entity recognition and fact extraction systems for russian. In: FactRuEval 2016: Evaluation of Named Entity Recognition and Fact Extraction Systems for Russian, pp. 688–705 (2016)
25. Stenetorp, P., Pyysalo, S., Topić, G., Ohta, T., Ananiadou, S., Tsujii, J.: Brat: a web-based tool for NLP-assisted text annotation. In: Proceedings of the Demonstrations at the 13th Conference of the European Chapter of the Association for Computational Linguistics, pp. 102–107. Association for Computational Linguistics (2012)
26. Suh, J.H., Park, C.H., Jeon, S.H.: Applying text and data mining techniques to forecasting the trend of petitions filed to e-people. Expert Syst. Appl. **37**(10), 7255–7268 (2010)
27. Tjong Kim Sang, E.F., De Meulder, F.: Introduction to the CoNLL-2003 shared task: Language-independent named entity recognition. In: Proceedings of the Seventh Conference on Natural Language Learning at HLT-NAACL 2003, pp. 142–147 (2003)
28. Walker, C., Strassel, S., Medero, J., Maeda, K.: Ace 2005 multilingual training corpus (2006). https://catalog.ldc.upenn.edu/LDC2006T06
29. Zuev, K.A., Indenbom, M.E.J.M.V.: Statistical machine translation with linguistic language model. In: Computational Linguistics and Intellectual Technologies: Proceedings of the International Conference "Dialog" [Komp'iuternaia Lingvistika i Intellektual'nye Tehnologii: Trudy Mezhdunarodnoj Konferentsii "Dialog'], Bekasovo, Russia, vol. 2, pp. 164–172 (2013)

On the Legal Issues of Face Processing Technologies

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Abstract. The article analyzes the problems and prospects of using recognition technologies for human faces. The authors note that their development over recent years brings together the problems of the right to a personal image and the right to privacy, enshrined in the constitutions of most democratic countries. This is due to the fact that these technologies make it difficult, and, in some cases, impossible (or inappropriate) to use traditional legal mechanisms to protect these rights. In this regard, the authors propose to extend the concept of personal integrity to the "digital forms of existence" of an individual reflected in personal images, videos, virtual accounts, etc.

The authors propose to put some approaches formulated in the article as the basis of the legal regulation of the use of facial processing technologies. In particular, there should be a legislative ban on the development and use of programs and systems that search and process photo and video images that are not publicly available, and legal liability measures should be established for its violation. On the contrary, a person's posting of such information in the public domain should be interpreted as his consent to their search and comparison.

Otherwise, issues should be resolved with the processing of photo and video images, as a result of which they are subjected to various kinds of distortions. Although the prohibition on creating such fakes is unreasonable, their publication and distribution may be restricted by law.

Keywords: Image processing · Face recognition technology · Deepfake · Personal data · Privacy law · Defense of honor and dignity · Total surveillance · E-government · Law transformation

1 Introduction

Over the past decade, Facial Recognition Technology (FRT) has gone through the final stages of its revolutionary development.

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A group of methods for preliminary processing of images in order to ensure invariance to changes in angle, scale, lighting, etc. develops for a long time and quite successfully [1–3]. In particular, scale invariance is inherent in high-order neocognitrons and neural networks [2, 4]. The problem of changes in orientation, angle, image displacement is overcome by highlighting areas of the face that are not subject to such changes [1, 5, 6].

Image comparison algorithms are being improved. The group of classical methods (elastic graph matching, hidden Markov models method [3], neural networks algorithms, principal component analysis – Eigen Face Method [7] and Fisher faces [2]) is supplemented by modern variations and new algorithms. Among them are Gabor wavelet [8], infrared analysis (it happens by analyzing the temperature generated by blood vessels under the facial skin) [9], 3D model analysis [10] and others. A good overview of recognition methods is presented in [11] and [12]. In [13], a literature review is carried out related to the advantages and disadvantages of recognition methods in practical areas, such as forensics, security control, automated surveillance systems, victim and missing-person identification and so on.

Significant assistance in training and testing recognition systems is provided by large-scale annotated face libraries from various developers, and methodologies for evaluating recognition algorithms based on them. Examples include FERRET, ORG, MALF, AFL [14, 15] and others.

As a result, there was a transition of quantity into quality. A significant amount of "building material" (algorithms, libraries, collections of images intended for training) is presented on the market. Every day there are new services, programs and information systems designed to identify individuals. Today, their capabilities depend not so much on the technologies used as on the volumes of available data for recognition – both primary, containing unrecognized images and video recordings (for example, from surveillance cameras), as well as processed, marked and identified data. Moreover, in the world of "big data" the availability of the most complete databases to a wide number of developers is only a matter of time.

The development of these technologies brings together the problems of the right to a personal image and the right to privacy, enshrined in the constitutions of most democratic countries. This is due to the fact that the indicated "transfer of quantity into quality" makes the use of traditional legal mechanisms for protecting these rights difficult, and, in some cases, impossible (or impractical). Creation of digital images of persons, their tracking in real time, etc. generate new legal facts that create, modify and terminate legal relations. All this testifies to the transformation of law under the influence of modern digital technologies, requiring lawyers to respond adequately to it.

Attention to legal problems associated with the creation and use of the systems in question is observed in numerous publications on jurisprudence, sociology, and philosophy. Among the issues that researchers are most worried about are privacy and compounding consumer risks [16], protection of civil rights [17], trends in building a total surveillance society [18], face recognition technology in the service of criminal elements, etc. The most complete review of the literature on this problem is presented in [19].

2 FRT and Civil Rights: Key Trends

Face recognition technologies today are part of regularly used biometric methods that automatically recognize a person based on his physical, biological or behavioral characteristics [20]. Since 2002, biometrics has been recognized as the main method of identification in documents standardized by the International Civil Aviation Organization (ICAO) at the UN. ICAO member countries accept FRT as the main and mandatory method of identification (which can be supplemented at the discretion of identification using fingerprints, scanning the iris, etc.) [20, 21].

Government agencies around the world use surveillance cameras in crowded areas, using automatic facial recognition technologies to identify and track individual movements: to control migration [22], search for offenders, check compliance with restrictions on movement (for example, to prevent the spread of an epidemic), etc. Intelligent face recognition systems are designed to ensure the detention of persons who have a ban on visiting certain places immediately upon their detection: "this will lead to the effective execution of this type of punishment, thereby preventing their new offenses" [23, 24]. In the infrastructure of the information society, face recognition technologies are gradually finding everyday application in the accounting systems of "electronic government", with the functioning of "smart cities", etc., as well as in critical situations for finding people during riots or disasters.

With the growth of the analytical potential of face recognition technologies and the expansion of their fields of application, the threat of violation of citizens' rights is becoming increasingly relevant and alarming. We are concerned about large-scale state projects to create biometric data bases (primarily personal images) without sufficient legal and procedural guarantees for their use. Threatening trends are intensifying, such as the practice of mass tracking, access to user data held by commercial enterprises; securing the obligations of telecommunication companies in various states to store data on user communications for a long period of time [25], attempts to weaken encryption and anonymity at the state level, and the exchange of intelligence data. The risks of hacking biometric databases both from public services and ordinary offenders are increasing [22].

Almost any state today can establish total control over a person's life, tracking every step of it through video cameras and other devices. For example, thanks to installed video cameras and a report by the US investigating authorities based on a transcript of the records, the whole world learned about the last three days of the life of Mikhail Lesin, the former Minister of the Russian Federation [28].

Of course, total control over a particular person or group of persons may be objectively necessary, for example, to prevent their illegal activities. However, at the same time, the use of face recognition technologies, coupled with other modern technologies, gives the state (and in some cases private companies) serious opportunities for invading the privacy of citizens.

The right of citizens to the inviolability of personal and family life is guaranteed not only by constitutional acts of most countries of the world, but also by international legal documents, including, for example, the Universal Declaration of Human Rights (Article 12) [29], the International Covenant on Civil and Political Rights (art. 17) [30] and the European Convention for the Protection of Human Rights and Fundamental

Freedoms (art. 8) [31]. The UN General Assembly, in its Resolution of December 18, 2013 No. 68/167 "The right to privacy in the digital age", expressed concern about new technologies for tracking citizens, urging all states to respect and protect the right to privacy, including context of digital communication.

Meanwhile, FRT development trends provide an opportunity to significantly reduce the citizen's privacy. With their help, the state can track the movement of a citizen, identify their habits, desires, circle of acquaintances and much more. Thanks to this, government officials can collect information about a person's actions, which, while not being formally unlawful, can, during disclosure, have the most detrimental effect on his life (about love affairs; social habits, certain diseases, etc.). It is quite obvious that such a "dossier" can be used to denigrate the opponents of the regime, blackmail them, etc. It should not be forgotten that information collected by the state about the personal lives of citizens can fall into private hands.

It is logical that the trend of restricting the use of face recognition technologies arises in a number of democratic countries. So, in 2019, San Francisco imposed a complete ban on the use of FRT by the police and other municipal services to counter potential abuse [32]. In October 2019, the forty largest world music festivals promised to abandon the use of this technology [33]. A lawsuit was filed against the developer of the Clearview AI application, widely used by US law enforcement to identify suspects. The complaint notes that the defendant "without obtaining any consent and without notice" used the Internet to covertly collect information about millions of American citizens. He downloaded about three billion photographs, and then used artificial intelligence algorithms to scan the geometry of the faces of each person depicted in the photographs [34]. According to human rights defenders, the method itself violates many privacy laws.

At the same time, in other countries the opposite trend is observed, aimed at building a system of total control. So, in China, personal space is steadily narrowing. In secondary schools, an experiment is being conducted on equipping classes with smart cameras, which can determine not only what the student is doing, but also his psycho-emotional state by facial expression [35]. A full-fledged system of "social rating" and continuous monitoring has been established for Uyghurs in the Xinjiang Uygur Autonomous Region of China. According to press reports, China has become the first country to use this technology for video surveillance of people based on ethnicity: "just like the recognition system tags "rec_female" or "rec_sunglasses", it also tags "rec_uygur". If one Uigur lives near the place of installation of the CCTV camera and, say, six Uighurs come to him within 20 days, the system will send an alarm notification to the police" [36].

It seems extremely controversial to introduce a moratorium on a certain group of data processing methods and declare them to be obviously illegal. We think so, not only because these methods are widely and effectively used "for peaceful purposes", but also because, according to the extremely accurate statement of Bruce Schneier, "attention to one specific identification method distracts from the nature of that observation society, … where the widespread mass surveillance is becoming the norm" [18]. Face recognition technologies are only a small part of the total surveillance system, in which identification is only the first step in the further processes of correlation and discrimination. It is important for companies and governments to distinguish between people in order to treat them differently (this includes displaying various advertisements, offering different

tariffs for services, and the special attitude of the state, for example, to persons identified as demonstrators).

3 FRT Legal Perspectives

Considering the prospects of legal regulation of the massive use of recognition technologies, first of all, we pay attention to the fact that they are currently used to identify and search for people both in the real world and in the virtual space. So, the Clearview AI mentioned above searches for photos of faces exclusively on an open network. The website of the service emphasizes that Clearview AI cannot search for any personal or protected information, including in personal accounts on social networks [37]. Thus, it allows the comparison and identification of photographs of a specific person with photographs and fragments of videos posted on the Internet. This allows you to get some information about the person, but the amount of such information depends on how much it is posted in open sources.

Clearview AI is not unique in this quality: services such as PimEyes, Searchfaces, popular search engines Google, Baidu, Yandex, etc. have similar functionality. Using them in some cases allows you to fully or partially deanonymize a person.

It must be said here that issues of anonymity on the Internet are reflected, in particular, in the Declaration on the Freedom of Communication on the Internet [38]. The Declaration, in particular, states that "Member States must respect the desire of Internet users not to reveal their identities. This does not prevent Member States from taking measures and cooperating with a view to identifying the perpetrators of criminal acts in accordance with national law, the Convention for the Protection of Human Rights and Fundamental Freedoms and other international agreements between law enforcement and justice authorities".

Thus, according to this document, states should not limit anonymity on the Internet to any legislative prohibitions and / or software and hardware. At the same time, they also have no obligation to protect this anonymity, deanonymization is permissible and appropriate for combating crime. From this perspective, the use of Clearview AI by law enforcement agencies seems to be quite normal.

Of course, deanonymization of persons through the use of photo recognition technology on the Internet itself can be used for illegal purposes. For example, such a scheme is used on dating sites - after obtaining a photograph of a married person and placing an advertisement for a lover, the criminals identify him and begin to blackmail him, threatening to disclose the corresponding correspondence, as well as other incriminating facts to his spouse. Indeed, in such cases, deanonymization plays a negative role, however, it seems that this should not be the basis for a general ban on the use of recognition technologies themselves. In the end, illegal use can be found for almost any new technology, however, when deciding on restrictions on its use, both potential risks and potential positive aspects of its application should be assessed.

According to international and local laws, the processing of personal data is possible only for strictly defined purposes and with the written consent of the subject of personal data (with some exceptions). The processing of biometric personal data is subject to even greater restrictions.

Photos and videos of a person relate to his personal data. The European Convention for the Protection of Individuals with regard to Automatic Processing of Personal Data [39] has established the possibility of identifying a person by information as a criterion for relevance of information to personal data.

The General Data Protection Regulation/ GDPR, which entered into force in May 2018, is currently the main normative act in the field of personal data protection of the European Union. This regulation applies to the processing of personal data produced in whole or in part by automated means. According to him, photographs of a human face are considered "biometric information", which is allowed to be processed only in cases expressly listed in Article 9 of this Regulation. The exceptions that make it possible to process personal data include, for example, the direct consent of the subject to the processing of his personal data, as well as the presence of a special public interest, in cases stipulated by law. Similar norms are enshrined in the local laws of a number of countries, for example, in the Russian law on personal data [27]. The latter also contains a definition of biometric personal data: these are the physiological and biological characteristics of a person that are used by the operator to establish the identity of the subject of personal data (Article 11). The Russian Federal Service for Supervision of Communications, Information Technologies and Mass Media explained that photographs and video images of people refer to biometric personal data in cases where they are used to identify a person (for example, photographic images of employees, visitors of state and municipal bodies, enterprises (organizations) contained in the access control system); and do not refer to biometric personal data if such a purpose of use is not set, or if the person has already been identified (for example, a photo in the employee's personal file) [40].

If you extend this approach to services that provide photo recognition services on the Internet, their operation will be completely prohibited. Of course, the system does not establish the identity of the person, but searches the network for similar or similar photos. However, in practice when using such technologies, the goal in most cases is precisely to establish an identity – by finding similar photographs, the researcher goes to the personal pages of identifiable persons on social networks; various sites containing personal information about them, etc.

Interestingly, the use of face recognition technology using video cameras using surveillance cameras also falls under the ban (but in this case, the law may make a special exception, for example, for the purpose of combating crime).

In our opinion, when assessing the acceptability of using FRT, it makes sense to distinguish between two situations: 1) when the information system searches and compares photo and video images with other photo and video images that are publicly available; 2) when the system uses closed databases (access to which was obtained illegally), searches through non-public pages on social networks, personal correspondence in the same social networks and instant messengers, etc. In the second case, of course, the functioning of this system should be interpreted as violating the right of citizens to privacy, respectively, the development and functioning of such systems should be prohibited with the establishment of liability measures for its violation. In the first case, in our opinion, one should proceed from the presumption that if information (photos and videos) is posted by a citizen in the public domain, he agrees to its processing. True, it will be necessary

to take into account situations when photo and video images were posted on a public site without the consent of the people who are shown on them.

4 Legal Problems of the Stage of Processing Human Images

The collection of graphic and video information with images of citizens is only the first necessary step in the functioning of face recognition technologies. As shown above, the collection and storage of such data is mainly associated with the threat of privacy violations (both as a result of mass leakage and as a result of uncontrolled use of search capabilities in relevant data). However, no less significant legal problems are associated with the data processing stage. Actions with data accumulated in such storages can be reduced to three universal operations:

– search for images matching certain parameters;
– identification of persons in given photographs and videos (to perform this operation, integration and interaction is required between the information system that accumulates the "raw" images and the systems that store identifying face data);
– finding correlations, for example, sampling images with the same faces, etc.

The principal thing is how the result of these operations is used further. Search or identification of a person is not an end in itself, but is necessary for further decision-making regarding this person in accordance with the specifics of the information system. As a rule, such a decision entails legal consequences. The most controversial aspects of using the technologies discussed are related to them.

First of all, it should be noted that the artificial intelligence algorithms used in face recognition systems do not have absolute accuracy. It is unlikely to be achieved in the near future. At the same time, some "bias" of the algorithms is noted, since errors are distributed unevenly. Most often, the problem stems from the unevenness of the training sample: if there are fewer representatives of some races in it than others, then the neural network will be worse at recognizing faces of that race. Such deficiencies were identified in the Gfycat face recognition system, which is worse than the Asians. Microsoft and IBM systems were 95% more accurate at recognizing women with fair skin. There are indications that Amazon Rekognition is more likely to make mistakes when comparing black faces, especially women [41]. Thus, recognition errors increase for small and rare ethnic groups. As rightly noted, these erroneous recognitions can lead, for example, to erroneous delays [42].

The second problem lies precisely in the fact that in recent years, government automatic decision-making systems are increasingly advocating for the "red line", which was designated back in 1981 by the creators of the Convention for the Protection of Individuals with Automatic Processing of Personal Data. This is a ban on decisions affecting human rights and freedoms that are made solely on the basis of automated processing of his personal data. The problem with information systems that make decisions based on the work of AI algorithms is compounded by the fact that legally significant decisions made by AI are almost impossible to protest, which significantly reduces guarantees of citizens' rights and the ability to control decision-making by government bodies using

AI technologies. The situation is aggravated by the fact that if a person tries to defend his rights violated by the algorithmized processing of his personal data in court, serious obstacles arise because many important information regarding the mechanisms for collecting and processing data is a commercial secret of IT giants. In addition, they often outsource operations that are questionable from the point of view of legal purity to third-party analytical organizations (for example, Facebook does this by transferring user data to companies such as Cambridge Analytica) [43].

Formally, a ban on the adoption of legally significant decisions through automated processing of personal data can be interpreted as follows: the result of such processing is mandatory considered by a person who directly makes a decision that affects the rights and legitimate interests of the subject of personal data. But in order to consciously and responsibly make such a decision, an authorized official must understand how the automated information system works, what algorithms are used to process the data, and is there any reason to believe that the system's solution is erroneous or does not comply with applicable law (exceptional case problem). When using "big data" and AI algorithms, a person will not be able to make an informed decision in principle, since the system turns into a "black box", the logic of which is inexplicable. Algorithms that work on "big data" do not find cause and effect relationships, but reveal correlations that, at best, can be intuitively understood but not explained. Neural networks build hyperplanes in the space of signs that separate classes of objects. In the process of setting up the network, weights of connections between neurons are determined, but the values of these weights have no semantics: these are just the parameters of the equations of separating hyperplanes. The prognostic value of a neural network is based on the hypothesis that it will be able to correctly classify new objects on the basis of their observed attributes, since they will fall into the area of space delimited on the basis of objects observed previously [44]. But a reasonable, understandable to man explanation why a given object was assigned by a neural network to a certain class and what is the probability of error in this particular case does not exist. It remains only to trust the machine - and this violates the spirit of the ban, even if formally the letter of the law is observed and the result issued by the neural network or other algorithms on "big data" is verified by a human.

For a long time, such fears did not apply specifically to face recognition systems, since the decision they made was reduced to detecting, tracking or identifying a specific person, and the further decision was made by government officials who could make a visual comparison and conclude that the automatic decision was correct. But as tracking systems expand and the number of relationships that are affected by pattern recognition systems increases, the share of automatism in decision making inevitably increases. So, in the context of the spread of the COVID-19 epidemic, the problem of controlling the movements of persons in quarantine and self-isolation becomes urgent. The Moscow Mayor's office has developed for this purpose the Social Monitoring application, which uses face recognition technology and requires regular confirmation of the citizen's presence in the required place using a selfie. The number of erroneous fines assigned automatically according to this application is amazing, despite the fact that in an epidemic, persons with limited mobility have very little opportunity to challenge them legally [45].

Finally, the border on which the legal grounds for processing raw data with images and videos of citizens pass is extremely unstable. In the fall of 2019, the Savelovsky District Court of Moscow refused to satisfy the requirements of A. Popova. She demanded to remove her images from the database and recognize the actions of the Department of Information Technology of the Main Directorate of the Ministry of Internal Affairs of Russia on the use of FRT in the "City CCTV System" as illegal. The judge pointed out that "the Department does not carry out activities aimed at establishing the identity of a particular citizen. The database does not contain personal data of citizens (name, etc.), as well as biometric personal data (iris, height, weight, etc.) that are necessary to establish the identity of a citizen. The face recognition algorithm compares the image coming from the cameras with the photo provided by the law enforcement agency. The Department does not receive personal data of persons, since the Department does not have the technical and legal ability to compare them. Thus, in the absence of a personal identification procedure, video images of citizens cannot be considered biometric personal data. Accordingly, there is no need to obtain the citizen's written consent for the processing of biometric personal data" [26].

This reasoning is unfounded, since the law considers any information related to a directly or indirectly identified individual as a personal data [27]. In the case under consideration, such a person was identified and brought to administrative responsibility precisely on the basis of an analysis of archived video recordings. The arguments that a particular operator cannot independently perform such identification, and the image recognition algorithms themselves can detect a match with only a 65% probability, are obviously untenable and would deprive the entire legal structure of personal data protection of meaning, leading to a vicious circle: there is nothing to protect before identifying a citizen by video, and after identification (recognition) it is too late. As for relatively public archives, databases, and individual photos and videos containing images of citizens, this logic is even more unacceptable. Thanks to the availability of millions of digital "profiles" of citizens in social networks, the capabilities of modern technologies for processing "big data" and numerous leaks of personal data databases, identifying a person by photo or video is only a matter of desire and means.

Finally, it should be noted that facial recognition is not the only technology associated with the processing of personal images of people, the use of which leads to violations of their rights. In recent years, technologies for making fake photos and videos that transfer facial features from a person's image to the target video (photo) with a high degree of verisimilitude have reached a certain technical perfection. This technology is called "deepfake". In global terms, the use of such technologies poses a threat to world security, since deepfake methods can be used to create videos of world leaders with fake speeches and other similar content aimed at discrediting, promoting hatred, etc. [46, 47]. But while national legislations usually provide legal means to counter such acts (for example, in the Russian Federation in 2019, a law establishing responsibility for the dissemination of unreliable socially significant information under the guise of reliable messages was adopted [48]), the problem of violation of personal rights using deepfake technologies is not fully understood and developed. Meanwhile, the personal rights of a citizen can be violated without the dissemination of forgeries for the purpose of falsification or discrimination. So, in 2019, the paid service DeepNude gained significant

popularity, the developers of which trained the neural network to "undress" the women depicted in photos, selecting and substituting Nude samples in the photo in automatic mode, the most appropriate figure. The service was so popular that the authors themselves were forced to close it, fearing numerous lawsuits. This problem is analyzed in more detail by one of the coauthors in the paper [49].

5 Conclusions and Prospects

Circumstances observed require the formation of common approaches regarding the restriction of the use of pattern recognition technologies. In our opinion, they should be based on the following theses:

1. It is not possible to draw a line between the legal and illegal use of technology. At least, the logic of the court decision discussed above does not work (only law enforcement agencies are able to compare data from cameras with the database of images - and carry out such a comparison for the purposes prescribed by law). In fact, in the world of "big data" and endless database leaks collected by both private companies and government services, potentially any entity can use the full power of face search and recognition technologies in relation to any information that is digitally accumulated about that person – both for publicly useful legitimate purposes (investigation of crimes, rescue of victims, etc.), and for private (targeted advertising, profiling clients) or completely illegal (blackmail, prosecution, etc.) purposes.
2. The ban on the creation and use of any technologies, algorithms, programs, is practically unpromising, this thesis has sufficient historical evidence. Not completely, but to some extent, the state restrictions imposed on developers of large information systems are effective (certification and restriction on the export of cryptographic tools; the requirement to place personal data bases of citizens on the territory of the state; the requirement to store user data for a certain period; the ban on storage and processing of personal data not determined by purposes for which the consent of the user is given, etc.). However, if such restrictions could be monitored and implemented in all cases, the problem discussed would not have stood at all, the basic principles established in international legislation on personal data would have been enough.
3. At this stage, it seems to us that the greatest vulnerability to the personal rights of citizens is entailed by the ability to create and use global databases of images that can be divided into two groups: personalized databases, based on which user identification can be carried out (most of these databases are created on the basis of open information) and databases that accumulate "raw" information about the facts of life of citizens (the most typical example is recordings from surveillance cameras).

Thus, first of all, regulatory prospects are seen in relation to technologies massively used by government bodies and large companies, which include face recognition technologies. The accumulation of videos with images of citizens, the creation of digital

profiles that can be compared, the use of intelligent algorithms to identify a person, the subsequent decisions and actions regarding such a person - each of these steps should be regulated as much as possible. Limitations should be worked out to strike a balance between ensuring freedom of citizens and security. In particular, it is possible to allow the creation of digital profiles only for a limited circle of persons (wanted offenders, missing persons, etc.), although in this case it will be difficult to identify persons who have committed an offense for the first time and who have come to the cameras. Severe restrictions should be imposed on the exchange of identification data, as well as the use of identification technologies by private companies, unless the user voluntarily agrees to identify his face (for example, to unlock a smartphone, etc.) with strict control of storage and the transmission of information arising from such goals.

Summing up, we note that, in our opinion, the possibilities of modern information technologies related to the processing of personal images of people require a new careful reading of such constitutional rights as the right to privacy, freedom and personal inviolability. So, the concept of personal integrity must be extended to the "digital forms of existence" of an individual - reflected, inter alia, in personal images, videos, virtual accounts. The right to privacy is not so much connected with the protection of communications (ensuring the confidentiality of mail and other items), but with the accumulation and processing of personal data of a person, including the same personal images and videos. This area of development of legal doctrine seems very promising for the coming periods of the development of the information society.

At the same time, it seems appropriate to put some approaches into the basis of legal regulation of the use of facial processing technologies, in particular, formulated by the authors of this article. In particular, programs and systems that search and process photo and video images that are not public must be prohibited. On the contrary, a person's posting of such information in the public domain should be interpreted as his consent to their search and comparison.

Issues with the processing of photo and video images, as a result of which they are subjected to various kinds of distortions, must be resolved differently. If the creation of such fakes is not realistic to ban, and it is not advisable, their publication and distribution may be restricted by law (although, apparently, such a restriction should not be absolute, but should depend on the goals pursued).

Of course, the implementation of the above approaches can be of a general nature, while in some cases deviations from them are possible. All this requires further work on this issue.

References

1. Moghaddam, B., Pentland, A.: Probabilistic Visual Learning for Object Representation. IEEE Trans. Pattern Anal. Mach. Intell. **19**, 696–710 (1997)
2. Belhumeur, P., Hespanha, J., Kriegman, D.: Eigenfaces vs fisherfaces: recognition using class specific linear projection. IEEE Trans. Pattern Anal. Mach. Intell. **19**, 711–720 (1997)
3. Samaria, F.: Face recognition using hidden markov models. PhD thesis, Engineering Department, Cambridge University (1994)
4. Foltyniewicz, R.: Efficient high order neural network for rotation, translation and distance invariant recognition of gray scale images. In: Lecture Notes in Computer Science - Computer Analysis of Images and Patterns, pp. 424–431 (1995)

5. Brunelli, R., Poggio, T.: Face recognition: features versus templates. IEEE Trans. Pattern Anal. Machine Intell. **15**(10), 235–241 (1993)
6. Oka, K., Sato, Y., Koike, H.: Real time fingertip tracking and gesture recognition. Proc. IEEE Comput. Graph. Appl. **22**(6), 64–71 (2002)
7. Turk, M., Pentland, A.: Eigen faces for recognition. Cognitive Neurosci. **3**(1), 71–86 (1991)
8. Senan, M., Abdullah, S., Kharudin, W., Saupi N.: CCTV quality assessment for forensics facial recognition analysis. In: 7th International Conference on Cloud Computing, Data Science & Engineering, Confluence, Noida, pp. 649–655 (2017)
9. Kong, S., Heo, J., Abidi, B., Paik, J., Abidi, M.: Recent advances in visual and infrared face recognition - a review. J. Comput. Vis. Image Understanding **97**(1), 103–135 (2005)
10. Hamouz, M., Tena, J.R., Kittler, J., Hilton, A., Illingworth, J.: 3D assisted face recognition: a survey. In: Koschan A., Pollefeys M., Abidi M. (eds.) 3D Imaging for Safety and Security. Computational Imaging and Vision, vol 35. Springer, Dordrecht (2007)
11. Celine, J., Agustin, S.: A summary of literature review: face recognition. Int. J. Eng. Sci. Res. Technol. **8**, 91–94 (2019)
12. Tolba, A., El-Baz, A., El-Harby, A.: Face recognition: a literature review. Int. J. Signal Process. **2**, 88–103 (2005)
13. Kaur, P., Krishan, K., Sharma, S.K., Kanchan, T.: Facial-recognition algorithms: a literature review. Medicine, Science and the Law. https://doi.org/10.1177/0025802419893168 (2020)
14. Phillips, P.J., Moon, H., Rizvi, S., Rauss, P.: The FERET evaluation methodology for face-recognition algorithms. IEEE Trans. Pattern Anal. Machine Intell. **22**, 1090–1104 (2000). https://doi.org/10.1109/34.879790
15. Kostinger, P.W.P.R., Kostinger, H.B.M.: Annotated facial landmarks in the wild. In: IEEE International Conference. Computer Vision Workshops, pp. 2144–2151 (2011)
16. Wright, E.: The future of facial recognition is not fully known: developing privacy and security regulatory mechanisms for facial recognition in the retail sector, 29 FordhamIntell. Prop. Media & Ent. L.J. 611 (2019). https://ir.lawnet.fordham.edu/iplj/vol29/iss2/6
17. Ruhrmann, H.: Protecting human rights in policy strategies for facial recognition technologyin law enforcement. Case Studies from the United Kingdom and the United States. CITRIS Policy Lab (2019). https://citrispolicylab.org/wp-content/uploads/2019/09/Facing-the-Future_Ruhrmann_CITRIS-Policy-Lab.pdf
18. Schneier, B.: We're banning facial recognition. We're Missing the Point. The New York Times (2020). https://www.nytimes.com/2020/01/20/opinion/facial-recognition-ban-privacy.html
19. Nakar, S., Greenbaum, D.: Now You See Me. Now You Still Do: Facial Recognition Technology and the Growing Lack of Privacy, 23 Boston U.Sci. & Tech. L. **88**, 116 (2017)
20. Rassolov, I., Chubukova, S., Mikurova, I.: Biometry in the context of personal data and genetic information: legal issues. Lexrussica **1**, 108–118 (2019). (in Russian)
21. Mamaev, V.: Biometrics: from premonition to materialization. Banking Rev. **3**, 70–73 (2018). (in Russian)
22. Romashov, P.: On the issue of the right to privacy in the digital age. Perm Legal almanac. Ann. Sci. J. **1**, 103–118 (2019). (in Russian)
23. Shavaleev, B.: Fulfillment of the administrative ban on visiting the venues of official sports competitions on the days of their holding. Administrative Law Process **7**, 80–82 (2017). (in Russian)
24. Stepanov, A.: Implementation of systems of intelligent face recognition at the objects of the Ministry of Internal Affairs of Russia in the Omsk region. Prospects and challenges of implementation. Information technology, communications and information protection of the Ministry of Internal Affairs of Russia, no. 2, pp. 151–152 (2012). (in Russian)

25. The combined cases of the European Court S-203/15 and S-698/15, Tele2 Sverige AB v. The Swedish Postal and Telecommunications Agency and the Minister of the Interior v. Watson, Decree of December 21, 2016, paragraph 107; CCPR/ C/ ZAF/ CO/ 1, paragraphs 42 to 43; and CCPR/ C/ CMR/ CO/ 5, paragraphs 39–40
26. Information on the case No. 02a-0577/2019. Courts of general jurisdiction of the city of Moscow. The official portal (2019). https://www.mos-gorsud.ru/rs/savyolovskij/cases/docs/content/d2ef41f1-b8a7-44ea-b4e9-80db9c9e28df
27. Federal Law of July 27, 2006 No. 152-FZ On Personal Data. Meeting of the legislation of the Russian Federation, July 31, 2006, N 31 (1 part), Art. 3451
28. Romanovskaya, O., Romanovsky, G.: Digital technologies and deconcentration of state power. Constitutional Municipal Law **8**, 36–40 (2019). (in Russian)
29. Universal Declaration of Human Rights (adopted by the UN General Assembly on 10.12.1948)
30. International Covenant on Civil and Political Rights (Adopted on December 16, 1966 by Resolution 2200 (XXI) at the 1496th plenary meeting of the UN General Assembly)
31. Convention for the Protection of Human Rights and Fundamental Freedoms (Concluded in Rome 04.11.1950)
32. Conger, K., Fausset, R., Kovaleski S.: San Francisco Bans Facial Recognition Technology. The New York Times (2019). https://www.nytimes.com/2019/05/14/us/facial-recognition-ban-san-francisco.html
33. Gurley, L.: 40 Major Music Festivals Have Pledged Not to Use Facial Recognition Technology. VICE (2019). https://www.vice.com/en_us/article/ywakpj/40-major-music-festivals-have-pledged-not-to-use-facial-recognition-technology
34. Khodakovsky, K.: Clearview AI application for face recognition is tried for an encroachment on freedom. 3DNews. https://3dnews.ru/1002294. (in Russian)
35. Antonova, N., Balkhaeva, S., Gaunova, J., et al.: The legal concept of robotization: a monograph. Moscow, Prospect (2019). (in Russian)
36. Face recognition now also serves for tracking people on a national basis. Security News (2019). http://www.secnews.ru/digest/24052.htm#axzz6Ca1psKI4. (in Russian)
37. Clearview AI. Official site. https://clearview.ai/
38. Declaration on the Freedom of Communication on the Internet adopted by the Committee of Ministers of the Council of Europe (Strasbourg, May 28, 2003)
39. Convention for the Protection of Individuals with regard to Automatic Processing of Personal Data (Concluded in Strasbourg on 01.28.1981) (together with the Amendments to the Convention for the Protection of Individuals with Automatic Processing of Personal Data (CETS No. 108) allowing the accession of European communities adopted by the Committee of Ministers in Strasbourg 06/15/1999)
40. Clarifications of the Federal Service for Supervision in the Sphere of Telecommunications, Information Technologies and Mass Communications dated August 30, 2013 "Clarifications on the issues of classifying photos, videos, fingerprints and other information as biometric personal data and the features of their processing"
41. Habr.com. Amazon Recognition Facial Recognition System Has Taken 28 US Congressmen for Criminals]. https://habr.com/ru/post/418509/ (2018). (in Russian)
42. Andreeva, O., Ivanov, V., Nesterov, A., Trubnikova, T.: Face recognition technologies in criminal proceedings: the problem of the grounds for the legal regulation of artificial intelligence. Bull. Tomsk State Univ. **449**, 201–212 (2019). https://doi.org/10.17223/15617793/449/25(inRussian)
43. Antonova, N., et al.: The Legal Concept of Robotization: A Monograph. Prospect, Moscow (2019). (in Russian)
44. Haykin, S.: Neural Networks: A Comprehensive Foundation (2nd Edition). Prentice Hall (1998)

45. Vasilchuk, T.: Antisocial monitoring. Muscovites continue to be fined for bad selfies and trips to the hospital. New Newspaper (2020). https://novayagazeta.ru/articles/2020/05/31/85630-antisotsialnyy-monitoring. (in Russian)
46. Chesney, R., Citron, D.: Deepfakes and the new disinformation war: the coming age of post-truth geopolitics. Foreign Affairs **98**, 147 (2019)
47. Bloomberg: How faking videos became easy and why that's so scary (2018). https://fortune.com/2018/09/11/deep-fakes-obama-video/
48. Federal Law of March 18, 2019 No. 27-ФЗ "On Amending the Code of the Russian Federation on Administrative Offenses". Meeting of the legislation of the Russian Federation, March 25, 2019, No. 12, Art. 1217
49. Amelin, R., Komkova, G., Kulikova, S.: Legal protection of personal image in digital relations: leading trends. In: Proceedings of the 6th International Conference on Social, Economic, and Academic Leadership (ICSEAL-6-2019). Advances in Social Science, Education and Humanities Research, vol. 441, pp. 382–390 (2020). https://doi.org/10.2991/assehr.k.200526.056

Survey Analysis System for Participatory Budgeting Studies: Saint Petersburg Case

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Abstract. The participatory budgeting as a part of e-Government becomes powerful approach that helps citizens to solve issues in the local area with support from government. Implementation of the participatory budgeting in new areas as well as its development is existing ones requires analysis of successful cases integrated with survey of local citizens. The paper addresses to the development of an approach that can be used to conduct surveys, analyze results and get statistics in semi-automatic way. Starting with an overview of top analytical tools, this paper identifies requirements and presents data-analysis system prototype. The prototype is focused on providing information space to analyze data. Data is gathered from various public and government information systems including surveys on participatory budgeting conducted by the governments. The system introduces data processing mechanics decisive for deeper data understanding. The paper also demonstrates prototype microservice architecture, including reasoning for each chosen technology. Prototype was evaluated on the survey conducted in Saint Petersburg municipality.

Keywords: Data analysis · Research automation · Participatory government · Microservice

1 Introduction

Nowadays municipalities see a participatory budgeting as a part of e-Government service that provides effective means of interacting with the residents. It allows government to respond quickly to residents' initiatives related to improving the quality of life and urban development by consolidating initiatives and supporting the best ones [1]. The use of this practice is associated with the need to take into account many features specific to each municipality that affect the final effectiveness of the implementation of initiative budgeting. An analysis of existing practice implementations based on data obtained from the Smart City systems in the context of various municipalities will allow to determine the factors affecting efficiency. It will help to create a system that provides recommendations

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for decision making on sustainable development of participatory budgeting within the framework of the Smart City [2].

In the social and humanitarian sphere, the implementation of the participatory budgeting can be considered as an innovative methodology for the development of democratic processes using modern information and communication technologies. Sustainable development of participatory budgeting will increase the general level of satisfaction with the life of the residents and contribute to the stability of society [3].

During the initial stages of participatory budgeting development, such information services as providing decision making support with data on various aspects of the territory development come to the fore. Increased requirements influenced the creation of special situation centers with Operations Room, Business Intelligence system or Decision Support System (DSS). Such systems combine various tools and technologies for data analysis and data processing in the corresponding subject area [4]. Their goal is to improve the quality of information for managerial decision making through implementing any new initiative in the region, including participatory budgeting. Besides data access, BI systems also provide tools that allow users to make conclusions and find optimal management solutions.

Policy analytics can be defined in various ways. The use of data-analysis techniques for making policy decisions have in fact several different terms. Policy analytics, policy modelling and policy informatics are most common among scholars and practitioners. However, there is no clarity as to where the boundaries of this concept are and what basic analytical methods it involves [4].

This paper presents results of a comprehensive study on E-participation interaction specifics between general population and government. The development of analytical tools that provide a multifaceted comparison of regional development aspects (namely 85 regions of the Russian Federation) is an important part of the abovementioned study. The questionnaire has been developed to gather data about how residents are involved in the Participatory Budgeting initiatives. The survey was conducted according to the questionnaire and the result had been processed to test system validity. Results of data analysis systems research, as well as the architecture of the created system, are presented in the paper along with the summarized results of the first stage of data analysis on participatory budgeting and e-participation development in the regions of the Russian Federation.

The rest of the paper is structured as follows. Section 2 provides overview of related works in the field of participatory budgeting studies. Section 3 defines requirements for participatory budgeting analysis systems in order to collect information about cases and make recommendations for the development of participatory budgeting systems. Section 4 provides architecture of participatory budgeting analysis system. Section 5 describes analysis system implementation and estimation results based on survey analysis from one of the Saint Petersburg municipal district.

2 Related Works

Participatory budgeting (PB) is one of the most popular democratic innovations nowadays. It is associated with high rates in relation to the mobilization of political inactive

citizens. It is also considered as an effective and efficient measure of budget policy, and as a special way of interaction between government and citizens (for example, projects that are effective for civil education, development of democratic relations in society). The main directions of research in the field of participatory budgeting are scientific works on the success of various models of introducing that practices in municipalities. Researchers analyze the forms of citizen engagement (in particular, study face-to-face meetings and electronic platforms), evaluate the effects of implementing PB [1, 5, 6], study the implementation schemes of PB: training the residents, imitation (repetition of successful regions), competition between participants, and forced implementation [7].

One of the best and widest examples of introducing participatory budgeting is Germany. When analyzing experience examples of implementation in German municipalities, the main research focus is concentrated on the development of PB practice (which municipalities use PB and why), the process (the role of the local administration and council, participation in discussions, specific actions and methods) and the result aspect/impact (results and impact on politics and citizens) [2, 6]. It is noted that, for example, in Germany, the average age of a PB participant is from 35 to 65 years, mainly people with higher education, but the share of those participating does not exceed 1.3% of the politically active population.

Characteristics analysis of the region and the needs of the population also should be considered during the PB study. The paper [8] use various characteristics to create a recommendation system for the development of proactive budgeting, which assesses various methods of using heterogeneous sources of data on the city and user preferences models to provide personalized recommendations of civilian proposals in three large US cities.

Many studies also note a lack of empirical evidence on similar projects around the world. The implementation of participatory budgeting requires financial and human resources, a thorough evaluation of projects, the study of the effects obtained from the introduction of PB are necessary. Existing studies of budgeting with the participation of the population provide very limited attention to how this participation tool was distributed to local authorities, which distribution mechanisms played a dominant role, and which participants and factors influenced its adoption [6, 7, 9].

In case of Russia, budget allocation at the regional and municipal level is mostly the prerogative of the executive and legislative branches. Citizens are poorly or even not involved in the budget process, and therefore there is a distrust of citizens in relation to budget policy [10]. In 2012, the Center “Res Publica” of European University of Saint Petersburg (EUSP) with the support of the Kudrin Foundation for the Support of Civil Initiatives, developed a participatory budgeting project, which is designed to expand the scope of citizen participation in the budget process [11]. Participatory budgeting makes it possible to improve and optimize the mechanism for making administrative decisions, since it provides a direct connection between citizens and the administration. [12] One of the most important functions of the project is educational, since in the course of its implementation it turned out that there is a certain basic set of knowledge about urban governance that needs to be highlighted for participating citizens in order to include them in the budget process. To this end, EUSP experts have created a booklet that talks about participatory budgeting for residents. The booklet describes the history of participatory

budgeting, the technology of its implementation and the results that it allows to achieve are analyzed. Since 2015, in agreement with the Finance Committee of St. Petersburg and the European University, the participatory budgeting program "Your Budget" has been launched, the data on which will also be used to implement this project [13].

3 Requirements for PB Data Analysis Systems

It is necessary to find out what criteria are mandatory for business intelligence data analysis systems to create a high-quality prototype of it. Research was carried out to identify the criteria for BI platform effective operation in policy informatics. T-Advisor analytics have established the following criteria for BI data analysis systems: infrastructure, teamwork, reporting, custom requests and ETL (Extract, Transform, Load) module criteria. Let's consider each of them in detail:

- *Infrastructure* criteria is important due to all BI platform tools should be implemented "in a coherent manner", including common metadata, unified object model, end-to-end security, administration and portal integration model, common query execution engine.
- A far as BI platform should provide tools for exchanging information between users, version control system and tools for assigning tasks to users and progress tracking the *teamwork* criteria is also should be taken into account.
- BI platform should provide tools for creating formatted and interactive *reports* with developed distribution and update mechanisms.
- System should provide functions for users to create and implement unique, non-standard, *custom requests* without assistance from IT-experts. BI platform should have a powerful semantic layer allowing users to search and extract required information from existing sources to fulfill *custom request* functionality. In addition, the system should have tools for requests audit to ensure their correct execution.
- BI platform should provide tools for extracting and converting data, i.e. proper formatting and processing in accordance with certain rules, data merging, as well as tools for loading data into storage or other databases (*ETL criteria*). Special mediators should be designed for connection to various data sources, such as DBMS, files, and information systems.

Also, in the research process, the following criteria were set for metadata management and information visualization aimed towards end users [14]:

- Metadata management. All tools within a single platform should be binded not only by a metadata model, but also by unified tools for searching, obtaining, storing, reusing and publishing metadata objects, such as arrays, hierarchies, sets, metrics and report design elements.
- Visualization. BI platform should provide tools for detailed, clear and understandable display of data in various formats and views.

When researching the impact of business analytics on the quality of decision-making in participatory budgeting, the following criteria were identified for data prediction and

research as well as for the development of custom BI applications and the availability of analytical dashboards [15]. The criteria were categorized according to BI systems basic functions (Environment; Data management; Content analysis and creation; Content presentation, see Table 1):

Table 1. BI systems with the highest scores

Criteria	Power BI	Tableau	Qlik	Alteryx
Environment				
Infrastructure	2	1	1	1
Custom requests	1	1	1	1
Development	1	2	2	1
Teamwork	1	2	1	1
Data management				
Metadata management	1	2	1	1
ETL	1	2	2	1
Content presentation				
Analytic dashboards	1	1	1	1
Visualization	2	2	1	1
Reporting	1	1	1	1
Content analysis and creation				
Data-drill	1	1	1	1
Data modeling, forecasting and research	2	1	2	1
Spatial OLAP	1	2	1	1

- *Development.* BI platform should provide tools for creating custom functions and applications. At the same time, such tools should be intuitive and user- friendly, preferably with a graphic interface and should not require programming skills from the users. In addition, development should support web services for solving such tasks as management, administration and information delivery.
- *Dashboards.* BI platform should provide tools for presenting data in a clear and intuitive way, using various graphs, indicators, etc. With dashboards, users should be able to monitor current state of key indicators and processes and compare them with target values.
- *Data modeling, prediction and research.* BI platform should provide tools for data classification and creation of their own nominal and quantitative scales, as well as mathematical tools for research and prediction.

Taking into account development of BI systems, some characteristics, e.g. operation in policy informatics or availability of geodata processing tools have to be viewed as a

mandatory criterion for its functionality. BI system should also provide tools for visualizing geospatial data and calculating multidimensional spatial and temporal statistical analysis [16].

In the course of the study, a tendency to develop tools for detailed presentation of data and data relationship was discovered. Such tools are called data drill and meet the following criteria: BI platform should provide tools for a deeper analysis and understanding of data by gradually increasing detail level for data in question.

4 Information System Prototype Architecture

Architecture of the future system should correspond with each criteria group. To meet all of the requirements the microservice architecture was chosen. The benefit of such approach is that each requirement can be covered by one or more independent micro-services. In other turn, microservices are integrating in the service that provide common interface to access data and functions of the BI system. Due to independency of system parts the output and available functions can be configured in a wide range for each type of users by turning on or off corresponding microservices. Interaction of microservices and overall system structure is shown on Fig. 1.

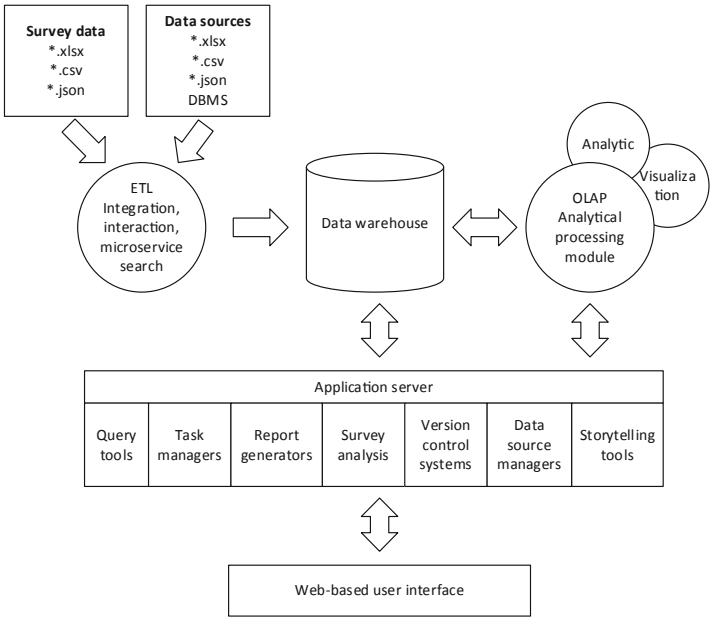

Fig. 1. Architecture of data analysis system

The following microservices should be developed to meet "Environment" criteria group:

1. Query tool for creating SQL-queries to process specific questions that are not in the main report.
2. Tool for creating custom calculations and functions over the data available in the system.
3. Version control subsystem that facilitates processing fluctuating information. Such version control subsystem should allow to store several versions of the same document, roll back to earlier versions, and to determine changes of timestamps and document authors.
4. Task manager for project management, visualizing current workflow, progress and assignees.

The following microservices should be developed to meet "Content presentation" criteria group:

1. Storytelling tools for better analytic report presentation, which would allow consolidating data within one dashboard.
2. Visualization tools for displaying data in a clear and understandable way.
3. Report center allowing users to share the results of their analytical research.

The following microservices should be developed to meet "Content presentation" criteria group:

1. Drill tools provide deep data analysis with drill-down, drill-a-side and drill-through methods.

    a. *Drill-a-side* - transition to a new analytical element or analytical dashboard when clicking a visual element within current analytical element, with axis values filters applied to corresponding visual elements, as well as internal filters for current analytical element and pre-defined values for template filters, if any.
    b. *Drill-down* - transition to a new analytical element when clicking a visual element within current analytical element, with filtering by the corresponding value of the first axis belonging to the current analytical element and axis replacement mechanism with replacing the latter to the next one in the hierarchy.
    c. *Drill-through* - transition to a source data table, when clicking a visual element inside the current analytical element, with axis values filters applied to corresponding visual elements, as well as template filters and an analytical element if available.

2. Spatial OLAP (SOLAP) technologies process geographic data, including visualization of geospatial data, interactive exploration of data, etc.
3. Analytics tools with access to various math statistic functions, such as correlation or trend line, for data modeling and research.

ETL microservice should be developed to meet "Data management" criteria group. ETL module should provide functions to extract data from different types of data sources

(structured, i.e. databases, XML, JSON, etc.; and unstructured, i.e. documents, messages, etc.). Additionally, ETL module should provide functions to clear and aggregate extracted data as well as provide the ability of new data creation or data structure transformation based on the existing data and rules, defined by the users.

5 Implementation

The section provides descriptions of two major micro-services developed during the research to analyze data of participatory budgeting in case of Saint Petersburg. The implementation estimation is based on the intermediate results of an empirical sociological study, which was conducted in December 2019–January 2020 in St. Petersburg on the basis of one of the city municipalities. The study was conducted as part of the Interreg BSR project "Empowering Participatory Budgeting in the Baltic Sea Region - EmPaci".

The project is aimed at building awareness and knowledge in the field of participatory/initiative budgeting, as well as strengthening relations between municipalities and citizens by providing ready-to-use methods, training programs and tools for the practical implementation of participatory budgeting. This will create the basis for a larger number of municipalities, necessary for the implementation of information security and facilitating the participation of citizens against the background of significant spatial fragmentation of the population.

A sociological study was carried out in the form of a questionnaire survey of citizens living in the municipality in order to identify the specific requirements of citizens to various participatory budgeting concepts and approaches. A sociological survey was conducted in order to prepare for a pilot project on the implementation of various PB practices in this municipality, for which it was necessary to assess the needs and requirements of citizens. In total, 690 questionnaires were collected (about 2% of the residents of the municipal district).

The questionnaire result data was presented in the form of an XLSX table, vertically there are unique numbers of respondents, and horizontally placed questions. Thus, each row corresponds to the respondent, and the columns are the answers. The survey consists of 40 questions and the "Trust" part, each question may contain one or more fields for the answer. After dividing each question into elementary parts containing only one field, 145 fields were left for further processing.

The survey consists of four categories: "Interest in politics and involvement"; "Place of residence of the respondent"; "Attitude to proactive budgeting"; "Trust in authority"; "Demographic Information".

For processing, it was necessary to carry out preliminary data preparation, which includes the following actions:

- Introduce end-to-end numbering of all response fields.
- Categorization of data for separate processing. Separation by category allows you to filter respondents' answers incorrect for only this category, leaving data for other categories.

- Validation of data. Each question is checked for omissions privately since some of the questions allow for the existence of an omission. Those answers whose values are not provided by the survey organizers are considered incorrect. Lines in which unexpected gaps were found or incorrect data are deleted.

The microservice for participatory budgeting survey analysis is based on the use of the Pandas library of the Python language. Auxiliary libraries are also used: “NumPy” - for working with arrays; “Matplotlib” - for graphical presentation of data. Jupyter - for creating an interactive user interface.

The following figures provides examples of survey analysis tool output, based on the processed data from the municipality of Saint Petersburg. Figure 2 and Fig. 3 provide example of age and status distribution. For the municipality of Saint Petersburg two main age clusters can be distinguished for people who had participated in the survey: from 35 to 45 and from 50 to 64. Most of them are employed and self-employed and for the elderly cluster – retired.

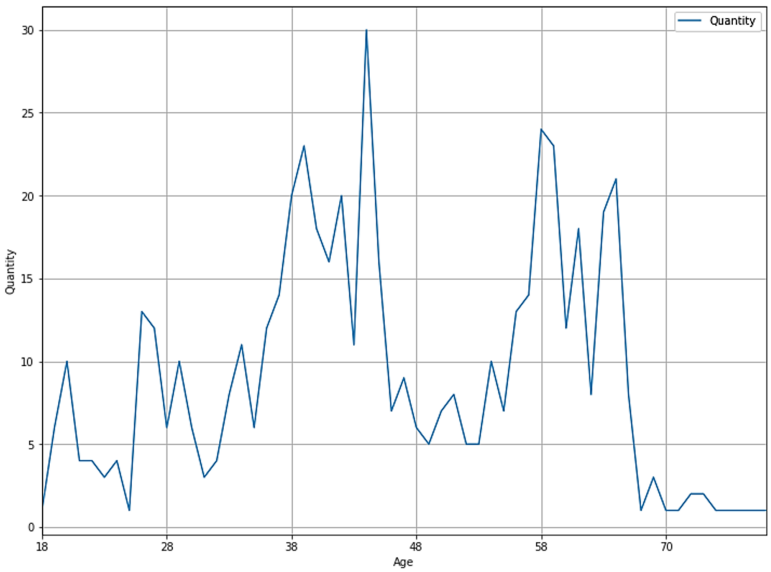

Fig. 2. Age distribution for municipality of Saint Petersburg survey for participatory budgeting

Figure 4 and Fig. 5 show distribution of answers for question about areas of possible participation budgeting projects. Most of them are concentrated on changes of health services, education, and social area. According to this results decision maker can be advised to search experts for project analysis with experience in these areas.

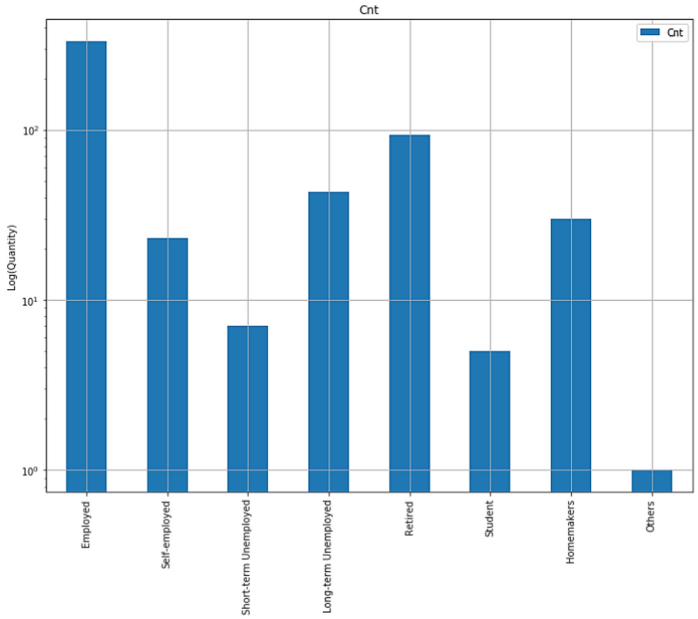

Fig. 3. Employment distribution for municipality of Saint Petersburg survey for participatory budgeting

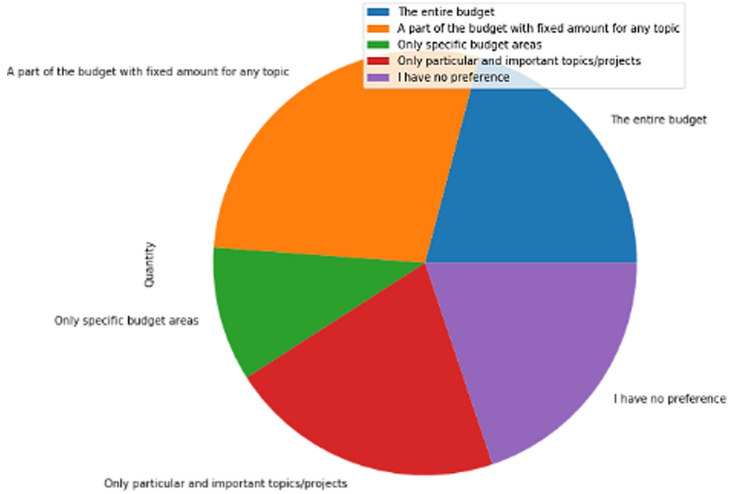

Fig. 4. Budget area distribution

Figure 6 shows distribution of opinions about need of discussion before PB project submission. The discussion itself is difficult but powerful tool to improve quality of project. The difficulty there is to gather experts that have great experience for particular kind of projects and provide place for discussion.

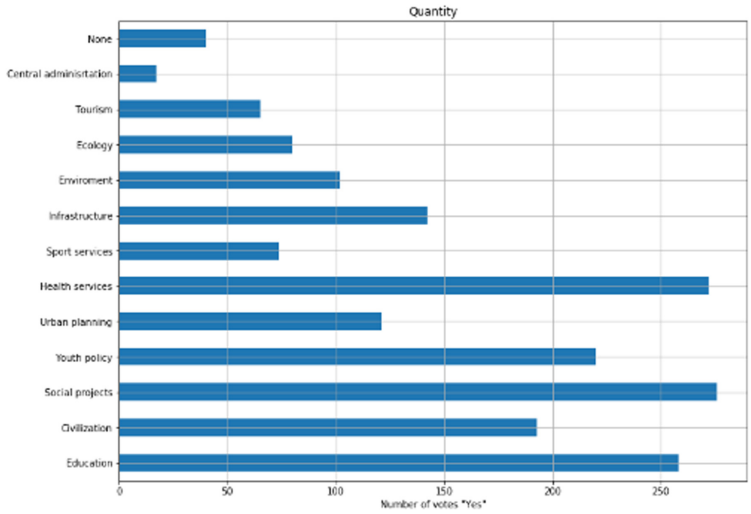

Fig. 5. Possible influence areas distribution

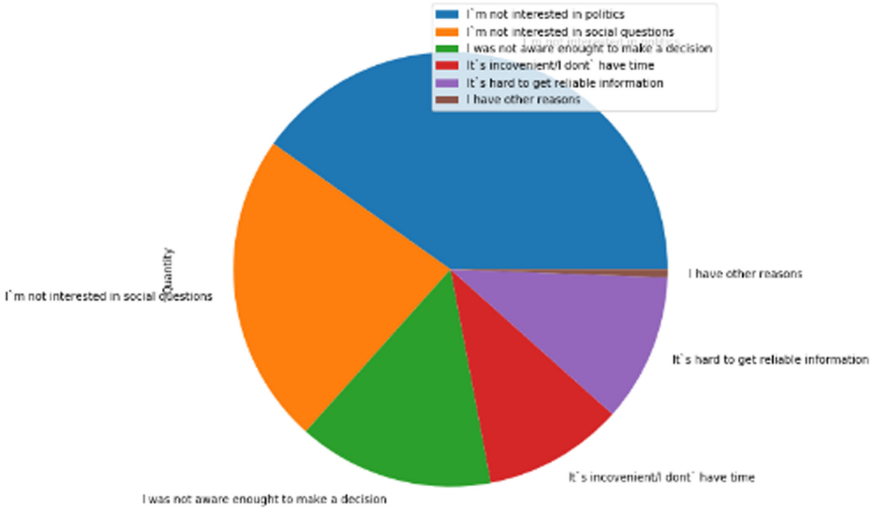

Fig. 6. Opinions on the need for discussion before submitting a project

6 Conclusion and Future Research

Based on the facts presented in the paper, development of tools that will help to make decisions about participatory budgeting implementation is important task. Such kind of tools allows to analyze city resident interests before implementing PB and provide functions for better service during project submission and implementation. The system could be expanded by adding new modules and functions that will be developed depending on users' needs.

Also, we clearly see the need for functional improvements that will be implemented in the near future. These include:

1. Geo-filters, such as lines and polygons, which would allow for finer visualization of geodata about participatory budgeting regions. Using of geodata could help to provide region-specific tools for developing PB projects and do more qualified expertise.
2. Combined interactive charts to display different sets of data with contrasting values.
3. Combining data from different OLAP cubes in one visual element.

There are plans to improve this system as a unified center for university researchers involved in digital development in Russian regions. The system could be connected to various data sources, including online portals accessible via Open Government Data protocols:

- statistical data on regional socio-economic development;
- numbers and indices of regional innovative progress;
- numbers and indices of public administration quality levels and corruption levels;
- specific indices related to regional digital development.

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References

1. Frieß, D., Porten-Cheé, P.: What do participants take away from local eParticipation?: Analyzing the success of local eParticipation initiatives from a democratic citizens' perspective. Anal. Kritik **40**, 1–29 (2018). https://doi.org/10.1515/auk-2018-0001
2. Bednarska-Olejniczak, D., Olejniczak, J., Svobodová, L.: Towards a smart and sustainable city with the involvement of public participation—the case of Wroclaw. Sustainability **11**, 332 (2019). https://doi.org/10.3390/su11020332
3. Murphy, A., Dahlhaus, P., Thompson, H.: Historic urban landscapes and visualising Ballarat: citizen participation for sustainable urban planning and design. In: CEUR Workshop Proceedings, pp. 41–46. CEUR-WS (2016)
4. Gil-Garcia, J.R., Pardo, T.A., Luna-Reyes, L.F.: Policy analytics: definitions, components, methods, and illustrative examples. In: Gil-Garcia, J.R., Pardo, T.A., Luna-Reyes, L.F. (eds.) Policy Analytics, Modelling, and Informatics. PAIT, vol. 24, pp. 1–16. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-61762-6_1
5. Touchton, M., Wampler, B., Spada, P.: The digital revolution and governance in Brazil: evidence from participatory budgeting. J. Inf. Technol. Polit. **16**, 154–168 (2019). https://doi.org/10.1080/19331681.2019.1613281
6. Schneider, S.H., Busse, S.: Participatory budgeting in Germany–a review of empirical findings. Int. J. Public Adm. **42**, 259–273 (2019). https://doi.org/10.1080/01900692.2018.1426601

7. Krenjova, J., Raudla, R.: Policy diffusion at the local level: participatory budgeting in Estonia. Urban Aff. Rev. **54**, 419–447 (2018). https://doi.org/10.1177/1078087416688961
8. Cantador, I., Cortés-Cediel, M.E., Fernández, M., Alani, H.: What's going on in my city? Recommender systems and electronic participatory budgeting. In: RecSys 2018 - 12th ACM Conference on Recommender Systems, pp. 219–223. Association for Computing Machinery, Inc., New York (2018). https://doi.org/10.1145/3240323.3240391
9. Rumbul, R., Parsons, A., Bramley, J.: Elite capture and co-optation in participatory budgeting in Mexico City. In: Edelmann, N., Parycek, P., Misuraca, G., Panagiotopoulos, P., Charalabidis, Y., Virkar, S. (eds.) ePart 2018. LNCS, vol. 11021, pp. 89–99. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-98578-7_8
10. Beuermann, D.W., Amelina, M.: Does participatory budgeting improve decentralized public service delivery? Experimental evidence from rural Russia. Econ. Gov. **19**(4), 339–379 (2018). https://doi.org/10.1007/s10101-018-0214-3
11. Participatory Budgeting in Russian Municipalities (2013–2018) | EUSP.org. https://eusp.org/en/projects/participatory-budgeting-in-russian-municipalities-2013-2018. Accessed 20 Feb 2020
12. Shulga, I., Shilov, L., Sukhova, A., Pojarski, P.: Can local participatory programs enhance public confidence. Social Protection and Jobs Discussion Paper, pp. 1–75 (2019). https://doi.org/10.1596/31810
13. Main Page | Official Web-Site of "Your Budget" Project. https://tvoybudget.spb.ru/. Accessed 20 Feb 2020
14. Chen, H., Chiang, R.H.L., Storey, V.C.: Business intelligence and analytics: from big data to big impact. MIS Q.: Manag. Inf. Syst. **36**, 1165–1188 (2012). https://doi.org/10.2307/41703503
15. Wieder, B., Ossimitz, M.L.: The impact of business intelligence on the quality of decision making - a mediation model. In: Procedia Computer Science, pp. 1163–1171. Elsevier B.V. (2015). https://doi.org/10.1016/j.procs.2015.08.599
16. El Morr, C.: Research Perspectives on the Role of Informatics in Health Policy and Management. IGI Global, Pennsylvania (2013)

Citizens' Attitudes to e-Government: A Study Across Ten Russian Regions

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Abstract. The evolution of e-governance and the institutionalization of digital government is accompanied by contradictory trends. Expanding the technological capabilities of providing electronic public services stipulates a more convenient and effective way for citizens and governments to interact. On the other hand, the innovative nature of e-communication with the e-government creates citizens' concerns about the security of personal data. Public sentiments associated with fears of increasing control over the population through the use of electronic services are becoming more pronounced. The increasing uncertainty and the lack of digital competencies actualizes the problem of trust in the e-government. This research examines Russian citizens' perceptions and attitudes towards digital government in terms of assessing their activity and level of trust in electronic services. The factor analysis was performed on the basis of data collected in telephone surveys across ten Russian regions.

Keywords: Digital government · Trust · Public participation · Public services · Factor analysis

1 Introduction

The processes of digitalization of public administration have been taking place in Russia over the past ten years. According to the National State program "Digital economy" by 2024, seven out of ten public services should be provided in digital form. Up to 90% of the document flow in public authorities must be carried out electronically. Researchers emphasize the existence of a direct correlation between the parameters of public administration quality and the Government Performance Index. Digital transformation of the public sector is a complex of social changes, which are associated with the development of digital technologies and their implementation in public administration. Digitalization creates special ecosystems of public authorities, non-governmental organizations, businesses, and citizens. The digital ecosystems (electronic platforms) supply resources for co-production and access to data, services, and content, based on interaction with the state [16]. Digitalization of public sector contributes additional value to the quality of public services, as well as increases the participation of citizens in the implementation of public control and political decision-making. Participatory governance concept is based on active involvement of citizens and co-production of a public product. The

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transition to digital public administration transforms the technological and political foundations of coordination structures. Electronic platforms offer open and neutral ways of communication, networking, while changing the institutions of public administration [18].

The processes of digitalization of public administration in Russian regions resulted with different dynamics of citizen engagement. This is due to the technical capabilities of the regions, the level of digital infrastructure development, and the digital competence of regional administrations in using information technologies in public governance. In addition, citizens themselves demonstrate different attitudes to electronic platforms, which is associated with two major factors. The first one is ensuring the information security of individuals. The second is the problem of trust, both individual and institutional, in the state. Individual trust is defined as a phenomenon and process that has a communicative nature. Some aspects of individual trust are related to group characteristics, as well as the logic of the process of social exchange and transfer of information. Institutional trust is determined by both political and economic factors. Digital transformation becomes a process that starts a group of governmental projects. The citizens' attitudes to e-platforms largely determine their success, as well as the prospects for effective interaction between society and the government.

The research is aimed to determine the factors that influence citizens' attitude to political institutions and e-government and e-platforms across ten Russian regions, as well as forming the necessary level of institutional trust that would encourage citizens to engage and proactively participate on e-platforms.

2 Literature Review

Currently, the political and administrative processes are taking on new forms and mechanisms that include components unusual for the old models, such as public expertise and evaluation, public forums, public-private commissions, and so on.

There are terms for these new forms of public participation in policy and decision making. For example, Warren calls these forms "managed democratization" [19]. Some scholars use the term "co-management". By drawing attention to citizen engagement and participation in public governance, Peter, Walker and Shannon give this process the name of participatory governance [17]. This partly independent trend in the modern theory of public administration summarizes the patterns of citizen engagement in politics, decision-making processes, and public service delivery.

It includes several conceptions such as "community engagement", "government involvement" or "integrated public management" [1, 10]. Therefore, the traditional problem of the relationship between politics and governance in these new concepts requires an understanding of the relationship between citizens and state institutions. While governmental performance issues remain, new challenges come to the fore: the sensitivity and responsibility of the government, political stability and the absence of violence, good organization (quality control), the rule of law and the fight against corruption.

In line with this research trend, the concepts of co-creation and co-production have become innovative for political science, public administration, and sociology. Initially, these concepts captured a new attitude to the provision of public services. Researchers

within this theoretical approach have criticized the market approach to the organization of production and provision of public services [3].

A new period in the development of these concepts relates to the era of digitalization of public administration. In recent years, studies on public policy development strongly considered the idea of co-production as the essential element. Compared to the categories of "cooperation", and "civic participation", this concept has expanded the understanding of the public policy cycle, studied the issues of political design, public policy management, included the stage of co-development and implementation of public values.

Co-production is a new topic for democratic public policy in an uncertain and complex environment. Researchers have focused on developing the idea of governance through cooperation, co-creation, and co-production of public policy. According to them, strengthening the collaboration in the public policy cycle would contribute to sustainable and inclusive development [4, 11].

The involvement of citizens in politics and its co-production increases confidence in the use of information technologies. These new competencies maintain relationships with government agencies. Researchers note that in the context of the growing role of digital technologies, there is a clear trend of decreasing confidence in public institutions, but at the same time there is a growing interest of citizens in politics. Keele links the dynamics of trust in government with the development of social capital [9]. MacDonald argues that against the backdrop of deepening income inequality in the U.S. public opinion about the redistribution of resources has mostly remained unchanged. This opinion asymmetry is perplexing because Americans are concerned about and aware of growing inequality according to him. He argues that trust in the government can smooth the imbalance [13]. Benay notes that the use of digital technologies to involve citizens in the decision-making process increases citizens' confidence in the government [2]. However, as other researchers say, creating an online system or service that people will trust, is a severe problem. For example, consumers sometimes avoid e-Commerce services because of concerns about their privacy or security. Currently, the number of studies aimed at identifying factors that affect user confidence in e-Commerce services. At the same time, creating reliable e-government services is a more complex task than organizing e-Commerce [15]. Taking into account the money spent on the development of digital government, as Mahmood emphasizes, the trend of declining confidence is an alarming indicator which requires systematic actions on the part of the government to change it [14].

The growing role of digital technologies in Russia's public administration resulted with contradictory trends in the sphere of interaction between society and the state. On the one hand, citizens are mastering new formats of interaction with the state in the electronic environment. People actively use the digital infrastructure of open government, websites and infomats, which allow them to receive public services quickly, at the lowest cost, as well as leave their feedback or suggestions for improving public services. On the other hand, the accumulation of experience in electronic interaction with public institutions is not strengthening trust in the state. Along with the general determinants of trust to the state as a political institution, in the electronic environment the level of uncertainty and

risks of citizens, connected with the necessity to realize interactions in a remote format, increases [8].

In this case, according to Coleman's point of view, the risks of information uncertainty should be eliminated as a result of an act of trust [5]. Accepting this point of view, in this study, we differentiate between two levels of trust. Trust in the state as a political institution coordinates public space [6], produces and distributes public goods. The second level is trust in the e-government infrastructure that ensures the possibility and efficiency of "transactions" between the state and the citizen (e.g. infomats, websites, payment systems, electronic signature). It appears that trust in the digital government becomes a complex social phenomenon, determined by many external and internal factors. Garfilkel, based on the research of drawing the work of Durkheim and Parsons, stresses that trust, being a condition of coordinated actions of the society members, reproduces stable, uniform social structures - guarantees of stabilization, which normalizes perception of the surrounding world and interactions between people [7, 20]. Involved in the digital space of interaction with political institutions, a citizen expects to see the traditional course of governmental procedures, a sequence of actions and management processes. Realizing his experience of interaction with the state in the real (analogue) environment, having already formed a level of trust, a citizen translates it into a digital format with an emphasis on convenience, transparency, and usability of electronic communication mechanisms. Closely connected with cultural determinants, including the digital culture of society and individuals, trust in the digital government is based on several fundamental principles:

1) expectations of certain parties' behavior (citizen-state), which is mostly managed by technological and procedural components, as well as by a high degree of individualization of a "user" of public services (through personal profiles);
2) expectations of parties' performance of assigned duties and limitations on abuse (first of all, it concerns normalization of the level of state control over citizens based on personal information, provided for the public services' operation);
3) state consolidation of state control over citizens based on personal information.

In the case when the listed conditions are not sufficiently fulfilled or are subjectively assessed by citizens as insufficient, the digital behavior of individuals may become distant or avoidant. For example, citizens insist on paper documents, prefer to use multifunctional public service centre rather than the site "Gosuslugi" (an electronic platform elaborated by Russian government to provide public services, the site was launched in 2009). Partly, trust is the result of an individual's active involvement in the digital environment and interaction with non-political institutions, social networks, e-commerce. At the same time, active involvement in the virtual space contributes to the formation of a sustainable system of expectations and a culture of performance, which in the future can be translated into interaction with the digital state.

The group of factors determining the attitude of Russian people towards e-government relates to the relationship between a citizen and the state in the digital environment on two levels. The subjective trust comes from the individual himself. It is determined by the level of personal digital culture and activities on the Internet with the state and other social institutions. *Objective* trust seems to be constructed by the

state; it is a policy of digitalization and virtualization of relations with the citizens as well as securitization of online processes. This policy involves building a unique digital environment and channels of communication with users (citizens) and stimulating trust relations. When alternatives are available (electronic/paper document circulation; real multi-functional centre/'Gosuslugi' website), a rational individual will seek to minimize risks (including those related to providing personal information on the Internet) and transaction costs [12]. There is a problem of information deficit: insufficient information support by the state for its activities in the digital space or low level of digital culture. This deficit may lead to disregard for the possibilities of the digital state, increasing fears related to electronic public services.

3 Research Design and Method

The main objective of this study is to identify the factors that determine Russian citizens' involvement in activities on the Internet and their perceptions of digital government.

1) To study whether or not citizens' perceived security, usability and convenience of electronic paper circulation and other digital instruments affect their confidence and willingness to adopt e-government?
2) To discuss the factors of trust to e-government in order to engage citizens with transactions and online consumption of public goods by using their data.

The factors considered to be affecting citizens' trust to adopt e-government we organize according to four main categories:

1) attitudes towards secure personal data, online instruments and processing systems as electronic document circulation;
2) level of individual culture and digital competence of users;
3) citizens' expectations of increasing state control and influence on personal life;
4) citizens' perceived technical and processing risks of using e-governance instruments (i.e. online transactions).

The theoretical model to be tested is presented in Fig. 1.

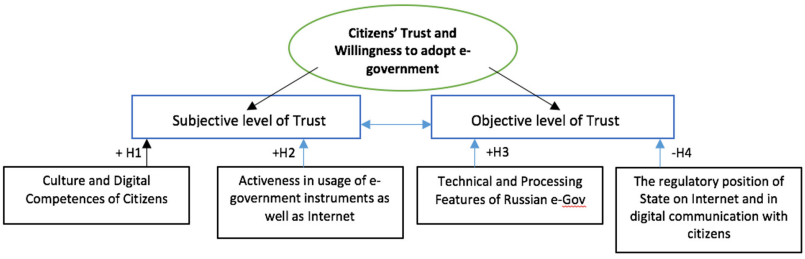

Fig. 1. Research model

Based on the theoretical model, we formulated *four hypotheses*:

H1: A citizen's level of digital literacy and competence as well as shared culture is positively related to the willingness to adopt e-government and its instruments of online communication.

H2: The increase of activeness of a citizen on the Internet may positively affect their willingness to use online e-government services, infomats, electronic signature.

H3: Technical and processing effectiveness and usability of online public services increase citizens' trust in e-government and their positive attitudes towards the implementation of digital communication with the state.

H4: The regulatory and information policy on the Internet and public sites may negatively affect citizens' trust to the e-government and their willingness to interact within the digital environment.

A survey instrument is a questionnaire (conducted via telephone interviews in ten Russian regions in November-December, 2019) consisting of three sections. Section 1 test citizens' activeness on the Internet and in public digital environment, usage of smartphones and e-government infrastructure. Section 2 covering some variables related to citizens' attitudes towards e-government, online public services, the regulatory policy of the state. Some questions test people's willingness to become engages with e-government. Section 3 relates to respondents' personal information (i.e., gender, age, education, occupation, personal income and region of a residence).

The sample size is 1200 people (from 18 years of age and aged over18). For the study, we selected ten regions of Russia, where, according to official data, digital government works better than in other subjects of the Russian Federation. The respondents of all ten surveyed areas were presented in equal numbers to compare the data on substantive issues correctly. The sample was quota based on unrelated features; gender, age, education and type of settlement are being control criteria. In the survey, women made up 55.9% and men 44.1%.

The proportion of respondents aged 18 to 24 years was 12.7%, 25 to 30 years - 11%, 31 to 39 years - 15.6%, 40 to 49 years - 17.3%, 50-59 years - 18.8%, 60 years and older - 24.6%.

Respondents with primary and incomplete secondary education made up 1.4%, full secondary (secondary school) — 10.2%, primary professional (school, lyceum) — 7.1%, secondary professional (technical school, college) - 26.1%, incomplete higher (3 years of higher education) - 4.3%, higher-51.0%.

Among the respondents, residents of the megalopolis and the regional centers made up 49.2%, other cities in the regions-26.0%, urban-type settlements-4.8%, villages, settlements, and villages — 20.0%.

4 Data Analysis

4.1 Activeness of Citizens on the Internet and Their Attitudes to Use e-Government Services

More than 92% of respondents use the Internet. Only 7.5% said they do not use the Internet at all. Their small number indicates that the Russian population is potentially

adapted to the conditions of the digital economy and is ready to use e-government services. Only one device for accessing the Internet is used by 28.9%, 2–44.3%. Three devices are already redundant, with only 13.0% using it. Four devices are used by 6.3% of respondents.10.2% of respondents do not use traditional Internet resources and social networks.

The mean of the Internet channels, networks, and messengers used is 5. However, the majority of the population (84.4%) consistently uses up to 7 resources of this type.

We must admit that the level of trust is not too high. The meaning falls on indicator 1, i.e. at least half of respondents trust only one source of information which is of priority for them, and almost 40% of respondents do not trust any such resource!

4.2 Usage of e-Government Services and Other Digital Public Instruments

One in four residents of the surveyed regions does not use any of the tools offered by e-government. This parameter is very high, indicating the need for more active work by public authorities to expand the list of services offered, develop programs to inform the population about such projects and improve information literacy of the population. 33.1% use only one tool (most often it is the "public services" portal), 29.5% use two tools, and less than 12% of respondents use three tools.

The mean of this indicator is 1. The majority of the population uses no more than two tools.

66.9% of respondents are registered and frequently use the 'Gosuslugi' portal. 33.1% might have heard and occasionally used the portal. Around 26.4% of Russian people never hear or use e-services provided by the state. Moreover, the majority of respondents never used infomants to get information about public services; only 7.5% reported about infomats as a convenient public information resource.

Russian people, according to the survey, are mostly using primarily one portal of e-public services 'Gosuslugi' (62,7% have hesitated to name any other existing national or regional public portals). Respondents do not value the electronic signature as a productive transactional tool; only 21,4% of respondents know and use it. However, 58,4% confirmed that they know but never use the electronic signature.

4.3 Technical and Processing Features of Russian e-Government

43.2% of respondents consider e-public services as entirely convenient and useful. At the same time, almost the same proportion of Russian people find them partly convenient and useful. The majority of the population (55,7%) supports and considers electronic document circulation as a progressive innovation. However, only 41,5% of people trusted electronic documents and noted that around 28.9% of their peers/friends and family share their attitudes.

Most people, 56,1% notice that electronic document circulation and management provided fast consideration of their inquiries to e-government and e-service provision. While 31,9% concerned about the privacy and security of personal data, 54.5% trust and think that their data secured and 51.1% feel safe in the process of electronic document circulation.

4.4 State Regulatory Regimes on the Internet and Citizens' Concerns About the Increasing Governmental Control Over People Through the e-Channels

People consider the application vis e-channels and e-devices as a more convenient way to get e-services (60.8%) and have moderate attitudes to the digital economy as a whole (56,3% of respondents express a stable positive attitude). However, regarding the citizens' concerns about state total controlling through e-governmental channels and portals, 69.3% of respondents express worries and say that there are grounds for alarm.

4.5 Subjective and Objective Trust to the State Institutions

The following two Tables 1 and 2 present calculations of the level of subjective and institutional trust in public authorities formed by citizens in the context of the growing role of e-government in the management and provision of public services. The presented data demonstrate a generally low level of public confidence in certain state institutions (the President of the Russian Federation, partly the government). It is essential to note that the level of trust of citizens to municipal and regional authorities that directly provide public services and ensure the operationalization of e-government in the field is low. This trend may lead to a reluctance to use electronic services, and the distant nature of the interaction between citizens and the digital government.

4.6 Factor Analysis

We have transformed features into binary dichotomous (encoded 1 and 0, in which 1 encoded the value of the element of interest to researchers, and 0 - other answers). The exception of absolute metric scales records the number of used means of digital government, the number of messengers, networks and Internet channels, as well as the number of user devices for access to the Internet. Then we conducted a factor analysis of the space of perception of residents of 10 regions about the digital government and indicators of their activity in the Internet space. The following Table 3 provides results that have been obtained in factor analysis.

As a result of factor analysis, six common latent factors were identified. They characterize the features of the population's attitude to e-government services. Elements have been arranged in order of decreasing importance for the people (from the strongest to the weakest).

Factor 1 - "Psychological trust in the reliability of public service tools and ensuring data confidentiality" - combines the following views of citizens. "Electronic document management ensures information security of citizens", "electronic platforms ensure the security of personal data", "increasing the use of electronic documents leads to total control by the state". The sign of the factor loading coefficient of the last variable named in this factor is negative. That influence means a negative impact on the attitude to e-government services.

Factor 2 - "Active use of e-government tools" - includes variables such as the use of public sites other than public services, the use of the portal 'Gosuslugi', and the use of electronic signatures. It is essential to underline that the fact that citizens use infomats

Table 1. Level of subjective trust to the state institutions

Trust to the state institutions	Trust absolutely	Rather trust	Trust in some ways, in some don't	Rather not trust	Don't trust absolutely	Difficult to answer	Overall	Balance of Trust	Anti rating of Trust
To Local Administrations and Community Administration	5,5	21,6	30,1	17,6	19,0	6,1	100,0	– 9,5	5
To Regional Parliament	6,3	17,2	26,3	18,2	20,3	11,6	100,0	– 15,0	3
To the Governor of the region	11,7	21,8	21,0	13,9	21,2	10,5	100,0	– 1,6	7
To the State Duma	7,1	15,5	23,9	20,6	25,2	7,6	100,0	– 23,2	2
To the Federal Council	8,7	17,9	24,6	15,8	20,4	12,7	100,0	– 9,6	4
The Russian Government	11,3	19,0	25,1	14,2	23,8	6,6	100,0	– 7,7	6
To the Head of the Government	8,6	14,6	19,6	13,8	34,4	8,9	100,0	– 25,0	1
To the President Vladimir Putin	27,8	22,5	16,9	9,5	17,9	5,5	100,0	+22,9	X

does not mean the experience of interacting with the digital government. The factor load coefficient of this variable is low for the second factor; it is related to the last one.

Factor 3 - "Trust in electronic document management" - includes such variables as trust in electronic document management, personal belief in existing forms of electronic document management, and support for replacing "paper" documents with electronic ones.

Factor 4 - "Culture and experience of using the Internet" - includes such variables as the number of messengers used, social networks and Internet channels for communication, trust in the Internet channels used, messengers and social networks, and the number of devices used to access the Internet. It directly characterizes the activity of citizens ' Internet communication. It should be noted that it is only in the 4th place, i.e. it is significant but does not play a decisive role in the use of e-government tools.

Factor 5 - "Influence of the State" - includes such variables as the sufficiency of informing the public about electronic services by the state, the convenience of currently existing electronic services, and trust in state institutions.

Factor 6 - "Technical characteristics of e-government services" - includes such variables as the use of infomats, increasing the speed of consideration of citizens ' issues

Table 2. Level of institutional trust and number of trusted state institutions, %*

Number of institutes	%	Accured %	Level of trust	%
0	38,7	38,7	Absent	38,7
1	15,6	54,3	Low	24,5
2	8,9	63,2		
3	7,6	70,8	Medium	18,2
4	5,7	76,5		
5	4,9	81,3		
6	5,6	86,9	High	18,6
7	4,0	91,0		
8	9,0	100,0		
Overall	100,0			100,0

*calculated variable

using electronic documents, a positive attitude to the development of the digital economy, and the convenience of submitting documents electronically.

4.7 Hypothesis Testing

According to conducted factor analysis and defined correlations between factors and citizen trust and willingness to interact with e-government, we may test our hypotheses.

H1: A citizen's level of digital literacy and competence as well as shared culture is positively related to the willingness to adopt e-government and its instruments of online communication.

We have determined the importance of the cultural factor and digital competence in the development of relations between citizens and the digital state. However, the significance is small, and the overall level of digital culture is not the dominant factor in the use of e-government tools by citizens. This hypothesis is not accepted.

H2: The increase of activeness of a citizen on the Internet may positively affect their willingness to use online e-government services, infomats, electronic signature.

Internet activity, frequency of use, and trust in public portals partly contribute to the expansion of citizens ' experience in the digital public environment. However, the use of infomats, as shown by the study, registration on state websites, does not mean that interaction with the digital government has become a common practice for Russians. The magnitude of the factor load is high, so the hypothesis is accepted.

H3: Technical and processing effectiveness and usability of online public services increase citizens' trust in e-government and their positive attitudes towards the implementation of digital communication with the state.

According to the factor analysis, the expansion of the state's technical and technological capabilities in the digital public environment has a positive impact on the involvement of citizens and the convenience of receiving public services. However, the factor load is very low, so the hypothesis is rejected.

Table 3. Component matrix after rotation*

Variables included in the analysis	Variables					
	1	2	3	4	5	6
Electronic document management ensures information security of citizens	0.786					
Electronic platforms keep personal data safe	0.748					
The increasing use of electronic documents leads to total control by the State	−0.667					
Use of public websites other than the portal 'Gosuslugi'		0.698				
Use of the portal 'Gosuslugi'		0.680				
Electronic signature use		0.451				
Public trust to electronic document management			0.705			
Personal trust in existing forms of electronic document management			0.704			
Support for replacing paper documents with electronic ones			0.653			
Number of messengers, social networks and Internet channels used for communication				0.795		
Trust in used Internet channels, messengers and social networks				0.775		
Number of devices used to access the Internet				0.516		
Sufficiency of informing the public about electronic services by the State					0.717	
Convenience of currently existing electronic services					0.628	
Trust in the institutions of state power					0.396	
Infomata use		0.270				−0.616
The electronic document increases the speed of consideration of citizens' inquiries						0.522
Positive attitude towards the digital economy						0.515
it is more convenient to submit documents electronically						0.465

* The method of the main components is used. Rotation method: varimax with Kaiser normalization. The rotation converged in eight iterations.

H4: The regulatory and information policy on the Internet and public sites may negatively affect citizens' trust to the e-government and their willingness to interact within the digital environment.

According to the study, citizens, are cautious about state regulatory policy on the Internet and see opportunities to expand state control over citizens through the activation of electronic document circulation, increasing the number of transactions of citizens in the public space of the digital economy. The factor load is high, and the hypothesis is accepted.

5 Conclusion

This research contributes to further understanding of the principles of participatory governance theory and the concept of co-production. The study concludes that the attitude of citizens to e-government and trust is the result of many processes. On the one hand, it is the development of conventional digital culture and the accumulation of experience in interacting with digital services in the commercial and public sector. On the other hand, this is a systematic work of the state to improve the institutional and technical mechanisms for providing electronic services, eliminating processing errors and failures. Moreover, the subjective attitudes of citizens to engage in relations with the digital government depends on personal and institutional trust in primary political institutions and the creation of a transparent, accessible, user-friendly electronic environment that provides citizens with opportunities to participatory governance. In addition, our research has shown that efforts are needed to develop digital literacy and intelligence. The accumulated experience of social interaction on the Internet is an impact factor for improving communication and co-production with the state.

State information policy is of paramount importance. It should support democratic principles of digital governance and ensure that citizens' interests are represented. In addition, information policy should contribute to ensuring security in relations between the state and the citizen.

Nowadays digital public space constitutes opportunities to strengthening network coordination of participants. The problems of combining horizontal and vertical coordination of interactions on state platforms are becoming relevant. This trend raises new research questions. What factors contribute to the strengthening of horizontal (network interactions) of citizens on state electronic platforms? What resources can be allocated and distributed to achieve public goals? Further detailed study of these issues will provide evidence-based policy proposals on how to make e-platforms a more effective and efficient way for citizens and governments to interact.

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References

1. Ansell, C., Gash, A.: Collaborative governance in theory and practice. J. Public Adm. Res. Theor. **18**(4), 543–571 (2008). https://doi.org/10.1093/jopart/mum032
2. Benay, A.: Government Digital: The Quest to Regain Public Trust. Dundurn, Toronto (2018)
3. Bovaird, T., Loffler E.: From engagement to co-production: how users and communities contribute to public services. In: Pestoff, V., Brandsen, T., Verschuere, B. (eds.) New Public Governance, the Third Sector and Co-production, pp. 35–60. Routledge, New York and London (2012)
4. Cabannes, Y.: Participatory budgeting: a significant contribution to participatory democracy. Environ. Urban **16**(1), 27–31 (2004). https://doi.org/10.1177/095624780401600104
5. Coleman, J.S.: Foundations of Social Theory. The Belknap Press of Harvard University Press. Cambridge, MA (1990)
6. Cooper, T., Thomas, J.: Nature or Nurture: A Crisis of Trust and Reason in the Digital Age. Book Printing, London (2019)
7. Garfinkel, H.: A conception of, and experiments with, "trust" as a condition for stable concerted actiYons. In: Harvey, O.J. (ed.) Motivation and Social Interaction, pp. 187–238. Ronald Press, New York (1963)
8. Kabanov, Y., Vidiasova, L.: C2G online trust, perceived government responsiveness and user experience. In: Lindgren, I., et al. (eds.) EGOV 2019. LNCS, vol. 11685, pp. 57–68. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-27325-5_5
9. Keele, L.: Social capital and the dynamics of trust in government. Am. J. Polit. Sci. **51**(2), 241–254 (2007). JSTOR, www.jstor.org/stable/4620063
10. Kernaghan, K.: Moving towards integrated public governance: improving service delivery through community engagement. Int. Rev. Adm. Sci. **75**(2), 239–254 (2009). https://doi.org/10.1177/0020852309104174
11. Krenjova, J., Raudla, R.: Policy diffusion at the local level: participatory budgeting in Estonia. Urban Aff. Rev. **3**(4), 1–29 (2017). https://doi.org/10.1177/1078087416688961
12. Luhmann, N.: Familiarity, confidence, trust: problems and alternatives. In: Gambetta, D. (ed.) Trust: Making and Breaking Cooperative Relations, electronic edition, Department of Sociology, University of Oxford, chapter 6, pp. 94–107 (2000). https://doi.org/10.2307/591021
13. Macdonald, D.: Trust in government and the American public's responsiveness to rising inequality. Polit. Res. Q. (2019). https://doi.org/10.1177/1065912919856110
14. Mahmood, M.: Does Digital Transformation of Government Lead to Enhanced Citizens' Trust and Confidence in Government? Springer International Publishing, Cham (2019). https://doi.org/10.1007/978-3-030-01759-0
15. Marsh, S., Patrick, A., Briggs, P.: Social Issues of trust and digital government. In: In Information Security and Ethics: Concepts, Methodologies, Tools, and Applications. edited by Hamid Nemati, pp. 2905–2914. IGI Global, Hershey, PA (2008). http://doi.org/10.4018/978-1-59904-937-3.ch033
16. OECD. Recommendation of the Council on Digital Government Strategies. OECD Publishing, Paris (2014)
17. Walker, P.E., Shannon, P.T.: Participatory governance: towards a strategic model. Community Dev. J. **46**(suppl_2), ii63–ii82, April 2011. https://doi.org/10.1093/cdj/bsr011
18. Smorgunov, L.V.: Institutionalization of governability and the problem of veillance in the space of digital communications. South- Russ. J. Soc. Sci. **20**(3), 62–75 (2019)
19. Warren, M.E.: Governance-driven democratization. Crit. Policy Stud. **3**(1), 3–13 (2009). https://doi.org/10.1080/19460170903158040
20. Watson, R.: Constitutive practices and garfinkel's notion of trust: revisited. J. Class. Sociol. **9**(4), 475–499 (2009). https://doi.org/10.1177/1468795X09344453

Artificial Intelligence in the "Our St. Petersburg" e-Participation Portal Functioning: Outcomes of Intellectual Classifier Development

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Abstract. The paper presents main results of the intellectual classifier development, which is the one of approaches to optimize the process of message submitting to the "Our St. Petersburg" portal and its further verification by special moderation services. Based on training data sample and 200 categories, the algorithm of automatic classification was trained using such classical methods of machine learning as naive Bayes classifier, decision trees, support vector machine and artificial neural networks. Metrics of the effectiveness and relevance of the developed solution are presented, statistics, results and analysis of testing on real data are presented, and prospects for further work are determined.

Keywords: Artificial intelligence · Machine learning · Natural language processing · Artificial neural networks · Classifier · e-participation

1 Introduction

Opportunities for increasing citizen participation in public policy and governance improves every year [1, 2]. The old feedback forms are being replaced with new ones, in which citizens receive important social and political information through open access to information and communication technologies, by which they share their informed opinions on a wide range of issues and directly influence the political processes of their state and regional governance. Concepts such as "e-government", "e-democracy", and "e-participation" are actively developing and expanding [3, 4].

Governments of many developed countries have already been using the latest technologies and tools and been strongly following world main trends in ICT and IoT fields development to solve their own key tasks in the field of public administration with the help of modern and effective tools.

Artificial intelligence (AI) is the main trend in the IT-development in the world. It is actively used by countries in processing Big Data, cloud computing operations, automating routine processes, optimizing IT-tools, improving services' quality, predicting risks, supporting decision-making [5–7] etc.

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The most well-known modern methods and approaches from the pack of AI tools (technologies) are machine learning methods, Natural Language Processing, Data Mining etc. In Russia, the relevance of these technologies is due to implementation of national program "Digital economy of Russian Federation" and National strategy for artificial intelligence development for the period up to 2030, approved by presidential decree № 490 of October 10, 2019.

In this paper, the "Our St. Petersburg" city portal was considered as an e-participation system. The portal has become one of the most effective tools of e-participation implemented in St. Petersburg, so many urban problems are quickly brought to the city administration and successfully solved in the shortest possible time. However, as a result, the load on the portal has increased significantly. During the functional and business analysis of the portal processes, described in [8], some shortcomings and problems were identified in the procedure for submitting messages to the portal and further working with them. Therefore, the main goal of the work was to increase the "Our St. Petersburg" portal activity effectiveness as one of e-participation systems by using artificial intelligence tools.

2 Process Optimization of Submitting Messages to the "Our St. Petersburg" Portal

2.1 About the "Our St. Petersburg" Portal

The "Our St. Petersburg" portal was created on the initiative of the Saint Petersburg Governor for the city residents operational interaction with Saint Petersburg authorities representatives [9]. The portal is developing: as of April 2020, more than 2.25 million messages about urban problems have been submitted, of which more than 2.2 million messages have already been resolved (more than 96% of the total number), and the number of registered users is more than 170 thousand people, still this figure continues to grow. By using this government resource citizens can send messages about various problems related to housing and urban improvement, the state of sidewalks and roads, illegal objects of trade and construction etc.

For about 6 years of portal existence (2014–2020) the following indicators were achieved:

- the number of problem categories increased 3.5 times: from 56 to 200;
- the number of authorities involved in the work increased by 2.4 times: from 23 to 56;
- the number of organizations/performers increased 57 times: from 54 to 3102;
- the number of personal accounts of applicants increased by 4.8 times: from 6344 to 30640;
- the number of users registered on the portal has increased by more than 10 times: from 17 thousand to 170 thousand;
- the number of initial reports of problems has increased by an average of more than 140 times.

Sent through the "Our St. Petersburg" portal messages without fail are considered by city services in strictly established terms depending on chosen category according

to the determined classifier of messages. After submission a portal user could receive information about the progress of sent messages' consideration and processing as well as to evaluate the response received.

2.2 Identified Shortcomings of Submitting Message to the Portal Process and Problem Solution

In the work [8] during the analysis of submitting message to the "Our St. Petersburg" portal process shortcomings and problems related to non-trivial classification of messages were found (inconvenience for the user to independently select a problem category out of 200 available (where according to statistics 20–25% of messages (1/4 part) are rejected due to incorrect category selection), a high load on the moderation services, which increases the time and efforts for reviewing and processing messages, so it was necessary to develop an approach to optimize the above process and improve the system effectiveness and also develop a solution to the problem.

As one of the solutions, it is proposed to design and develop automatic classification of citizens' messages. In order to minimize the risk of erroneous user definition of the category and to increase the efficiency of moderation service for processing incoming messages, the following approach to solving this problem is proposed:

- to submit a problem message it is necessary to exclude the obligation for the user to choose a problem category from the Classifier on his own or enter keywords in the search form: for this purpose, the user needs just to describe the problem in the form of a message text. Follow the procedure when submitting, such as specifying the location of an existing problem on a map and uploading supporting photos, save.
- for moderation service to develop the module of automatic text message classification which will present result of work in the form of the ranked list from three certain categories with the corresponding percent of classification accuracy for the subsequent choice by the moderator.

To solve this problem of process automation it was proposed to use the main methods of machine learning and natural language processing, analyze and compare their results and reduce the task of process automation to a standard type of machine learning tasks – classification task. Thus, the main solution was to develop an intellectual classifier based on the algorithm for automatically classifying citizens' messages using artificial intelligence tools.

3 Intellectual Message Classifier Development

The process of developing an intellectual message classifier meant designing the interaction of a new software solution with the existing functionality of the "Our St. Petersburg" portal, which provides the process of submitting a message and further work with it, and directly developing an algorithm that allows automatically classifying the user's message category of problems from the portal classifier, and developing a web module for

the user's and moderator's personal accounts that allows us to optimize the process of submitting and working with messages.

The main core of the intellectual classifier is an algorithm for automatically classifying citizens' messages based on artificial intelligence tools. The major purpose of this algorithm is to automatically determine the problem category of recorded in the portal classifier by the text of the message submitted by a citizen on the "Our St. Petersburg" portal.

To build a classification model based on analysis of works the following machine learning methods were chosen, showing traditionally good results when working with text information: naive Bayesian classifier [10], decision tree [11], support vector machine (SVM) [12] and artificial neural networks [13]. Three types of neural networks with different architectures have been proposed: feed-forward neural network (FFNN), convolutional neural network (CNN) and recurrent neural network (RNN) with LSTM block. Each of methods has its advantages and disadvantages, but each has good results in classification problems, so it was decided to apply different methods and architectures and analyze the result within conditions of stated problem.

The model was developed with Python programming language. Keras framework (with an add-on over TensorFlow mechanisms) and scikit-learn library were used to implement machine learning methods and configure classification models.

Natural language processing methods were also used to process and prepare data for the correct operation of the algorithm.

1.5 million data of citizens' messages were fetched from portal database. Submitted to the portal messages have already got a category that were defined by user himself, so messages checked and accepted by the moderation service were used as data. According to common world practice data were divided into training and test samples in a ratio of 80/20. This approach allowed us to obtain objective estimates of trained model classification accuracy.

For the model to be able to work with incoming data stream, it was necessary to pre-process and represent it in numerical form. At preliminary stage all obtained data was processed: punctuation marks, invisible symbols and numbers were removed, words were converted to lower case and initial form (for words with different prefixes, suffixes and endings) [14].

TF-IDF measure [15] was used to represent an array of data in the form of numeric vectors, which reflects importance of using each word from a certain set of words (number of words in the set determines the dimension of vector) in each body of text. Also, technique helped to exclude the most frequently encountered words (for example, prepositions and conjunctions) or Vice versa rarely encountered, because such words carry little useful information and only add information noise to unstructured text bodies.

Another point of improving search for significant features in the text was formation of a stop-words list, which mainly includes names of streets or urban facilities, also do not have a significant impact on the definition of problem category.

As another Natural Language Processing method, Word2Vec algorithms [16] were used to represent words in vector space. Algorithms used text context to form numerical representations of words, so words used in the same context had similar vectors. This

approach also provided an effective way to identify significant features in text to improve the result of classification.

After training model with different methods tests were conducted since a test sample. To assess quality of trained model we used mean metric F-measure [17].

The results of trained models with different machine learning methods are presented in the Table 1 below:

Table 1. F-measure and training time for different machine learning methods

	Machine learning method's name					
	Naive Bayesian classifier	Decision tree	SVM	FFNN	CNN	RNN with LSTM
F-measure (%)	65.2%	67.6%	71.0%	80.1%	82.9%	81.9%
Model's training time	20 min	5 h 14 min	56 min	1 h 35 min	2 h 5 min	2 h 35 min

According to analysis of presented F-measure accuracies indicators the best and quite fast learning method machine learning, which was applicable in our classification tasks, was convolutional neural network (CNN), which showed almost 83% of accuracy in identifying problem category based on the body of text message. The model with a recurrent neural network (RNN) with an LSTM block, which is traditionally one of the best in text classification problems nowadays, performed slightly worse (i.e. a difference of 1%). However, we decided to use all three algorithms based in neural networks as the best performed in intellectual message classifier development.

4 Testing and Analysis of the Intellectual Message Classifier

The results of training and testing models during the implementation of the algorithm for automatic classification of citizens' messages are presented below. In addition, statistics are provided on the accuracy of determining categories of problems by the intelligent classifier in comparison with the solutions of moderators and users to assess the quality of the developed models. The results were also analyzed and prospects for further implementation and maintenance of the developed software solution were determined.

We received statistics on new real data that were received on the portal from June 3 to June 16, 2019. The number of all new messages for 2 weeks was 32548. The result is shown in the diagram (Fig. 1).

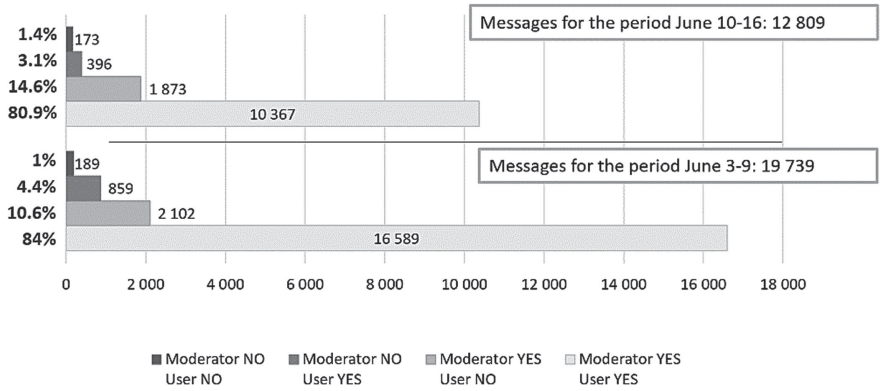

Fig. 1. Messages statistics for June 2019

To calculate statistics, the best model based on convolutional neural networks (CNN) was used, showing an average classification accuracy of 82.99%.

The value "Moderator YES User YES" means that the problem category defined by the CNN model coincided with the both decisions of the moderator and the user, i.e. all three entities identified the problem category in the same way based on the message submitted to the portal. According to statistics, this scenario is most likely—more than 80% of the total number of messages sent for two time periods.

The value "Moderator YES User NO" means that the CNN model correctly identified the category of problems like the moderator's decision, but the user was wrong (i.e. their message could have been rejected). This value is the most significant for the model, because in this case, it determines its high quality and efficiency, which can help reduce the percentage of rejection of messages due to incorrectly selected categories on the portal. The probability of this situation occurring was more than 11% according to statistics.

The value "Moderator NO User YES" indicates a situation when both the CNN model and the user incorrectly identified the problem category based on the message, because it did not match the moderator's decision. In this case, there are two possible events: either the model was trained on inappropriate examples and made an error, or the model and the user defined the category correctly, but due to inattention or other factors, the moderator rejected this message. This situation occurs in no more than 4% of cases according to the statistics provided.

The value "Moderator NO User NO" means that the CNN model incorrectly defined the category and did not match the user's decision. This situation is the worst for the model, because it could have incorrectly identified a category, thus allowing the user to reject this message, even though the user correctly specified the problem category based on their message. However, this situation occurs quite rarely and does not exceed 1.5% of cases.

Based on the analysis of test results, it turned out that the intellectual classifier showed 95% accuracy in determining the category of problems in messages for the specified period.

5 Discussion

Obtained results of intellectual classifier development showed us the opportunities of decreasing percentage of users' mistakes in problem category choosing and increasing comfort while working on city "Our St. Petersburg" portal. This fact may be a key point of users' loyalty and trust to government services increasing. Also, classifier became a good helper for moderators in checking correctness of messages' problem category therefore reducing time for this checking. In future, this may lead to the possibility of completely replacing manual way with an automatic method for problem categories classifying and checking especially in popular categories.

Class of artificial neural networks showed again best results within traditional methods in task of text classification. However, there is still not a high precision of category prediction (less than 85%) so future research can take into improvement of classification by changing types of neural networks, their combination and assembling, tuning hyperparameters, using more balanced and relevant dataset for relearning.

Outcomes of using these kinds of neural networks showed also good results in working with multiple classes (over 100) and imbalanced data. By the way, presented set of methods and data could be toolkit for future investigations not only in text area because we can feed methods with different data but in various fields where we come across multiple classification task of highly sparse data, for instance from finding cancer abnormalities in Oncology to music recommendations.

6 Conclusions

This paper described the identified shortcomings in the process of messages submitting to the "Our St. Petersburg" portal and its optimization.

The stage of development of an algorithm for automatic classification of citizens' messages by categories on the "Our St. Petersburg" portal based on machine learning methods was described. The algorithm was trained on data previously divided into training and test samples in the ratio of 80/20, respectively, as well as analyzed and presented in vector form using natural language processing methods.

The best method of machine learning used in the automatic classification algorithm was the convolutional neural network (CNN), which showed an average accuracy (i.e. F-measure) of category determination of about 83%. The developed algorithm with this method was used in testing on real data for a certain period to determine the effectiveness and relevance of the developed solution.

Based on the analysis of the results obtained, a reduction in the average time for processing 1 message from the moderator by at least 30% (which will allow us to meet the deadline for processing the message in accordance with the rules) was noticed. The percentage of rejecting messages due to incorrectly selected categories has also decreased (from 20–25% to 15–20%, i.e. by at least 5%), the user experience with the portal has improved, and the process of submitting a message to the portal for the user has been simplified.

An important vector of this topic development is the possibility of using the results in projects for the development of information systems for electronic interaction of citizens

with authorities that provide feedback in the ecosystem of the Smart city. One of the key tasks that ensures semantic compatibility of various industry components of a Smart city is the need to create and maintain a classifier of urban objects that describes these objects in all their various uses. Creating tools that reduce labor costs when classifying multiple objects is a very promising task.

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References

1. Jansen, A.: The understanding of ICTs in public sector and its impact on governance. In: Scholl, H.J., Janssen, M., Wimmer, M.A., Moe, C.E., Flak, L.S. (eds.) EGOV 2012. LNCS, vol. 7443, pp. 174–186. Springer, Heidelberg (2012). https://doi.org/10.1007/978-3-642-33489-4_15
2. Chugunov, A.V., Rybalchenko, P.A.: E-participation system development in St. Petersburg: the case of "our Petersburg" Portal, 2014–2018. Inf. Resour. Russ. **6**, 27–34 (2018)
3. Krylov, A.A.: "E-participation" as a form of political and civic activity in the internet space. In: Proceedings of the Southwest State University. Series: History and Law, vol. 8, 2(27), pp. 143–148 (2018)
4. Chugunov, A.V.: Cooperation of citizens with the authority as a feedback channel in e-participation: institutionalization issues. Vlast' **10**, 59–66 (2017)
5. Pandya, J.: The Geopolitics of Artificial Intelligence. https://www.forbes.com/sites/cognitiveworld/2019/01/28/the-geopolitics-of-artificial-intelligence/#5a4b420979e1
6. Dutton, T.: An Overview of National AI Strategies. https://medium.com/politics-ai/an-overview-of-national-ai-strategies-2a70ec6edfd
7. Kosorukov, A.A.: Artificial intelligence technologies in the modern public administration. Sociodinamika **5**, 43–58 (2019). https://doi.org/10.25136/2409-7144.2019.5.29714
8. Begen, P., Chugunov, A.V.: Intellectual classifier development of citizens' messages on the "our St. Petersburg" portal: experience in using machine learning methods. In: CEUR Workshop Proceedings, vol. 2543, pp. 82–92 (2020)
9. O portale. https://gorod.gov.spb.ru/about/
10. Barsegyan, A.A., Kupriyanov, M.S., Holod, I.I., Tess, M.D., Elizarov, S.I.: Analiz dannyh i processov: ucheb. Posobie. 3d izd., pererab. i dop. BHV-Peterburg, St. Petersburg (2009)
11. Aggarwal, C.C.: Data Classification: Algorithms and Applications, 1st edn. Chapman & Hall/CRC, London (2014)
12. Colas, F., Brazdil, P.: Comparison of SVM and some older classification algorithms in text classification tasks. In: Bramer, M. (ed.) IFIP AI 2006. IIFIP, vol. 217, pp. 169–178. Springer, Boston, MA (2006). https://doi.org/10.1007/978-0-387-34747-9_18
13. Prasanna, P.L., Rao, D.R.: Text classification using artificial neural networks. Int. J. Eng. Technol. **7**(1.1), 603–606 (2018)
14. Zibert, A.O., Hrustalev, V.I.: Development of a system for determining the existence of adoption in the works of the students. Methods of preparation of automatic text processing. Universum: Tekhnicheskie nauki: elektron. nauchn. zhurn. **4**(5) (2014)
15. Ingersoll, G.S., Morton, T.S., Ferris, E.L.: Taming Text: How To Find, Organize, and Manipulate It. Per. s angl. Slinkin, A.A. DMK Press, Moscow (2015)
16. Mikolov, T., Chen, K., Corrado, G., Dean, J.: Efficient estimation of word representations in vector space (2013)
17. Sasaki, Y.: The truth of the F-measure. Teach. Tutor. Mater. **1**(5), 1–5 (2007)

E-City: Smart Cities and Urban Governance

Analysis Methods of Spatial Structure Metrics for Assessment of Area Development Effectiveness

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Abstract. Cities are different in their organization, but perform the same key functions everywhere in the World. However, cities sometimes provide their residents with radically different living conditions despite their apparent identity. Is it possible to compare different cities looking at their spatial structure? How to evaluate the relevant parameters? How to objectively describe living conditions, taking into account the existing nature of the use of the territory? The presence of a sufficient number of life support objects, their correct location and accessibility ultimately determine the environment quality for people life activity. The morphology of urban development is determined by the planning and zoning of the territory, urban planning standards, in which there are such indicators of regulation of development as the building coefficient, the density of the road network, the maximum and average number of buildings floors, etc. In this regard, it is proposed to introduce a systematic indicator of the quality of the urban environment, such as the area coherence, which will allow to assess the development conformity of provision infrastructure to meets the population needs. The paper discusses the analysis of urban space structure and suggests methods for measure metrics that will objectively assess the infrastructure provision of a particular section of the urban area, as well as obtain an integral indicator of urban environment quality. It is proposed to use the methods of geospatial data analysis and GIS technology to do this.

Keywords: Assessment methods · Spatial structure metrics · Urban area · City · Area coherence · Consumer properties class · Provision infrastructure · Development quality assessment · Floor/Area Ratio (FAR) · Quarter · OpenStreetMap · QGIS

1 Introduction

The issue of assessing the effectiveness of area development cannot be resolved without the analysis of life quality indicators. There are more than 200 different indexes and

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ratings of cities in the world, which are used to assess the quality of life. The methodology for calculating the Urban Sustainability Index (USI) developed by the McKinsey Global Institute [1] and the rating of cities by the quality of life of the Mercer consulting group [2] are most famous foreign methodologies for analyzing the quality of the urban environment. USI takes into account the characteristics of the urban environment such as population density, intensity of public transport use and the area of landscaping of public space, and Mercer analyzes housing, social and economic conditions, not taking into account the quality of urban development [3].

The urban environment quality index developed by the specialists of Strelka Design Bureau [4] is designed to monitor the urban environment in all 1114 cities of Russia, regardless of their size, number of inhabitants, climate and other factors. The index is compiled for each city based on six types of space and five assessment criteria [5]. The methodology that based on these studies was approved for the formation of an urban environment quality index (Decree of the Government of the Russian Federation dated March 23, 2019 No. 510-r), which is used to identify the competitive advantages of cities and the constraints of cities development [6].

A common drawback of existing approaches is that they do not take into account the properties of urban space, the structure of the territory, and the processes of its transformation [7]. Nevertheless, urban morphology is determined by the planning and zoning of the territory, urban planning standards, in which there are such indicators of building regulation as the building area coefficient, the road network density, the maximum and average number of building floors, etc. [8–10]. These indicators are used in the development of urban planning documentation in Russia. But their impact on the quality of the urban environment is not described in current standards. Although it is important that cities understand how to achieve their development goals using existing tools for urban development regulation and zoning [11].

The presence of a sufficient number of life support objects, their correct location and accessibility are ultimately determine the quality of the living environment of people. In this regard, it is proposed to introduce a systemic indicator of urban environment quality, such as the area coherence (AC), which will allow to assess the development conformity of provision infrastructure to meets the population needs.

The studies of urban space are necessary to measure this indicator, and to make it possible to objectively assess the provision of infrastructure for a particular section of the urban area and summarize the data obtained. It is proposed to use for this analysis of geospatial data and GIS technology.

2 Overview of Modern Approaches to Area Development Effectiveness Assessment

The UN sustainable development goals contain a number of indicators characterizing the level of development of the provision infrastructure. For example, goal No. 11 “Sustainable Cities and Communities” of the Habitat program contains a number of indicators that measure the success of its achievement, such as accessibility to public transport and open spaces, number of people, air quality, etc. [12].

Modern practice involves zoning of city area for various purposes. So, transport zoning is used to fulfill the individual needs of users in using the transport network, but the same tool allows various stakeholders to solve the inverse problem, including the redistribution of traffic flows, increasing transportation profitability, developing certain territories by stimulating traffic, etc. [13]. Zoning is a tool for planning the area development in land management and architecture and is used for dividing land into plots with different purpose and legal regime for use, establishing urban planning regulations [14]. In addition, the functional zoning that differentiates the spaces according to the predominant location of buildings for the same purpose for the formation of a common development strategy and the efficient use of territories with different characteristics in terms of climate, transport accessibility, resource component and other essential parameters is customary for urban areas [15].

An integral part of zoning is the requirements for urban morphology, which affects the quality of the urban environment. For example, the use of the Ratio of open Spaces index for the design of urban neighborhoods in order to reduce PM10 concentration is recommended for regulation of development [16]. Also, a lot of modern research is aimed at determining the compact urban form and the negative consequences of urban sprawl. There are many studies that a higher density and compact urban form have a positive effect on the quality of life [17], accessibility of urban infrastructure objects [18], safety [19] and social connections quality [20].

Solving issues of sound zoning, choosing the optimal urban form and building morphology can contribute to the achievement of local environmental improvements and global development goals. This also counteracts the spread of infectious diseases and climate change, since, for example, building density affects the energy efficiency of buildings and the availability of infrastructure, etc. [21].

3 Approach to Development Quality Assessment of Urban Area

The zoning tasks in the existing settings are focused on planning the territory development from the point of view of urban planners, land planners and developers and do not take into account the real needs of residents, which, moreover, can change quite quickly. Total dependence on regulations leads to an unreasonable choice of urban planning decisions and a decrease in the efficiency of the use of the territory. In this regard, a new approach to solving the zoning problem of an urban area, based on an analysis of its consumer properties, is proposed. We introduce the following definitions:

Class of consumer properties (CPC) is the nature of actual area use structure, that determined by the combination of provision infrastructure objects located on it or within the radius of close influence.

Provision infrastructure (PI) is a complex of spatial objects and interconnected structures that make up the material basis for functional subsystems of implementation of people life activity needs in an urbanized area. The following types of objects can be distinguished in the complex of objects and structures that constitute PI:

- Objects to ensure the physiological needs of man.
- Objects to ensure the security.

- Objects to ensure the socialization.
- Objects to ensure the self-realization.

Coherence research is carried out for ultralocal sections of area (UlA), for which it is proposed to use squares with a side of 250 m [22], and for which the accessibility parameters will be calculated for objects within 750 m of walking path (PWA) in all directions from the center of UlA. At the same time, all objects of the territory have functional of needs fulfillment with a characteristic common feature, which can be attributed to a specific functional stratum (FS), representing the minimum complex of a typical PI.

The composition of the parameters for assessing coherence and identifying CPC is proposed to be considered as a system of indicators, including the following groups:

- Local indicators (LI) determine the CPC of territory section and characterize its staffing with the objects of PI of walking accessibility that characteristic this consumer class of territory, for example:
  - Ratio of the area of all floors of residential real estate objects to UlA square (%).
  - Number of housing offers for rent at UlA (pcs).
  - Share of UlA area under residential real estate (%).
  - Share of housing provided with centralized heat, water, electricity and wastewater services in the total housing stock of UlA (%).
  - Share of UlA area with green spaces (%).
  - Number of medical institutions in PWA (pcs).
- Central indicators (CI) are characterize the staffing of the entire urbanized area under consideration with PI objects, which are the single key socio-economic and infrastructural artifacts for UlA of which should be ensured isochronous connection with all area fragments of certain CPC correlating with them:
  - UlA with "network" objects (CI_{NO}), for example:
    - Services of public-state relations such as the MFC, civil registry offices, police, tax inspection, courts.
    - Legal organizations.
  - UlA with unique objects (CI_{UO}), for example:
    - Long-distance transport hubs.
    - Higher education institutions.
    - Stadiums and sports complexes.
- Integration indicators (II) are characterize the interconnectedness of the entire urbanized territory under consideration and complementary CPC, as well as the isochronous connectedness of the objects forming the CI with all equidistant area fragments of certain CPC correlating with them:

- Connection of all UlA with all other UlA in the area under consideration through a public transport route network (isosurface), II_{PT}.
- Connection of all UlA with all other UlA in the area under consideration through a road network (isosurface), II_{RN}.
- Availability of UlA with CI objects for all UlA of the area under consideration through a public transport route network using relative II (isosurface), II_{CIpt}.
- Availability of UlA with CI objects for all UlA of the area under consideration through a road network using relative II (isosurface), II_{CIrn}.

- Structural indicators (SI) are characterize the approach to the placement of PI and the use of urbanized area:

  - Share of the built-up area of UlA (%).
  - Ratio of the area of all floors of all real estate objects to UlA square (%).
  - Average area of a quarter on UlA as estimated in a sliding accessibility window (sq.m).
  - Road network density on UlA (km/sq.km).
  - Ratio of road network area to UlA area without water objects (%).

Assessment of the current level of coherence is performed separately for each of the selected parameters for each UlA.

The stratum integral coherence indicator for each UlA is calculated as the arithmetic mean of all parameters characterizing a certain FS. In this case, the parameters measured in absolute units are standardized.

A single indicator of area coherence is formed from the given values of indicators system:

$$AC = <LI, CI, II>, \tag{1}$$

where LI is calculated as the arithmetic mean of FS relative values on the scale from the zero FS value to its maximum for UlA in the entire area under consideration;

CI consists of four indicators, calculated as the combined availability of CI_{NO} and CI_{UO} using personal and public transport:

$$CI = <CI_{NO},\ CI_{UO},\ II_{CIpt},\ II_{CIrn}>, \tag{2}$$

i.e. average availability of all objects that are separately included in CI_{NO} and CI_{UO} for each UlA through the road network and the public transport route network;

II is taken into account in the form of two parameters that reflect the absolute values of the connectivity of all UlA through the road network and the public transport route network:

$$II = <II_{RN},\ II_{PT}>. \tag{3}$$

4 Methods for Assessment of Area Structure Metrics

OpenStreetMap (OSM) [23] data will use as a cartographic basis for research. OSM currently has fairly comprehensive data on settlements in Europe, Asia and North America, which allows the use of data on buildings and the road network in the study of urban development. This is quite enough to analyze existing build up areas, which can be supplemented with clarifying data and allow to move on to more detailed researching. For example, OSM data for Russian cities can be supplemented with the following information from the register of apartment buildings from the "ReformGKH" service [24]:

- Living area.
- Year of construction.
- Provision by housing and communal services.

OSM data that can be directly used as characteristics of an area:

- Road graph.
- Class of roads and number of lanes.
- Land use (border coordinates, types; park, housing, cottages, industrial objects, military objects).
- Buildings (border coordinates, types).
- Public transport stops.
- Basic objects of social services (schools, kindergartens, hospitals, etc.).
- Natural objects (water bodies, wetlands, forests, grasslands etc.).
- Leisure objects such as soccer fields.

It is necessary to create methods for determining the basic data for measure spatial structure metrics of the system of indicators. Spatial structure metrics calculates for every municipality. Information on the boundaries of municipalities is taken from OSM. The calculation for each indicator will help to use the data for several municipalities at once, which can be combined into a single agglomeration.

This paper will explore approaches to measure the following spatial structure metrics:

- Median coefficient of built-up area.
- Median coefficient of floor/area ratio (FAR).
- Median quarter size.
- Road network density (km/sq.km).
- Ratio of street area to urban area excluding water bodies (Dubelier coefficient).

In the future, it is possible to add other spatial structure metrics, or to exclude those for which information cannot be obtained from open sources at the moment.

4.1 Method for Measure of Built-Up Area

There are several methods to analyse built-up area:

- By dividing the area into cells with 250 per 250 m (standard distance to a stop).
- Through quarterly valuation.

Analysis of built-up area by cell is great for study the amount of city area occupied by buildings. The use of cells of 1000 per 1000 m is suitable to determine the average street density, since this metric is measured in km/sq.km, or is direct division of the total length of all streets by the total area of the territory. The regular grid approach is effective for large-scale calculations carried out simultaneously for several cities or, if necessary, a universal comparison of parameters.

It is necessary to formulate an approach to the automated determination of quarters to obtain a detailed picture of specific coefficients associated with the justification of some planning decisions for quarters and blocks, when assessing the territory according to GIS data. A quarter consists of several land plots on which buildings are located, and which are completely or partially surrounded by streets and/or area occupied by natural objects (water bodies, sharp changes in relief, etc.). If the quarters are not analyzed, then it will not be possible to objectively draw up recommendations that can be used, for example, for the preparation of territorial planning documents. On the other hand, different quarters were built at different times, their size depends on the needs of the time when they were built. It will be necessary to find patterns and determine those that are required in various conditions based on the available quarters. For this purpose, a methodology was developed for determine quarters from OSM data.

All water bodies are cut from the polygon of municipality territory, except for pools. Water objects are cut according to the attributes "water" and "coastline". Then it is needed to determine the boundaries of the quarters. The approximate width of the streets and railway lines passing through the city are needed to determine for this. The vast majority of streets consist of carriageways and sidewalks. OSM has separate data for roadways with one line for each direction of travel and for sidewalks. Unfortunately, the data on the sidewalks are not sufficient to be used everywhere, so the "sidewalk coefficient" was introduced. The value of this coefficient is 1.25, because for the narrowest street with a carriageway width of 6 m (3 m per lane) the sidewalk width of 0.75 m per line. 1.5 m from 6 m is 25%. The width of the street is determined by multiplying the width of the carriageway with the sidewalk coefficient. Then the width of the carriageway is determined by the following algorithm:

1. If the width of the carriageway is indicated, then it is used.
2. If the number of lanes is indicated, then the multiplying of the number of lanes by 3 m is used.
3. If there is both width and number of lanes, then width is preferred.

4. If neither the width nor the number of lanes are indicated, but it is known that one-way traffic, then the width is 3.6 m.
5. The width of the railway lines is taken as 3 m, except for those that have the value "tram".
6. The value 3 × 1.25 is entered for "tram".
7. The value of 3 m is used if nothing is known except the type of road.

Cutting a border polygon with roads with the following field values "highway" in OSM: "motorway", "trunk", "primary", "secondary", "tertiary", "residential", "motorway_link", "trunk_link", "primary_link", "secondary_link", "tertiary_link", as well as railways, except for those that have "light rail" in the "railway" column, because often the metro is written to OSM in this way. At the same time, the following types of "highway" roads were not taken into account when determining the quarters: "footway", "path", "footpath", "service", "steps", "corridor". "racetrack".

It is necessary to take into account the boundaries of the street in the received polygons. To do this, it is necessary to create a buffer from each line of the road that meets the condition above and equal to half the width of the street. Street buffers are cut from the existing polygon of the municipality territory without water bodies.

A generalized algorithm for the automated procedure for determining quarters can be represented as follows:

1. Obtaining the city territory from OSM polygon *P*.
2. Cutting *P* by objects with attributes "water" and "coastline".
3. Obtaining data on road graph in accordance with the value of the "highway" field (see the text above).
4. Converting the road graph into "lanes" *R* with the required width (see the algorithm in the text above) in accordance with the sidewalk coefficient.
5. Calculation of the ratio of area *R* to area *P*.
6. Cutting *R* from *P*.

The calculation of the built-up area is to find the ratio of the sum of the bases of all buildings that intersect with the quarter to the quarter area [25]. This allows to take into account buildings that are not completely in one block. Since the analysis of cities will use data on the median built-up area of the quarter. The critical errors at which the built-up area will be more than one are leveled.

The application of the obtained algorithm allows for the available data to determine built-up area. Calculations by this method were performed using the QGIS geographic information system and showed acceptable accuracy of the results. At the moment, the algorithm is implemented for five cities: Saint-Petersburg, Berlin, Singapore, Kolkata and Montreal (see Fig. 1).

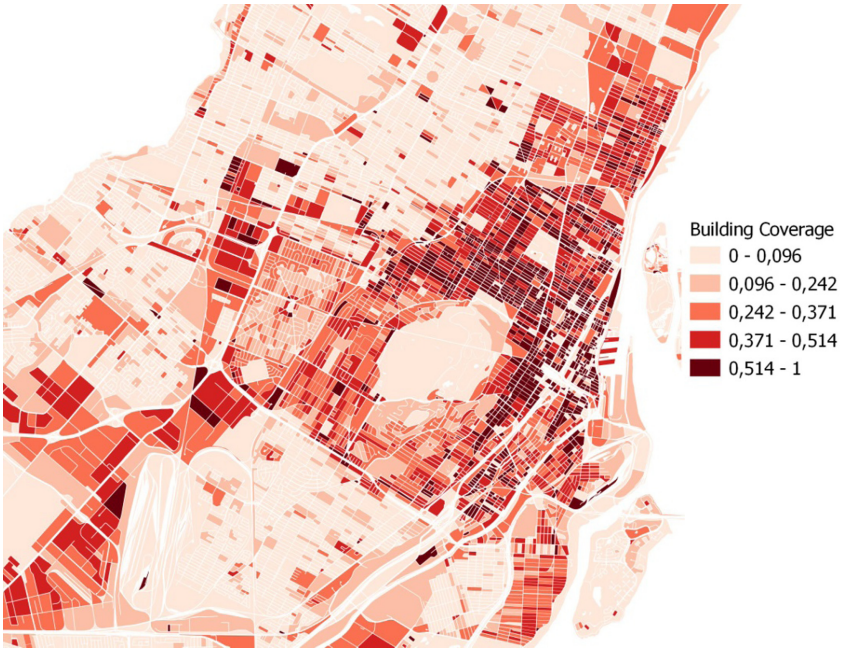

Fig. 1. Calculation of built-up area coefficient (on the example of the central part of Montreal).

4.2 Method for Measure the Ratio of Buildings Total Floor Area to Area upon Which Them Are Built

The next step is to determine the building density coefficient (FAR), which is equal to the ratio of the areas of all floors of the building, including stairways, wall thickness and other non-residential parts of the building, to the area of the land [26]. This will be the ratio of the sum of the areas of all floors of all buildings in the quarter to the quarter area (see Fig. 2). It is advisable, for example, to use the "ReformaGKH" data for Russia in addition to OSM data in order to increase the accuracy of FAR determination.

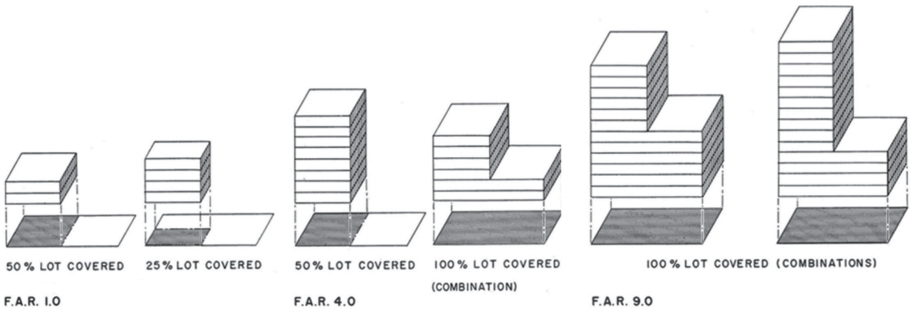

Fig. 2. Illustrations of Floor/Area Ratio variants [27].

The following algorithm was used to obtain data on the number of floors for buildings:

1. Objects with the field "building" of the meaning "garage", "garages", "roof", "shed", "hut", "hangar", "stadium", "warehouse", "kiosk", "bungalow", "farm" are accepted as one-story.
2. Objects with the field "building" of the meaning "semidetached_house", "house", "detached" are accepted as two-story.
3. Objects with the field "building" of the meaning "train_station", "school", "kindergarden", "chapel", "cathedral", "church", "mosque", "religious", "synagogue", "temple", "shrine" are accepted as three-story.
4. The number of floors of other objects is determined by the number of floors of the nearest buildings.
5. The value is taken equal to 1 where the number of floors is indicated as 0.
6. The value is indicated by the number of floors of the nearest building when not specifying an integer.

Changes the building density of an area that is used for housing or work are show by FAR. This data can help in assessing the infrastructure load of an area.

The generalized calculation algorithm can be represented as follows:

- For $i := 0$ to N, where N – number of grid cells (quarter).
  - Obtain the contours of the buildings included in the cell for the i-th cell.
  - For $j := 0$ to M, where M is the number of contours of buildings.
    - Cut the contour of the building along the border of the cell.
    - Calculate the area in accordance with the above conditions.
  - Get the total density of buildings in the cell.
  - Calculate FAR values for a given cell.

The results of the study for the Berlin presented in Fig. 3 and for the St. Petersburg is in Fig. 4. Large quarters with an average FAR of 0.1 to 1 consist mainly of buildings for industrial purposes. It is also noticeable how the amount of space in buildings used for workplaces or housing is fragmentarily distributed outside the approximate boundaries of pre-revolutionary development of St. Petersburg. On Fig. 5 presents the results of calculations for St. Petersburg with reference to a regular grid.

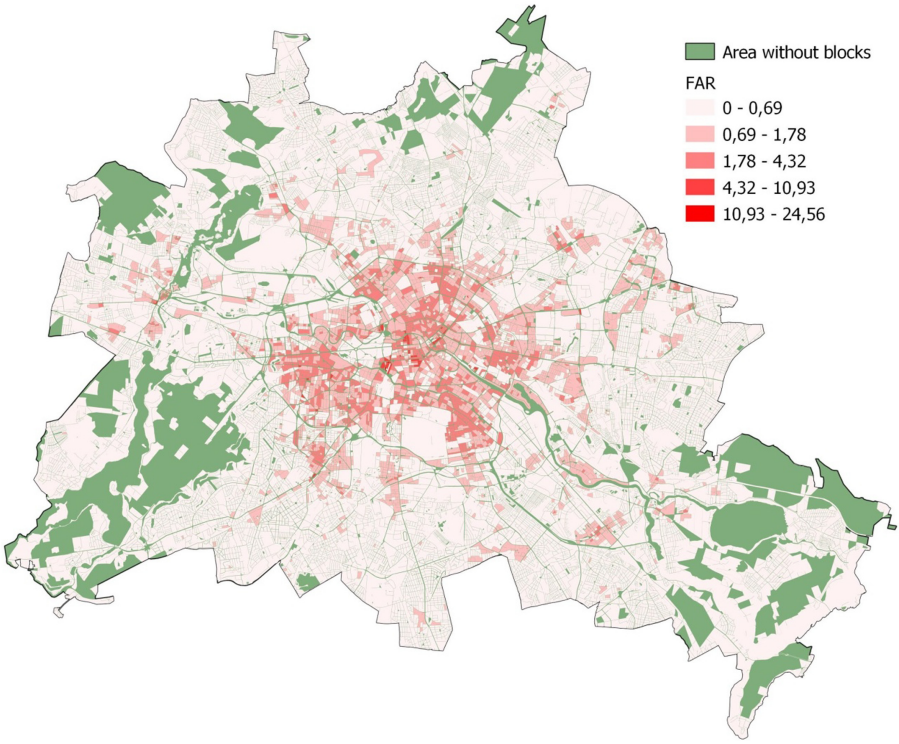

Fig. 3. Calculation of FAR (on the example of Berlin).

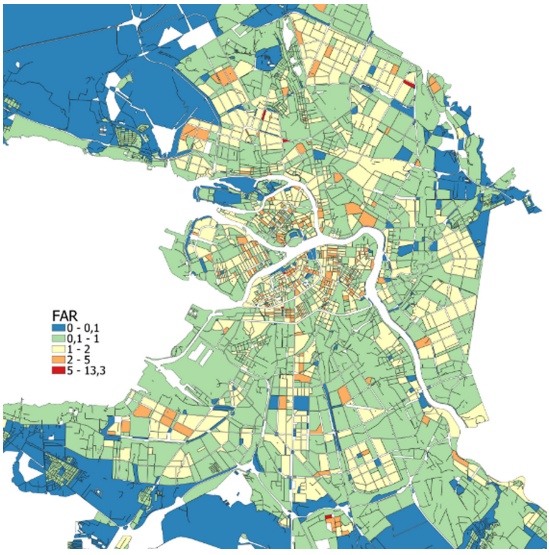

Fig. 4. Calculation of FAR (on the example of St. Petersburg).

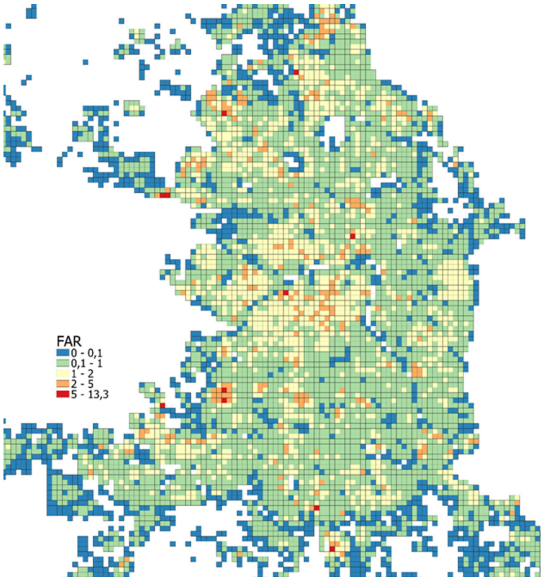

Fig. 5. Calculation of FAR with reference to the grid (on the example of St. Petersburg).

4.3 Method for Measure of Median City Quarter Size

The median area value of all quarters is determined by estimating the median quarter size. The sample does not take into account objects with an area of less than 1000 sq.m in order to exclude errors in determining the area occupied by road infrastructure.

The generalized calculation algorithm can be represented as follows:

- For $i := 0$ to N, where N – number of grid cells (quarter).
  - Calculate the area for the i-th cell.
- Calculate the median value of the quarter size, provided that the area is $\{>\}1000$ sq.m.

4.4 Method for Measure of Road Network Density

Past studies have shown that there is no linear dependence of the density of the road network when using all the data of the road graph without classification with an assessment of its availability [28]. The dominant hypothesis in this paper is that the density of the road network correlates with the size of the block, and therefore affects how favorable the environment is for pedestrians and cyclists. In the current paper, the classification of the road graph in part 3.1 was carried out, based on which the density of the road network for the entire area of the city is determined. The density of the road network is determined by the formula, where the ratio of the sum of the lengths of all streets to the area of the city is calculated.

The generalized calculation algorithm can be represented as follows [29]:

- For $i := 0$ to N, where N – number of grid cells (quarter).
  - Calculate the road network density for the i-th cell.
- Calculate the total value of the road network density for the entire city from the calculated data.

4.5 Method for Measure of Dubelier Coefficient

Two parameters (area of streets and urban area), which have already been determined when calculating the quarters, will be required to calculate the Dubelier coefficient, which is called in western sources LAS (Land Allocated to Streets).

Dubelier coefficient determined by the ratio of streets area to urban area [30]. Determining the area of streets is carried out by creating buffers from the roads with the following field value "highway" in OSM as "motorway", "trunk", "primary", "secondary", "track", "tertiary", "residential", "motorway_link", "trunk_link", "primary_link", "secondary_link", "tertiary_link", as well as railways with the value "tram" in the column "railway", which corresponds to tram lines.

4.6 Measure Example of Structure Metrics of Coherence for Different Cities

Comparison will be made for cities with a population of 3.6 to 5.5 million people, information about which is in the reports "kfzteile24" [31] and "Numbeo" [32]: Saint-Petersburg, Berlin, Montreal, Kolkata, Singapore.

A comparison of cities is presented as a set of absolute metric values for each of the cities. Absolute values for each metric are collected according to these metrics for each grid cell, if this parameter involves binding to the grid. The generalized calculation algorithm can be represented as follows:

- For $i := 0$ to N, where N – the number of parameters that are snapped to the grid.
  - Calculate the "absolute" value for the i-th metric.

The "admin_level" attribute is indicated for reference, when minimizing the metrics for a comparative study, since the value of this metric corresponding to the city territory in different countries may differ in connection with different administrative and territorial divisions. The obtained calculation results are presented in the Table 1.

Table 1. Convolution of data on structural indicators calculated.

Name	Admin_level	Median built-up area	Median FAR	Median quarter size	Road network density	Dubelier coefficient (LAS)
Saint-Petersburg	4	0,136	0,381	21121,56	5,02	0,078
Berlin	4	0,193	0,293	21394,86	10,02	0,160
Singapore	2	0,363	1,55	18229,06	12,89	0,111
Agglomération de Montreal	6	0,337	0,692	13020,00	14,31	0,221
Kolkata	5	0,368	0,979	8761,98	12,30	0,158

5 Conclusion

The development and testing of methods for calculating of structure indicators of urban space based on open OSM data has shown its effectiveness in obtaining assessments of infrastructural provision, which means it can become the basis for planning urban development and improving the efficiency of territories use. The proposed methods can be used to support decision-making both during the construction of new area and the reconstruction of existing ones.

The main problems of the implementation of the proposed approach associated with the incompleteness of the information presented in OSM are identified. Therefore, it is proposed to introduce an assessment of the occupancy of data on buildings to increase the effectiveness of research on specific cities: on the availability of spatial information and semantics, especially regarding buildings. In addition, it is worth paying attention to the use of verification tools from sources whose information quality is higher than OSM when calculating the metrics. Evaluation data can be combined with other data from various sources about buildings and land use, for example, data from the Housing and Utilities Reform service in Russia, for analysis of processes taking place in cities. Satellite imagery data [33], such as Landsat8, which are open data, can be used to increase the information content of the built-up area data.

Further research involves the development of methods for calculating all parameters that make up local, central and integration indicators, as well as the development of decision support methodology to achieve the expected level of coherence. It is also planned to add the ability to integrate data from various sources (raster images, state GIS, data from the unified state real estate registry, etc.). Reasonable recommendations for urban planners to improve the quality of the urban environment, based on modeling processes of changing the spatial structure of cities can be gotten by expanding the functionality of the methods and increasing their accuracy. In addition, correlation estimates with indicators of urban infrastructure use can be made for all parameters calculated.

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References

1. Urban Sustainability Index (USI). McKinsey Global Institutem. http://www.urbanchinainitiative.org/en/research/usi.html. Accessed 02 Dec 2019
2. Quality of Living City Ranking. Mercer. https://mobilityexchange.mercer.com/Insights/quality-of-living-rankings. Accessed 21 Nov 2019
3. Parygin, D.S., Malikov, V.P., Golubev, A.V., Sadovnikova, N.P., Petrova, T.M., Finogeev, A.G.: Categorical data processing for real estate objects valuation using statistical analysis. J. Phys. Conf. Ser. **1015**, 032102 (2018). IOP Publishing
4. A new tool designed by Strelka KB makes it possible to diagnose a city's problems. https://strelkamag.com/en/article/russian-cities-index. Accessed 18 Oct 2019
5. Methodology. Urban Environment Quality Index. https://индекс-городов.рф/#/methodology. Accessed 25 Dec 2019
6. Decree of the Government of the Russian Federation of March 23, 2019 N 510-r "On approval of the Methodology for the formation of an urban environment quality index". https://legalacts.ru/doc/rasporjazhenie-pravitelstva-rf-ot-23032019-n-510-r-ob-utverzhdenii/. Accessed 21 Dec 2019
7. Ovsiannikova, T.Y., Nikolaenko, M.N.: Quality assessment of urban environment. IOP Conf. Ser. Mater. Sci. Eng. **71**, 012051 (2015). IOP Publishing
8. Banister, D.: Energy use, transport and settlement patterns. In: Sustainable Development and Urban Form, pp. 160–181 (1992)
9. Breheny, M.: Counter-urbanisation and sustainable urban forms. In: Cities in Competition: Productive and Sust. Cities for the 21st Century (1995)
10. Whitehand, J.W.R.: British urban morphology: the Conzenian traditional. Urban Morphol. **5**(2), 103–109 (2001)
11. Complex Territory Development Standard. https://дом.рф/development/urban/printsipy-kompleksnogo-razvitiya-territoriy/. Accessed 15 May 2020
12. Sustainable Development Goal 11. https://sustainabledevelopment.un.org/sdg11. Accessed 17 May 2020
13. Why do you need zoning in the subway? https://zen.yandex.ru/media/grosh/zachem-nujno-zonirovanie-v-metro-5c595ed8aae2cb00ac08d94c. Accessed 05 Feb 2020
14. Uvarova, E.L.: Zoning as a method of territorial planning. In: Izvestiya SPbGAU, vol. 44, pp. 230–235 (2016)
15. Functional zoning of city territory. https://rusjurist.ru/stroitelstvo/funkcionalnoe_zonirovanie_territorii_goroda/. Accessed 30 Jan 2020
16. Silva, L.T., Monteiro, J.P.: The influence of urban form on environmental quality within a medium-sized city. Proc. Eng. **161**, 2046–2052 (2016)
17. Mouratidis, K.: Is compact city livable? The impact of compact versus sprawled neighbourhoods on neighbourhood satisfaction. Urban Stud. **55**, 2408–2430 (2018)
18. Lang, W., Chen, T., Chan, E.H.W., Yung, E.H.K., Lee, T.C.F.: Understanding livable dense urban form for shaping the landscape of community facilities in Hong Kong using fine-scale measurements. Cities **84**, 34–45 (2019)
19. Jenks, M.: The sustainable city: a good and secure quality of life? In: Growing Compact: Urban Form, Density and Sustainability, New York, NY, USA (2017)
20. Talen, E.: Sense of community and neighbourhood form: an assessment of the social doctrine of new urbanism. Urban Stud. **36**, 1361–1379 (1999)
21. Dawodua, A., Cheshmehzangi, A.: Impact of floor area ratio (FAR) on energy consumption at meso scale in China: case study of Ningbo. Energy Proc. **105**, 3449–3455 (2017)
22. Parygin, D.S., Aleshkevich, A.A., Golubev, A.V., Smykovskaya, T.K., Finogeev, A.G.: Map data-driven assessment of urban areas accessibility. J. Phys. Conf. Ser. **1015**, 042048 (2018). IOP Publishing

23. OpenStreetMap is the free wiki world map. https://www.openstreetmap.org/. Accessed 18 Feb 2020
24. Housing and Communal Services Reform Fund. https://www.reformagkh.ru/. Accessed 10 Feb 2020
25. SP 42.13330.2016. Town-planning. Planning and development of urban and rural settlements. http://docs.cntd.ru/document/456054209. Accessed 11 Dec 2019
26. American society of planning officials. Floor Area Ratio. Information Report No. 111, June 1958. American Planning Association. https://www.planning.org/pas/reports/report111.htm. Accessed 10 Jan 2020
27. Lewis, H.M.: New Zoning Plan for the District of Columbia, Columbia (1956)
28. Mikhailov, A.Yu., Golovnykh, I.M.: Current trends in the design and reconstruction of urban road networks, Novosibirsk (2004)
29. Parygin, D., Aleshkevich, A., Golubev, A., Sadovnikova, N., Shcherbakov, M.V., Savina, O.: Development the methodology of urban area transport coherence assessment. In: Kravets, A.G., Groumpos, P.P., Shcherbakov, M., Kultsova, M. (eds.) CIT&DS 2019, Part I. CCIS, vol. 1083, pp. 369–381. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-29743-5_30
30. Dubelir, G.D.: City planning (1910)
31. Best and Worst Cities to Drive 2017. https://www.kfzteile24.de/best-and-worst-cities-to-drive-usd. Accessed 19 Jan 2020
32. Cost of Living. https://www.numbeo.com. Accessed 21 Jan 2020
33. Golubev, A., Sadovnikova, N., Parygin, D., Glinyanova, I., Finogeev, A., Shcherbakov, M.: Woody plants area estimation using ordinary satellite images and deep learning. In: Alexandrov, D.A., Boukhanovsky, A.V., Chugunov, A.V., Kabanov, Y., Koltsova, O. (eds.) DTGS 2018, Part I. CCIS, vol. 858, pp. 302–313. Springer, Cham (2018). https://doi.org/10.1007/978-3-030-02843-5_24

E-Participation Mechanisms at Municipal Level in Saint-Petersburg: Expert Survey Results

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Abstract. This paper presents the expert survey results on e-participation development at municipal level in Saint Petersburg. The research was based on the institutional approach. The institutional model of e-participation functioning showing 6 communication channels between government and citizens was used in the research design: portals of urban issues, e-receptions, participatory budgeting technologies, e-voting, crowdsourcing platforms, and personal visits. 50 experts from the city administration, municipalities, house and communal services companies, and subordinated institutions took part in the survey. The survey revealed the most frequently used channels for communicating with citizens: responses to citizens' requests and applications at Governor's e-reception and portal "Our Petersburg". According to the survey, the most effective channels for applying for various problems and solving them are "Our Petersburg" portal, as well as personal appeals of citizens to government bodies. The research results could be of interest for the development of practical recommendations for the municipal administrations for e-participation activities organization.

Keywords: E-participation · Expert poll · Information channel · E-participation model

1 Introduction

E-participation topic is not new at the international arena. However, the interest in it continues to grow in the following directions: e-participation concepts development, methodology for e-participation evaluation, criteria for e-participation portals' assessment, the best practices case-studies etc. At the same time the focus of attention should be directed to the different levels of participation and its' opportunities.

In Russia, much attention has been paid to e-participation portals' development in the conditions of information society and digital economy development. Having a 3-layers' structure (federal-regional-municipal) of the authorities, e-participation mechanisms consider to touch first of all the municipal level. At this level the citizens can react on the urban issues, detect certain inconsistencies and shortcomings of the current improvement, and can be actively involved into city management. This layer is the closest and understandable to the population. In fact, residents are now provided with many channels for communication with authorities, but as practice shows, such interaction is not always evaluated by both sides of the participants as positive.

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This paper is devoted to the study of e-participation channels used at the municipal level in St. Petersburg and their efficiency. The paper consists of five sections. The literature review provides an overview of previous research in e-participation field, the methodology proposes a model of e-participation channels operation in Russia. The research results draws the main trends revealed from expert poll, and discussion and conclusion section highlights the main trends, research limitations and prospects for future investigations.

2 Literature Review

In the modern world, information technologies are increasingly used to ensure civic participation in federal, regional and municipal government. The active involvement of citizens in the development, adoption, implementation and monitoring of authority decisions is one of the most important principles of the effectiveness of modern public administration [25]. The development of channels of interaction with citizens allows authorities to more accurately understand the needs and interests of society, given them in government decisions. This reduces the risks of conflicts of interest, resistance to the execution of decisions and thereby increases the quality and effectiveness of the socio-economic policy [20].

The issue of e-participation has become an active topic of discussion not only at the state level, but also in the scientific, educational and expert community. General issues of political inclusion of citizens through information and communication technologies were discussed in the works of A. Macintosh [13, 14], S. Smith [22] and Y. Zheng [28]. Factors stimulating civic inclusion in the social and political process via the Internet were examined by M.R. Vicente and A. Novo [26], H.N. Delopous [4]. Some researchers note that the use of new communication channels can make a significant contribution to community participation projects [5].

The phenomenon of e-participation is closest to the concepts of «e-governance» and «open government». The concept of «open government» is expressed in the principles of transparency, citizen participation and cooperation. The development of this concept was largely facilitated by the development of information and communication technologies, as from the technical point of view, both the opening of information and the participation of citizens were simplified. A. Meijer, D. Curtin and M. Hillebrandt in their review of «open government» identified two main areas of this concept: ensuring free access for citizens to government information and providing data on the activities of the authorities, as well as the implementation of citizen participation in decision-making processes [15].

With the increasing availability of the Internet in general and mobile technologies, the use of electronic services also has become a modern indicator of the growth of public administration efficiency. Efficiency is expressed in reducing transaction costs of interaction and increasing the availability of information for citizens, increasing the level of convenience and quality of their participation in government decisions (by providing timely access to the necessary information) [17].

Local government is an important level of government for e-participation as citizens feel they are more personally involved and have a high expectation about the effect of participating in the decision-making processes of their municipality [8]. Some studies

note that most contact citizens have with the government takes place at the municipal level [10]. Thus, it is important to consider the e-participation tools that are used to interact with citizens at the municipal level.

In world practice, there are three main types of interaction between citizens and authorities [16]: information, consultations, active participation. This classification was introduced by the Organization for Economic Co-operation and Development (OECD) in 2001. In 2003, this classification was transformed in the context of e-participation by the United Nations. In the UN typology, e-participation tools are divided into 3 categories: information, consultation and e-decision making [7]. In 2007, this classification was supplemented by the International Association for Public Participation with the following types of interaction [23]: collaborating and empowerment.

As a result, attention began to focus not only on the types of interaction, but also on the tools themselves, through which interaction between citizens and government bodies is carried out [1]. In 2004, A. Macintosh identified 9 main mechanisms of e-participation: webcast, FAQ, blog, opinion poll, chat room, discussion forum, petitioning, virtual community, alert service [13].

The interaction of the government with citizens, public organizations and business is mainly carried out using electronic platforms and web technologies [12]. In modern literature, types of public electronic services are divided according to the government concepts. E-government and t-government (transformational government) relate to the provision of public services, while e-participation platforms belong to the third type of electronic services - l-government (lean government). Lean government is a new wave which is appearing as a response to traditional approaches – like e-government and t-government and aims at reducing the complexity of the public sector by simplifying and streamlining organizational structures and processes, at the same time at stimulating innovation by mobilizing stakeholders [9]. In l-government, public organizations introduce platforms facilitating innovation and interactions with other public organizations, business and citizens, and focus on their role. There are different approaches in creating of public electronic services based on government concept:

The type of e-government uses the *«Front-end» approach*, when the existing processes and procedures for the provision of public services are not changing, and an external web interface is created for them.

Type t-government uses the *«Front-end + Back-end»* approach: with the development of the web interface strategic organizational changes take place in the processes and procedures for providing government services in order to optimize them.

The l-government type uses the *«Network manage & orchestrate»* approach: creation of electronic platforms for the interaction of citizens, non-governmental organizations and government agencies to solve socio-economic problems. Integration of public platforms with private platforms (Facebook, Vkontakte, LinkedIn, etc.), narrowing the function of government to coordination.

Thus, the platforms for e-participation at the municipal level can be attributed to the l-government concept [18]. For this concept is typical to provide a web-platform on the principle of «Network management & orchestration»: an active role of citizens and a coordinating role of government. Analyzing the levels of e-participation, it is worth noting that informing citizens on an electronic platform (publishing documents,

announcements, etc.) will not be sufficient for effective public participation. Studies show that two-way interaction between society and the government is required and provides an opportunity for citizens to express their opinions and influence decisions [6]. The second level of e-participation is characterized by the opportunity for citizens to discuss issues on the agenda with the authorities on a discussion platform. The third level of electronic public participation complements the platform functionality with online survey capabilities. With their help, users determine the priority of tasks (rank), give grades on a scale (1 - low, 10 - high) or express an emotional reaction (like/dislike) [21]. The last, most developed level of e-participation is the online decision-making system. This system should allow making joint decisions online, including changing/introducing new alternatives for discussion and justifying them.

In Russia a series of regional of e-participation projects was launched in 2012. In St. Petersburg, the social movement «Beautiful Petersburg» (https://красивыйпетербург.рф/) began to use Internet technologies to organize citizens' appeals to administrative structures. On this portal, residents of St. Petersburg can send a complaint on any of the city problems, thereby giving a start to its solution. In 2014, on the initiative of the Governor of St. Petersburg, the «Our Petersburg» portal was created. This portal allows citizens report on urban problems, monitor their implementation and evaluate the work of service organizations. Similar portals, providing interactive interaction between authorities, began to be created in many regions of Russia.

Based on existing Russian e-participation portals, 3 channels of interaction between citizens and authorities were defined [2]:

- The official channel that ensures the functioning of the electronic services system (e-government);
- An unofficial channel represented by information systems of public organizations and movements (e-participation initiated by citizens);
- an official channel that provides government feedback with citizens through information systems created and supported by authorities or subordinate organizations (e-participation initiated by the government).

Most of the e-participation portals at the municipal level in Russia allows only to collect complaints and suggestions, which mostly related to the problems of housing and communal services and transport. This right is defined by the legislation of the Russian Federation, therefore the creation of portals for aggregating citizens' complaints and suggestions is a web-interface for existing processes and procedures for providing public services that have not been changed.

Modern studies demonstrate that even in developed democracies, e-participation projects do not bring the results for which they were designed and are often at the level of symbolic participation [19]. Delegation practices are extremely rare [24] and most e-government initiatives to engage citizens in decision-making processes are limited to information flow from government to citizens (G2C, G2B, G2G) [11].

3 Research Methodology

To solve research problems, we used the institutional model for e-participation functioning, developed by a research group led by A.V. Chugunov [3]. The model is based on the institutional environment of sustainable development of the city/region, including the institutions of civil society and the main actors of interaction (citizens, public organizations and business). The logic of the model assumes that urban development projects in the course of their implementation bring effects that affect the institutional environment of sustainable development of the city, where "feedback" is formed, which through the actions of actors using one of the channels of communication with the authorities (technologies, methods and procedures of electronic participation of citizens in the management of the municipality/region), enters the governing bodies.

According to the model, the following C2G communication channels were evaluated: urban issues portals, participatory budgeting, e-receptions, e-voting, crowdsourcing platforms, and personal visits to the authorities. Each channel was measured by a set of socio-economic, organizational and technological criteria.

The set of socio-economic criteria included:

- demand for citizens,
- demand for public organizations,
- demand for business, costs for users,
- IT skills of users.

The group of organizational criteria included:

- the effectiveness of solving the problem,
- expediency of use in government,
- the costs to the government,
- flexibility of the channel for collecting feedback,
- the barriers for use in the field of regulatory regulation.

Technological criteria for evaluating the communication channel included:

- the probability of technical errors and failures,
- inequality in access to technology,
- the reliability of the identification system.

The study was conducted using the expert survey method. At the previous stages of the study, the interest of the research group was turned to citizens as direct participants in electronic interaction [27]. This time, attention was focused on the position of representatives of the authorities and other organizations involved in citizens' appeals consideration. Such an approach made it possible to draw the picture of expert community opinions and assessments.

The experts were 50 representatives of authorities, management companies, subordinate institutions that are involved in interacting with the public through various communication channels. The experts' occupation is presented at Fig. 1.

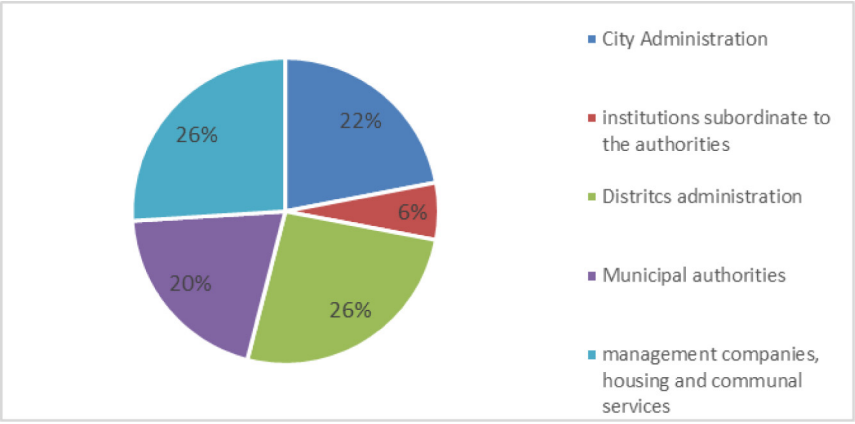

Fig. 1. The experts' occupation structure, 2020

The main criterion for the selection of experts was the experience in interacting with citizens using electronic channels. Among the respondents, 38% - have more than 10 years of administrative experience, 34% - from 5–10 years, 14% - from 3 to 5 years, 14% - up to 3 years. In addition, 18% more than 10 years interact with citizens through electronic channels, 34% - from 5 to 10 years, 30% - from 3 to 5 years and 18% - less than 3 years of experience.

Within the framework of the survey, experts could choose several subject areas with which the performance of their official duties is associated. According to the survey, 46% deal with public utilities and engineering infrastructure, 34% deal with environmental safety and land improvement issues, 20% deal with information technology, 24% deal with the consumer market and entrepreneurship, 26% deal with the transport sector, 10% each with industry, foreign economic activities and social policy, 12% - in sports, and less than 5% in the fields of culture, strategic complex, tourism, education, health.

4 Research Results

According to the results of the survey, the vast majority of respondents (67.3%) each week interact with citizens in one way or another as a part of their duties. Every fifth expert said that he did it often enough, once a month. The remaining experts (12%) said that they rarely interact with citizens, only for urgent needs.

E-participation channels in St. Petersburg already have some history. One of the oldest initiatives is the electronic reception of the Governor, which collects applications from citizens at the official website of the City Administration. There is also a city portal for solving city problems "Our Petersburg". In addition, there is a platform created by city activists "Beautiful Petersburg", also aimed at filing applications for urban problems and finding solutions to them. Not so long ago, the project "Your Budget" was launched, which allows collecting initiatives and proposals of citizens on budgeting.

The survey revealed the most frequently used channels for communicating with citizens: responses to citizens' requests and applications at Governor's e-reception and portal "Our Petersburg" (Fig. 2).

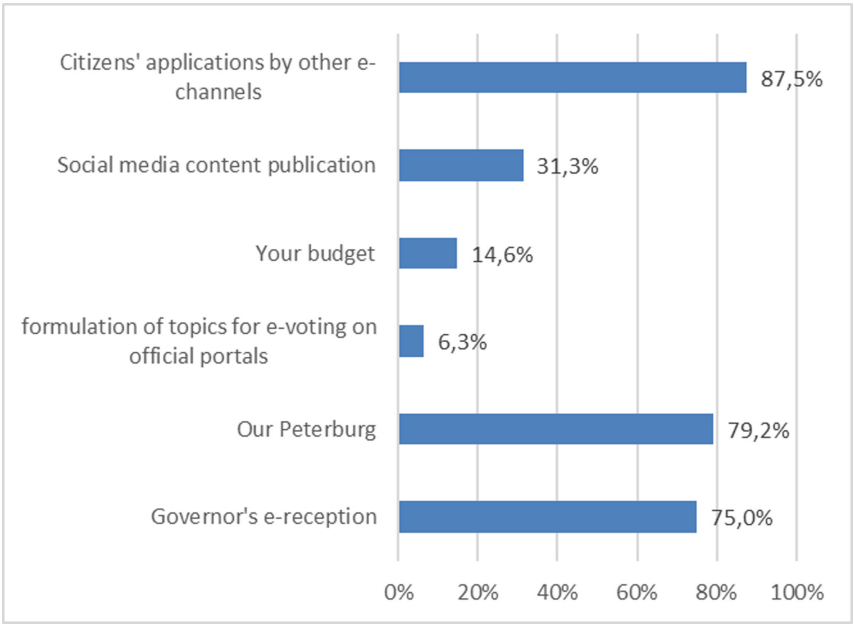

Fig. 2. Distribution of answers to the question "Do your tasks related to the functioning of electronic channels fall within your responsibilities?"

According to experts, the most popular from the citizens' point of view are portals for solving urban problems, electronic receptions, as well as personal visits to authorities (Table 1). It is noteworthy that electronic reception and face-to-face conversations are also most in demand for public organizations and representatives of the business community. Experts did not note the large costs for citizens through any of the proposed channels. Experts are inclined to believe that usage of the presented channels does not require a high level of IT skills from the user.

According to the survey, the most effective channels for applying for various problems and solving them are Our Petersburg portal, as well as personal appeals of citizens to government bodies. Experts assessed the greatest feasibility for the authorities to use such channels as e-receptions, portals of city problems and direct communication with applicants in the authorities (Table 2). At the same time, the same channels were marked as the channels with the highest costs for the authorities. The most flexible channel for collecting feedback from citizens, experts called face-to-face visits. If we talk about the regulatory regulation of the use of various channels, then in this area, experts did not note significant problems and contradictions.

Table 1. Experts' assessment of e-participation channels, socio-economic dimension, 5 point scale, 2020

	Urban issues portals	Participatory budgeting	E-receptions	E-voting	Crowd sourcing	Personal visit
Demand by citizens	**4,4**	1,9	**4,2**	2,1	0,9	**4,5**
Demand by public organizations	1,9	0,9	3,2	1,2	0,7	4,1
Demand by business	2,5	1,3	3,1	1,2	1	3,7
High costs for users	1,4	1,5	1	0,9	1,2	1,7
Need for a high level of users' qualification	2,2	1,9	1,6	1,5	1,3	1,5

Table 2. Experts' assessment of e-participation channels, organisational dimension, 5 point scale, 2020

	Urban issues portals	Participatory budgeting	E-receptions	E-voting	Crowd sourcing	Personal visit
Effectiveness of problem solving	4,4	2,1	4	2,4	1,6	4,4
Expediency of use from a position of authorities	4,1	2,3	4,1	2,5	1,7	4,2
High costs to authorities	4	2,7	3,4	2,4	1,8	3,6
Channels' flexibility for feedback collection	3,7	2,2	3,7	2,1	1,4	4,3
Regulatory barriers to use	2,4	2,1	1,2	2,1	1,6	1,2

The block of technological evaluation criteria received lower scores from experts (Table 3). The experts attributed the probability of failures and inaccuracies primarily to electronic communication channels. Experts consider the least reliable from the point of view of identification systems portals of initiative budgeting, as well as electronic voting systems and crowdsourcing platforms.

Table 3. Experts' assessment of e-participation channels, technological dimension, 5 point scale, 2020

	Urban issues portals	Participatory budgeting	E-receptions	E-voting	Crowd sourcing	Personal visit
The probability of errors	2,5	2,2	1,5	2	1,5	1,1
Inequality in access to technology	2	1,8	1,5	1,7	1,2	0,9
Identity system reliability	3,4	2,6	3,7	2,5	2,2	4,5

According to the results of the survey, 76% of experts rated the experience of interacting with citizens as a whole as positive and constructive, according to the results of which some decision was made. Another 19% believe that following the results of the interaction, certain steps were taken towards solving the problem, but this did not lead to an effective solution. And a little less than 5% rated this experience as unconstructive, the dialogue did not take place.

The vast majority of experts (85.4%) noted positive changes after the start of the functioning of the electronic participation portals, namely, the authorities began to respond more sensitively and quickly to their requests. 4% of the experts who participated in the survey believe that everything remains as before, and 10% notice the changes in a negative direction.

According to half of the experts (52%), the use of electronic participation technologies can have a real impact on decision-making focused on the development of the city. Another third partially agree with this statement. 12% of experts disagree with the fact that the mechanisms of electronic participation can really affect the city government (Fig. 3).

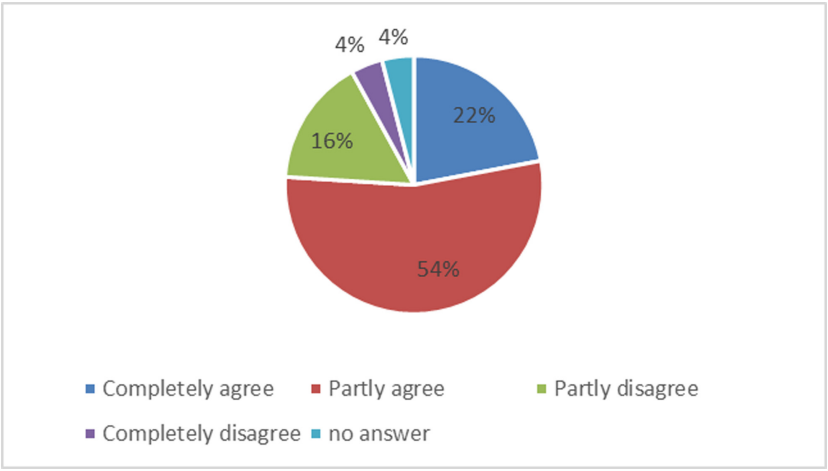

Fig. 3. Distributions of the experts' answers to the question "Do you think that the use of electronic participation technologies significantly complicates the work of government bodies and this negatively affects other areas of work?", %

5 Conclusion and Discussion

The study made it possible to obtain new empirical data on the channels of electronic participation of citizens used at the municipal level in St. Petersburg. The authors drew attention to electronic and non-electronic communication channels, actively functioning and only developing (crowdsourcing platforms, electronic voting).

According to experts, personal visits of the population to authorities were recognized as one of the most effective for solving various problems that concern citizens. In addition, quite popular and long-functioning platforms received the highest expert ratings in each area: "Our Petersburg" portal and the Governor's e-reception.

Experts associated certain concerns related to user costs and the inflexibility of various methods with channels such as sites for participatory budgeting, electronic voting, and crowdsourcing.

The relevance of the study is emphasized by the participation of the expert community from all types of structures involved in the interaction of citizens. Limitations of the study are connected with the fact that the city does not conduct representative surveys of the population to evaluate the feedback channels. Having access to such data, it would be possible to compare expert opinions with citizens' assessments in order to develop appropriate and scientifically based recommendations on the development of electronic participation tools at the municipal level.

The future research direction will be focused on the explanation of C2G and B2G channels' efficiency from the citizens and business point of view with the perspective to develop on this base a set of practical recommendations for the municipal administrations for e-participation activities organization and development.

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References

1. Albrecht, S., Kohlrausch, N., Kubicek, H., Lippa, B.: eParticipation – Electronic Participation of Citizens and the Business Community in eGovernment. Institut fur Informations management Bremen (2008). https://www.ifib.de/publikationsdateien/study_e-participation_engl.pdf. Accessed 26 May 2020
2. Chugunov, A.V.: Electronic participation as a feedback channel between authorities and citizens: problems of institutionalization. Azimuth Sci. Res. Econ. Manage. **5**(17), 453–459 (2016)
3. Chugunov, A.V., Karachay, V.A.: Electronic participation and participatory budgeting as feedback mechanisms in the smart city model. Adm. Consult. **11**, 163–179 (2019). https://doi.org/10.22394/1726-1139-2019-11-163-179. (in Russian)
4. Delopous, H.N.: Barriers and opportunities for the adoption of e-governance services. Int. Scholary Sci. Res. Innov. **4**(6), 883–886 (2010)
5. Donders, M., Hartmann, T., Kokx, A.: E-participation in urban planning: getting and keeping citizens involved. Inter. J. E-Plann. Res. **3**(2), 54–69 (2014)
6. Drummond, W.J., French, S.P.: The future of GIS in planning: converging technologies and diverging interests. J. Am. Plann. Assoc. **74**(2), 61–174 (2008)
7. E-participation index UNPACS. https://publicadministration.un.org/egovkb/en-us/About/Overview/E-Participation. Accessed 26 May 2020
8. European Commission: European e-Government 2005-2007: Taking stock of good practice and progress towards implementation of the i2010 eGovernment Action Plan. Research for the Directorate General for Information Society and Media (2007)
9. Janssen, M., Estevez, E.: Lean government and platform-based governance - doing more with less. Gov. Inf. Q. **30**, 1–8 (2013)
10. Kafentzis, K., Goulandris, V., Alexopoulos, P.: E-dialogos: a holistic approach for enhancing e-Participation in local government. In: EuroSpace Group (ed.) E-Gov. 2.0: Pave the Way for e-Participation, pp. 162–171 (2009)
11. Kushchu, I., Kuscu, H.: From E-government to M-government: facing the inevitable. In: Proceedings of the 3rd European conference on E-Government (ECEG03), Trinity College, Dublin, pp. 253–260 (2003)
12. Lember, V., Kattel, R., Tônurist, P.: Technological capacity in the public sector: the case of Estonia. Int. Rev. Admin. Sci. **84**, 214–230 (2018)
13. Macintosh, A.: Characterizing E-participation in policy-making. In: Proceedings of the 37th Hawaii International Conference on System Sciences, vol. 5 (2004). https://ieeexplore.ieee.org/abstract/document/1265300. Accessed 26 May 2020
14. Macintosh, A., Coleman, S., Schneeberger, A.: eParticipation: the research gaps. In: Macintosh, A., Tambouris, E. (eds.) ePart 2009. LNCS, vol. 5694, pp. 1–11. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-642-03781-8_1
15. Meijer, A.J., Curtin, D., Hillebrandt, M.: Open government: connecting vision and voice. Int. Rev. Admin. Sci. **78**(1), 10–29 (2012)
16. OECD Handbook on Information, Consultation and Public Participation in Policymaking "Citizens as Partners" (2001). http://www.internationalbudget.org/wp-content/uploads/Citizens-as-Partners-OECD-Handbook.pdf. Accessed 26 May 2020

17. Pina, V., Torres, L., Royo, S.: Comparing online with offline citizen engagement for climate change: findings from Austria, Germany and Spain. Gov. Inf. Q. **1**(34), 26–36 (2017)
18. Reddick, C., Norris, D.: E-participation in local governments: an examination of political-managerial support and impacts. Transf. Gov. People Process Policy **7**(4), 453–476 (2013)
19. Revyakin, S.A.: On the effectiveness of electronic platforms for citizen participation in public administration. Issues State Municipal Adm. **2**, 94–113 (2018)
20. Revyakin, S.A.: Functionality of e-participation platforms: why social networks? Issues State Municipal Gov. **3**, 88–106 (2019)
21. Seltzer, E., Mahmoudi, D.: Citizen participation, open innovation, and crowd-sourcing challenges and opportunities for planning. J. Plann. Lit. **28**(1), 3–18 (2013)
22. Smith, S.: Main benefits of eParticipation developments in the EU. In: Report prepared for Unit H2– first version, Deliverable 1.3a., eGovernment and CIP Operations, EuropeanCommission (2008)
23. The International Association of Public Participation (IAP2). https://iap2canada.ca/Resources/Documents/0702-Foundations-Spectrum-MW-rev2%20(1).pdf. Accessed 26 May 2020
24. Thiel, S.K., Lehner, U.: Exploring the effects of game elements in m-participation. In: Proceedings of the 2015 British HCI Conference (British HCI 2015), vol. 1, pp. 65–73 (2015)
25. van Veenstra, A.F., Janssen, M., Boon, A.: Measure to improve: a study of eParticipation in Frontrunner Dutch municipalities. In: Tambouris, E., Macintosh, A., de Bruijn, H. (eds.) ePart 2011. LNCS, vol. 6847, pp. 157–168. Springer, Heidelberg (2011). https://doi.org/10.1007/978-3-642-23333-3_14
26. Vicente, M.R., Novo, A.: An empirical analysis of e-participation. The role of social networks and e-government over citizens' online engagement. Gov. Inf. Q. **31**(3), 379–387 (2014)
27. Vidiasova, L., Cronemberger, F.: Discrepancies in perceptions of smart city initiatives in Saint Petersburg, Russia. Sustain. Cities Society **59**, 102158 (2020)
28. Zheng, Y.: The impact of E-participation on corruption: a cross-country analysis. Int. Rev. Pub. Adm. **21**(2), 91–103 (2016)

Smart Solutions for Implementation of Sustainable Development Goals (SDGs) in Arctic Cities

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Abstract. Arctic cities exist in hash weather conditions and are particularly sensitive to climate change. To solve these problems the Arctic cities require "smart" solutions to become more sustainable and effective and be able to adapt to climate change influence. The aim of the research is to find out the main solutions for smart and sustainable strategies implemented in the Arctic cities based on the international experience. The case study was chosen as the main research method. Information was obtained from several Arctic cities as Reykjavik (Iceland), Umea (Sweden), Oulu (Finland) and Anchorage (USA) as well as several Russian cities included in the Arctic zone of the Russian Federation (AZRF). Along with temperature increase the main features of northern cities primarily include low temperatures, strong winds, heavy rainfall, insufficient solar radiation. All these require more amount of energy for heating of buildings, which leads to an increase in greenhouse gas emissions and, consequently, climate change influence. To combat with climate change some smart solutions for reduction of greenhouse gases were implemented by using alternative energy, electric vehicles, smart parking, energy-efficient buildings, intelligent building management, smart heating and lighting systems, heated sidewalks could be used for solving climate change problems. The results of the case-study show that smart solutions being implemented in Arctic cities mentioned above correlate with many UN SDGs, especially the goals 7 - «Affordable and Clean Energy», 12 - «Responsible Consumption and Production», 13 - «Climate Action» and others as 9, 11, 8, 3.

Keywords: Arctic cities · Arctic region · Smart solutions · Sustainable Development Goals · Smart Sustainable City · Climate change

1 Introduction

More than 4 million people live in the Arctic region today, however, despite the rather harsh climatic conditions, this region is characterized by a high level of urbanization. The UN predicts that urban residents will constitute more than 70% of the Arctic population by the middle of the century [1]. Rapid urbanization increases the burden on the resource base and increases the demand for energy, water, as well as utilities, education, and health. Also, cities make a significant contribution to environmental degradation at the local,

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regional, and global levels. At the same time, the adverse climatic and meteorological conditions of the Arctic increase the concentration of pollutants in the atmosphere, thereby worsening air quality and adversely affecting the population.

The relevance of this research is that the geographical and climatic conditions of the Arctic create certain obstacles to the development of modern cities and are also particularly sensitive to climate change. The magnitude of the temperature increase in the Arctic is twice as much as the world average [2]. To solve these problems the Arctic cities require "smart" solutions to become more sustainable, effective, and comfortable and to be able to adapt to climate change influence. Innovative and technological projects can open up great opportunities for socio-economic growth in the Arctic region.

The aim of the research is to find out the main solutions for smart strategies to achieve sustainable development goals (SDGs) and its implementation in the Arctic cities based on international experience. The main research method is case study, expressed in the description and analysis of specific Arctic cities, their smart technologies and strategic planning documents.

The structure of the paper is as follows: after Introduction Literature review is presenting the Smart and Sustainable cities concept and research, following by Arctic cities and sustainable development part that discussed sustainable development approach implemented in Arctic cities. Then Smart solutions in Arctic cities: Reykjavik; Umea; Oulu; Anchorage are presented and discussed including analysis of the international experience of smart solutions for Arctic cities implementing SDGs presented in Registry of such solutions. After that, a brief description of Smart city initiatives of cities of the Arctic zone of the Russian Federation (AZRF) is presented following by Conclusion.

2 Literature Review

The concept of Smart City appeared several years ago and starting from 2015 is closely connected to sustainable city vision. The term "smart city" is based on the idea that different urban systems become interconnected through ICTs to increase their efficiency. However, there is still no clear definition of the term "smart city", as well as a generally accepted framework and indicators. For example, Latin American projects tend to focus on improving security and management effectiveness; Asian - to improve infrastructure and mobility; Europeans often focus on improving the efficiency of public services, creating a more socially oriented society and improving the welfare of citizens [3]. Many authors from all over the world investigate the smart city agenda as Neirotti et al., [3], Caragliu et al. [4], Schaffers et al., [5], Piro et al., [6]. Among the first was the European Smart Cities Initiative, started at the Center of Regional Sciences at Vienna University of Technology. In the Report [7], six key characteristics of "smart city" were identified as Smart Governance; Smart Economy; Smart Mobility; Smart Environment; Smart People; Smart Living.

Starting from 2013 a new approach was manifested as "Smart Sustainable City" (SSC) as Höjer & Wangel [8], Bibri & Krogstie [9], Shmelev and Shmeleva [10–12]; and many others indicate. The most comprehensive study of this concept is the work of the Focus Group on Smart Sustainable Cities (FG-SSC), formed in 2013 by the International Telecommunication Union (ITU). The FG-SSC completed its two-year

study in 2015 with the publication "Shaping smarter and more sustainable cities: Striving for sustainable development goals" [13], which analyzes 166 existing definitions of smart cities from various sources in order to create an accurate comprehensive definition for SSC. M. Höjer and J. Wangel [8] suggested the definition that is closely related to the definition of sustainable development of Brundtland UN Commission. According to the definition "smart sustainable city" is a city that satisfies the needs of its current residents; does not compromise the ability of future generations to meet their needs and, thus, does not exceed local or planetary environmental constraints and is supported by ICT.

The problem of urban development, taking into account natural and climatic conditions, started to be investigated since the 1980s, while the research was devoted mainly to urban planning, architecture and design, suitable for the harsh climate of the northern latitudes. For example, N. Pressman in his "Sustainable winter cities: Future directions for planning, policy and design" [14] and "Reshaping Winter Cities: Concepts, Strategies and Trends" [15] considers new measures to reduce pollution, increase resource efficiency and sustainability of Northern cities. Among other notable studies, the following works can be distinguished: Martus V.M. "Design for northern climates: Cold-climate planning and environmental design" [16], Rogers W.C. "The Winter City Book" [17], Oikarinen E.M. "Urban design with weather variability - Adaptive capacity approaches towards Northern climate now and in the future" [18], C.S.B. Grimmond "Climate and more sustainable cities: Climate information for improved planning and management of cities (Producers/Capabilities Perspective)" [19]. These papers address issues of architecture, planning and sustainable urban development in cold climates. Mainly literary sources are dealing with sustainable and smart city planning in Northern Europe, the most significant include: "Nordic Action on Climate Change" by Nordic Council of Ministers [20], "Nordic solutions for Sustainable Cities" by Arup [21], "White Paper on Nordic Sustainable Cities", Borges et al. [22], the publications of the Nordregio research center [23].

3 Arctic Cities and Sustainable Development

Today, more than 50% of the world's population lives in cities, and this share is expected to increase to 66% in 2050 [24]. Cities concentrate the most complex global problems of the 21st century, including poverty, inequality, unemployment, environmental degradation, climate change, etc. These problems create the need for a complete rethinking of the development and formation of strategic and innovative approaches to urban planning and urban governance. For Arctic Cities in conditions of limited natural and mineral resources, as well as in a changing climate, the most important SDGs are SDG 12 («Responsible Consumption and Production») and SDG 13 («Climate Action») and SDG 7 – «Affordable and Clean Energy». It is also necessary to separately mention SDG 11 – «Sustainable cities and communities».

The development of the city and the quality of its environment are largely determined by its geographical location (latitude, continentality, proximity to water, terrain, etc.) and, accordingly, the climate characteristic of this location. One of the main goals of urban development is to adapt cities to the climate and how it can contribute to increased sustainability. The main features of Northern Cities caused by climatic conditions primarily

include low temperatures, strong winds, heavy rainfall, insufficient solar radiation, icing of roads, frozen soils. Such conditions require the generation of more amount of energy for heating of buildings, which leads to an increase in greenhouse gas emissions and, consequently, an increase in temperature and climate change influence. In addition, due to low temperatures in Northern cities, air quality deteriorates from time to time.

Attempts to create a "climate-responsive" northern urban structure (driven by climatic conditions) are part of a relatively recent phenomenon and area of research. In connection with the international movement "winter city" [14], it became necessary to conduct national and local actions aimed at improving comfort for all residents of the North. The "winter city" movement proposed principles for resolving urban planning issues in the far north. For example, many cities have introduced heating systems on the sidewalks of pedestrian zones in the city center so that there is no snow and ice there in winter. In high latitudes, it is important to provide good lighting in public places, because during most of the winter these areas lack sunlight. Particular attention should be paid to the use of insulation and thermal insulation of structures to increase energy efficiency. Severe climatic conditions also lead to high requirements for the design of buildings: foundation, surface layers, insulation, roof, etc. Climate-oriented, smart, and energy-efficient approaches and projects will create a combined effect to improve the sustainability and resilience of cities if they are carefully integrated on a micro- and mesoscale.

There is a large amount of literature and online sources devoted to the sustainable development of Northern cities, especially Scandinavian ones. The Northern Europe region was one of the first to develop the concepts of smart and sustainable cities, thereby accumulating enough experience. An important feature is the coordination of actions of all countries in the region, aimed at achieving sustainable development. The main structures of Northern Europe for sustainable development and the environment include the following: mentioned already Research Center Nordregio, Nordic Development Fund [25], Nordic Smart Cities Network [26], Nordic Innovation [27], Nordic co-operation [28]. It is worth noting that one of the main topics raised in articles and reports of the above organizations is the problem of climate change. Arctic cities chose the reduction of greenhouse gas volumes as the main method of combating this phenomenon. Countries contribute to the sustainable development of cities by eliminating the dependence of emissions on economic growth. So, from 1990 to 2011, the total GDP of the Nordic countries grew by 55%, and emissions in the region decreased by 9% [20].

4 Smart Solutions in Arctic Cities

Within the framework of the Rome Declaration, adopted at the forum «Shaping Smarter and More Sustainable Cities: Striving for Sustainable Development Goals» (09.05.16, Rome) the role of information and communication technologies (ICT) in ensuring sustainable urban development was examined [29]. Cities must become smarter, with technological solutions being put in place to address a wide range of common urban challenges. Smart sustainable cities contribute to improving energy efficiency technologies, reducing environmental pollution, increasing social integration, and are also able to provide enterprises with a high return on investment. To determine the smart technologies

specific to the Arctic region the case study was chosen as the main research method, based on information about several Arctic cities as Reykjavik (Iceland), Umea (Sweden), Oulu (Finland) and Anchorage (USA).

4.1 Reykjavik

Reykjavik is the northernmost capital of the world and is located in a subarctic climate. However, winter temperatures rarely drop below −10–15 °C. The proximity to the warm North Atlantic current forms relatively mild winters and cool summers. The coastal location of the city makes it prone to strong winds and heavy rainfall.

Iceland, primarily due to Reykjavik, is currently the most sustainable country in the world with 100% renewable sources of hydro and geothermal energy. The city of Reykjavik in 2014 and was awarded the title of the greenest city in the world from the Green City Times [30]. Reykjavik uses geothermal and hydropower for all electricity and heating consumption. The main emphasis of the Reykjavik municipal development plan in recent years has been to create suitable conditions for continuous socio-economic growth and to meet the requirements of the expected population and industry growth.

In Reykjavik, all residential and commercial buildings are heated geothermally using district heating. Greenhouse gas emissions in Reykjavik are insignificant compared to international indicators, they amounted to 2.8 tons of CO_2 per person in 2013. Transport is a major source of greenhouse gas emissions. In the municipal plan for 2010–2030, the goal is to increase the share of public transport from 4% to 12% [31]. Also, there are currently no taxes on the import of electric vehicles in Reykjavik. After the first electric charging station was opened in 2014, the share of owners of electric vehicles increased by 700%, as a result of which the market share of electric vehicles on clean batteries amounted to 2.74%. Along with changing the transportation structure, developing new energy sources and improved waste management system, Reykjavik aims to reduce greenhouse gas emissions by 20% by 2030 compared to 2007 and 73% by 2050 [32]. These measures are aimed at combating climate change, which is already noticeable in Iceland, as well as throughout the Arctic region.

New solutions require modernization of urban infrastructure, considering the future. The purpose of the Smart City concept in Reykjavik is an innovation for city residents, for example, in the field of transport, welfare, education and culture. In the framework of this concept, in addition to the above decisions regarding new sources of energy and the spread of electric transport, various ICTs and other innovative technologies are being introduced into the city structure. Reykjavik has developed an intelligent waste management system that includes separate waste collection, smart garbage containers and waste management. These solutions are presented partly in Table 1.

4.2 Umea

Umea is a fast-growing city in northern Sweden, located 600 km north of Stockholm. It has a subarctic climate with short and rather warm summers, but long and frosty winters. Umea is a center of education, technical and medical research. One of the seven strategic long-term goals of urban development is that Umea's growth is achieved with social, environmental, and economic sustainability, aimed at seeing 200,000 citizens by

2050. One possible solution to achieving these goals is the concept of a Smart City. The innovative Smart City district is located just east of the center of Umea, in the university area, and includes residential, educational and research institutions of two universities, a regional hospital, as well as public, entertainment and commercial buildings. The development of this concept is dedicated to the RUGGEDISED project [33]. This is a major collaborative project that is part of Horizon 2020. Umea City Council, Umea University and various private companies are working together to turn the campus into a viable and sustainable smart city. The solutions developed at RUGGEDISED may be applicable in other parts of Umea. In the coming years, 40 million SEK will be invested in the campus to become the so-called "smart city". This project can be a good example for other cities in Sweden and Europe to become a smart sustainable city. The technological solutions that are being implemented as part of this project include [33]:

- Smart City connection to 100% renewable energy;
- Peak load variation management and peak power control;
- Geothermal heating/cooling storage;
- Intelligent building control and end user involvement;
- Energy optimized electric BRT-station;
- EV-charging infrastructure hub;
- Energy-efficient land use through flexible green parking pay off;
- Smart open-data city platform;
- Demand-side management technology in a university campus.

Another interesting solution, which is not yet included in this strategy, is to equip bus stops with special daylight mimic panels to combat seasonal affective disorder and depression in winter when there is an acute shortage of sunlight in the city. This project is implemented by Umea Energi, which installed special lamps at 30 city bus stops. It is worth noting that after their installation, the use of buses in the city doubled. Umea Energi subsequently installed similar lamps in a local high school to enhance students' mental health, energy, and concentration during classes. Two of Umea's main environmental concerns are CO_2 emissions from transport and air quality in the city center. The implementation of a comprehensive plan, the creation of new urban infrastructure, as well as the use of environmentally friendly vehicles are key in solving these problems. Therefore, the main goal is to reduce CO_2 emissions in the city due to less energy consumption and sustainable transport. The main smart solutions of Umea are presented in Table 1. As we can see, most of these technologies just solve the problem of excessive heat and energy consumption, which leads to increased energy efficiency, saving resources and money, as well as reducing emissions of pollutants.

4.3 Oulu

Oulu is the largest city in Northern Finland and, like Umea, is a scientific and educational center. In the strategy of urban development until 2026 [34], the vision of the city lies in its formation as a center of sustainable growth in the North. It will combine a fun atmosphere with advanced technologies, developed entrepreneurship and skilled labor, as well as an original and developing culture. Oulu citizens will have a fully digitized and

automated city that supports their needs for health and well-being, education, culture, housing, construction, and business.

In January 2015, Oulu launched a development project called "Roadmap to a smart Arctic specialization", in the framework of which various technological solutions and practices for northern cities are developed, created, and tested. The main areas of Oulu's smart specialization are [35]: ICT and software sector; chains of main industries: metal processing and wood processing; "clean" technologies, including energy; healthcare and innovative technologies. The choice made within the framework of the clever specialization of the Oulu region considers the structure of enterprises and industry of the region, the research base, international position, national innovation policy, as well as the strengths and capabilities of the region. In general, among smart Oulu technologies that have already been introduced or are only being piloted need to be mentioned: wireless networks (panOULU, 5G); SenCity smart lighting project; modernization of old and construction of new energy-efficient buildings (E2Rebuild project), as well as various innovations in healthcare sector. Innovations related to sensors, chipsets, information systems, cloud services and artificial intelligence are based on 5G networks. Some of the smart solutions in Oulu are also presented in Table 1.

A major project is being implemented in Oulu today to create a test center for smart city design. For this purpose, the Hiukkawaara district was chosen - the territory previously occupied by the military garrison. Now Hiukkawaara has a pilot area to test innovative solutions in energy efficiency, renewable energy, and other innovative technologies. This area was built during two projects: RESCA Oulu and Future Buildings and Renewable Energy. The goal of these projects was to develop and use the latest technology of the Internet of things IoT with various types of renewable energy sources. Hiukkawaara is designated as a sustainable northern winter city - "a convenient, smart and energy-efficient urban area that is the center of urban life all year round" [36]. Hiukkawaara is an Arctic smart city, a climate-friendly design model in the northern hemisphere. It is planned that by 2035 the population of Hiukkawaara will be 20,000 people. The main directions of the smart sustainable development of Hiukkawaara include [36]:

- energy efficient ICT for smart city;
- intelligent electrical networks;
- alternative and renewable energy sources;
- the ecological water supply system;
- centralized waste management;
- functional and environmentally friendly public transport.

One of the main goals of urban development in Oulu, like in most Northern cities, is an adaptation to climate change. Following the climate strategy of the Oulu region, adopted in 2009, the city seeks to contribute to the slowdown of climate change by constantly reducing greenhouse gas emissions. It pledged to reduce greenhouse gas emissions by 20% by 2020. The above smart and sustainable technologies are aimed at improving energy efficiency and reducing resource consumption.

4.4 Anchorage

Located in the south of central Alaska, Anchorage is the business, transportation, financial, commercial, and military center of the entire state. Anchorage belongs to the subarctic climate zone. At the same time, the climate here changes twice as fast as in other states of the USA. Anchorage is experiencing more cases of freezing-thaw, more rainfall, a longer season of fires. All this threatens the infrastructure, health, and well-being of residents.

Anchorage city authorities designed several strategic planning documents related to the development of certain areas of the city: transport planning, waste management, energy, etc. They contain the main innovative solutions in these areas, which contribute to increasing the sustainability and vitality of the city. In addition, Anchorage has a separate Climate Action Plan [37], whose goal is to reduce greenhouse gas emissions by 80% by 2050, with an interim target of 40% by 2030. Many actions in this regard address the root cause of climate change by reducing greenhouse gas emissions. This action plan addresses the full range of areas such as buildings and energy, land use and transport, solid waste, health, and education.

Key elements include accessible, open data exchange to create transparency in the community, which allows the public to participate in solving urban problems. The use of ICTs in various key municipal sectors, such as water, energy, and transport, will make more effective decisions and optimize the use of resources. Geographic Information Technology (GIS) is a critical supporting technology that supports Anchorage's vision, which feeds all major municipal systems. Also, the fundamental components of the smart sustainable development of the municipality are renewable energy sources (including from landfill gas), the introduction of low or zero-emissions vehicles, energy-efficient buildings. Part of these solutions is presented in Table 1.

5 Smart Solutions for Arctic Cities Implementing SDGs: International Experience

The information analyzed as part of the case study was structured and presented in Registry (Table 1) and reflects the experience of smart and sustainable innovations in the Arctic cities, which can be applied to other cities with similar environmental conditions. The following information is presented in the Registry: the name of the project or a specific smart solution, a description of the innovation, the effects obtained from the implementation, and the sustainable development goals that can be achieved using this technology or instrument. Most of the solutions presented are basic innovations: they are common in many cities around the world. They include the use of alternative energy sources, electric vehicles, energy-efficient buildings, intelligent heating systems, smart lighting, smart parking. Most of these technologies are aimed at reducing energy consumption and reducing greenhouse gas emissions into the atmosphere for combating climate change. In the Arctic region, smart city technologies are especially effective - any energy saving leads to significant savings.

Table 1. Registry of smart solutions in Arctic cities for implementing SDGs

Title	City	SDG	Description	Effects
Heat storage system [33]	Umea	7, 9, 11, 12, 13	Geothermal heat/cold storage connecting different buildings to better distribute energy in cold climate	Lower power consumption Reducing greenhouse gas emissions through better use of energy
Energy optimized BRT-station [33]	Umea	9, 11, 13	The public transport stops equipped with intelligent lighting and sound for fast landing and energy saving	CO_2 reduction Energy saving for electric buses
Intelligent building management [33]	Umea	8, 9, 11, 12, 13	Smart energy management system provides monitoring of the internal energy consumption in building	CO_2 reduction Reduces unnecessary resource use Energy saved for future use
Smart trash bins [31]	Reykjavik	9, 11, 12	Containers equipped with sensors sending notifications when containers are close to full so public utilities can plan their routes efficiently	Optimize traffic of garbage trucks Reduce waste collection time Money saving
Smart street lighting [21]	Reykjavik, Torshavn, Anchorage	7, 9, 11, 12, 13	Sensors built into the lights allows control unit to receive real-time information about weather conditions, pedestrian traffic, etc.	LEDs provide energy savings of 37% Upgrading 12,000 Anchorage streetlights saves about $ 780,000 a year

(*continued*)

Table 1. (*continued*)

Title	City	SDG	Description	Effects
Heated sidewalks [21]	Reykjavik, Oslo	9, 11, 12	Installation of a heating system designed to melt snow and ice in cold periods on icy sidewalks and parking lots	Saving money on snow removal Prevention of accidents and injuries to citizens
Road weather information system [37]	Anchorage	8, 9, 11	Network of weather stations located along the road. Real-time data on the asphalt and weather conditions send directly to the office	Improves timely maintenance Improves efficiency of the winter service
Smart parking [37]	Reykjavik, Oulu, Anchorage	9, 11, 13	Smart parking is equipped with sensors for quick and convenient search for parking spaces, security, and automation of the parking	Parking optimization, saving time and resources Reduced pollution by reducing driving time
Heated transport stops [38]	Edmonton, Winnipeg	3, 9, 11	The stop pavilion equipped with 1500 W electric heaters under the seats, as well as a door to keep warm	Improving the comfort of waiting for public transport
Electric vehicles [21]	Reykjavik, Oslo, Anchorage	3, 7, 9, 11, 12, 13	Replacement of diesel vehicles with electric or vehicles running on cleaner fuels	Reykjavik saved 600,000 liters of gasoline in 2010 Reykjavik saved 1,400 tons of CO_2 in 2010

6 Smart Solutions for Cities of the Arctic Zone of the Russian Federation (AZRF)

Russian is an active partner in different international as Arctic council member [39], co-organizer and conductor of the International Arctic Forum [40], the International Arctic Summit “Arctic and offshore projects: prospects, innovations and development

of regions" [41], and local Arctic initiatives as Project Office of Arctic Development (PORA) [42].

The Smart City project is being implemented as part of the national project "Housing and Urban Environment" and part of the national program "Digital Economy". It is aimed at improving the competitiveness of Russian cities, creating an effective urban management system, safe and comfortable living conditions for citizens and is based on 5 key principles [43]: focus on people; manufacturability of urban infrastructure; improving the quality of urban resource management; a comfortable and safe environment; emphasis on economic efficiency, including the service component of the urban environment.

The Ministry of Construction, Housing and Utilities of the Russian Federation approved the Smart City Standard in 2019 [44] - a set of basic and additional measures to be performed by all the cities participating in the departmental digitalization project "Smart City" by 2024. In the approved Standard, all decisions are divided into several key areas: urban management, smart utilities, innovations for the urban environment, smart urban transport, intelligent public safety systems, intelligent environmental safety systems, communications network infrastructure, tourism and service [44]. At the same time, the Standard is more aimed at digitalization and automation of urban management and urban economy paying less attention to the social aspect and sustainability principles of urban development.

Regional Smart City programs were adopted in Russian Arctic only in 2019, so not enough data of their implementation is available right now. The city of Murmansk is one of the first to launch the regional project "Smart Cities of the Murmansk Region" designed for the period 2019-2024. The project is coordinated by the Ministry of Energy and Housing Management and Utilities of the Murmansk Region. Also, implementation of the Smart City project started in other municipalities of the Russian Arctic in Norilsk, Arkhangelsk, Vorkuta, Salekhard and some other settlements. "Smart City Solutions Bank" as an open compendium of technologies and developments based on Smart City Standard was created to host projects that have already proven their effectiveness and can be widely applied in Russian cities [45].

For the most part, in all the cities examined, the basic set of smart solutions is the same: hardware-software complex "Safe city", digital services for taking citizens' opinions and electronic voting, implementing information technologies in the housing and communal services management system. Table 2 presents examples of smart technologies used in the cities of the Russian Arctic from the official platform - "Smart City Solutions Bank" [45] corresponding to SDGs.

In the Arctic cities of Russia all solutions are concentrated directly on the introduction of digital technologies in the urban economy on the local level. However, this is not enough, given the depth of the socio-economic and environmental problems of the Russian Arctic. In such circumstances, an integrated approach to the use of modern technologies is required to improve the quality of life and well-being in cities, as factors that can reduce the current rate of outflow of the Arctic cities population.

However, international cases demonstrate a clear focus on energy efficiency, reducing resource consumption, reducing CO_2 emissions, combating the effects of climate change, improving the quality of life. This is the specific result of smart technologies use in the

Table 2. Smart solutions in cities of AZRF for implementing SDGs [45]

Title	City	SDG	Description	Effects
Smart meter	Murmansk, Norilsk, Arkhangelsk, Severodvinsk	9, 11	Implementation of a comprehensive automatic energy metering system	Creation of a unified accounting system for energy resources Simplified collection of payments
Automated lighting control system	Arkhangelsk, Kirovsk, Monchegorsk, Murmansk	9, 11, 12, 13	Remote control and adjustment of lighting objects depending on environmental conditions	Reduced energy consumption up to 40−85% Lower operating costs
Wasteout, waste management system	Salekhard, Nadym	9, 11, 13	Metering devices record the fact of filling or emptying the garbage container	Cost saving on containers Monitoring the quality of garbage collection CO_2 reduction
GOST, Automated transport management system	Arkhangelsk	9, 11	System for managing and monitoring the operation of public transport	Automation of dispatcher's work Improving the quality of traffic Saving passenger time
ITLINE, bus information system	Kirovsk	9, 11	The system includes a smart board, sound duplication of information, the call button emergency services	Improving the comfort of using public transport
Intelligent building management system	Murmansk	9, 11, 12, 13	An automated system manages all the engineering systems in the building	Lower power consumption Saving money to pay for energy

(*continued*)

Table 2. (*continued*)

Title	City	SDG	Description	Effects
"Mobile lineman" for utilities	Arkhangelsk	9, 11	The system of semi-automatic reading of meters for resource consumption	Reduction of losses in grids by 3.6 times Increasing the efficiency of one controller by 2.6 times

harsh natural conditions of the Arctic region, which we do not see yet in the Russian Arctic cities. Thus, based on the international experience we examine the formation of an integrated concept of smart sustainable cities the Russian cities need to follow.

7 Conclusion

An analysis of the international experience in following the Smart and sustainable innovations in four Arctic cities allows to determine the common features of the Northern cities, the main problems, and their solutions. We need to notice that several measures of adaptation to climate change are of great importance for these cities. The main method of combat with climate change is the reduction of greenhouse gases by using alternative energy, electric vehicles, energy-efficient buildings, smart heating, and lighting systems.

The result of the case study shows that smart solutions being implemented in Arctic cities mentioned above correlate with many UN Sustainable Development Goals SD, especially the goals 7, 8, 9, 11, 12, 13. Most projects in the Arctic are aimed at improving energy efficiency, which corresponds to goal 7 – «Affordable and Clean Energy» and goal 12 – «Responsible Consumption and Production». The processing of resources and their secondary use provides a transition to rational patterns of consumption and production, creating the basis for recycling. Measures to combat climate change correspond to SDG 13 – «Climate Action». This topic is especially important precisely in Arctic cities, where climatic change is most noticeable and painful. Decarbonization and an emphasis on environmental sustainability improves the quality of the environment, which contributes to health and well-being (SDG 3). Innovative technologies corresponding to SDG 9, «Industry, Innovation and Infrastructure», are developed by high-tech industries, which generally increase their share in the economy of the city and country. All solutions investigated in the research correspond to the SDG 11 - «Sustainable cities and communities». Nearly all Arctic cities as international cases showed following SDG 11 that corresponds to many different aspects of city life.

The presented research showed that Arctic cities in Russia are doing their first steps in the direction of Smart Cities and accepting the sustainable development agenda. Cases of Arctic cities demonstrated that such smart instruments as smart lighting and heat supply systems, intelligent building management, electric cars, alternative energy sources, smart parking, heated sidewalks could be used in Russian cities for solving such

problems as emissions and pollution, irrational use of natural resources, climate change, problems of transport infrastructure and navigation, excessive money spending.

References

1. Arctic Circle. http://www.arcticcircle.org
2. ACIA: Impacts of Warming Arctic: Arctic Climate Impact Assessment. Cambridge University Press, Cambridge (2004)
3. Neirotti, P., De Marco, A., Cagliano, A.C., Mangano, G., Scorrano, F.: Current Trends in Smart City initiatives: some stylized facts. Cities Int. J. Urban Policy Plann. **38**, 25–36 (2014)
4. Caragliu, A., Del Bo, C., Nijkamp, P.: Smart cities in Europe. J. Urban Technol. **18**(2), 65–82 (2011)
5. Schaffers, H., Komninos, N., et al.: Landscape and Roadmap of Future Internet and Smart Cities (2012)
6. Piro, G., Cianci, I., Grieco, L.A., Boggia, G., Camarda, P.: Information centric services in smart cities. J. Syst. Softw. **88**, 169–188 (2014)
7. Giffinger, R., et al.: Smart cities ranking of European medium-sized cities. Centre of Regional Science, Vienna UT (2007)
8. Höjer, M., Wangel, J.: Smart sustainable cities: definition and challenges. In: Hilty, L.M., Aebischer, B. (eds.) ICT Innovations for Sustainability. AISC, vol. 310, pp. 333–349. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-09228-7_20
9. Bibri, S.E., Krogstie, J.: On the social shaping dimensions of smart sustainable cities. A study in science, technology and society. Sustain. Cities Soc. **29**, 219–246 (2017a)
10. Shmelev, S.E., Shmeleva, I.A.: Global urban sustainability assessment: a multidimensional approach. Sustain. Dev. **26**(6), 904–920 (2018)
11. Shmelev, S.E., Shmeleva, I.A.: Multidimensional sustainability benchmarking for smart megacities. Cities **92**, 134–163 (2019)
12. Shmeleva, I.A., Shmelev, S.E.: How smart is sustainable and how sustainable is smart. In: Shmelev, S.E. (ed.) Sustainable Cities Reimagined: Multidimensional Assessment and Smart Solutions, pp. 316–328. Routledge, London (2020)
13. ITU: Shaping Smarter and More Sustainable Cities: Striving for Sustainable Development Goals. ITU-T Focus Group on Smart Sustainable Cities, Geneva (2015)
14. Pressman, N.: Sustainable winter cities: future directions for planning, policy and design. Atmos. Environ. **30**(3), 521–529 (1996)
15. Pressman, N.: Reshaping Winter Cities: Concepts, Strategies and Trends. Published under the auspices of Livable Winter City Association. University of Waterloo Press, Waterloo (1985)
16. Martus, V.M.: Design for Northern Climates: Cold-Climate Planning and Environmental Design, 1st edn. Van Nostrand Reinhold, New York (1988)
17. Rogers, W.C., Hanson, J.K.: The Winter City Book. Dorn Book, Edina (1980)
18. Oikarinen, E.M.: Urban design with weather variability – adaptive capacity approaches towards Northern climate now and in the future. In: Proceedings of the Annual Architectural Research Symposium in Finland, pp. 119–132 (2014)
19. Grimmond, C.S.B., Roth, M., Oke, T.R.: Climate and more sustainable cities: climate information for improved planning and management of cities (Producers/Capabilities Perspective). Proc. Environ. Sci. **1**(1), 247–274 (2010)
20. Nordic Action on Climate Change. http://norden.diva-portal.org/smash/get/diva2:768493/FULLTEXT01.pdf
21. Nordic solutions for Sustainable Cities. https://www.arup.com/perspectives/publications/research/section/nordic-solutions-for-sustainable-cities

22. White Paper on Nordic Sustainable Cities. http://www.nordregio.se/nordicsustainablecities
23. Nordregio. https://nordregio.org/
24. United Nations. World Urbanization Prospects. https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.pdf
25. Nordic Development Fund. https://www.ndf.fi/
26. Nordic Smart City Network. https://nscn.eu/
27. Nordic Innovation. https://www.nordicinnovation.org/
28. Nordic Co-operation. https://www.norden.org/en
29. ITU. https://www.itu.int/pub/T-TUT-SSCIOT-2016-1
30. Global Destination Sustainability Index. https://www.gds-index.com/
31. Reykjavík Municipal Plan 2010-2030. https://reykjavik.is/sites/default/files/reykjavik-municipal-plan-2010-2030.pdf
32. City of Reykjavik's Climate Policy. https://reykjavik.is/sites/default/files/reykjavik_action_plan_carbon_neutral_by_2040.pdf
33. RUGGEDISED. http://www.ruggedised.eu
34. Oulu – The Light of the North. City strategy 2026. https://www.ouka.fi/documents/52058/17394318/ENG_Oulu2026_kaupunkistrategia.pdf/f9b8f26b-43a4-4b64-838a-fe0dde2a52eb
35. Council of Oulu Region. https://www.pohjois-pohjanmaa.fi/index.php?315
36. Hiukkavaara. Sustainable Arctic Winter City. https://www.ouka.fi/c/document_library/get_file?uuid=dcae27f5-eaa8-40ed-8e0f-caf04180c3c7&groupId=139863
37. Anchorage Climate Action Plan. http://www.muni.org/Departments/Mayor/AWARE/ResilientAnchorage/Documents/2019%20Anchorage%20Climate%20Action%20Plan_ADOPTED.pdf
38. City of Edmonton. https://www.edmonton.ca/ets/riding-ets.aspx
39. Arctic Council. https://arctic-council.org
40. International Arctic Forum. https://forumarctica.ru/en
41. International Arctic Summit "Arctic and offshore projects: prospects, innovations and development of regions" (ARCTIC 2020 SPb), St. Petersburg, 20–21 February 2020. https://www.arctic-summit.ru
42. Project Office of Arctic Development (PORA). https://www.porarctic.ru
43. Guidelines for the Preparation of the Regional Project «Smart Cities» (Metodicheskie rekomendacii po podgotovke regional'nogo proekta «Umnye goroda»). http://www.minstroyrf.ru/upload/iblock/620/Metodicheskie-rekomendatsii.docx
44. Basic and additional requirements for smart cities (Standard of "Smart Cities") (Bazovye i dopolnitel'nye trebovaniya k umnym gorodam (standart «Umnyj gorod»)). http://www.minstroyrf.ru/upload/iblock/74f/Standart.pdf
45. Smart City Solutions Bank (Bank reshenij umnogo goroda). https://russiasmartcity.ru

Modelling Twilight Illuminance in Urban Area Using Machine Learning Techniques

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Abstract. Illumination plays an important role in urban life. Recent technology developments make it possible to increase the quality of streetlight services. However, the cost of their implementation is high. The effectiveness of such improvements could be analyzed using calculated optimal time schedule for outdoor lighting which considers weather conditions and the possibility of light dimming. For this purpose, an estimation of illuminance during the twilight is needed. This study introduces new procedure for modelling twilight illuminance in urban area using machine learning algorithms. The model is estimated based on the illuminance records collected by the light sensor. The obtained results are consistent with the measurement values distribution and can be used as approximation of twilight illuminance specific for a certain location.

Keywords: Urban illumination · Twilight illuminance · Illuminance model · Illuminance measurements · Random forest · Oversampling · Kernel density estimation

1 Introduction

The main aim of urban illumination is to increase safety and comfort of pedestrian and vehicular traffic. It has a significant impact on crime rate, road safety statistics, pedestrian mobility, and public health [1, 2].

The illumination parameters are strictly regulated by the corresponding standards and rules, but the issue of street-light design rationality remains to be challenging [3]. Apart from such basic criteria as visibility and safety, there should also be taken into consideration social, aesthetical, and economic aspects [4]. Moreover, recent technology advances allow to enhance the quality of street lighting services [5].

State-of-the-art technologies, like the Internet of things (IoT), make it possible to provide in real time the required illuminance level and facilitate cost and energy efficiency [6]. However, the current urban illumination technologies are rather conservative and the cost of IoT technologies implementation is high. Therefore, a procedure is needed to prove the effectiveness of using the IoT technologies for urban illumination. One of the approaches is to calculate the optimal time schedule for outdoor lighting which accounts for the sky condition and the possibility of light dimming. An appropriate estimation of the optimal time schedule could be made based on a twilight illuminance model,

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allowing to simulate the lighting parameters of the city on the climate scale. From this perspective, modelling twilight illuminance in urban area with taking into consideration outdoor parameters becomes a relevant task.

2 Related Works

Among the illuminance models, daylight availability estimation is of prime interest. Daylight illuminance data has many applications in ecology, agriculture, architecture, and power industry. It is used for energy-efficient design and operating solar energy conversion systems [7].

However, solar irradiance and illuminance data is not widely available due to the high measurement cost and complexity of equipment calibration and maintenance [8, 9]. Therefore, researches had to develop alternative methods to acquire high frequency illuminance level series.

The most popular approach involves obtaining illuminance level from more widely measured solar irradiance data through luminous efficacy [7]. Luminous efficacy is defined as the ratio between illuminance level and corresponding irradiance. There are numerous studies deriving mathematical functions for luminous efficacy under various sky conditions which include clearness and brightness [10, 11]. Sky ratio is usually calculated based on solar irradiance and its component values [12]. In recent years, studies applying machine learning algorithms have appeared [7, 13]. For example, Tíba and Leal [13] have developed the multilayer perceptron (MLP) artificial neural network, which slightly outperforms classical models.

At the same time, due to lack of solar irradiance data, there have also appeared a range of studies devoted to modelling of solar irradiation and illuminance level. Models developed within this approach represent mathematical functions of solar altitude angle, which are estimated for various sky conditions [14–16]. Sky conditions are determined by the irradiance measurements as in the case with luminous efficacy. Alternatively, Hongkong, S. [9] used the MLP artificial neural network to predict solar irradiance and illuminance level based on solar altitude angle and sky ratio, which was measured by the adaptive observation system (AOS) in real time.

As for twilight illuminance, there were several attempts to estimate the illuminance level for a range of sky types and solar altitude angles [17]. However, to the author's knowledge no models of twilight illuminance have been developed.

The present work aims to fill the gap in twilight illuminance modelling. The two main illuminance factors are considered: solar altitude angle and sky condition data. It should be underlined that unlike the previous works the sky condition data is taken from the freely available source – European Centre for Medium-Range Weather Forecasts (ECMRWF) [18].

The results of the research can be used to control light measurement sensors in automatic lighting control systems [19], as well as for light climate research using stochastic modelling methods [20].

3 Illuminance Measuring in Urban Environment

Illuminance data was collected by the device based on the ambient light sensor BH1750 (see Fig. 1). It measures light intensity using the photo diode with approximately human eye response. The measurements are transformed into 16-bit digital signals by analog-to-digital converter. The result is given in lux with 1-lux precision in high-resolution mode. BH1750 was connected to a Wemos D1 Mini board programmed in the Arduino IDE. The data acquisition program produced records at 1-min intervals. To protect the device from moisture, a 3D printed case was constructed.

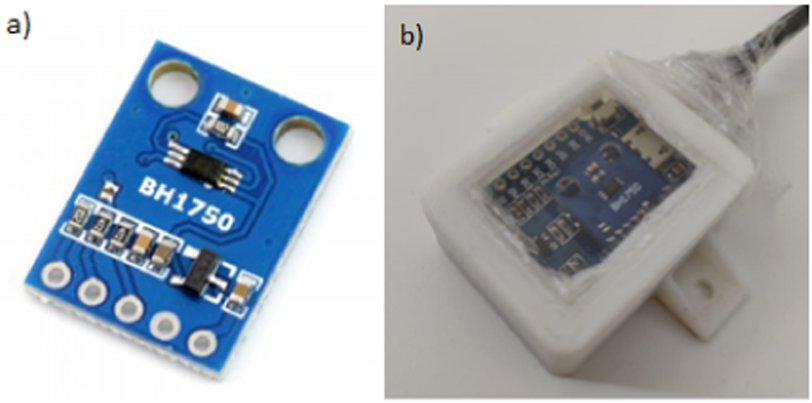

Fig. 1. Assembled light measuring device (b) with BH1750 sensor (a)

The illuminance measurements took place at the ITMO University, which is located at 59°56′N, 30°17′E. The device was installed on the horizontal surface, which was free from the obstructions and artificial lighting. The data was collected during the period from July 23, 2019 to September 12, 2019 and covered a variety of weather conditions. Data acquisition process started before sunset and ended after sunrise.

As a result, the measurements for 49 civil twilights were recorded. The civil twilight is defined as the period between the time when the sun is 0.8333° below the horizon and the time when the sun is 6° below the horizon [21]. The solar altitude angle was calculated using two python packages: Astral [22] and Pysolar [23]. Astral allows to define the approximate period of twilight, whereas Pysolar determines the solar altitude angle considering the information about the location and time. Such procedure was used, because Pysolar is more accurate, but there is no function, which directly allows to get the time of twilight events. The examples of obtained measurements and their approximations are presented in Fig. 2.

As can be seen on Fig. 2, an exponential function fits well to the twilight illuminance curve. The moment of intersection between the illuminance curve and the norm defines the optimal lighting hours. Obviously, this moment heavily depends on the highest illuminance level during the twilight, which is determined by the weather conditions. According to the measurement records, the mean value of the lowest illuminance level during twilights equals 1.4 lx with sample standard deviation of 1.1 lx. Therefore, this

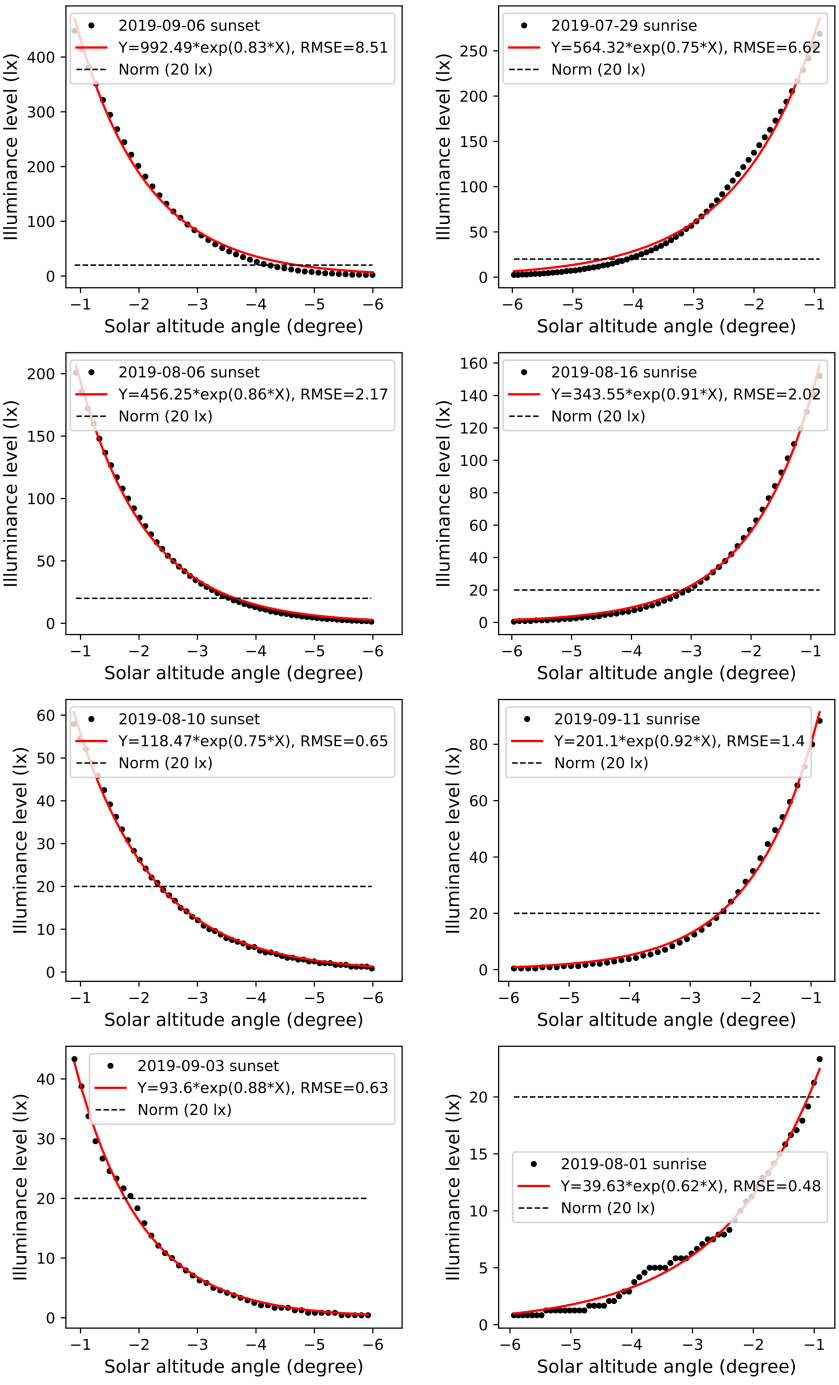

Fig. 2. The examples of twilight illuminance measurements and their approximations

value does not have a significant influence on the curve form and its estimated mean value can be used for modelling. The twilight illuminance model can be derived by solving exponential equation system using the information about the highest and lowest illuminance values during the twilight:

$$\begin{cases} Y_{min} = a \cdot e^{bXmin} \\ Y_{max} = a \cdot e^{bXmax} \end{cases}, \tag{1}$$

where X_{min} and X_{max} equal the lowest and the highest solar altitude angle during the twilight. Y_{min} represents the lowest illuminance level, estimated as 1.4 lx. Y_{max} equals the highest illuminance level, determined by weather conditions.

Consequently, the illuminance modelling problem can be reduced to the regression task of estimating the relationship between the highest illuminance level during the twilight and weather conditions.

4 Physics of Twilight Luminance

Twilight illuminance modelling is a physically deterministic problem. During twilight, the Sun is not directly observable, as it is below the horizon. However, the sunlight approaches the Earth's surface, and illuminance gradually changes as the Sun sinks below the horizon (Fig. 2). Theoretical considerations for the twilight process are schematically drawn in Fig. 3.

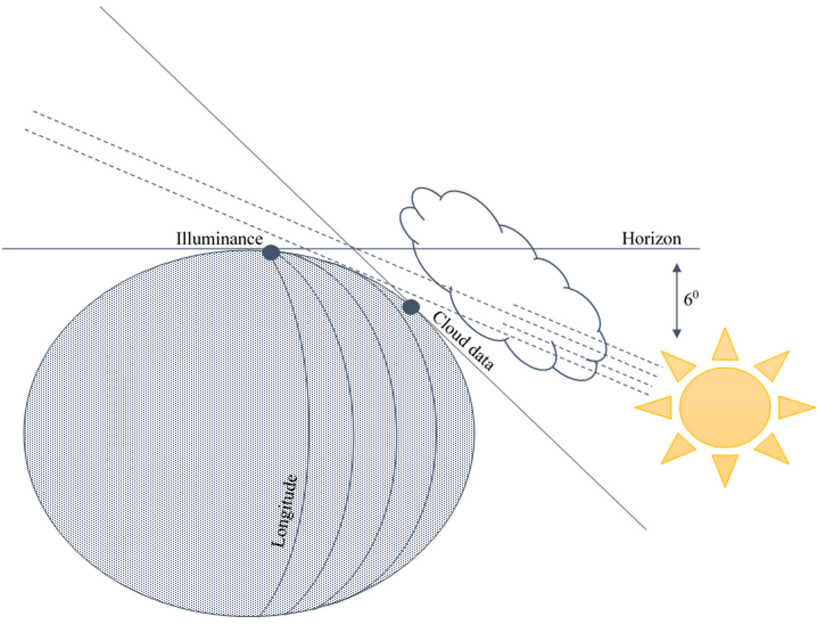

Fig. 3. Twilight luminance scheme

The observable twilight effects depend on atmospheric conditions, refraction, amounts of multiple scattering and absorption on the observer's line of vision [24]. Consequently, the twilight illuminance at the observer's location depends on the atmosphere state on the line of sunset/sunrise. For this reason, cloud variables for a range of longitudes and a given latitude should be analyzed. In other words, such solar altitude angle above the horizon should be found, which gives the best explanation for the illuminance variability during the twilight at the observer's location.

5 Illuminance Factors

The key illuminance factor is solar altitude angle. As related works review showed, the other significant factor relates to sky condition. Unlike the previous studies, here the sky condition data was not associated with measurements and was independently taken from the freely available source (ECMRWF) [18]. Sky condition variables considered relate to cloud coverage and are given in Table 1. Various cloud cover parameters were used, because the resulting factor – total cloud cover could not solely explain the variability of illuminance levels.

The relationship between the highest illuminance levels and cloud variables for the proposed solar altitude angle (0.35°) is presented in Fig. 4. The upper corner shows

Table 1. Cloud variables description (Source: [18])

Name	Units	Description
Total cloud cover	Dimensionless	Defines the proportion of a grid box covered by cloud. Assumptions are made about the degree of overlap between clouds at different heights. Values vary from 0 to 1
High cloud cover	Dimensionless	Defines the proportion of a grid box covered by cloud occurring in the high levels of the troposphere. Values vary from 0 to 1
Medium cloud cover	Dimensionless	Defines the proportion of a grid box covered by cloud occurring in the middle levels of the troposphere. Values vary from 0 to 1
Low cloud cover	Dimensionless	Defines the proportion of a grid box covered by cloud occurring in the lower levels of the troposphere. Values vary from 0 to 1
Total column cloud ice water	kg m-2	The amount of ice contained within clouds in a column extending from the surface of the Earth to the top of the atmosphere
Total column cloud liquid water	kg m-2	The amount of liquid water contained within cloud droplets in a column extending from the surface of the Earth to the top of the atmosphere
Cloud base height	km	The height above the Earth's surface of the base of the lowest cloud layer

pairwise correlation, the diagonal illustrates variable distribution. The scatter plots of factor values are presented in the lower corner. The correlation values indicate low linear dependence between the variables, although the atmosphere state evidently influences the illuminance level. Therefore, it can be concluded, that a complex model is needed to associate illuminance levels with cloud variables.

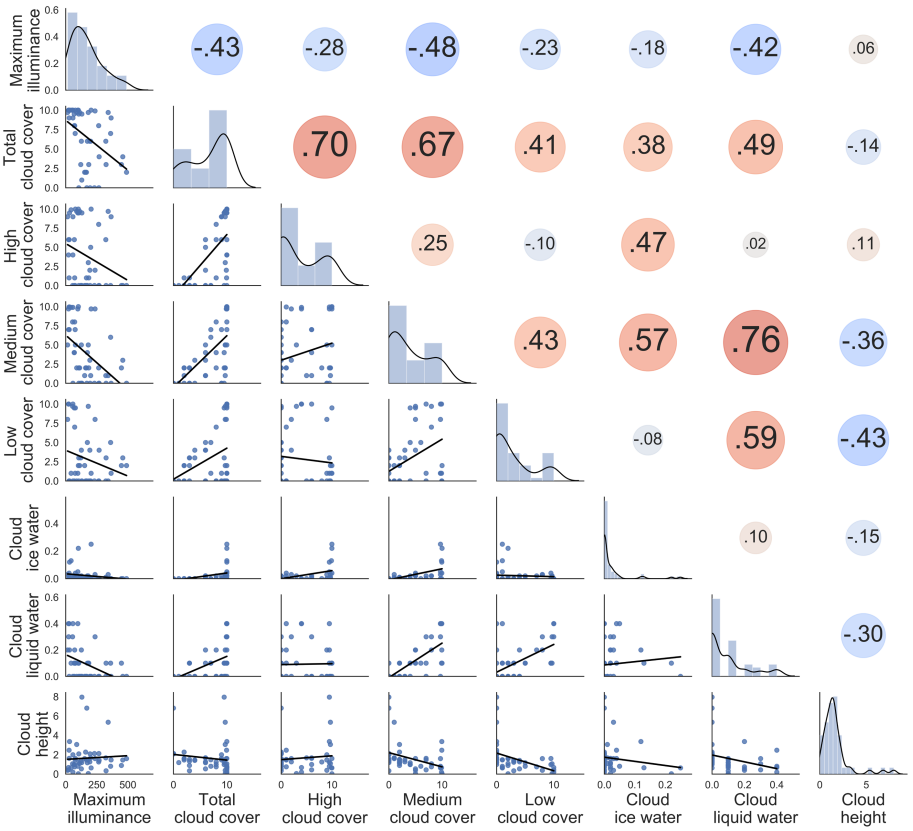

Fig. 4. Illuminance factors pair plot

6 Machine Learning Model for Twilight Illuminance Prediction Based on Cloud Data

6.1 Method

Modelling was performed based on 49 twilight illuminance records, therefore one of the challenges was small sample size. Moreover, the sample was imbalanced due to lack of high illuminance values. There are two main approaches to handle this problem: under-sampling the majority class and over-sampling the minority class [25]. Given the small

sample size the imbalance problem was solved by over-sampling the minority classes using synthetic minority over-sampling technique (SMOTE). SMOTE generates synthetic samples based on nearest neighbors defined by the k-nearest neighbors algorithm [25]. It is implemented in imbalanced-learn – an open-source python toolbox [26].

Model predictors included 6 cloud variables. The cloud height factor was deleted from the sample as an uncertain parameter. As factors pair plot (Fig. 4) demonstrated low linear dependence, a non-linear supervised learning algorithm – Random Forest was chosen for model estimation. It has a high prediction accuracy in case of complex data structure and generalization capacity [27].

Due to small sample size ensemble learning was applied to random forest regressions to increase their efficiency. The original sample was randomly split into train and test sets, with test set containing 10% of imbalanced sample. The base learner was trained, and root-mean-square errors (RMSE) for train and test sets were calculated. This procedure was repeated for 1000 times, then 20% of models with the lowest RMSE values for train and test sets were chosen. The obtained predictions from these models were averaged. In the end the result was corrected in accordance the constraints, which equal to maximum and minimum values of measured twilight illuminance.

6.2 Model Performance Estimation

The model performance was estimated by the distribution of R^2 score for train set. However, due to small sample size, additional quality tests were needed. For example, kernel density estimation (KDE) for measured and predicted illuminance could be compared. In this case, KDE for illuminance records serves as the climate norm. Thus, KDE curve for predicted illuminance should be consistent with its form.

In order to get robust climate norm estimation, confidence intervals for KDE were constructed using bootstrapping technique [28]. The predictions were made for every twilight of the period equivalent the measurements dates (from July 23 to September 12) for 2010−2019 years. This procedure was performed using cloud data for different solar altitude angles. It was expected that at some positive solar altitude value KDE consistent with the climate norm would be obtained.

Figure 5 and Fig. 6 demonstrate the results of model performance estimation for different solar altitude angles. The angle value of −0.83 as the moment of twilight start corresponds to the longitude close to the measurement location. The highest R^2 values are obtained for the angles equal to −0.83 and 0.35. However, KDE for predictions made by the 0.35-degree model looks more like KDE for illuminance measurements. In other words, the cloud data for the solar altitude angle of 0.35° allows to explain the variability of twilight illuminance to some extent and obtain predictions, which are consistent with the climate norm.

Additionally, feature contribution for the chosen model was analyzed. The importance scores for each element of ensemble were summarized and scaled as percentage of the maximum score. As a result, the most significant factors were obtained: total cloud cover (100%), medium cloud cover (73%) and low cloud cover (65%).

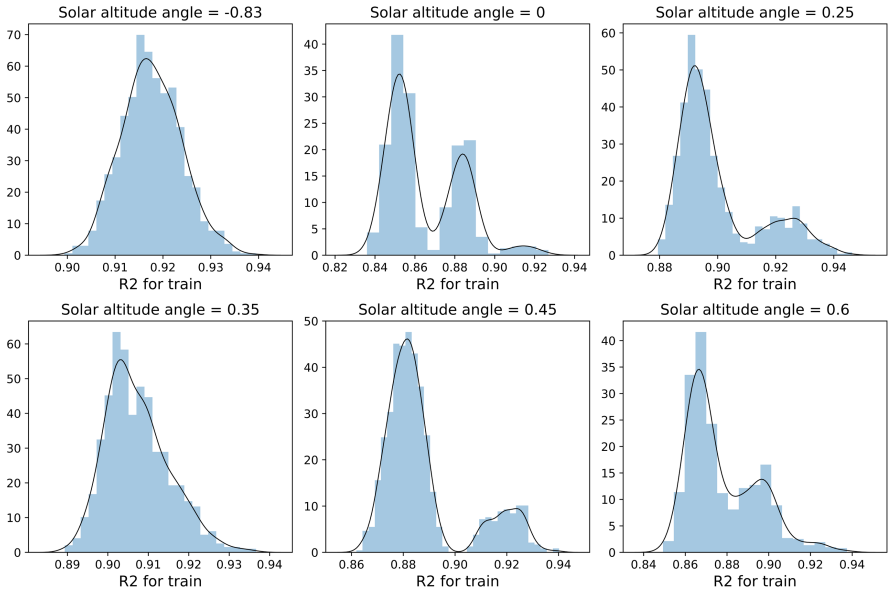

Fig. 5. R2 for train set distribution

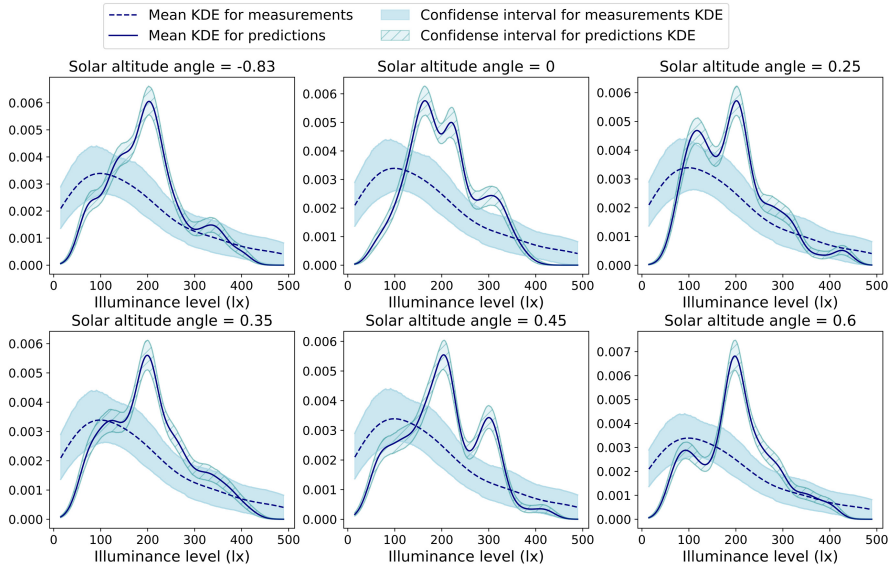

Fig. 6. Confidence intervals for KDE

6.3 Accounting for Systematic Error

The resulting model for solar altitude angle of 0.35 was corrected for systematic error. The error function was estimated by repeating ensemble learning for 1000 times. The

obtained result is described as:

$$Y = 0.000006 \times X^3 - 0.005 \times X^2 + X - 21.11, \quad (2)$$

where X represents ensemble predictions. KDE analysis for the resulting model which considers systematic error is shown in Fig. 7.

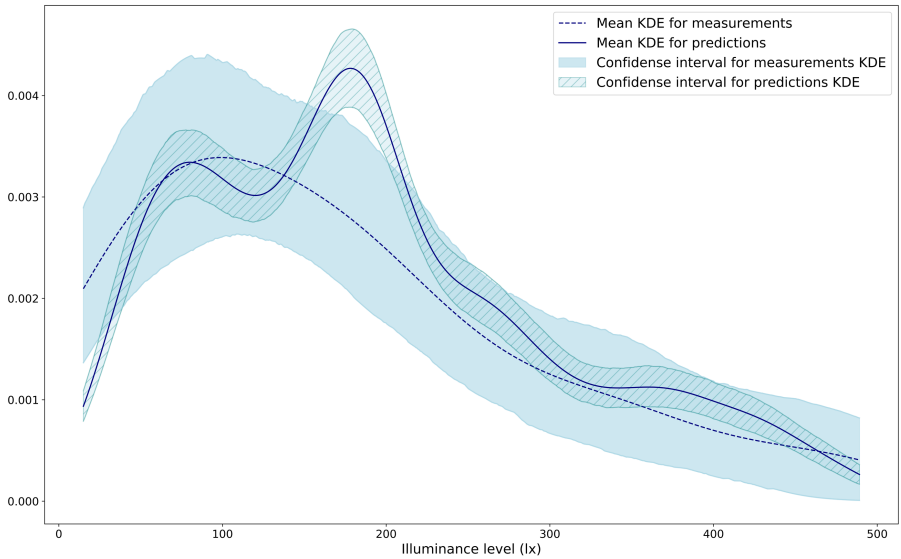

Fig. 7. KDE analysis for the resulting model

Similarity of interval estimations for the measurements and predictions can be formalized by the ratio between the value of their overlapped area and the area of KDE confidence interval for predictions. The area values were calculated as polygon areas using python package Shapely [29]. The 'KDE similarity index" for the resulting model has value of 79%.

6.4 Model Comparison

The performance of obtained illuminance model was compared to several base machine learning algorithms (random forest model, multi-layer perceptron regressor) and to random forest ensemble estimated by the author's procedure except for oversampling technique. The comparison results are given in Table 2.

Random Forest and MLP regressors were fitted using sample splits, which give the lowest RMSE and the highest R^2 values for train and test sets. Table 2 shows, that KDE similarity index for these models is much lower than for ensemble. Therefore, it can be concluded that standard machine learning algorithms show poor performance when dealing with small sized samples.

Furthermore, it should be noted that such over-sampling procedure as SMOTE leads to a substantial increase in KDE similarity index. However, other statistical indicators,

Table 2. Model performance comparison

Metric	RF ensemble + SMOTE[a]	RF ensemble[b]	Random Forest	MLP regressor
KDE similarity index[c]	79%	51%	45%	27%
R^2 for train set	0.9	0.83	0.84	0.36
R^2 for test set	−0.02	−0.45	0.9	0.95
RMSE for train set	38.37	51.61	50.05	100.53
RMSE for test set	70.41	74.16	22.57	14.52
MAE for train set[d]	28.35	42.76	42.45	80.44
MAE for test set	58.89	65.14	19.22	11.6
MAPE for train set[e]	24.65%	41.77%	44.14%	67.92%
MAPE for test set	69.57%	86.95%	13.9%	10.44%

[a]Model derived by the authors.
[b]Model derived by the authors without SMOTE.
[c]Index calculation procedure is described in 6.3.
[d]Mean absolute error.
[e]Mean absolute percentage error.

e.g. R^2 for test, state the low quality of the resulting model. This fact can be explained by the small size of test subset. Generally, in such tasks the qualitative analysis and KDE assessment become more relevant.

7 Results

Twilight illuminance modelling is an unconventional problem. A large variety of factors influence this phenomenon. Nowadays there is no existing physical illuminance model, for this reason only an empirical model could be derived.

Due to a short observation period, the main challenge was dealing with a small sized sample while estimating a range of uncorrelated with illuminance factors. Thus, to get robust estimations such special procedures were used as over-sampling, ensemble learning, bootstrapping and others.

As a result, twilight illuminance model was derived, which makes predictions that are consistent with the climate norm. The norm is defined by the confidence intervals for KDE calculated for measurements. This model makes predictions for the highest illuminance value during the twilight. Based on this value it is possible to derive the function for illuminance curve as described in 3.

The obtained predictions for illuminance curve can be used to calculate the optimal time schedule for outdoor lighting. The predicted illuminance level for Saint Petersburg

for a three-month period was compared to a standard level of urban illuminance equal to 20 lx. The optimal time for switching-on was defined by the moment when illuminance level becomes lower than the norm. An example of the resulting optimal time schedule is shown in Fig. 8.

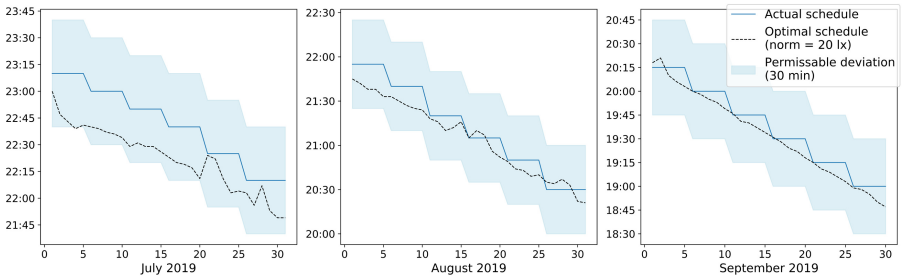

Fig. 8. Optimal time schedule for outdoor lighting in Saint Petersburg

The optimal time schedule for Saint Petersburg lies within the permissible deviation interval set by the authorities. Thus, weather conditions consideration insignificantly changed the switching-on time in this case. However, it should be noted, that in July variation of switching-on time is higher. This fact can be explained by the duration of twilight period. It is longer for the months, which are close to the day of summer and winter solstice. Consequently, during these months weather conditions consideration could facilitate the illuminance requirements fulfilment. If more accurate time schedule estimations are required, then interval estimations for the time schedule could be derived.

However, the key limitation of this model consists in a short observation period, as there is no information about the twilight illuminance under other weather conditions, for example in winter when albedo is higher. For this reason, further research including illuminance measuring is required.

8 Conclusion

This study introduces new procedure for modelling twilight illuminance in urban area using machine learning algorithms. The model predictions are consistent with the measurement values distribution and can serve as an appropriate estimation of twilight illuminance specific for a certain location. Thus, the theoretical contribution of this paper consists in generalizable methodology for twilight illuminance modelling, which can be applied for any location and measurements volume.

Model estimations could be used to derive the optimal time schedule for outdoor lighting which considers sky condition and the possibility of light dimming. The resulting time schedule could be analyzed from two perspectives: the cost-effectiveness of implementing IoT technologies and the accuracy of current lighting scheme. As a result, technological improvements could be made to increase the quality of street lighting services. Another example of practical use could be anomaly detection in the light sensor data as the model is robust to outliers.

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References

1. Painter, K.: The influence of street lighting improvements on crime, fear and pedestrian street use, after dark. Landsc. Urban Plan. **35**(2–3), 193–201 (1996)
2. Green, J., et al.: Reduced street lighting at night and health: a rapid appraisal of public views in England and Wales. Health Place **34**, 171–180 (2015)
3. Choi, A.S., et al.: Rational-design process and evaluation of street-lighting design for apartment complexes. Build. Environ. **42**(8), 3001–3013 (2007)
4. Sender, A.V., et al.: An algorithm for search automation of lighting sources optimal arrangement in urban environment. Nauchno-Tekhnicheskii Vestnik Informatsionnykh Tekhnologii, Mekhaniki i Optiki **18**(1), 122–132 (2018)
5. Pantoni, R., Brandão, D.: A confirmation-based geocast routing algorithm for street lighting systems. Comput. Electr. Eng. **37**(6), 1147–1159 (2011)
6. Wojnicki, I., et al.: Application of distributed graph transformations to automated generation of control patterns for intelligent lighting systems. J. Comput. Sci. **23**, 20–30 (2017)
7. Li, D.H.W., Lou, S.: Review of solar irradiance and daylight illuminance modeling and sky classification. Renew. Energy **126**, 445–453 (2018)
8. Chen, J.-L., Li, G.-S.: Evaluation of support vector machine for estimation of solar radiation from measured meteorological variables. Theoret. Appl. Climatol. **115**(3-4), 627–638 (2013). https://doi.org/10.1007/s00704-013-0924-y
9. Hongkong, S.: ANN-based model with adaptive observation system for estimation solar irradiance and illuminance on horizontal surface. J. Res. Appl. Mech. Eng. **6**(2), 82–94 (2018)
10. Perez, R., et al.: Modeling daylight availability and irradiance components from direct and global irradiance. Sol. Energy **4**(5), 271–289 (1990)
11. Robledo, L., Soler, A.: Luminous efficacy of direct solar radiation for all sky types. Energy **26**(7), 669–677 (2001)
12. Fakra, A.H., et al.: A simple evaluation of global and diffuse luminous efficacy for all sky conditions in tropical and humid climate. Renew. Energy **36**(1), 298–306 (2011)
13. Tíba, C., Leal, S.S.: Measuring and modelling illuminance in the semi-arid Northeast of Brazil. Renew. Energy **48**, 464–472 (2012)
14. Junsiri, J., et al.: The challenge of all sky luminance modeling and its availability for electric light saving in interior spaces at Mahasarakham, Thailand. Int. J. Phys. Sci. **7**(4), 550–559 (2012)
15. Lam, J.C., Li, D.H.W.: Daylight availability in Hong Kong and energy implications. Int. J. Ambient Energy **17**(2), 79–88 (1996)
16. Pattanasethanon, S., et al.: All sky modeling daylight availability and illuminance/irradiance on horizontal plane for Mahasarakham, Thailand. Energy Convers. Manage. **48**(5), 1601–1614 (2007)
17. Jeske, H.: 7.4.5 luminance during twilight and at night. In: Fischer, G. (ed.) Physical and Chemical Properties of the Air, Landolt-Börnstein - Group V Geophysics, vol. 4B, pp. 287–288. Springer, Heidelberg (1988). https://doi.org/10.1007/10333390_48
18. ERA5 hourly data on single levels from 1979 to present. https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels. Accessed 12 Feb 2020
19. Boukhanovsky, A.V., Ivanov, S.V.: Stochastic simulation of inhomogeneous metocean fields. Part III: high-performance parallel algorithms. In: Sloot, Peter M.A., Abramson, D., Bogdanov, A.V., Gorbachev, Y.E., Dongarra, J.J., Zomaya, A.Y. (eds.) ICCS 2003. LNCS, vol. 2658, pp. 234–244. Springer, Heidelberg (2003). https://doi.org/10.1007/3-540-44862-4_26

20. Lopez, J.L.A., et al.: Data quality control for St. Petersburg flood warning system. Proc. Comput. Sci. **80**, 2128–2140 (2016)
21. Forsythe, W.C., et al.: A model comparison for daylength as a function of latitude and day of year. Ecol. Model. **80**(1), 87–95 (1995)
22. Astral package. https://pypi.org/project/astral/. Accessed 19 Feb 2020
23. Pysolar package. https://pysolar.readthedocs.io/en/latest/. Accessed 19 Feb 2020
24. Jeske, H.: 7.5 twilight phenomena. In: Fischer, G. (ed.) Physical and Chemical Properties of the Air, Landolt-Börnstein - Group V Geophysics, vol. 4B, pp. 307–314. Springer, Heidelberg (1988). https://doi.org/10.1007/10333390_53
25. Chawla, N.V., et al.: SMOTE: synthetic minority over-sampling technique. J. Artif. Intell. Res. **16**, 321–357 (2002)
26. Lemaître, G., Nogueira, F., Aridas, C.K.: Imbalanced-learn: A python toolbox to tackle the curse of imbalanced datasets in machine learning. J. Mach. Learn. Res. **18**(1), 559–563 (2017)
27. Hastie, T., Tibshirani, R., Friedman, J.: The Elements of Statistical Learning. Springer Series in Statistics, 2nd edn. Springer, New York (2009). https://doi.org/10.1007/978-0-387-84858-7
28. Fiorio, C.V.: Confidence intervals for kernel density estimation. Stata J. **4**(2), 168–179 (2004)
29. Shapely package. https://pypi.org/project/Shapely/. Accessed 19 Feb 2020

Evaluating a City's Public Service Infrastructure Based on Online Data

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Abstract. The paper deals with evaluation of the quality of public service infrastructure in the city of Kronstadt, the historical part of Saint-Petersburg agglomeration. Public services are considered as FMCG, cultural and recreational venues people use in everyday life. We consider the quality of public services through a set of objective (availability, accessibility, variability) and subjective (users perception) indicators. We measure the quality of public service infrastructure based on the data from open digital sources, such as Technical Passports of Houses from Open Data of Saint-Petersburg Platform, Google Maps, Google Places, and validate usability of services based on a sociological survey. We illustrate our analysis with maps which provide a detailed view on the localization, accessibility, variability of the service infrastructure. We conclude that public service infrastructure in Kronstadt does not address the needs of the dormitory areas which make up one third of all citizens of the city.

Keywords: Public service infrastructure · Mapping public services · Quality of urban environment · Online data

1 Introduction

The purpose of the paper is to assess the quality of the existing service infrastructure in the city of Kronstadt, one of the administrative districts of the city of St. Petersburg. Public service infrastructure in this context is understood to be composed of all establishments active in the service and cultural economy that are open to the public and target a wide range of consumers. This includes establishments in the FMCG segment, recreational, cultural, sports facilities and places. The quality of public service infrastructure can be determined by the localization of services, the uniformness of their distribution in the city, the functional segmentation of services as well as the indicators of the service establishments' popularity and comprehension within customers. The quality of public service infrastructure can be measured using objective criteria – unambiguously interpreted, measurable characteristics such as the quantity and density of service establishments, their location, price levels, and the like – and through subjective characteristics that reflect the perception of these services by their customers. A recent trend in the social sciences has been to compare such characteristics in order to obtain

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a detailed picture of the phenomenon being studied. However, such studies are still rare in the context of analyzing public services in the city. Open data provided by the city government and user-generated data coming from users of LBSN gives a helping hand for such studies on a large scale of the whole cities or their particular areas.

The methodology of our study is structured as follows. First, on the basis of the data from an governmental open data source, the technical passports of St. Petersburg's multi-apartment buildings, we create a map of Kronstadt's population structure. Second, based on the data from Google Maps, another openly accessed resource, we form a map of service establishments in the city. Third, based on the check-ins data and the comments about these establishments generated by customers using the Google Places rating platform, we map the service infrastructure's other qualities – namely, the establishments' attendance and the quality of the services provided. Next, we compare the findings to reveal the relation between supply and demand for services and analyze their objective and subjective quality. In addition, we validate the results obtained from the online open sources with a sociological survey of residents living in different areas of Kronstadt regarding social need in public services. As a result, we draw conclusions about the current mismatch between the public service infrastructure, on the one hand, and the settlement structure and demand for services in Kronstadt, on the other.

2 Literature Review

City services include all those establishments and places that are open to all population groups (consumers) without restriction and which, in addition to their primary function (selling goods or providing services), also carry out certain public space functions – for example by serving as a meeting place, place of communication, or place of collective action. Such establishments may include shops, especially mom-and-pop shops [1] which are patronized by the locals and where one can not only buy wares but also find out the street's latest news; cafés and bars, where one can chat with acquaintances and bartenders or meet one's friends or the regulars [2]; theaters and creative public spaces, where one can not only get involved in cultural activities, but also meet friends and feel a part of a cultural community [3]. The general term for such places is "third places," which is the term used by R. Oldenburg [2]. Third places, in addition to their main economic or cultural function, perform a number of additional socially significant functions as well: they serve as an intermediate point between home and work, a place for meeting both strangers and old friends, a factory for forging social ties at one's place of (permanent) residence, a clearinghouse of information, gossip, and news, as well as a spot for trading services and household items. They foster socialization among visitors and among the youth, become the crucibles of folk and local culture, help consolidate political activity, and so on. The conditions for the formation of third places are their availability, perceived quality, and diversity. In addition, the availability of various services within walking distance affects the full development of urban subcenters [4]. Lack of services leads to the formation of urban outskirts and mono-functional areas (such as "dormitory districts"). The uneven quality of daily service infrastructure – places of retail and entertainment – contributes to the economic and cultural segregation of urban communities [5, 6]. The quality of urban services even affects the psychological state

of citizens; for example, supermarkets have been found to create the state of increased concentration and anxiety, while cozy cafés promote relaxation, so the residents' ability to use a variety of services is necessary for ensuring their psychological well-being and balance [7, 8]. Thus, a developed service infrastructure near places of residence can be an indicator of a high-quality urban environment.

To determine the functional content of urban areas, their points of interest, and the quality of urban places and urban services, online data – including data generated by users on social networks – has been widely used in recent studies [9–11]. Geo-referenced photographs serve as material for studying perceptions of security, social (economic) class, and uniqueness of different urban areas [8, 12]. The digital trails left by consumers allow us to characterize the distribution of various types of activities in the city [13] and even determine the particular natural habitats forming due to service infrastructure [14, 15]. Geolocation data allows us to determine service diversity [16] and the level of urban service deprivation [17]. Geotagged social media platforms, including Twitter and Instagram, become a source for data assessing neighborhoods' accessibility, traffic, foot traffic, and demand for various types of services - for example, parks [18, 19], retail [20], or bars [21]. Quantitative analysis includes an assessment of the segregation of city services throughout the city in terms of popularity, number of positive (or negative) reviews, and target visitor groups [22]. Qualitative analysis includes case studies of various groups of services in certain areas or city streets based on the content of comments regarding those services or the visual components of photographs taken at those establishments, if they are analyzed in detail [23]. Analysis of urban services makes it possible to give recommendations on optimizing their placement and typology, providing a service to owners as well as to city managers [8].

3 Analysis of the Structure of Settlement in the City of Kronstadt

As an object of study, this article focuses on the city of Kronstadt, which is in turn a part of the city of St. Petersburg, Russia. Founded in 1704, Kronstadt is located on the island of Kotlin, which provides it with access to the Gulf of Finland. The city was founded by Peter I as a waterfront fortification (which accounts for the presence of numerous forts off the island's shoreline) and as a base for shipbuilding (which accounts for the interesting urban fabric found in the city center – in particular, the presence of docks and canals). In Soviet times, Kronstadt was a closed, militarized city focused on naval building and industrial production. Until the completion of two "wings" of the dam in 2011, which linked the island with the mainland on two sides through a motorway, Kronstadt had been connected to the rest of the city only through water-based transport links. Since 1996, however, the island is an open city, a status which has led to a reorganization of the local economy and the social composition of Kronstadt's population. Today, Kronstadt is an aging city; young people are leaving Kronstadt for (mainland) St. Petersburg in order to study (there are 2 secondary educational institutions and 2 specialized schools) and to work. Despite the continued presence of military bases, a logistics center, and some industry, Kronstadt's urban fabric is deteriorating – a fact which can be easily corroborated visually by looking at the numerous dilapidated residential buildings and cultural heritage sites, including those located in the central part of the city. Despite its economic difficulties,

Kronstadt is a city which shows great potential for the development of a high-quality urban environment (in view of the area's human-scale, green environment). Also, the city is a virtual treasure-trove of attractions, many related to its storied military and science-history past, which establishes its potential as a destination for tourism. In 2019, the government launched the development of a tourism cluster in Kronstadt titled "Kronstadt - the city of forts" [24]. The potential for the development of waterfront recreation facilities, including the opening of beaches and the development of water and air-water sports facilities is evident; however, even this strategy is not being pursued systematically and is currently supported only by a handful of yacht clubs and informal communities. One of St. Petersburg's most beautiful cathedrals, Morskoy Cathedral, is also located in Kronstadt. The cathedral boasts a unique architecture and history, which is attractive for pilgrims and religious tourists. St. Petersburg officials speak a lot about the development of the city, but actual improvements of the quality of life and urban environment and the realization of tourism potential have so far remained purely theoretical.

Located on an island with an area of 19.35 km^2 and a population of 44,321 (according to the official statistics for 2019), Kronstadt is a convenient object for studying thanks to its compactness. Despite the fact that the eastern part of the Kotlin island is usually called Kronstadt, the settlement of residents is not limited to the historical city. An analysis of the open sources and passports of multi-apartment buildings in Kronstadt shows that the population is grouped in two areas of the island - the historic Kronstadt and the high-rise 19th quarter in the central part of the Kotlin Island, located between the exits from the two wings of the dam. These two residential areas are separated by industrial terrain and wasteland. In addition, a smaller housing area, the 16th quarter, constitutes essentially a separate area, as it is separated from the city center by the Kronverksky Canal and a stretch of pedestrian-unfriendly space. Figure 1 presents the heat map of population density of Kronstadt, showing the main areas of settlement. The map was created based

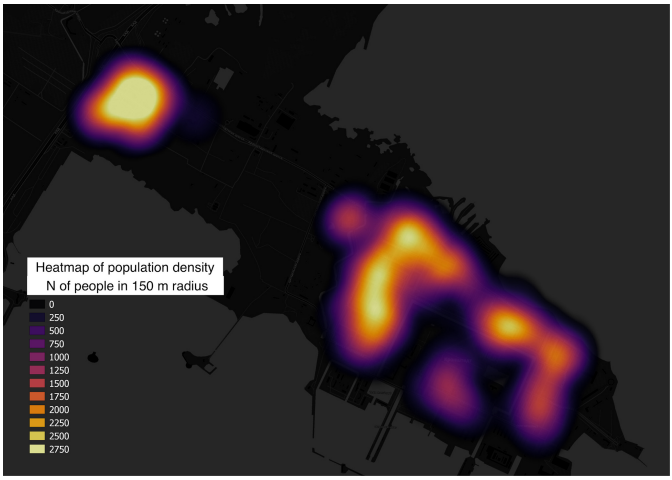

Fig. 1. Kronstadt population density, based on the apartment building passports.

on the open data from the official portal of the Government of St. Petersburg (the section on technical and economic passports of apartment buildings) [25].

Based on the same data, a map of the number of floors of residential buildings was built (Fig. 2). In the relatively new residential quarter, the 19th, which was built during the 1970s, the number of floors is several times higher than in the city center. A pilot environmental study conducted in the fall of 2018 shows that all typical problems of new residential quarters are observed in the 19th quarter: a fractured, fenced-off public space environment, the poor quality and small number of public spaces, the low level of social control exercised over the territory by its residents (the "street eyes"). However, there are also some positives: the number of floors of the buildings is not particularly high (in comparison with the new mass-housing districts elsewhere in St. Petersburg), there are relatively large open spaces between buildings, and the common areas combine several functions, targeting different age categories of residents. The city center is an example of a "human scale" urban environment with a low number of floors (under 5), which makes it comfortable and cozy for the residents. At the same time, however, the abundance of dilapidated buildings, abandoned terrain, and fenced-off, unlighted zones in the center sets the tone and both conveys a subjective feeling of danger while also creating objective conditions facilitating criminal behavior.

Fig. 2. Building heights (number of stories) in the city of Kronstadt.

Figure 3 shows an analytical breakdown of residential buildings by settlement area - the 19th quarter, the 16th quarter (separated from the central area by the Kronverksky Channel), and the heterogeneous central area itself. The breakdown is based on the structure of the divider-barriers between the natural and built environments, as well as on the psychological perception of the structure of the city, which was revealed during interviews with local residents. This partition allows the larger center to be compared, in terms of area and population, with the smaller "dormitory districts." The putative western part is formed along the main street, the Lenin Avenue. The northern part is the

"Mountain district," to use the vernacular naming. The southern part, separated from the rest of the center by the Obvodny Channel, is the greenest area, full of historical sites located along the waterfront; it also boasts access to the sea. The eastern part is formed by the Komsomolskaya, Ammerman, and Manuilsky streets and is bounded by the territory of the military hospital to the east and the Kronstadt marine plant to the south. The map shows the ratio between the number of buildings and the number of inhabitants across these areas. The two most populated are the western part of the center (about 19,000 inhabitants) and the 19th quarter (about 10,500 inhabitants).

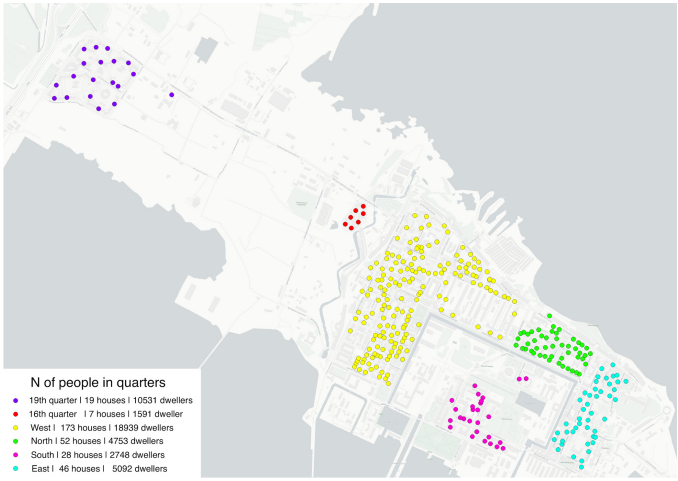

Fig. 3. The number of inhabitants by area of settlement in the city of Kronstadt.

4 The Structure and Localization of Public Services in Kronstadt

The presence of high-quality, diverse points of interest in the immediate vicinity of one's place of residence is one of the components of the quality of urban life. Open data can be used not only to study the structure of a settlement, but also to form a map of the localization of services in a city. To have an overview of the structure and localization of public services in Kronstadt, we used data from one of the most popular search platforms Google Maps. It is worth noting that, according to several of Russia's marketing analytics agencies, Google's services are very popular among both consumers and business managers. According to the statistics by LiveInternet, the share of Russian-speaking Google users is growing annually [26]. It stood at 56.4% as of August 2019, significantly exceeding Yandex's 41% (and the other services' 2.6%). The average daily number of search engine visits for the month of August 2019 among all Russian-speaking users was 40,756,800 for Yandex and 56,012,783 for Google. In Russia, 85% of smartphones

use the Android operating system, in which Google Maps are preinstalled. Each time a customer leaves a venue, the Google Maps app asks her to leave a review and rate it. A sample of Kronstadt venues collected from Google Maps on November 11, 2018, includes 1,055 elements.

Figure 4 shows the heat map of services' density based on Google Maps data. The localization of establishments generally corresponds to the settlement division into the central and dormitory areas, however the historical center's dominance is obvious and venue localisation is not even.

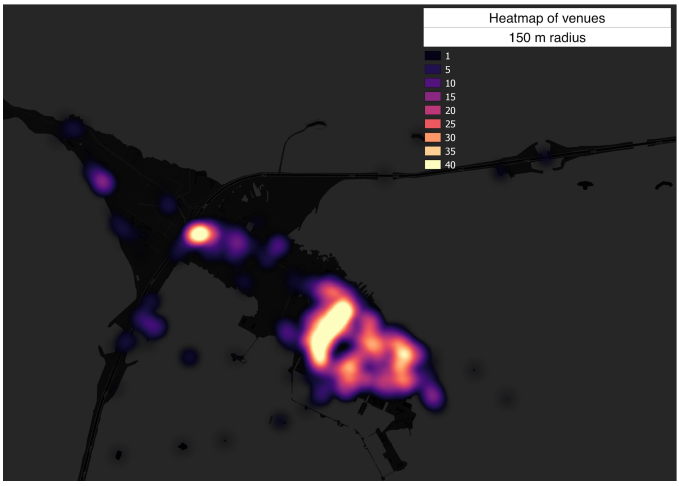

Fig. 4. Heat map of venues in Kronstadt, according to Google Maps data.

Another objective characteristic of service infrastructure is the functional diversity of services. There are many types of venues in Google Maps, and to run functional analysis we recode the venues as follows (Table 1).

Table 1. Categories of services based on Google Maps data.

Category label	Types of venues
Магазин (Shops)	Supermarkets, food shops
Администрация (Administration)	Administrative offices
Религия (Religion)	Churches, cathedrals
Культура (Culture)	Galeries, museums, theaters
Памятник (Monument)	Monuments, plaques, obelisks
Индустрия красоты (Beauty industry)	Hair and beauty salons, solariums

(*continued*)

Table 1. (*continued*)

Category label	Types of venues
Питание (Food)	Cafés, restaurants, bars, bistros, canteens
Рекреация (Recreation)	Parks, squares, promenades, walking routes
Спорт (Sports)	Sports complexes, gyms, fitness clubs, winter sports arenas
Бытовые услуги (Household services)	Workshops, repair shops, tailor shops
Медицина (Healthcare)	Hospitals, local clinics, medical centers
Финансы (Finances)	Banks, ATMs
Промышленность (Industry)	Plants, factories, ports, warehouses
Образование (Education)	Kindergartens, schools, technical schools, specialized schools (art, music, sports)
Транспорт (Transportation)	Public transportation stops and terminals
Авто (Auto)	Auto-services, garages and body shops

The recoding eventually gives us 16 types of venues, which we map to compare the functional profiles of the public service infrastructure across different city residential quarters (Fig. 5).

Such a comparison shows that not only the actual amount, but also the diversity of public services in the 16th and the 19th quarters leaves much to be desired. In the 16th quarter there are no services at all, while in the 19th quarter only FMCG establishments are present (Fig. 5 below). If we compare the shares of the various categories of the services for one central area resident and for one remote area resident the imbalance in the provision of services to Kronstadt residents will become apparent. For example, the availability of stores in the Western central areas and in the 19th quarter is the same – at least 4 stores for 4,500 people; however, food establishments in the central areas are at least 2 for 4,500 people, while in the 19th quarter there are 2 for 10,500 people; there are 2 recreational establishments (comparable in area) for 10,500 people in the 19th quarter versus at least 2 for 4,500 people in the central areas; in terms of cultural places, there are exactly 0 in the 19th quarter and at least 1 for 8,000 people in the center.

Fig. 5. Localization of establishments of various categories in the center (above) and in the 19th quarter (below) in Kronstadt.

Subjective characteristics of the service infrastructure are related to the ability of the establishments to become "points of interest" for residents – that is, their ability to attract attention and generate customer flows. To determine such properties of the service infrastructure of Kronstadt, we will use data from the Google Places rating platform. The platform's data allows us to evaluate services in terms of consumer demand, based on such parameters as: the overall venue rating (the average rating using a 5-point scale and based on the totality of visitor ratings), the number of visitor reviews, the contents of visitor reviews.

A sample of visitor reviews from Google Places included 10,304 user reviews collected between November 11, 2017 and November 11, 2018. Presented below are the maps of venues weighted by their popularity and broken down by functional category (Fig. 6). As can be seen, Kronstadt's historical part is very diverse and boasts many food

establishments (cafés, restaurants, bars, bistros, canteens), shops, monuments, places of recreation, and cultural venues. It includes the most important cultural attraction, which is also the core of the city mental map, - Morskoy Cathedral; recreational establishments are not far behind, especially Petrovsky Park. Western quarter also contains Kronstadt's "gastronomy mecca" - the Lenin Street with the most popular food establishments. Quite ambiguous finding is that Pyaterochka supermarket and Kronstadtskaya confectionery factory shop compete with the food establishments and the historical places in popularity. Against this background of service diversity in the central parts of the city, the functional structure of the 19th quarter looks quite poor. The main (and the only popular) service here is the Pyaterochka supermarket. There are no cultural and historical institutions, and recreation is limited to a small Katernikov Square. At the same time the area boasts three popular automobile establishments (which is not an obvious advantage).

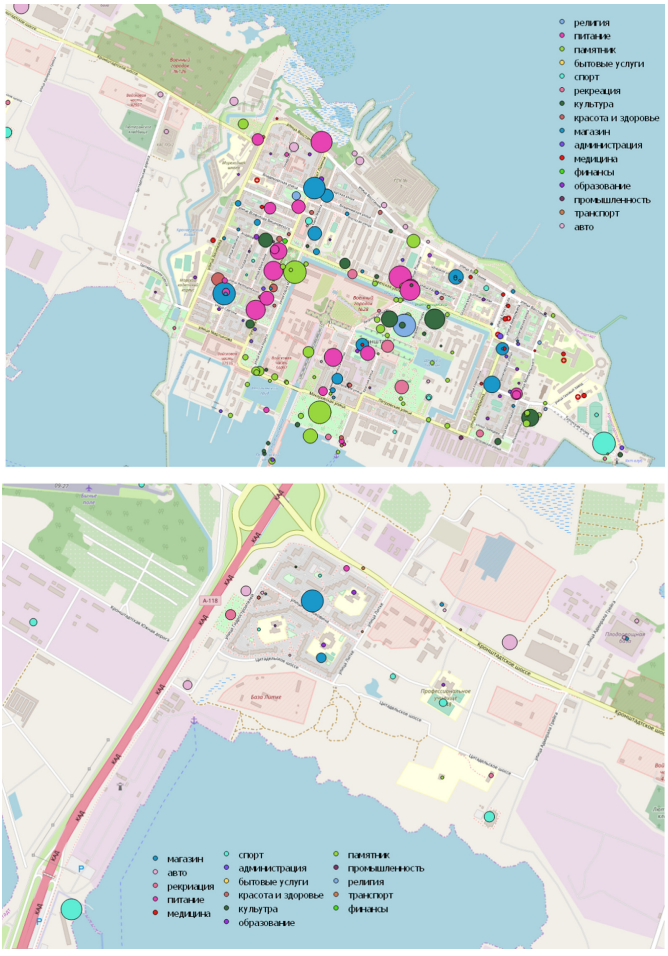

Fig. 6. The functional structure of services in the central part (above) and in the 19th quarter (below) of Kronstadt, weighted by number of reviews per service in Google Places.

Qualitative analysis of the reviews of food establishments (namely, the number of reviews and their quality) in the city center and in the 19th quarter shows the difference in quality between the areas. In the 19th quarter, the maximum number of reviews for food establishments is 3; the reviews themselves are mostly negative or ambiguous, for example: "what a weird stall: they always say [their stuff] is fresh, but in the end, everything comes out old and tough; good for buying beer only or for looking at the seller." At the same time, Lenin Avenue can rightfully be called the main gastronomic artery of the city: this is where all the popular food establishments in Kronstadt are located (the Skazka café boasts the maximum number of comments, 416; the lower number of reviews, 218, are left for the Strelets café). Various types of food establishments are present on this street, including restaurants, coffeeshops, bars, and bistros.

5 Demand for Public Services Based on a Sociological Survey

To validate the relevance of the results obtained with Google Places data about perceived quality of services (e.g. popularity), we use the results of a sociological survey conducted by authors of the paper among the residents of Kronstadt. In September, 2018, 70 respondents living in Kronstadt (46 respondents from the city center and 24 from the 19th and 16th quarters) were interviewed, which makes up a representative sample for the number of the citizens in different areas. Table 2 sums up data on the number of visits to various destinations, representing the demand upon public services. Both the residents of the central and remote areas actively visit food establishments - cafes, canteens, and restaurants, which, as we saw earlier, are located exclusively in the city center. At that, city centre residents go to cafes and restaurants much more often than those in remote areas, which is probably due to the availability of these venues. The overwhelming majority of city residents visit parks and squares more than 3 times a month, which describes the need for this type of social infrastructure, especially among residents of the dormitory 16th and 19th quarters. However, these areas, as shown earlier, are virtually deprived of this kind of public service.

Table 2. Frequency of visits to various destinations in the city of Kronstadt among residents of the center and dormitory districts.

Type of destination	Centre	16–19 q-s	Centre	16–19 q-s	Centre	16–19 q-s	Centre	16–19 q-s
	once per month		2–3 times per month		>than 3 times per month		none	
Кафе Café	4	0	13	14	16	3	13	7
Ресторан Restaurant	7	1	7	11	4	0	28	12
Библиотека Library	0	1	9	9	2	0	35	14

(*continued*)

Table 2. (*continued*)

Галерея Gallery	5	3	4	6	5	0	32	15
Спортзал Gym	1	0	10	8	8	4	27	12
Баня Sauna	5	2	8	3	3	0	30	19
Парк Park	0	0	9	2	30	20	7	2
Форт Fort	2	0	10	4	2	1	32	19
Береговая зона Coastline	2	2	17	10	16	4	11	8

The localization of all services visited by the survey respondents, regardless of their area of residence, is shown on the map in Fig. 7. As one can see, the vast majority of the places visited are located in the central part of the city. Near the dormitory quarters, residents visit the promenades located along the coastlines and at the wings of the dam, as well as the gyms and saunaы (while the number of the latter is still lower than in the center). Thus, there exists a pronounced demand for the services located in the central part of the city on the part of the dormitory quarters' residents; just like the residents of the center, they want to use the various services, but unlike the latter they are forced to travel in order to do so. The sociological validation proves the conclusions received based on the online Google Maps and Google Places data and their comparison to the data on the character of settlement in the city of Kronstadt.

Fig. 7. Localization and functional structure of public services used by respondents of the sociological survey.

6 Conclusions

Data from open sources can serve as the basis for assessing the quality of the service infrastructure in a city. Apartment building passports allow one to determine the structure of the settlement and thus the objective structure of the demand. The partitioning into areas of settlement makes it possible to achieve comparability between different parts of a city in terms of quality of their urban environment and quality of life. In our study, in addition to the historical center usually associated with Kronstadt, two areas of mass housing in the city, namely the 16th and 19th quarters, were analyzed. Quarters 19 and 16 comprise 28% of the city's total population and should be taken into account during the planning of service infrastructure and its placement.

One source of data suitable for analyzing the objective characteristics of services infrastructure (namely its localization and typology), is Google's suite of products; Google Maps and Google Places are the most popular in Russia and therefore, the most representative compared with similar platforms. The functional diversity and localization of service infrastructure can be analyzed using Google Maps; it is recommended to use the categorization of establishments under analysis (i.e. the breakdown by type of service), which is formed according to the objectives of the study. In the context of this article, analysis of the localization and diversity of the venues shows that provision of the venues in the central and remote areas is uneven and hence quality of service infrastructure is low and does not account for the specifics of the demand. Additionally data from Google Places allows obtaining measures of perceived quality (here - venues' popularity). Comparison among popular places in the remote and central areas of Kronstadt shows that the main (and only) popular point of interest in the 19th quarter is a supermarket, while the centre has major popular cultural, gastronomic, lifestyle destinations to go except for the shops.

For validating data from open sources, it is advisable to use opinion poll data in order to avoid the error of non-representativeness of online data and to obtain additional information to interpret the results. The results of the sociological survey show that among all residents of Kronstadt, regardless of their place of residence, the most popular public services are food establishments (cafes, restaurants) and parks. However, these popular venues are unevenly distributed: in the 19th quarter, there are only two places to eat and they are not popular, while all others in demand are actually located in the city center; furthermore, there are no such establishments in the 16th quarter. Similar inconsistency is observed in the provision of green areas. The map of popular services mentioned by respondents shows that consumption practices of the dwellers of the different city quarters are concentrated in the city centre. At the same time, the sociological survey shows possible alternatives for leisure activities near the dormitory quarters (coastal zones, gyms, and saunas).

Thus, data from open sources makes it possible to reveal both the objective and subjective measurement of the quality of the public service infrastructure. Validation of the results of service infrastructure analysis through sociological survey enhances the reliability of the conclusions. In the process of creating a human-oriented structure of services and the optimal placement of service infrastructure facilities all populated areas of the city must be taken into account.

References

1. Jacobs, J.: The Death and Life of Great American Cities. Random House, New York (1961)
2. Oldenburg, R.: The café as a third place. In: Tjora, A., Scambler, G. (eds.) Café Society, pp. 7–21. Palgrave Macmillan US, New York (2013). https://doi.org/10.1057/9781137275936_2
3. Montgomery, J.: The story of temple bar: creating Dublin's cultural quarter. Plann. Pract. Res. **10**(2), 135–172 (1995)
4. Speck, J.: Walkable City: How Downtown Can Save America, One Step at a Time. Farrar, Straus and Giroux, New York (2012)
5. Aksenov, K.E.: Evolution of the types of shopping and spatial organization of retail trade in the post-Soviet metropolis. Reg. Res. Russ. **6**(4), 375–386 (2016). https://doi.org/10.1134/S2079970516040043
6. Axenov, K.: Retail, services and leisure. In: URBAN EURASIA. Cities in Transformation. DOM Publishers, Berlin (2017)
7. Rosenbaum, M.: Restorative servicescapes: restoring directed attention in third places. J. Serv. Manage. **20**(2), 173–191 (2009)
8. Al-Barrak, L., Kanjo, E., Younis, E.M.G.: NeuroPlace: categorizing urban places according to mental states. PLoS ONE **12**(9), e0183890 (2017)
9. Dunkel, A.: Visualizing the perceived environment using crowdsourced photo geodata. Landscape Urban Plann. **142**, 173–186 (2015)
10. Jiang, S., Alves, A., Rodrigues, F., Ferreira, J., Pereira, F.C.: Mining point-of-interest data from social networks for urban land use classification and disaggregation. Comput. Environ. Urban Syst. **53**, 36–46 (2015)
11. Boy, J.D., Uitermark, J.: How to study the city on instagram. PLoS ONE **11**(6), e0158161 (2016)
12. Salesses, P., Schechtner, K., Hidalgo, C.A.: The collaborative image of the city: mapping the inequality of urban perception. PLoS ONE **8**(7), e68400 (2013)
13. Agryzkov, T., Mart., P., Tortosa, L., Vicent, J.F.: Measuring urban activities using Foursquare data and network analysis: a case study of Murcia (Spain). Int. J. Geogr. Inf. Sci. **31**(1), 1–22 (2016)
14. Cranshaw, J., Schwartz, R., Hong, J.I., Sadeh, N.: The livehoods project: utilizing social media to understand the dynamics of a city. In: International AAAI Conference on Weblogs and Social Media, p. 58 (2012)
15. Nenko, A., Koniukhov, A., Petrova, M.: Areas of habitation in the city: improving urban management based on check-in data and mental mapping. In: Chugunov, A., Misnikov, Y., Roshchin, E., Trutnev, D. (eds.) EGOSE 2018. CCIS, vol. 947, pp. 235–248. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-13283-5_18
16. Nenko, A., Konyukhov, A., Mityagin, S.: Urban data and spatial segregation: analysis of food services clusters in St. Petersburg, Russia. In: Shi, Y., Fu, H., Tian, Y., Krzhizhanovskaya, V.V., Lees, M.H., Dongarra, J., Sloot, P.M.A. (eds.) ICCS 2018. LNCS, vol. 10862, pp. 683–690. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-93713-7_65
17. Quercia, D., Saez, D.: Mining urban deprivation from Foursquare: implicit crowdsourcing of city land use. IEEE Pervasive Comput. **13**(2), 30–36 (2014)
18. Roberts, H.V.: Using Twitter data in urban green space research: a case study and critical evaluation. Appl. Geogr. **81**, 13–20 (2017)
19. Hamstead, Z.A., Fisher, D., Ilieva, R.T., Wood, S.A., McPhearson, T., Kremer, P.: Geolocated social media as a rapid indicator of park visitation and equitable park access. Comput. Environ. Urban Syst. **72**, 38–50 (2018)
20. Lloyd, A., Cheshire, J.: Deriving retail centre locations and catchments from geo-tagged twitter data. Comput. Environ. Urban Syst. **61**, 108–118 (2017)

21. Bentley, F., Cramer, H., Müller, J.: Beyond the bar: the places where location based services are used in the city. Pers. Ubiquit. Comput. **19**(1), 217–223 (2015)
22. Kelly, J.M., Swindel, D.: Service quality variation across urban space: first steps toward a model of citizen satisfaction. J. Urban Aff. **24**(3), 271–288 (2002)
23. Lee, M., Farzan, R., Butler, B.: This is not just a café: toward capturing the dynamics of urban places. In: The CityLab Workshop in 10th International AAAI Conference on Web and Social Media (ICWSM), pp. 20–25 (2016)
24. Kronstadt the City of Forts Project. https://www.кронштадт.рф (https://xn-80aiqmelqc4c.xn-p1ai/). Accessed 01 Mar 2020
25. Open Data of Saint-Petersburg Platform, Technical Passports of Houses. https://data.gov.spb.ru/opendata/7840013199-passports_houses/?search_all=паспорта%20многоквартирных%20домов. Accessed 01 Mar 2020
26. LiveInternet. https://www.liveinternet.ru/stat/ru/index.html. Accessed 01 Mar 2020

Intelligent Unmanned Aerial Vehicle Technology in Urban Environments

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Abstract. Sustainable development of megacities requires a transition to the new management methods and technologies, based on the wide use of a large amount of heterogeneous data. Managing the urban economy needs to consider environmental restrictions, environmental monitoring tasks, engineering facilities, and transport. Operational control over the urban environment and the surrounding area can be produced using unmanned aerial vehicles (UAVs), and the collected data can be processed using a wide range of software and hardware technologies related to the field of artificial intelligence. However, along with any fairly new technology, intelligent unmanned technologies have both advantages and disadvantages. Strengths are mobility and efficiency, relative cheapness, the possibility of a high degree of automation, whereas weaknesses are short flight time, dependence on weather conditions, the certain outstanding tasks of data management and processing. This paper considers the possibilities of using intelligent unmanned technologies based on UAVs for solving the problems of monitoring the urban environment of the Kazakhstan megalopolises. Consideration is also being given to the scope for extending possibilities of applying these technologies to the field of environmental monitoring, monitoring of hazardous geological processes, technical constructions and vehicles. Furthermore, technological and economic issues, as well as necessary data processing technologies, are discussed. The economic effect of the use of IUVAT is estimated at $ 70-200 million, but it requires solving a set of data processing, control and technical problems.

Keywords: Unmanned aerial vehicles · Smart city · Urban environment · Environmental pollution monitoring · Monitoring hazardous geological and geophysical processes · Monitoring of technical and engineering constructions · Machine learning · Deep learning · Multi-Criteria decision support systems

1 Introduction

Over the past 15 years, there has been significant urban population growth in Kazakhstan, especially in Almaty, Astana, and Shymkent. The obstacles of large cities of Kazakhstan,

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arising due to their intensive growth, are very similar to those of other million-plus cities with the same regional characteristics. For example, Almaty has one of the highest levels of atmospheric pollution (228 in terms of cleanliness (pollution index) among 273 registered cities [1]), due to its location in a mountain basin and increased seismic activity in the region.

In this regard, to reduce the severity of the environmental problems of growing megacities, the risks of catastrophic phenomena associated with dangerous geophysical and technological processes and increase the economic efficiency of urban management, new technologies are needed that are associated not only with production and manufacturing technologies but also with the collection, processing and analysis of data in the manufacturing process, social life, management of large spatially distributed systems, taking into account environmental and agroecological processes, quality of technical systems and life support systems.

It should be noted that the quality of algorithms and software products for data processing has reached a high level. Most modern products, including those for big data processing, are available, can be mastered and put into practice. Computing resources also cannot be considered a critical obstacle to data processing tasks. There is also the option of using resources of supercomputers or graphic processors in combination with machine learning methods applied in practice [2].

Thus, on the one hand, complex and efficient calculations are the subject of advanced scientific research [3]. On the other hand, these calculations are completely technically secure and they are widely used in areas with significant data sources, e.g. in the field of medicine [4].

The lack of sufficient "clean" data is a key concern. The data that should be processed is often fragmented, has some inconsistent timestamps, multi-format and incomplete data.

At the same time, successes in urban management are usually associated with the collection and practical application of large amounts of data, including spatially distributed resources and objects for the purpose of monitoring and process control. This data can be collected using stationary systems, platforms with low mobility (for example, using cars) and several types of highly mobile platforms (spacecraft, aerial photography, unmanned aerial vehicles (UAVs)). Among the listed technologies, UAVs have very serious advantages in obtaining data of a small and partly medium scale in terms of efficiency, cost, and resolution (see https://osf.io/2wvh3/?view_only=2ec37d853ac9423caeef2bcc2fef3538).

It is necessary to solve the problem of developing technologies for data collection using highly mobile platforms and data processing in order to support decision-making in the city management system.

The use of such data is relevant when specialists deal with spatially distributed technical or natural systems. Such systems in the city include a significant group of human life support systems, transport, technical and architectural structures, etc. Such kind of problems could be solved with the use of intelligent technologies, which above all include machine learning systems and decision support. In this regard, the set of solutions combining artificial intelligence systems and UAV-based platforms will be called Intelligent unmanned aerial vehicle technology (IUAVT).

In this paper, we consider the economic and technological prerequisites for the use of UAV-based data acquisition systems in an urban environment to solve the following problems:

- Monitoring hazardous geophysical processes
- Environmental pollution monitoring
- Monitoring of technical and engineering structures
- Traffic monitoring

In addition to a brief literature review, we provide an assessment of the economic potential of using intelligent unmanned technologies to solve these problems. We determine research areas and problems that need to be solved to use them effectively.

The work consists of three main sections.

Section 2 is devoted to the analysis of the prerequisites for the use of intelligent UAVs in solving the overloaded tasks of the urban economy.

Section 3 briefly describes data processing and decision support methods.

Section 4 considers the previous review and discusses advantages and limitations of IUAVT.

In conclusion, we summarize the analysis and formulate the objectives of the study and development.

2 Prerequisites for the Use of UAVs in Urban Management

2.1 Monitoring of Environmental Pollution

Environmental pollution is one of the most serious problems facing humankind. Air pollutants affect the climate system and hydrological cycle [5], human health [6], and agriculture [7]. In terms of effects on human health, polluted air increases mortality and morbidity as a result of a higher risk of coronary heart disease, cerebrovascular disease, lung cancer, chronic obstructive pulmonary disease (COPD) and respiratory infections.

The use of UAVs equipped with a complex of analytical, spectrometric and gamma-radiometric equipment and cameras of various spectral ranges with subsequent automatic processing of the collected data is one of the promising practices for solving the problems of monitoring the environmental situation in cities and outside settlements [8].

The environmental situation in Kazakhstan is quite tense due to intensive economic development and the inadequacy of existing environmental monitoring and control systems [9]. The capabilities of such monitoring can be significantly expanded using not only stationary points but also UAVs.

The direct economic consequences of polluted air were estimated in 2013. The increase in healthcare costs for reasons related to air pollution in the four selected regions of Kazakhstan amounted to 1,341 million 600 thousand dollars. Based on the World Bank estimates, it was concluded that reduction of at least 1 μg of particulate matter per cubic meter (mgm/m^3) would result in annual savings of $ 56.7 million in healthcare by reducing premature mortality and increasing labor productivity (fewer sickness absence) [10].

A system using AI and UAVs will allow more frequent measurements, for example, twice a month, which will reduce the number of cases of environmental violations. For example, the use of unmanned aerial vehicles to monitor environmental pollution in Dubai has reduced the number of industrial environmental violations by 47% in the first half of 2018 compared to the same period in 2017 [11]. According to the Dongguan City Environmental Protection Bureau (China), the use of unmanned aerial vehicles to detect pollution helped the city identify and punish tens of thousands of polluting factories, as well as reduce the number of smog days to 12, compared to 104 in 2015 [12]. Despite such striking examples, the use of IUAVT to control environmental pollution is at an early stage.

To effectively solve the problems of environmental monitoring, it is necessary to develop methods of control over emissions of hazardous substances in production and transport based on heterogeneous data obtained from the UAV.

The tasks for improving the UAV potential in this area include an increase of flight time and carrying capacity, as well as an enhancement of accuracy, sensitivity of sensors and data processing software (e.g. computer vision systems).

The use of unmanned technologies combined with artificial intelligence will tighten the regulation of the economic activity of enterprises by increasing inspection checks from 2 to 24 per year. This methodology can lead to fewer violations and lower emissions. With a possible reduction in the number of industrial environmental violations by 47%, the cost of paying for emissions into the environment can be reduced by 89,7 million dollars. At the same time, by lowering the levels of PM10 and PM2.5 by 1 μg, the annual savings in the healthcare sector can amount to 56.7 million dollars.

2.2 Monitoring Hazardous Geophysical Processes

The main types of dangerous geophysical processes (HGP) are widespread in Kazakhstan, such as landslides and talus, mudflows, erosion, subsidence, flooding, waterlogging, salinization, deflation, desertification, and land degradation, which can negatively affect the development of Kazakhstan.

Over the past five years 12 emergencies have occurred in Kazakhstan, 1760 houses in 35 villages have been flooded, and 340 livestock have been killed. A total of 48 people has died during natural disasters in the country. The annual damage from floods is estimated at $ 200 million [13].

This makes it necessary to study the laws of development and activation of the most significant HGP with the help of new technologies.

UAVs are used to identify and map landslides. In [14], a temporary series of aerial photographs were used to determine the displacement of the Tessin landslide in Italy. Work on assessing the consequences of mudflows is promising. In a short time span of days, a large amount of information can be obtained, that helps to reliably reconstruct the current situation. Photographing gravity-slope processes allows us to clearly capture the situation that occurred after a major natural disaster formation. Studies of erosion-gravity processes by remote methods (e.g., using UAVs) have not yet been reflected in legislative acts, since these works are at an early stage [15], however, the use of UAVs for such studies is economically profitable. The elimination of the consequences of natural

and man-made disasters is also considered in the context of the use of UAVs, which can be used to organize communications and deliver small cargoes [16].

Therefore, taking into account the economic feasibility and the possibility of disaster prevention, it is necessary to develop methods for monitoring and forecasting dangerous geological processes and changes in engineering structures using artificial intelligence based on data obtained with the help of UAVs.

Based on the specifics of the monitoring task, the main tasks of a possible study are image recognition and classification methods.

The rough estimate reveals that about 650 thousand dollars are needed to conduct HGP monitoring using helicopter technology in the conditions of the Southern Mining District of Kazakhstan, while the use of UAVs will require from 17 to 170 thousand dollars depending on the cost of the UAV and equipment. Cost reduction due to emergency prevention on the example of annual floods by 5% will yield additional savings of $ 10 million. Preventing damage from mudflows could amount to hundreds of millions of dollars.

2.3 Monitoring of Technical and Engineering Structures

Technical and engineering structures in the new conditions require new approaches in solving operational problems. These approaches actively investigated in the framework of the paradigm of the industrial Internet of things (Industrial IoT - IIoT). IIoT application areas: transportation systems and vehicles, agricultural systems and machinery, mining and related equipment, construction, houses, and systems provided a safe living environment, such as firefighting equipment, medical devices, and personal products, etc. [17]. IIoT plays a significant role in the new industrial revolution - Industry 4.0 [18], providing a new type of business model [19].

UAVs are used in construction to control the process, build three-dimensional models, control safety, and damage assessment [20]. The use of UAVs for maintaining the building information system (BIM) is of great promise. Despite the limitations noted (difficulties in navigating and flying inside the building; incomplete programming interfaces between BIM and UAV programs; the need for greater flight autonomy and the development of decision support tools based on the data collected), the use of UAVs provides regular collection of three-dimensional data, high speed of access to most places, including hard-to-reach construction sites [21].

To collect information about the condition of equipment and structures UAVs are using. Their use is especially justified in the case of inaccessible places (for example, blades of wind generators) and extended sections (for example, pipelines). In particular, in [22], machine vision methods are considered in combination with deep learning to classify the destruction of wind turbine blades. In [23], UAVs and noise sensors are being considered in the problem of detecting and predicting their failures. The advantages of UAVs are the following: the ability to access hard-to-reach areas, quick decision-making, the possibility of using UAV groups to inspect many sites, as well as the disadvantages: weather dependence, flight restrictions, equipment weight limitations. In [24], the monitoring process of vast areas of photovoltaic stations using UAVs and thermal imagers is considered. To monitor steel constructions UAVs with the complex of visual, ultrasonic, laser scanning and thermal imagers are used (Fig. 1).

Fig. 1. The use of UAVs in monitoring steel structures (pipelines and boiler rooms pipes) [25]

It is 2 times cheaper to use UAVs in combination with machine vision systems than using helicopters for air patrolling pipelines [26]. UAV application requires solving the computer vision problems like recognition, identification and control of changes, and reducing dependence on weather conditions and increasing of flight time.

Thus, it is necessary to develop monitoring methods in the construction and operation of buildings and structures that will allow obtaining a significant economic effect.

2.4 Traffic Monitoring

Within the city, thanks to speed, UAVs can be used to quickly reach the traffic accident site in order to assess the situation and, if necessary, deliver first-aid kits to victims waiting for ambulances, to notify vehicles in the district that this section of the road should be avoided. A rapid response will prevent traffic jams and reduce the risk of increased accidents on certain road sections. The use of UAVs to monitor traffic flows for traffic congestion analysis of certain road sections as part of traffic jams control will collect the necessary data that will be needed to solve the problem of traffic optimization [27]. According to [28, 29], the economic losses from traffic jams and accidents in the Republic of Kazakhstan are about 3304675 thousand dollars a year. The reduction of these losses by at least 2% promises an economic effect of about 66093 thousand dollars. Taking into account the share of motor vehicles in three megacities of Kazakhstan (43.5%), the annual economic effect for the megacities can be estimated at 28,750 thousand dollars.

The pros and cons of using UAV for solving traffic monitoring tasks are given in Table 1.

Table 1. Pros and cons of UAV applications in traffic monitoring processes

Tasks to be solved	Advantages	Limitations
Assessment of the situation, delivery of small loads (first-aid kits), notification of road users, monitoring of road and pedestrian traffic, search and tracking of potentially dangerous road users, organization of communication	Mobility and independence from communications, urgency and high speed, data availability for research purposes, organization of communication if necessary	Limited flight time, weather dependence, limited payload, limitations in solving computational problems on board of the UAVs, legal restrictions on the use of UAVs in urban conditions

Effective transport monitoring using UAV requires solving a number of specific computer vision problems and technical problems mentioned in the table.

3 Methods of Data Analysis and Decision Support

Despite the significant differences between these monitoring tasks, they are united by the need to collect and process significant volumes of heterogeneous data on spatially distributed objects and systems. The collected data is used to formulate solutions to optimize management processes.

The knowledge of specialists, who can evaluate the received data, can give possible alternatives and develop a solution to solve such problems is widely used at present. At the same time, the data collected, for example, by UAVs in a wide spectral range, differ in features characteristic of big data: they are heterogeneous, often incomplete, have a large volume, and change rapidly. It is noticeable that the evaluation by traditional methods only by a person can be difficult due to the increasing number of estimated parameters and the volumes of collected data.

ML methods are used in cases when there are no strict formal methods for solving the problem, but there are significant amounts of structured data.

It is known that ML methods are divided into two broad groups [30–32]: Unsupervised Learning (UL) [33] or cluster analysis and Supervised Learning (SL) [34].

UL solves the clustering problem when a set of previously unmarked objects is divided into groups by an automatic procedure based on the properties of these objects [35, 36]. However, tuning these algorithms also requires expert judgment.

SL solves the problem of classification or regression. These algorithms include: k-Nearest-Neighbor (k-NN)) [37–39], Logistic regression, Decision Tree (DT), Support Vector Classifier (SVM) [40], artificial neural networks (ANN) [41–43], composition of algorithms (in particular, boosting [44]), deep learning networks (Deep Learning Networks), for example, Long short-term memory (LSTM) [45], convolutional neural networks (CNN), etc. Mathematical models of the above methods are also described in [46].

One of the significant components of a UAV is computer vision, which should solve the tasks of object identification (cv1), object verification (cv2), object recognition (cv3), determining the distance to objects and their visible characteristics (speed, size, etc.) (cv4). Computer vision problems are usually solved with a use of SL models. The most advanced algorithm for solving the cv1 problem is the YOLO algorithm [47–49], as well as recurrent CNN (R-CNN) [50] and its modifications such as Fast R-CNN [51] which use convolution implementation of sliding windows to classify all the proposed regions and Faster R-CNN [52] which use convolutional network to identify “in one pass” boundaries, of the object in the image. An example of the Usage of such networks for traffic evaluation in Almaty has shown in Fig. 2 provided by the Flycam [53].

However, the first experiments show that for effective monitoring of urban traffic, it is necessary to solve the problems of distance estimation, speed calculation, and more detailed recognition of urban traffic participants.

Fig. 2. Recognition of traffic objects in Almaty

To solve problems cv1, 2, 3, the so-called Siamese networks [54] are effectively used, when two images are processed by two identical pre-trained networks. As a result, image vectors are calculated, which are then compared with each other using the triple component loss function (Triplet loss).

Methods for solving the cv4 problem depend on the subject area and the technical support. Note that to configure deep neural networks, sets of labeled images ImageNet [55], Open Images [56], COCO Dataset [57], FaceNet [58] widely used.

Thus, the use of pre-trained deep neural networks in combination with new algorithms allows us to solve real-time verification and recognition problems. However, pre-trained models are broad-spectrum models. To solve highly specialized problems, it will be necessary to create specialized data sets and models of neural networks. Notable computational costs that require the use of power-consuming and large-sized processor devices are the limitation in the application of these algorithms onboard UAVs.

In general, the use of ML requires solving scientific and technical problems related to data preprocessing, selecting or developing optimal algorithms for identification, classification, verification and recognition from the point of view of computational costs and accuracy, and choosing a data processing stack suitable for both stationary and field conditions. The solution to these problems will be of great scientific and applied value in many UAV applications.

The results obtained at the data processing stage are used in the future to develop solutions, including the involvement of expert knowledge.

Decision making under conditions of heterogeneous criteria (multiple-criteria decision making - MCDM) is widely used in decision support systems (DSS) [59–61]. Such methods make it possible to obtain a result even in the case of incomplete data and inconsistency of the chosen alternatives [62].

These methods are often used to assess spatially distributed resources. An important step in the application of these methods is to obtain knowledge from experts (knowledge extraction) [63], which include methods of iterative discussion by a committee of experts (Delphi [64, 65]) and various ways of ranking decision criteria (parameters) based on Likert scales [66], Mokken [67], AHP (analytical hierarchy process) [68] and others.

When using MCDM, especially in combination with ML, there are a number of important scientific tasks, which include the selection of the optimal method for collecting expert assessments, the development of methods and algorithms for the combined use of ML and MCDM to solve problems of processing spatially distributed data, solving problems of managing groups of interacting UAVs, such as, including flight route determination, path planning, collision avoidance and swarm coordination [69, 70].

4 Discussion

The analysis shows that UAVs are already being used to solve a number of urban management tasks, for instance:

- Monitoring of environmental pollution
- Monitoring hazardous geophysical processes
- Monitoring of technical and engineering structures
- Traffic monitoring

These tasks, of course, can be solved using more traditional approaches like ground observations, airplanes, helicopters, satellites. However, the use of these technologies generally has the following limitations: low control frequency, low mobility, low resolution, and high cost. Compared to traditional technologies, IUAVT has the following significant advantages: mobility and independence from communications, urgency and high speed, data availability for research purposes, organization of communication if necessary.

The economic effect of the use of IUAVT in the conditions of urban agglomerations of Kazakhstan is estimated at $70–200 million (Table 2).

However, like any new technology IUAVT has the following inherent restrictions: limited flight time, weather dependence, limited payload, limitations in solving computational problems on board of the UAVs, legal restrictions on the use of UAVs in urban environments. In addition, difficulties in flight control outside the GPS range and indoors, limited accuracy and sensitivity of onboard sensors. Moreover, computer vision tasks for specific UAV applications are not fully solved.

The collected data is fragmented. It is necessary to develop decision support systems in the designated areas.

At the same time, the developed machine learning technologies effectively solve the problems of object recognition and identification. Secondly, there is progress in the development of spatial decision support systems. These solutions in combination with UAVs allow us to talk about the emergence of a new technology that can overcome many of the disadvantages described above.

Table 2. Intelligent technology based on UAVs in urban environments

Task	Key prerequisites	Annual expenses in dollars	Directions of research and development	Scientific and technical problems that need to be solved	Economic potential of the solution for megacities of the Republic of Kazakhstan	Total in the Republic of Kazakhstan
Environmental pollution monitoring	Significant economic losses, a threat to public health	1 554 920 588	It is necessary to develop methods for the operational control of hazardous emissions based on heterogeneous data obtained from the UAV	Increase in flight duration, carrying capacity, accuracy and sensitivity of sensors, data processing software, including computer vision systems	29 047 532	145 237 662
Monitoring hazardous geophysical processes	Significant economic losses and a threat to life and health	200 000 000	In order to realize the possibility of emergency preventing, it is necessary to develop methods of operational monitoring and forecasting of dangerous geological processes and changes in engineering structures using UAVs and data analysis	Development of methods for recognition and classification of images in this subject area	34 000 000	68 000 000
Task	Key prerequisites	Annual expenses in dollars	Directions of research and development	Scientific and technical problems that need to be solved	Economic potential of the solution for megacities of the Republic of Kazakhstan	Total in the Republic of Kazakhstan

(*continued*)

Table 2. (*continued*)

Task	Key prerequisites	Annual expenses in dollars	Directions of research and development	Scientific and technical problems that need to be solved	Economic potential of the solution for megacities of the Republic of Kazakhstan	Total in the Republic of Kazakhstan
Monitoring of technical and engineering structures	The need to collect information on the status of equipment and structures, especially in hard-to-reach places to meet the objectives of the Industry 4.0		It is necessary to develop methods for monitoring engineering structures using computer vision systems and machine learning to detect and prevent violations in their work and predict their condition.	Software for solving the problems of machine vision, image classification, indoor operations and control of interacting UAV groups	8 157 000	
Traffic monitoring	Significant economic losses, a threat to public health	3 304 675 325	It is necessary to develop a system for operational traffic monitoring, tracking of potentially dangerous road users and forecasting traffic situation	Increasing flight duration, increasing the computational power of onboard processors, solving the problems of processing large video streams outside a UAV	28 750 675	66 093 506
Total					70 955 207	221 331 169

5 Conclusion

There are promising prerequisites for the use of a combination of UAVs and intellectual technologies in the urban economy. First of all, UAVs are already used for solving tasks of environmental monitoring, traffic, technical and engineering structures, geophysical processes, as well as help prevent the dangerous consequences of economic activities

and natural processes. Secondly, the technologies that effectively solve the problems of object recognition and identification (deep neural networks: LSTM, CNN, RNN and pre-trained models) have been developed. Thirdly, a large volume of marked images (ImageNet, Open Images, COCO Dataset) have been accumulated, suitable for solving semantically complex problems of graphic image recognition. Fourthly, technologies of parallel processing and storage of large amounts of video data have been developed.

Thus, due to mobility, efficiency and relative cheapness, UAVs are becoming an important tool for ensuring the sustainable development of megacities and improving the urban environment.

The union of intelligent systems and UAV-based platforms forms an intelligent unmanned aerial vehicle technology (IUAVT).

Necessity to use IUAVT to solve the above problems of urban management is determined by economic and social preconditions. The economic effect in the conditions of the Republic of Kazakhstan (RK) can be estimated in the range from 70 to 200 million dollars.

At the same time, in the process of applying IUAVT, methods of overcoming technical limitations (limited battery capacity, significant dependence on weather conditions, limiting the payload weight), solving data processing problems (pattern recognition and classification for special cases, processing large volumes of data) and control (flight indoors and without a GPS signal, flight of a UAV group) should be proposed. It is also required to take into account the legal restrictions on the use of UAVs in urban environments for some countries.

References

1. Current Pollution Index by city. https://www.numbeo.com/pollution/rankings_current.jsp. Accessed 26 Feb 2020
2. Qiu, J., et al.: A survey of machine learning for big data processing. EURASIP J. Adv. Signal Process. **2016**(1), 67 (2016)
3. Zhang, Q., et al.: A survey on deep learning for big data. Inf. Fusion **42**, 146–157 (2018)
4. Mukhamedyev, R.I., Kuchin, Y., Denis, K., Murzakhmetov, S., Symagulov, A., Yakunin, K.: Assessment of the dynamics of publication activity in the field of natural language processing and deep learning. In: Alexandrov, D.A., Boukhanovsky, A.V., Chugunov, A.V., Kabanov, Y., Koltsova, O., Musabirov, I. (eds.) DTGS 2019. CCIS, vol. 1038, pp. 744–753. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-37858-5_63
5. Ramanathan, V., et al.: Aerosols, climate, and the hydrological cycle. Science **294**(5549), 2119–2124 (2001)
6. Cohen, A.J., et al.: Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the global burden of diseases study 2015. The Lancet **389**(10082), 1907–1918 (2017)
7. Chameides, W.L., et al.: Case study of the effects of atmospheric aerosols and regional haze on agriculture: an opportunity to enhance crop yields in China through emission controls? Proc. Nat. Acad. Sci. **96**(24), 13626–13633 (1999)
8. Noor, N.M., Abdullah, A., Hashim, M.: Remote sensing UAV/drones and its applications for urban areas: a review. In: IOP Conference Series: Earth and Environmental Science, vol. 169(1), p. 012003. IOP (2018)

9. Russell, A., et al.: A spatial survey of environmental indicators for Kazakhstan: an examination of current conditions and future needs. Int. J. Environ. Res. **12**(5), 735–748 (2018)
10. Joint Economic Research Program (JERP) of the World Bank and the Ministry of the Environment and Water Resources of the Republic of Kazakhstan "On the way to environmentally friendly industry and improved monitoring of air quality in Kazakhstan", pp. 6–7 (2013)
11. Drone inspections help cut pollution by half. https://gulfnews.com/uae/environment/drone-inspections-help-cut-pollution-by-half-1.2263928. Accessed 26 Feb 2020
12. How China's cutting-edge drones are transforming the nation. https://www.scmp.com/news/china/society/article/2105798/how-chinas-cutting-edge-drones-are-transforming-nation. Accessed 26 Feb 2020
13. Chronicle of floods in Kazakhstan since 2010. https://dixinews.kz/articles/proishestviya/13779/. Accessed 26 Feb 2020
14. Hervás, J., et al.: Monitoring landslides from optical remotely sensed imagery: the case history of Tessina landslide, Italy. Geomorphology **54**(1–2), 63–75 (2003)
15. Makarov, S.A., Atutova, Z.H.V., Shekhovtsov, A.I.: Primeneniye bespilotnykh letatel'nykh apparatov v geograficheskikh issledovaniyakh. In: Materialy Vserossiyskoy nauchno-prakticheskoy konferentsii, Irkutsk: Izdatel'stvo Instituta geografii im. V.B. Sochavy SO RAN, p. 135 (2018)
16. Aljehani, M., Inoue, M.: Performance evaluation of multi-UAV system in post-disaster application: Validated by HITL simulator. IEEE Access **7**, 64386–64400 (2019)
17. Da Xu, L., He, W., Li, S.: Internet of things in industries: a survey. IEEE Trans. Ind. Inform. **10**(4), 2233–2243 (2014)
18. Del Giudice, M.: Discovering the Internet of Things (IoT): technology and business process management, inside and outside the innovative firms. Bus. Process Manage. J. **22**(2) (2016)
19. Gilchrist, A.: Industry 4.0: the industrial internet of things. Apress (2016)
20. Tatum, C., Junshan, L.: Unmanned aircraft system applications in construction. Procedia Eng. **196**, 167–175 (2017)
21. Dupont, Q.F., Chua, D.K., Tashrif, A., Abbott, E.L.: Potential applications of UAV along the construction's value chain. Procedia Eng. **182**, 165–173 (2017)
22. Kumar, N.M., et al.: On the technologies empowering drones for intelligent monitoring of solar photovoltaic power plants. Procedia Comput. Sci. **133**, 585–593 (2018)
23. Moraleda, V.B., Marugán, A.P., Márquez, F.P.G.: Acoustic maintenance management employing unmanned aerial vehicles in renewable energies. In: Xu, J., Cooke, F.L., Gen, M., Ahmed, S.E. (eds.) ICMSEM 2018. LNMIE, pp. 969–981. Springer, Cham (2019). https://doi.org/10.1007/978-3-319-93351-1_76
24. Montoya, J.C., Muñoz, C.Q.G., Márquez, F.P.G.: Remote condition monitoring for photovoltaic systems. In: Non-Destructive Testing and Condition Monitoring Techniques for Renewable Energy Industrial Assets, pp. 133–142. Butterworth-Heinemann (2020)
25. Chen, Q., et al.: Defect detection and health monitoring of steel structure based on UAV integrated with image processing system. In: Journal of Physics: Conference Series, vol. 1176(5), pp. 52–74. IOP Publishing (2019)
26. Gazprom saved on patrolling gas pipelines. https://www.interfax.ru/business/506122. Accessed 26 Feb 2020
27. Shakhatreh, H., et al.: Unmanned aerial vehicles (UAVs): a survey on civil applications and key research challenges. IEEE Access **7**, 48572–48634 (2019)
28. Traffic jammed. https://online.zakon.kz/Document/?doc_id=30109492#pos=7;-245. Accessed 26 Feb 2020
29. Due to an accident in 2014, Kazakhstan lost more than a trillion tenge. https://www.caravan.kz/gazeta/izza-dtp-v-2014-godu-kazakhstan-poteryal-bolee-trilliona-tenge-386516/. Accessed 26 Feb 2020

30. Taiwo, O.A.: Types of machine learning algorithms. New Adv. Mach. Learn. **3**, 19–48 (2010)
31. Hamza, A., et al.: Taxonomy of machine learning algorithms to classify realtime interactive applications. Int. J. Comput. Netw. Wireless Commun. **2**(1), 69–73 (2012)
32. Muhamedyev, R.: Machine learning methods: an overview. Comput. Model. New Technol. **19**(6), 14–29 (2015)
33. Hastie, T., Tibshirani, R., Friedman, J.: The Elements of Statistical Learning. SSS. Springer, New York (2009). https://doi.org/10.1007/978-0-387-84858-7
34. Kotsiantis, S.B., Zaharakis, I., Pintelas, P.: Supervised machine learning: a review of classification techniques. Emerg. Artif. Intell. Appl. Comput. Eng. **160**, 3–24 (2007)
35. Jain, A.K., Murty, M.N., Flynn, P.J.: Data clustering: a review. ACM Comput. Surv. (CSUR) **31**(3), 264–323 (1999)
36. Barbakh W.A., Wu Y., Fyfe C.: Review of clustering algorithms. In: Non-Standard Parameter Adaptation for Exploratory Data Analysis. Studies in Computational Intelligence, vol 249. Springer, Berlin, Heidelberg (2009). https://doi.org/10.1007/978–3-642-04005-4_2
37. Altman, N.S.: An introduction to kernel and nearest-neighbor nonparametric regression. Am. Stat. **46**(3), 175–185 (1992)
38. Dudani, S.A.: The distance-weighted k-nearest-neighbor rule. IEEE Trans. Syst. Man Cybern. **4**, 325–327 (1976)
39. K-nearest neighbor algorithm. http://en.wikipedia.org/wiki/K-nearest_neighbor_algorithm. Accessed 26 Feb 2020
40. Cortes, C., Vapnik, V.: Support-vector networks. Mach. Learn. **20**(3), 273–297 (1995)
41. Guoqiang, P.Z.: Neural networks for classification: a survey. IEEE Trans. Syst. Man Cybern. Part C Appl. Rev. **30**(4), 451–462 (2000)
42. The Neural Network Zoo. http://www.asimovinstitute.org/neural-network-zoo/. Accessed 26 Feb 2020
43. Schmidhuber, J.: Deep learning in neural networks: an overview. Neural Netw. **61**, 85–117 (2015)
44. Friedman, J.H.: Greedy function approximation: a gradient boosting machine. Ann. Stat. pp. 1189–1232 (2001)
45. Hochreiter, S., Schmidhuber, J.: Long short-term memory. Neural Comput. **9**(8), 1735–1780 (1997)
46. Kuchin, Y., Mukhamediev, R., Yakunin, K.: One method of generating synthetic data to assess the upper limit of machine learning algorithms performance. Cogent Eng. **7**(1), 1718821 (2020)
47. Redmon, J., et al.: You only look once: Unified, real-time object detection. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pp. 779–788 (2016)
48. The official YOLO website. https://pjreddie.com/darknet/yolo/. Accessed 26 Feb 2020
49. YAD2K: Yet Another Darknet 2 Keras. https://github.com/allanzelener/YAD2K. Accessed 26 Feb 2020
50. Girshick, R., et al.: Rich feature hierarchies for accurate object detection and semantic segmentation. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pp. 580–587 (2014)
51. Girshick, R.: Fast R-CNN. In: Proceedings of the IEEE International Conference on Computer Vision, pp. 1440–1448 (2015)
52. Ren, S., et al.: Faster R-CNN: towards real-time object detection with region proposal networks. IEEE Trans. Pattern Anal. Mach. Intell. **39**(6), 1137–1149 (2015)
53. TOO "FlyCam" Proizvodstvo BPLA v Respublike Kazakhstan. https://www.flycam.kz. Accessed 26 Feb 2020
54. Taigman, Y., et al.: Deepface: closing the gap to human-level performance in face verification. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pp. 1701–1708 (2014)

55. ImageNet. http://image-net.org/index. Accessed 26 Feb 2020
56. Open Images Dataset M5 + Extensions. https://storage.googleapis.com/openimages/web/index.html. Accessed 26 Feb 2020
57. COCO dataset. http://cocodataset.org/#home. Accessed 26 Feb 2020
58. Schroff, F., Kalenichenko, D., Philbin, J.: Facenet: a unified embedding for face recognition and clustering. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pp. 815–823 (2015)
59. Scott, J., et al.: A decision support system for supplier selection and order allocation in stochastic, multi-stakeholder and multi-criteria environments. Int. J. Prod. Econ. **166**, 226–237 (2015)
60. Mardani, A., et al.: Sustainable and renewable energy: an overview of the application of multiple criteria decision-making techniques and approaches. Sustainability **7**(10), 13947–13984 (2015)
61. Wanderer, T., Herle, S.: Creating a spatial multi-criteria decision support system for energy related integrated environmental impact assessment. Environ. Impact Assess. Rev. **52**, 2–8 (2015)
62. Muhamedyev, R., et al.: Multi-criteria spatial decision-making support system for renewable energy development in Kazakhstan. IEEE Access **7**, 122275–122288 (2019)
63. Jelassi, M.T., Ozernoy, V.M.: A framework for building an expert system for MCDM models selection. In: Lockett A.G., Islei G. (eds.) Improving Decision Making in Organisations. Lecture Notes in Economics and Mathematical Systems, vol 335. Springer, Berlin, Heidelberg (1989). https://doi.org/10.1007/978-3-642-49298-3_52
64. Dalkey, N., Helmer, O.: An experimental application of the Delphi method to the use of experts. Manage. Sci. **9**(3), 458–467 (1963)
65. Okoli, C., Pawlowski, S.D.: The Delphi method as a research tool: an example, design considerations and applications. Inf. Manage. **42**(1), 15–29 (2004)
66. Allen, I.E., Seaman, C.A.: Likert scales and data analyses. Qual. Prog. **40**(7), 64–65 (2007)
67. Mokken, R.J.: A Theory and Procedure of Scale Analysis: With Applications in Political Research. Walter de Gruyter, 1 (2011)
68. Saaty T.L.: Group decision making and the AHP. In: Golden B.L., Wasil E.A., Harker P.T. (eds.) The Analytic Hierarchy Process. Springer, Berlin, Heidelberg (1989). https://doi.org/10.1007/978-3-642-50244-6_4
69. Alexopoulos, A., Kandil, A., Orzechowski, P., Badreddin, E.: A comparative study of collision avoidance techniques for unmanned aerial vehicles. In: IEEE International Conference on Systems, Man, and Cybernetics, pp. 1969–1974. IEEE (2013)
70. Pham, H., Smolka, S.A., Stoller, S.D., Phan, D., Yang, J.: A survey on unmanned aerial vehicle collision avoidance systems. https://arxiv.org/abs/1508.07723. Accessed 26 Feb 2020

E-Economy: Digital Economy and Consumer Behavior

Comparison of Intelligent Classification Algorithms for Workplace Learning System in High-Tech Service-Oriented Companies

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Abstract. We investigate the characteristic of several intelligent algorithms for the program dialogue module of the support system of development personnel of high-tech service-oriented companies. Briefly describes the parametric model of workplace learning as base for personnel development and the most appropriate approaches to the formation of specific staff competencies. One of the elements of the proposed system is the means of answering personnel professional questions. In such applications, an important role is played by means of preliminary classification of queries that allow to narrow the search domain and increase the relevance. Three approaches to classifying of questions were compared: The Naive Bayes classifier, Random Forest Classifier and neural network. A comparative assessment of such approaches was carried out.

Keywords: Dialogue system · Text classification · Naive Bayes · Random forest · Neural network · Small dataset

1 Introduction

Modern high-tech companies build their business around providing services to the customer, rather than selling the product to the customer. This property gives them significant advantages in the market [1, 2]. We will call such companies high - tech service-oriented companies (HSOC). The market for high-tech services in most niches is characterized by high competition, and significant dynamics of technology change. Therefore, both the composition of the service and the quality of its providing are very important. Therefore, HSOC must pay considerable attention to the development of the staff's technological competence in the latest industry solutions, innovation activity and communication skills. This is especially relevant for small and medium-sized enterprises and startups, for which the contribution of an individual employee to the final success is significant.

Different approaches are used – professional courses, conferences, e-learning, and workplace learning. The latter is obviously useful if the service of a company has its specifics or a high rate of change.

In previous work [3], the question of the structure, specifics, and composition of the workplace learning was discussed in detail. Briefly review the basic concepts, provisions, and conclusions, which are necessary for this paper.

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In the research [4], workplace learning is divided into formal and informal. Formal methods include conferences, refresher courses, using in-house tutorials, and so on. Informal workpalce learning is based on the employee's personal initiative and can take the form of communication with colleagues or a team leader, Web-searfing and experiment in a model or real environment. These acts arise in connection with current work tasks. Therefore, informal workplace learning is often sporadic and, unlike formal workplace learning, does not have a pre-defined form and structure.

Surveys show that HSOC's staff prefer an informal workplace learning with such approaches as daily work experience, knowledge sharing within the work team or the leader, and personal Web-searching [4]. At the same time, researchers note the existence of pedagogical, qualification, and resource problems for informal workplace learning [4–7]. In our work [3], we have identified ways of informal workplace learning that provide the necessary competencies for HSOC staff and developed methods and software tools to support such ways of workplace learning, which remove some recourses restrictions and allow provide indirect control of the informal learning process.

To identify the mentioned methods and software support tools, we used the analysis of a combined parametric model based on several models of pedagogical processes:

– parameterizing model of the pedagogical process [8]:

$$Learning\ process = <Learning\ activities, Learning\ outcomes, Assessment>, \quad (1)$$

– model for pedagogical system [9]:

$$PS = <T, P, C, A, F>, \quad (2)$$

– and workplace learning model proposed in [10]:

$$CF = <Location\ of\ the\ learning\ (Off\ the\ job\ /\ On\ the\ job);\ Degree\ of\ planning\ (Unstructured\ /\ Structured);\ Role\ of\ trainer/facilitator\ (Passive\ /\ Active)>. \quad (3)$$

Note that model (3) is a conceptual framework of workplace learning.

In [1], we correlated these models and, using rough sets methods and content analysis, identified means to support workplace learning for HSOC. These include means of teaching personnel in a real-work environment, means of estimating employee web-behavior, means of answering employees' professional questions.

In last means the methods of formal concept analysis and of relational concept analysis were used and good results were achieved [11]. At the same time, the approach with automatic classification of requests, that is common for knowledge base and Help Desk systems was not used. Such classification involves separating requests by a predefined set of classes <K>. Each element K_i is an entity that corresponds to the subject area. These can be supported services, service components in any superposition (subsystems, programming languages, frameworks, role's administrative authority, stage of business process etc.). In the task statement [11], K_i is an additional attribute for searching for

a facilitator for consulting or expert to actualize an ontological model. However, in the developed system, this approach was not used in its pure form, and there are reasons to believe that its implementation may be appropriate.

Thus, the task of this paper includes:

- identifying the specific of workplace learning processes for HSOC, related to initial requests processing in the dialog module,
- identification the specific of the existing datasets,
- identifying the main suitable approaches and algorithms for classification,
- identification of the most suitable algorithms for specific conditions.

2 Applying Classification Approaches for Means of Answering Employees' Professional Questions

2.1 General Information and Main Problems

We are going to support an employee in a typical situation processing with customer requests. These requests are given in the form of short text messages. Another case described in detail in [11] is the process of answering professional questions from employees in the internal dialog system. Both approaches can be organized as a three-level support service built in accordance with ITIL[1] principles. In [11], the automatic system was introduced as Level 0, which analyzed incoming requests and found the most appropriate sections of the knowledge base and reference system. Now we propose to modify this module to transmit to the Level 1 both recommendation and an automatically defined class K_i. This information extends the ability to support the work of the employees and serves as implicit workspace learning. The proposed change to the means of answering employees' professional questions architecture is shown in Fig. 1.

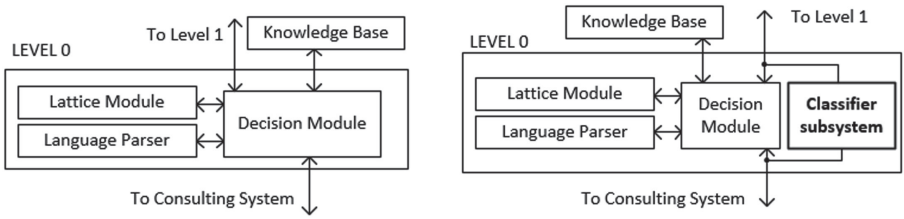

Fig. 1. Proposed modification of the Level 0 subsystem architecture.

There are many papers [12–15] devoted to the comparison of intelligent algorithms for text classification. However, research have been realized for datasets with certain characteristics. Such datasets are characterized by both a large volume (more than 100,000 text units) and a certain context (reviews of products or movies, requests for rescue, etc.). The context of each message is precisely defined by external attributes (product

[1] 2011 ITIL v3 (IT Infrastructure Library v3 2011 Edition).

or movie id, geotags, timestamps, hashtags). Another important feature of these research is the use of open data with free access. The results of these research can be used only in a limited way for the purpose of this paper, just in the case of large and super-large HSOC. Such organizations already have long-accumulated data sets in Help Desk and Service Desk systems, where text units often are already reliably and correctly attributed during common work processing.

At the same time for small and medium HSOC typical:

- need to work with small datasets (2–3 thousand records),
- short length of each individual unit in the dataset (about fifty words),
- inability to use external specialized datasets due to legal requirements or commercial secrecy considerations,
- significant impact of erroneous object markup due to the high relative significance of an individual object in whole dataset,
- strong influence of implicit factors. For example, when different text units containing similar or identical sets of keywords are assigned to different classes K_i by the expert, based on the expert's knowledge, that is, based on data structures that are not present in the system at all,
- presence of "garbage" keywords in text units, for example, when the author of a text message makes suggestions on a topic.

All this makes important to compare the main intelligent text classification algorithms in a case of small and medium HSOC. In addition, there are language dependency, contextual dependency, and social dependency, but these issues are beyond the scope of this paper.

2.2 The Specificity of the Dataset

We used an open dataset[2]. This dataset is a set of messages to first line technical support. Each case is represented as a text block. The dataset contains 3000 records. Each entry is marked with one of five categories - Ki. As shown in Table 1, the data set is evenly distributed across categories.

Text blocks have a length of 2 (!) up to 927 words, including prepositions, articles, and so on. The distribution of the number of text blocks by length is shown in Fig. 2.

It is obvious that the main part of messages are text blocks about 25 words long. Moreover, even very short messages (2–5 words long) have significant content and cannot be discarded (for example: "hello please fill date", "forgot cable return", "access sa").

At the same time, different text blocks containing similar keywords have different categories. For example: "Hello, please provide a valid **license** as soon as possible appears my expired thank you engineer" as a Database, "Hello dear requires a Visual Studio **license** the ability to provide considers engineer mob" as an Application.

The analysis is complicated, because the text blocks contain the author's name, words in Spanish, and a description of several tasks in one block.

[2] https://github.com/karolzak/support-tickets-classification#22-dataset

Table 1. The number of text blocks per categories

Categories	Number of text blocks
Application	600
Database	600
Network	600
Security	600
User maintenance	600
In total	3000

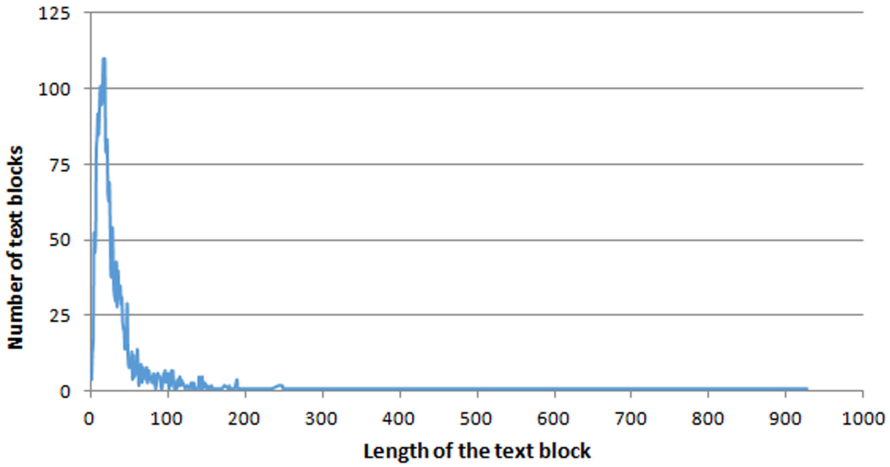

Fig. 2. Distribution of text blocks by length.

The analysis shows that the investigated dataset is suitable for the characteristics given in Sect. 2.1 and can be used to compare the main intelligent text classification algorithms in a case of small and medium HSOC.

3 Method and Material

3.1 Experiment Methodology

Three intelligent text classification algorithms were selected for comparison: Naive Bayes classifier, Random Forest Classifier and Neural Network. These algorithms are independent of natural language. This is important because the situation of working in a heterogeneous language environment is typical for HSOC (for example, to provide services in foreign countries or localize software). A special program in Python was developed to compare the algorithms. The experiment was performed in the following steps:

– two parts were selected from the original dataset – one for training algorithms, and the second for testing. The division is carried out in a ratio of 1 to 9 for each of the predefined K_i classes. Thus, the training sample was only 300 messages.
– It was performed traditional text preprocessing. Then all text blocks were represented as vectors of numbers.
– All three algorithms were trained. The program code implements the train_model() function that passes data to the desired algorithm.
– All algorithms were checked on the test part of the dataset. For each case, the accuracy of determining the message class K_i was calculated. Comparison of accuracy values is used to compare the efficiency of algorithms in specified conditions.

3.2 Data Preprocessing

Text preprocessing contained converting text to lowercase, removing prepositions etc. Significant entities and abbreviations were preserved during the cleaning. The shortest messages (up to 5 words) were checked manually, and obviously incorrect ones were deleted.

It was necessary to represent text blocks as vectors of numbers that reflect the importance of each word. To calculate the weights of words we used a combined measure of the importance of Tf-Idf (term frequency and inverse document frequency).

$$tf - idf(t, d, D) = tf(t, d) \times idf(t, D) \tag{4,}$$

$$tf(t, d) = \frac{n_t}{\sum_k n_k} \tag{5}$$

$$idf(t, D) = \log \frac{|D|}{|\{d_i \in D | t \in d_i\}|} \tag{6}$$

Where n_t is the number of occurrences of the word t in document d from the collection of documents D. In our case, D is the set of all text blocks.

3.3 Naive Bayes Classifier

In this paper, we used the implementation of the Naive Bayesian Classifier-*naive_bayes* from the *sklearn* library. The Naive Bayesian Classifier is a simple probabilistic classifier based on the Bayes theorem [16]. It is important that properties are considered independent. The K_i class of the text block was determined by the maximum probability value (7). Where x_i is the property vector.

$$K = argmax_{i=1\ldots k} \left(p(K_i) \prod_{j=1}^{N} p(x_j | K_i) \right) \tag{7}$$

3.4 Random Forest Classifier

Random Forest Classifier is an algorithm that uses an ensemble of decision trees. Classification is carried out by voting. Each tree assigns an object to one of the classes, and the class that the largest number of trees voted for wins [17]. To implement the classifier, we use the *sklearn* library again.

3.5 Neural Network

Neural networks are widely used for solving classification problems [18]. We used Feed-forward Neural Network because implementations of more complex structures such Recurrent, Convolutive or Long short-term memory networks are experimental and complicated for quick realization [12, 18]. The network architecture is shown in Fig. 3.

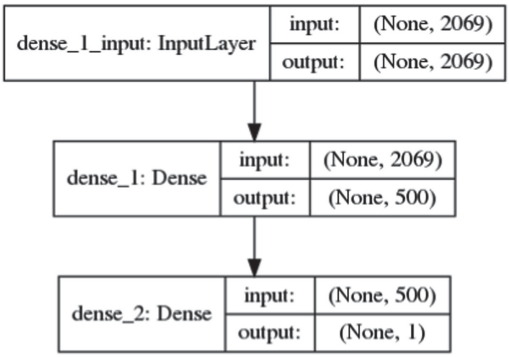

Fig. 3. The neural network architecture.

The resource and time constraints on retraining that are typical for small HSOC made us choose such a simple architecture. Due to these limitations, we used the activation function ReLU (rectified linear unit) since it is devoid of resource-intensive operations and provides fast learning. For the same reasons, the early stop method was chosen to determine the number of learning epochs. Network performance comparisons were made every 5 epochs. As a result, it was found that after 100 epochs, the network performance drops and it goes into a state of retraining.

4 Results

Under the described conditions, all three algorithms were trained, and accuracy was calculated on the test part of the datasets. Accuracy is the proportion of messages by which the classifier made the right decision. It is important to note that accuracy is not often used to evaluate a Naive Bayes classifier, but in our dataset, the number of messages of each class is the same, so accuracy is applicable in this case. The results of the accuracy calculation for each of the three text classification algorithms are shown in Table 2. They are ordered according to the decreasing result.

As one can see, nearly accurate values were obtained for the compared algorithms, bit Naive Bayes showed slightly better results. In addition, Naive Bayes is characterized by simplicity in comparison with other classification algorithms, which allows Naive Bayes to better adapt to working with small, low-quality datasets. Indirectly, the reliability of the results is confirmed by the fact that similar accuracy values were obtained by other researchers who worked with small datasets [19].

Table 2. Result of comparison.

Algorithm	Accuracy
Naive Bayes classifier	0,748
Random forest classifier	0,722
Neural network	0,694

5 Conclusions

All the objectives of the research were achieved.

The specifics of workplace learning processes for small HSOC associated with the initial processing of requests in the dialog module were identified. This specificity lies in the fact that for small HSOC, the use of the dialog system [3] corresponds to the content of the activities and preferences of HSOC employees, at the same time, the capabilities of the dialog module can be expanded by additional classification of message texts, for example, to determine the topic or find the most suitable facilitator.

Features of typical datasets for small HSOC were identified. It was shown that data sets with which small and medium-sized HSOCs start working are characterized by a small volume (2–3 thousand records) with a small length of each the records themselves, a strong influence of erroneous unit markup due to the high specific significance of a single unit, a strong influence of implicit factors, and the presence of garbage keywords in units. In addition, it is difficult or impossible to access ready-made data sets of other owners.

The following set of suitable approaches and algorithms for text classification was selected: Naive Bayes classifier, Random Forest Classifier, and Neural Network classification. The selection criteria were independence from the natural language, undemanding access to resources, quick start, and widespread support for methods in common software libraries.

Among these classification algorithms, slightly better results are obtained for Naive Bayes and it provides higher reliability in low quality datasets conditions.

As a further work, we plan to realize the results clarification with other similar datasets. The influence of the dataset specificity on the results obtained is obvious. Therefore, additional experiments will allow us to make more general conclusions.

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References

1. Zakrzewska – Bielawska, A.: High technology company – concept, nature, characteristics. In: Mastorakis, N., Mladenov, V., Zaharim, A., Aida Bulucea, C. (eds.). Recent Advances in Management, Marketing, Finances, pp. 93–98. WSEAS Press, Penang (2010)

2. Wolf, M., Terrell, D.: The high-tech industry, what is it and why it matters to our economic future. Beyond the Numbers: Employment and Unemployment, Washington, DC, vol. 5, no. 8. Bureau of Labor Statistics (2016)
3. Beresnev, A.D., Boytsov, V.V., Dobrenko, D.A., Egorov, N.V., Gusarova, N.F.: Workplace Learning For Personnel Of High-Tech Service-Oriented Companies. In: 12th annual International Conference of Education, Research and Innovation, Seville, Spain, pp. 9693–9703. IATED (2019)
4. Hart, J.: Modern workplace learning: a framework for continuous improvement, learning and development (2019). https://www.modernworkplacelearning.com/cild/. Accessed 15 Feb 2020
5. Sweeney, F.: Workplace learning: the evolution of IT learning. https://www.theceomagazine.com/business/management-leadership/workplace-learning-the-evolution-of-it-learning/. Accessed 18 Feb 2020
6. Dieffenbach, J., Diemand-Yauman, C.: Workplace learning: what's it worth? https://www.forbes.com/sites/civicnation/2019/04/23/workplace-learning-whats-it-worth/#a3d83cf25c34. Accessed 01 Mar 2020
7. Ghosh, S.: The future of workplace learning: top trends and predictions for 2019–2020. https://indecommdigital.com/insight/the-future-of-workplace-learning-top-trends-and-predictions-for-2019-2020/. Accessed 01 Mar 2020
8. Biggs, J., Tang, C.: Teaching for Quality Learning at University. McGraw-Hill and Open University Press, Maidenhead (2011)
9. Simonov, V.P.: Educational Management: Know How in Education. Vysshee Obrazovanie Publ, Moscow (2006)
10. Jacobs, R.L.: A proposed conceptual framework of workplace learning. Hum. Resour. Dev. Rev. **2**(8), 133–150 (2009)
11. Beresnev, A., Zhdankin, A., Lobantsev, A., Vasiliev, A., Vedernikov, N., Gusarova, N.: Dialogue system for service desk of complex software systems based on relational concept analysis. In: Proceedings of the 2019 2nd International Conference on Geoinformatics and Data Analysis 2019, Prague, vol. F148261, pp. 31–36 (2019)
12. Romanov, A., Kozlova, E., Lomotin, K.: Application of NLP algorithms: automatic text classifier tool. In: Alexandrov, D.A., Boukhanovsky, A.V., Chugunov, A.V., Kabanov, Y., Koltsova, O. (eds.) DTGS 2018. CCIS, vol. 859, pp. 310–323. Springer, Cham (2018). https://doi.org/10.1007/978-3-030-02846-6_25
13. Alharbi, A.N., Alnnamlah, H.: Liyakathunisa: Classification of customer tweets using big data analytics. In: Alenezi M., Qureshi B. (eds) 5th International Symposium on Data Mining Applications. Advances in Intelligent Systems and Computing, vol. 753, pp. 169–180. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-78753-4_13
14. Hong, Y., Sinnott, R.O.: A social media platform for infectious disease analytics. In: Gervasi, O., Ryu, Y., et al. (eds.) ICCSA 2018. LNCS, vol. 10960, pp. 526–540. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-95162-1_36
15. Agogo, D., Hess, T.J.: Scale development using Twitter data: applying contemporary natural language processing methods in IS research. In: Deokar, A.V., Gupta, A., Iyer, L.S., Jones, M.C. (eds.) Analytics and Data Science. AIS, pp. 163–178. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-58097-5_12
16. Murphy, K.: Naive Bayes classifiers. In: Lectures, pp. 1–5. University of British Columbia, Vancouver (2006)
17. Breiman, L.: Random forests. Mach. Learn. **45**(1), 5–32 (2001). https://doi.org/10.1023/A:1010933404324

18. Zhang, Z.: Artificial neural network. In: Zhang, Z. (ed.) Multivariate Time Series Analysis in Climate and Environmental Research, pp. 1–35. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-67340-0
19. Bashar, M.A., Nayak, R., Suzor, N., Weir, B.: Misogynistic tweet detection: modelling CNN with small datasets. In: Islam, R., Koh, Y.S., Zhao, Y., Warwick, G., Stirling, D., Li, C.-T., Islam, Z. (eds.) AusDM 2018. CCIS, vol. 996, pp. 3–16. Springer, Singapore (2019). https://doi.org/10.1007/978-981-13-6661-1_1

Why Entrepreneurial Competencies Are Essential for Business and Management Specialists in the Digital Economy Age?

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Abstract. The study identifies the need to develop the entrepreneurial competencies of specialists in business and management in the digital economy age and reveals the understanding of opportunities and risks of the digital transformation of the economy. It provides a theoretical framework, based on a scientometric analysis of publications on digital economy with VOSviewer Software and an extensive literature review, emphasizing the necessity of entrepreneurial competencies in the digital economy. The results of the exploratory qualitative study show how undergraduate students in management and business explain what digital economy is and who is the manager in the digital age, and explain opportunities and threats that they associate with the digital transformation. The paper discusses the results and major problems concerning the students' perception of the digital economy and a manager in the digital context. This study contributes to the research that focuses on the development of management and entrepreneurship in the digital economy.

Keywords: Digital economy · Entrepreneurship · Management · Managers' competencies · Scientometric analytics

1 Introduction

Nowadays business models and approaches to manage enterprises, in the digital economy age, have received growing attention from both academic researchers and practitioners, due to the increasing importance of the ongoing innovation process to keep competitive advantages. The managers' competencies required, in the digital economy age, are also points of researchers' attention. Engaging startups, launching corporate accelerators, and internal entrepreneurship, to enhance business development, based on innovations, became a common practice.

Despite the significant growth in the number of scientific publications, there is no clear understanding of the opportunities and threats of digital transformation in society.

The purpose of this study is to emphasize the need to develop the entrepreneurial competencies of specialists in business and management, in the digital economy age,

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and reveal an understanding of opportunities and risks of the digital transformation of the economy, by undergraduate students in business and management. The paper is structured as follows. First, the authors provide a scientometric review on the digital economy with VOSviewer and focus on the theoretical frameworks - the digital economy and the need for entrepreneurial competencies for business development. Second, the paper describes the findings from a qualitative study, exploring the students' understanding of the digital economy and the opportunities and threats associated with the digital transformation. The authors discuss further research issues concerning the development of management and entrepreneurship in the digital economy from an educational perspective.

2 Scientometric Overview of the Research on Digital Economy

We use a scientometric analysis of papers to provide an overview of the recent research (since 2011) on digital economy, business and management challenges in the digital age.

Publications indexed in Web of Science (WoS, webofknowledge.com) or Scopus (scopus.com) global citation databases were selected for the analysis using the following criteria: (1) Period 2011–2019; (2) Subject areas: Economics, Business and Management, Social Sciences; (3) Occurrence of at least one of the terms *digital economy*, *digital age*, *digital transformation* at the title, abstract or keywords.

The data obtained from WoS and Scopus were merged, and duplicates were excluded. The final database contains 1472 papers (the main sample). 106 of these publications that contain entrepreneurship, entrepreneur's competencies or entrepreneurial education were selected to a sub-sample by "*entprepren**" request. Figure 1 shows the growing interest in digital economy research and the increasing percentage of publications that have mentioned entrepreneurship issues (from 2.78% to 9.12%).

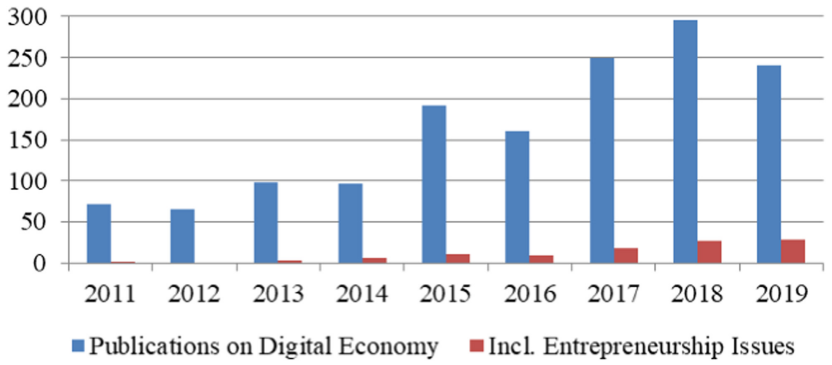

Fig. 1. Number of publications devoted to digital economy, by year. Source: Calculated based on the data from the Web of Science (webofknowledge.com)

VOSviewer Software (http://www.vosviewer.com) was used to analyze the keywords and visualize the networks. The special thesaurus was developed to combine keywords in different forms or similar meanings (for example, *business models* and *business model*,

digital entrepreneurship and *entrepreneurship*). The VosViewer parameters were set to default values (attraction = 2, repulsion = 0). Association method was used for normalization.

The main sample contains 4554 different authors' keywords. A co-occurrence map was developed for 25 author keywords used 15 times and more (Fig. 2). It illustrates which keywords appear together in the publications. Items are colored by cluster. The details on frequencies of occurrence, total link strength and the thematic cluster assigned by VOSviewer, for each keyword are indicated in Table 1. The association strength option was applied to normalize the strength of the links between keywords for clustering.

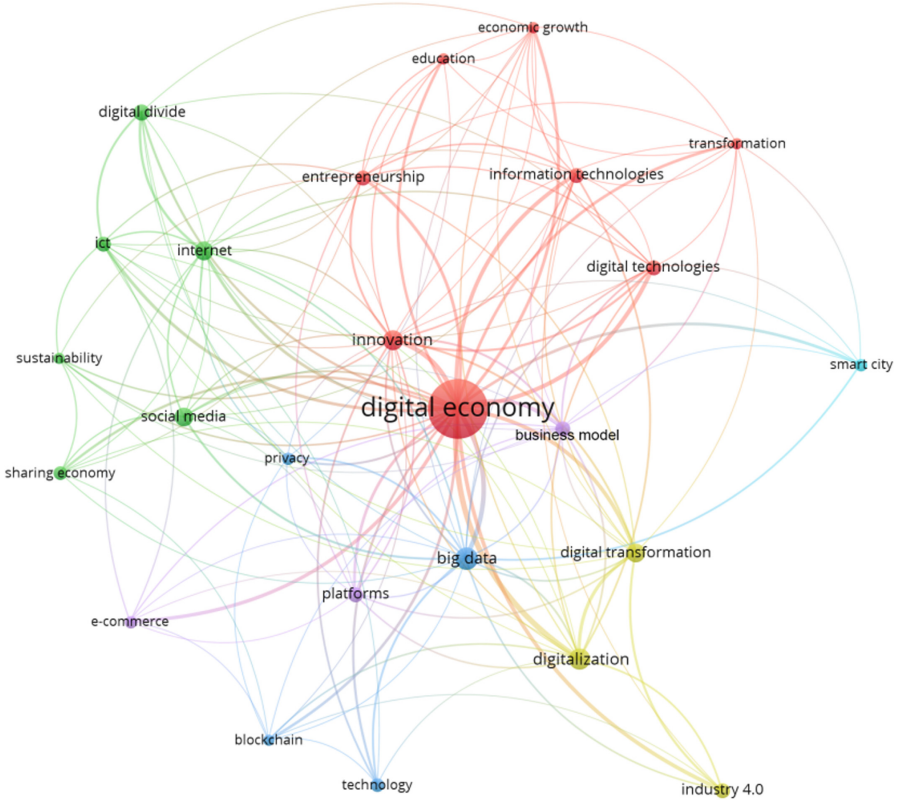

Fig. 2. Co-occurrence map of keywords in articles on digital economy. Source: Authors' analysis with VOSviewer (http://www.vosviewer.com)

The central concept is *digital economy* (437 occurrences) it belongs to the Red cluster. It is vital to note that *innovation, economic growth, entrepreneurship*, and *education* are also parts of the Red cluster.

The Green cluster addresses social media, sharing economy, information communication, and sustainability issues. The Yellow cluster deals with the context description

Table 1. Keywords of publications on digital economy indexed in WoS or Scopus, 2011–2019.

№	Keyword	Occurrences	Total link strength	Cluster
1	**Digital Economy**	**437**	**277**	**Red**
2	Digitalization	59	77	Yellow
3	**Innovation**	**52**	**76**	**Red**
4	Big data	65	70	Blue
5	Digital transformation	46	55	Yellow
6	**Digital Technologies**	**31**	**44**	**Red**
7	Business model	27	41	Violet
8	Internet	45	39	Green
9	**Information technologies**	**28**	**38**	**Red**
10	**Entrepreneurship**	**29**	**33**	**Red**
11	ICT	27	30	Green
12	Industry 4.0	29	30	Yellow
13	Platforms	30	27	Violet
14	Digital divide	32	24	Green
15	**Economic Growth**	**15**	**24**	**Red**
16	E-commerce	22	23	Violet
17	Social media	46	21	Green
18	**Transformation**	**16**	**20**	**Red**
19	Blockchain	16	19	Blue
20	Technology	26	18	Blue
21	Smart city	22	17	L.Blue
22	**Education**	**15**	**16**	**Red**
23	Privacy	21	16	Blue
24	Sharing economy	26	16	Green
25	Sustainability	18	13	Green

Source: Authors' analysis with VOSviewer (http://www.vosviewer.com), 1472 publications

such as digitalization and industry 4.0. The Violet cluster concentrates on business models and e-commerce. The Blue cluster is focused on big data, blockchain, and privacy concerns. Finally, the Light Blue cluster is devoted to smart cities.

Following the increasing attention to the role of entrepreneurial competencies in enterprise management in the digital economy age, another co-occurrence map was developed for 106 papers that have relevant mentions (Fig. 3).

The sub-sample has 462 different author keywords (the same thesaurus was used), 8 keywords used 4 times and more: *digital economy* (35 times), *entrepreneurship* (29), *innovation* (11), *digital transformation* (5), *informational technologies* (4), *education*

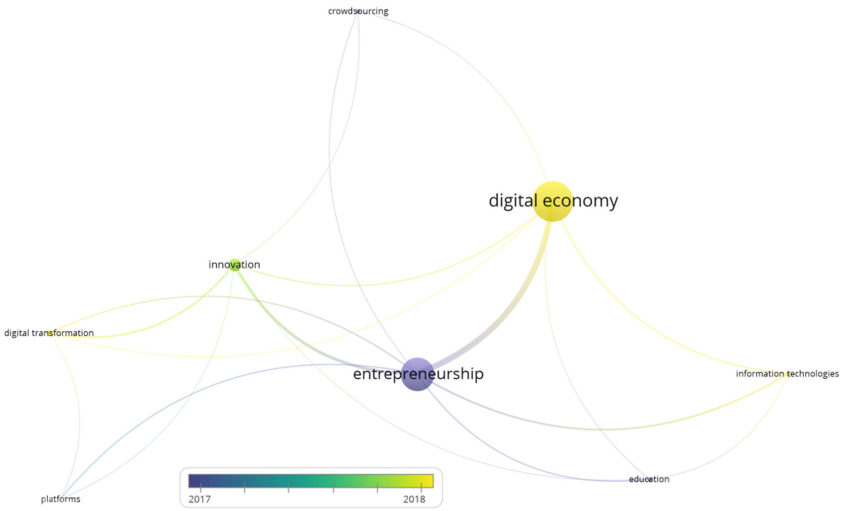

Fig. 3. Co-occurrence map of keywords in articles on entrepreneurship in digital economy. Source: Authors' analysis with VOSviewer (http://www.vosviewer.com)

(4), *platforms* (4), and *crowdsourcing* (4). Keywords are colored based on the average publication year of the paper.

Figure 3 demonstrates that the co-occurrence of *entrepreneurship* and *digital economy* is a recent trend.

3 Theoretical Frameworks: Digital Economy and the Need of Entrepreneurial Competencies

Digital economy and digital transformation became important phenomena for research in social sciences. Recent papers contribute to the understanding of different aspects: general issues of the digital transformation [1, 15, 24, 28, 48, 60, 62], business models [3, 10–12, 36–38, 41, 46] and customer relationships in the digital economy age [9, 19, 22, 30, 43, 64], business development strategies [4, 8, 25, 32, 47, 63], entrepreneurship and entrepreneurial education [5, 7, 14, 18, 26, 40, 50]. Researchers highlight the need to identify and use the capabilities provided by digital transformation [34, 35, 65] and the importance to develop relevant professional competencies to manage digital enterprises [16, 40, 42, 45, 50].

The digitalization of enterprises in Russia was studied by Skolkovo and the National Agency for Financial Research (NAFI) [56]. The main attention was paid to the ability of companies in Russia to operate in the digital economy. The research demonstrates that Russian companies admit that digital business transformation is necessary. However, many of them face difficulties because of the low flexibility and inertia of the actual business processes as well as some issues related to the enterprise management approach. Digital transformation requires development of the new approaches for both small and large businesses. Engaging entrepreneurial ventures and corporate accelerators, as part of a company's innovation strategy became a common practice worldwide [21, 27, 39, 66].

Entrepreneurial orientation is becoming highly important within existing organizations [51]. A lot of attention has been paid to compare similarities and differences between entrepreneurs and corporate leaders on their personality aspects and motivational characteristics [6, 29]. These studies support the opinion that entrepreneurs and managers differ in some aspects, as well as have much in common.

Scholars continue to argue whether entrepreneurs are born with special personal qualities or made. Recent studies support the idea that entrepreneurial competencies could be developed intentionally [29, 33, 50, 54]. Moreover, entrepreneurial competencies are vital for successful company management in the digital economy age [42, 50, 57], since the identification of market opportunities and new ways to use their potential in the dynamic environment, are the primary functions of entrepreneurs [23]. Development of entrepreneurial competencies increases the likelihood of a person becoming an entrepreneur and the desire to work with innovations in established companies [59].

Entrepreneurship and entrepreneurial education are emerging phenomena in Russia; they are relatively new areas of academic research [2, 40, 61, 68]. The digital transformation of the economy affects entrepreneurial practices and changes approaches to enterprise management [17, 20, 31, 44, 58]. According to research, entrepreneurship is a substantial source of economic growth [13, 49, 52, 55]. Entrepreneurship creates workplaces and develops new opportunities for professional fulfillment. At the same time, the supportive institutional environment is crucial to entrepreneurship development. The studies address the interaction of formal institutions and their impact on entrepreneurship activity and entrepreneurial intentions [13, 31, 53, 54]. Researchers suggest that programs focused on developing entrepreneurial competencies might improve digital competence and enhance the ability to build collaborative networks [50]. Many educational programs (e.g., in Europe) generally address the SMEs (small and medium enterprises), though, in the digital age, there is an urgent need for entrepreneurs who can manage growth-oriented firms and corporations [67].

Since the demand for business and management educational programs developing competent managers, leaders, and entrepreneurs in the digital economy age is high, it is reasonable to explore how young students understand the emerging phenomena of the digital economy and digital transformation and how they perceive the peculiarities of the managers in general. We assume the results could provide valuable insights on the competencies needed for business and management specialists in the digital economy.

4 An Empirical Study and Findings: Digital Economy and Manager in the Digital Economy Age

4.1 Methodology

The exploratory qualitative study, aimed at discovering the understanding of the digital economy, opportunities, and risks associated with the digital transformation and characteristics of the managers in the digital age among undergraduate students. Brief semi-structured interviews were conducted with a sample of 52 first-year undergraduate business and management students (age range 17–19 years, 50% male and 50% female).

Participants were asked questions that clarified how they perceive relevant issues (e.g., nature of the digital economy, manager qualities) and analyze current transformation processes in the digital age (e.g., opportunities and risks associated with the digital transformation). Preliminary study results, derived from the interviews, open up avenues for further educational programs' development (e.g., find misperception or gaps in knowledge to deal with existing blind spots).

The interview guide included the following questions:

(1) What is the digital economy?
(2) What are the opportunities of the digital transformation?
(3) What are the threats of the digital transformation?
(4) How could you describe a manager in the new digital age?
(5) What qualities are required for a manager in the digital economy?

The collected qualitative data were carefully analyzed to identify a shared vision of the respondents and highlight major insights on the research issues.

4.2 Results

Digital Economy. Describing the meaning of the digital economy, junior students provided short descriptions and evocative associations. According to their responses, the digital economy could be explained as "economic activities based on the digital technologies". There is a strong belief that the digital economy is "the economy of the 21st century", where new technologies (e.g., Internet, computers) are actively applied and/or developed and commercialized.

Some interviewees emphasized the role of changes and the speed affecting various processes: "*in the new economy, the majority of the processes are executed by computers, it's possible to use artificial intelligence…digitalization is done to accelerate and optimize processes of the organization management", "…modern economy is adapted to rapid changes associated with digitalization, introduction of the digital tools in production, in service provision and other business processes"*.

Many respondents (31 students) characterized the digital economy using different trends. Among the most popular mentioned were Artificial Intelligence (AI), Internet of Things (IoT), Augmented Reality (AR), Virtual Reality (VR), total automation (associated with robotization), computerization, and globalization.

About one-quarter of all respondents (11 students) highlighted that the digital economy is *"a complicated system of economic, social, cultural relationships centered around digital information and communications technologies (ICTs)"*. They help or create businesses (e.g., e-businesses involved in e-commerce practices).

Opportunities and Threats. In response to a question about the opportunities that are connected with the digital transformation, interviewees faced difficulties to list and formulate possible perspectives of the digitalization. The most common answers included *general responses* (e.g., "rapid progress", "simplification/facilitation and acceleration of

processes"), *economic, business and entrepreneurial aspects* (e.g., "reduction of operating costs (fewer routine tasks and operations)", "substantial increase in productivity", "worldwide market access", "new business models", "room for creativity"), *sociocultural aspects* (e.g., "getting closer to each other because of the different cultural experiences", "new digital society", "robots will make our life easier, incurring hazardous activities (explosive depots, mines, etc.)").

Some participants (17 students) expressed a positive and enthusiastic attitude towards digital transformation. One of the respondents stressed: "*It provides an opportunity for a breakthrough. To overcome a large development gap, it's necessary to implement a special Digital Economy Program. Correct and valid implementation is a key aspect of leapfrogging"*.

When students were asked to list threats, most of them (42 respondents) mentioned the problem of unemployment, noting the reasons such as the lack of qualifications, development of artificial intelligence and intelligent robots. Many students worried about the rise of the machines: *"people will be fired, they will be replaced by machines – no people will be needed in the future"*. Moreover, there was an opinion that the unemployment rate would grow, quality and living standards would decline.

The other threats concerned *privacy issues* (cyber-crime, viruses, hacking), *social issues* (lack of social and emotional interactions, virtual migration, privacy blurring), *cultural issues* (decadence of culture). Overall, students highlighted the unpredictability of new technologies.

Managers in the Digital Age and Their Qualities. The compilation of the responses helped to present *general explanation*: the manager in the new age is a person who plans, organizes, coordinates and controls different organizational processes with the help of advanced digital technologies; who is aware of and able to use new digital products (e.g., programs, systems); who applies information technologies to drive an organization's transformation; in some specific cases, who can model and implement new methods or products for digitalization of the company. Specifically, analysis of the interviews showed the following interesting points touched on by the respondents:

a) General context:

…managers in the digital age could be named "digital economy managers" or "digital leader". He works "in" or "with" the digital economy.

…manager in the digital age works under the conditions where most of the processes are already automated and digitized.

b) Way of management:

…modern managers might be able to manage, either remotely from the working place, or at work using various digital tools and programs.

…manager in the 21st century, uses new methods in managing an organization in the industry 4.0 and digital economy.

c) Role of technologies in business:

…manager uses digital "channels" to create new projects, solve problems… he introduces new technologies for creating and developing products.

…manager is knowledgeable in technology, particularly in programming languages; he leads projects and works with programmers.

d) Connection with IT:

…an IT-savvy manager takes the organization to a new digital level that is important for 21st-century companies.

…most of his work is related to the IT-sphere…he works in the IT field with the Internet of Things, Cloud computing, etc.

Concerning a question of the qualities required for a manager in the digital economy, young respondents emphasized quick decision-making, fast learning, and the ability to adapt quickly in the fast-changing world. They noted the role of the specific skills (networking, leadership, analytical and digital skills, etc.), which are critical to success. The primary focus was on technology knowledge and technical proficiency. Some interviewees also noticed how important it might be to have "the ability to learn and retrain", "manager's involvement in innovation", "relevance of professional knowledge", "ability to create digital workplaces", "ability to delegate control", "ability to manage digital processes, virtual teams", etc.

4.3 Discussion

The results obtained from the present study allowed us, not only to identify how undergraduate business and management students understand the digital economy and its opportunities and threats, peculiarities of a manager in the digital age, but also to determine their general attitude to the issues.

Interestingly, students were aware of different mega-trends of the digital transformation, namely they heard about the most discussed. Though some of them understood the digital economy as a new, complex system with advanced technologies affecting economic, social relationships etc., most respondents had quite general awareness about the digital economy. It is vital to expand their perception (from simplified and straightforward to complex and sophisticated) and increase their awareness about recently-emerging phenomena, in particular an understanding of the digital economy's practical implications.

Judging from the remarks, unemployment is a primary threat of the digital transformation. Nobody mentioned moral and ethical issues, which are probably one of the sore points of the digital age. Most of the mentioned threats and opportunities are those broadcasted by mass media. Younger generations' understanding is based on the media and stereotypes available in the information environment. The last is a key driver forming social reality, a new culture, and shaping the vitality of society. A poor information environment could destroy the prosperous digital future of our society. To realize critical

causes, problems, threats, and opportunities, it is necessary to develop special competencies (e.g., critical thinking, learning to learn competency). More research is needed on education topics to answer the question "which knowledge and skills are necessary to develop unbiased thinking?".

Moreover, the question about the opportunities posed the greatest difficulty. Future managers and entrepreneurs have to see opportunities to create new projects, products, and businesses. Further studies might be focused on the competencies of the future managers and entrepreneurial leaders and problems of development.

Junior students perceive a manager in the digital age as an individual who combines managerial and entrepreneurial activities. A digital manager of today is a leader demonstrating entrepreneurial qualities and skills. Future research directions encompass the following questions: (1) which qualities and competencies are critical? (2) which of the competencies should be developed at university? (3) how appropriate competencies could be developed?

Overall, it is worth noting that the results revealed the importance of entrepreneurship in the digital context. Special mention was made of creativity and innovation, communication (e.g., network development), critical thinking, and leadership. These are entrepreneurial competencies fostering an entrepreneurial mindset that is vital for developing or managing new innovative ideas, products, technologies, business models, projects and modes of organization, as well as managing ambiguity and uncertainty, being able to seize the opportunities and meet the challenges of today's digital world. Different empirical studies, that were reviewed in the theoretical part of the paper, support the opinion that entrepreneurial competencies are vital to becoming a successful manager and leader to develop sustainable business in the digital environment.

5 Conclusion and Future Research

The scientometric analysis supports that digital economy is actively researched area and particular attention of the researchers is paid to address the need for innovation, economic growth, entrepreneurship, and education issues in the context of digital economy. Based on the analysis of the publications, the necessity of entrepreneurial competencies in the digital economy is identified.

Using a qualitative study of students' understanding of digital economy and the opportunities and threats associated with the digital transformation, the authors reveal major problems concerning the students' perception of the digital economy and a manager in the digital context.

Overall, the pilot study provided valuable results in research questions and indicated pressing issues for the new works. More research is needed to investigate what particular entrepreneurial competencies are needed for future corporate leaders, managers, and entrepreneurs to encourage creation of new processes and products in a dynamically changing digital business environment.

It is required to conduct quantitative research evaluating and comparing the perception of the threats and opportunities in the digital framework among different samples and groups. Future research directions should include qualitative/quantitative studies exploring the modern educational tracks/processes contributing to the development of the appropriate managerial and entrepreneurial competencies in the digital age.

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References

1. Akatkin, Y. et al.: Digital economy: Conceptual architecture of a digital economic sector ecosystem. Bus. Inf. **4**, 17–28 (2017). https://doi.org/10.17323/1998-0663.2017.4.17.28
2. Askerov, P.F., et al.: Digital economy as a priority direction for the development of modern innovative entrepreneurship in Russia. Espacios **39**, 41 (2018)
3. Benghozi, P.J., Salvador, E.: Are traditional industrial partnerships so strategic for research spin-off development? Some evidence from the Italian case. Entrepreneurship Reg. Dev. **26**(1–2), 47–79 (2014). https://doi.org/10.1080/08985626.2013.860194
4. Bloodgood, J.M.: Knowledge acquisition and firm competitiveness: the role of complements and knowledge source. J. Knowl. Manage. **23**(1), 46–66 (2019). https://doi.org/10.1108/JKM-09-2017-0430
5. Bögenhold, D.: From hybrid entrepreneurs to entrepreneurial billionaires: observations on the socioeconomic heterogeneity of self-employment. Am. Behav. Sci. **63**(2), 129–146 (2019). https://doi.org/10.1177/0002764218794231
6. Brandstätter, H.: Personality aspects of entrepreneurship: a look at five meta-analyses. Personality Individ. Differ. **51**(3), 222–230 (2011). https://doi.org/10.1016/j.paid.2010.07.007
7. Burtch, G., et al.: Can you gig it? An empirical examination of the gig economy and entrepreneurial activity. Manage. Sci. **64**(12), 5497–5520 (2018). https://doi.org/10.1287/mnsc.2017.2916
8. Caseiro, N., Coelho, A.: Business intelligence and competitiveness: the mediating role of entrepreneurial orientation. Competitiveness Rev. **28**(2), 213–226 (2018). https://doi.org/10.1108/CR-09-2016-0054
9. Dal Zotto, P., et al.: Customers becoming creators: how firms leverage technology and consumers for new value. J. Bus. Strategy **39**(4), 42–65 (2018). https://doi.org/10.1108/JBS-06-2017-0087
10. Dementiev, V., et al.: Impact of digital economy on the transformation of models of business activity organization within corporations. Espacios **38**, 48 (2017)
11. Duhăneanu, M., Marin, F.: Digital agenda for europe – risks and opportunities in a digital economy. Q. Access Success **15**, 57–66 (2014)
12. Eferin, Y. et al.: Digital platforms in Russia: competition between national and foreign multi-sided platforms stimulates growth and innovation. Digital Policy Regul. Gov. (2019). https://doi.org/10.1108/DPRG-11-2018-0065
13. Estrin, S., Prevezer, M.: The role of informal institutions in corporate governance: Brazil, Russia, India, and China compared. Asia Pac. J. Manage. **28**(1), 41–67 (2010). https://doi.org/10.1007/s10490-010-9229-1
14. Feldman, M., Lowe, N.: Triangulating regional economies: realizing the promise of digital data. Res. Policy **44**(9), 1785–1793 (2015). https://doi.org/10.1016/j.respol.2015.01.015
15. Filatova, O., Golubev, V., Stetsko, E.: Digital transformation in the eurasian economic union: prospects and challenges. In: Alexandrov, D.A., Boukhanovsky, A.V., Chugunov, A.V., Kabanov, Y., Koltsova, O. (eds.) DTGS 2018. CCIS, vol. 858, pp. 90–101. Springer, Cham (2018). https://doi.org/10.1007/978-3-030-02843-5_8

16. Fleacă, E.: Entrepreneurial curriculum through digital-age learning in higher education - a process-based model. TEM J. **6**, 591–598 (2017). https://doi.org/10.18421/TEM63-22
17. Gupta, V., et al.: Entrepreneurial leadership: developing and measuring a cross-cultural construct. J. Bus. Ventur. **19**(2), 241–260 (2004). https://doi.org/10.1016/S0883-9026(03)00040-5
18. Hafezieh, N., et al.: Exploration of process and competitive factors of entrepreneurship in digital space: a multiple case study in Iran. Educ. Bus. Soc. Contemp. Middle Eastern Issues **4**(4), 267–279 (2011). https://doi.org/10.1108/17537981111190051
19. Halliday, S.V.: User-generated content about brands: understanding its creators and consumers. J. Bus. Res. **69**(1), 137–144 (2016). https://doi.org/10.1016/j.jbusres.2015.07.027
20. Harrison, C., et al.: Entrepreneurial leadership in a developing economy: a skill-based analysis. J. Small Bus. Enterp. Dev. **25**(3), 521–548 (2018). https://doi.org/10.1108/JSBED-05-2017-0160
21. Ireland, R.D., et al.: Conceptualizing corporate entrepreneurship strategy. Entrepreneurship Theory Pract. **33**(1), 19–46 (2009). https://doi.org/10.1111/j.1540-6520.2008.00279.x
22. Jonker, N.: What drives the adoption of crypto-payments by online retailers? Electron. Commer. Res. Appl. **35** (2019). https://doi.org/10.1016/j.elerap.2019.100848
23. Joshi, M.P., Yermish, I.: The digital economy: a golden opportunity for entrepreneurs? New England J. Entrepreneurship **3**(1), 15–21 (2000)
24. Jovanović, M. et al.: Digitalization and society's sustainable development – Measures and implications. Zbornik Radova Ekonomskog Fakultet au Rijeci **36**(2), 905–928 (2018). https://doi.org/10.18045/zbefri.2018.2.905
25. Kazarenkova, N. et al.: Transformation of the Russian banking system in digital economy. In: Proceedings of the 33rd International Business Information Management Association Conference, IBIMA 2019: Education Excellence and Innovation Management through Vision 2020, pp. 1456–1461 (2019)
26. Kazlauskaitė, R. et al.: The speed and extent of new venture internationalisation in the emerging economy context. Entrepreneurial Bus. Econ. Rev. **3**(2), 41–52 (2015). https://doi.org/10.15678/EBER.2015.030204
27. Kohler, T.: Corporate accelerators: building bridges between corporations and startups. Bus. Horiz. **59**(3), 347–357 (2016). https://doi.org/10.1016/j.bushor.2016.01.008
28. Lebedeva, L.F.: Digital transformation in the socio-labor sphere: New challenges and opportunities. World Econ. Int. Relat. **63**(12), 42–49 (2019). https://doi.org/10.20542/0131-2227-2019-63-12-42-49
29. Lechner, C.M., et al.: What drives future business leaders? How work values and gender shape young adults' entrepreneurial and leadership aspirations. J. Vocat. Behav. **107**, 57–70 (2018). https://doi.org/10.1016/j.jvb.2018.03.004
30. Lee, S.M., et al.: What determines an engaging website?: An empirical study of website characteristics and operational performance. J. High Technol. Manage. Res. **22**(1), 67–79 (2011). https://doi.org/10.1016/j.hitech.2011.04.002
31. Leitch, C.M., et al.: The development of entrepreneurial leadership: the role of human, social and institutional capital. Br. J. Manag. **24**(3), 347–366 (2013). https://doi.org/10.1111/j.1467-8551.2011.00808.x
32. Li, W., et al.: e-Leadership through strategic alignment: an empirical study of small- and medium-sized enterprises in the digital age. J. Inf. Technol. **31**(2), 185–206 (2016). https://doi.org/10.1057/jit.2016.10
33. Liñán, F., et al.: Factors affecting entrepreneurial intention levels: a role for education. Int. Entrepreneurship Manage. J. **7**(2), 195–218 (2011). https://doi.org/10.1007/s11365-010-0154-z

34. Muramalla, V.S.S.R., Al-Hazza, A.M.: Entrepreneurial strategies and factors stimulate the business of tech startups. Int. J. Financ. Res. **10**(3), 360–370 (2019). https://doi.org/10.5430/ijfr.v10n3p360
35. Nambisan, S., et al.: The digital transformation of innovation and entrepreneurship: progress, challenges and key themes. Res. Policy **48**, 8 (2019). https://doi.org/10.1016/j.respol.2019.03.018
36. Ng, I.C.L.: New business and economic models in the connected digital economy. J. Revenue Pricing Manag. **13**(2), 149–155 (2014). https://doi.org/10.1057/rpm.2013.27
37. Ng, I.C.L., Wakenshaw, S.Y.L.: The Internet-of-Things: review and research directions. Int. J. Res. Mark. **34**(1), 3–21 (2017). https://doi.org/10.1016/j.ijresmar.2016.11.003
38. Nylén, D., Holmström, J.: Digital innovation strategy: a framework for diagnosing and improving digital product and service innovation. Bus. Horiz. **58**(1), 57–67 (2015). https://doi.org/10.1016/j.bushor.2014.09.001
39. Provasnek, A.K., et al.: Sustainable corporate entrepreneurship: performance and strategies toward innovation. Bus. Strategy Environ. **26**(4), 521–535 (2017). https://doi.org/10.1002/bse.1934
40. Ramazanov, A. V. et al.: Development of youth entrepreneurship in Russia in the conditions of digital economy. J. Soc. Sci. Res. **2018**(5), 99–102 (2018). https://doi.org/10.32861/jssr.spi5.99.102
41. Ranasinghe, W.T., et al.: An analysis of product-place co-branding: the case of Ceylon Tea. Asia Pacific J. Mark. Logist. **29**(1), 200–214 (2017). https://doi.org/10.1108/APJML-10-2015-0156
42. Ratzinger, D., Amess, K., Greenman, A., Mosey, S.: The impact of digital start-up founders' higher education on reaching equity investment milestones. J. Technol. Transfer **43**(3), 760–778 (2017). https://doi.org/10.1007/s10961-017-9627-3
43. Rebiazina, V., Shalaeva, A., Smirnova, M.: Do Russian consumers understand and accept the sharing economy as a new digital business model? In: Alexandrov, D.A., Boukhanovsky, A.V., Chugunov, A.V., Kabanov, Y., Koltsova, O. (eds.) DTGS 2018. CCIS, vol. 858, pp. 386–401. Springer, Cham (2018). https://doi.org/10.1007/978-3-030-02843-5_31
44. Renko, M., et al.: Understanding and measuring entrepreneurial leadership style. J. Small Bus. Manage. **53**(1), 54–74 (2015). https://doi.org/10.1111/jsbm.12086
45. Ruggieri, A., Mosconi, E.M., Poponi, S., Silvestri, C.: Digital innovation in the job market: an explorative study on cloud working platforms. In: Torre, T., Braccini, A.M., Spinelli, R. (eds.) Empowering Organizations. LNISO, vol. 11, pp. 273–283. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-23784-8_21
46. Ruggieri, R., et al.: The impact of digital platforms on business models: an empirical investigation on innovative start-ups. Manage. Mark. **13**(4), 1210–1225 (2018). https://doi.org/10.2478/mmcks-2018-0032
47. Sánchez-Gutiérrez, J., et al.: The impact on competitiveness of customer value creation through relationship capabilities and marketing innovation. J. Bus. Ind. Mark. **34**(3), 618–627 (2019). https://doi.org/10.1108/JBIM-03-2017-0081
48. Schweer, D., Sahl, J.C.: The digital transformation of industry – the benefit for Germany. In: Abolhassan, F. (ed.) The Drivers of Digital Transformation. MP, pp. 23–31. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-31824-0_3
49. Scott, M.G., Twomey, D.F.: The long-term supply of entrepreneurs: students' career aspirations in relation to entrepreneurship. J. Small Bus. Manage. **26**(4), 5–13 (1988)
50. Scuotto, V., Morellato, M.: Entrepreneurial knowledge and digital competence: keys for a success of student entrepreneurship. J. Knowl. Econ. **4**(3), 293–303 (2013). https://doi.org/10.1007/s13132-013-0155-6
51. Shane, S., Venkataraman, S.: The promise of entrepreneurship as a field of research. Acad. Manag. Rev. **25**(1), 217–226 (2000). https://doi.org/10.5465/amr.2000.2791611

52. Shirokova, G., et al.: Entrepreneurial orientation and firm performance in different environmental settings: contingency and configurational approaches. J. Small Bus. Enterp. Dev. **23**(3), 703–727 (2016). https://doi.org/10.1108/JSBED-09-2015-0132
53. Shirokova, G., et al.: Exploring the intention–behavior link in student entrepreneurship: moderating effects of individual and environmental characteristics. Eur. Manag. J. **34**(4), 386–399 (2016). https://doi.org/10.1016/j.emj.2015.12.007
54. Shirokova, G., McDougall-Covin, P.: The role of social networks and institutions in the internationalization of Russian entrepreneurial firms: do they matter? J. Int. Entrepreneurship **10**(3), 177–199 (2012). https://doi.org/10.1007/s10843-012-0091-8
55. Shirokova, G., Tsukanova, T.: Internationalization of SMEs from transition economies: institutional perspectives. In: Etemad, H., Madsen, T.K., Rasmussen, E.S. and Servais, P. (eds.) Current Issues in International Entrepreneurship, pp. 174–198. Edward Elgar Publishing, Cheltenham (2013). https://doi.org/10.4337/9781781953426.00013
56. Skolkovo, NAFI: Digital Economy and Russian Companies (2018)
57. Stroiteleva, T.G., Kalinicheva, E.Y., Vukovich, G.G., Osipov, V.S.: Peculiarities and problems of formation of industry 4.0 in modern Russia. In: Popkova, E.G., Ragulina, Y.V., Bogoviz, A.V. (eds.) Industry 4.0: Industrial Revolution of the 21st Century. SSDC, vol. 169, pp. 145–153. Springer, Cham (2019). https://doi.org/10.1007/978-3-319-94310-7_14
58. Tarabishy, A., et al.: The entrepreneurial leader's impact on the organization's performance in dynamic markets. J. Private Equity (2005). https://doi.org/10.3905/jpe.2005.580519
59. The Danish Foundation for Entrepreneurship: Impact of Entrepreneurship Education in Denmark - 2014 (2014)
60. Vasin, S., et al.: Emerging trends and opportunities for industry 4.0 development in Russia. Eur. Res. Stud. J. **21**(3), 63–76 (2018)
61. Veselovsky, M.Y., et al.: Financial and economic mechanisms of promoting innovative activity in the context of the digital economy formation. Entrepreneurship Sustain. Issues **5**(3), 672–681 (2018). https://doi.org/10.9770/jesi.2018.5.3(19)
62. Vial, G.: Understanding digital transformation: a review and a research agenda. J. Strateg. Inf. Syst. **28**(2), 118–144 (2019). https://doi.org/10.1016/j.jsis.2019.01.003
63. Viglia, G., et al.: The determinants of stakeholder engagement in digital platforms. J. Bus. Res. **89**, 404–410 (2018). https://doi.org/10.1016/j.jbusres.2017.12.029
64. Waldfogel, J.: How digitization has created a golden age of music, movies, books, and television. J. Econ. Perspect. **31**(3), 195–214 (2017). https://doi.org/10.1257/jep.31.3.195
65. Warner, K.S.R., Wäger, M.: Building dynamic capabilities for digital transformation: an ongoing process of strategic renewal. Long Range Plann. **52**, 1–24 (2018). https://doi.org/10.1016/j.lrp.2018.12.001
66. Weiblen, T., Chesbrough, H.W.: Engaging with startups to enhance corporate innovation. Calif. Manag. Rev. **57**(2), 66–90 (2015). https://doi.org/10.1525/cmr.2015.57.2.66
67. Wilson, K.: Entrepreneurship education in Europe. In: Potter, J. (ed.) Entrepreneurship and Higher Education, pp. 119–138. OECD Publishing, Paris (2008). https://doi.org/10.1787/9789264044104-7-en
68. Zhura, S., et al.: Development of self-employment in the context of digital economy. J. Soc. Sci. Res. **2018**(3), 423–428 (2018). https://doi.org/10.32861/jssr.spi3.423.428

The Younger Generation Collaborative Consumption Adoption Factors: Empirical Evidence from the Russian Market

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Abstract. Increased attention to the growth of collaborative consumption (CC) is primarily connected to rapid digital transformation and spread of information technology, in both developed and emerging markets. CC affects most areas of everyday life, changing transportation methods (Uber), short-term rent (Airbnb), ways of entertainment (Youtube), tasks (TaskRabbit), and financing (Kickstarter). As the younger generation representatives grew up in the era of social network and cyberspace, CC seems essential for them. The main objective of this study is to identify the typology of young customers based on their attitude to CC adoption factors in emerging markets, and specifically, the Russian market. The paper attempts to bridge the theoretical gaps by analyzing and systematizing different approaches to understanding the phenomenon of CC, considering the factors that affect CC of different generations. Based on the results of an online survey of 2038 Russian users, CC adoption factors for the younger generation have been identified. Based on the results of the online survey of 2038 Russian CC services users, seven factors of the CC adoption by the younger generation: difficulty of CC adoption, risk of fraud, economic and environmental benefits, hygienic issues, ownership as a status symbol, CC as a modern lifestyle, social norms, and approval of the reference group; and five clusters of the CC users have been identified.

Keywords: Collaborative consumption · Adoption factors · The younger generation · Generation Y · Generation Z · Emerging markets · Russia

1 Introduction

The development of technologies, transformation of the existing economic models, appearance of the new ones, and a technological breakthrough, leads to the fourth industrial revolution [39] and to significant global progress. Digital transformation caused by the dramatic development of the Internet and mobile technologies, creates the preconditions for the emergence of collaborative consumption as a new digital model.

Despite the fact that the basic principles of collaborative consumption (CC) have been known for a long time, for example, sports goods, flat renting and libraries [5], it was the development of information technology and digital transformation that allowed this business model to grow from almost nothing to a pool of global enterprises valued

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at billions of dollars. CC affects most areas of everyday life, changing transportation methods (Uber, BlaBlaCar, Delimobile), short-term rent (Airbnb), ways of entertainment (Netflix, Youtube), tasks (TaskRabbit), and financing (Kickstarter).

Currently, researchers and practitioners have not developed a unified approach to the definition of the terms "collaborative consumption", "sharing economy", and "collaborative economy". The term "collaborative economy" is understood not only as consumption, but also borrowing, the use of something that was previously in use [22, 27, 41], responsible consumption and altruistic intentions [44]. "Access-based consumption" combines both elements of collaborative, and "anti-consumption" [2], in which CC stimulates a decrease in the rate of consumption of new products [30, 32, 38]. By summarizing the approaches proposed by various studies of the phenomenon of CC [4, 5, 8], we can estimate that its main idea is in making profit through economic exchange, barter, rent for temporary access to goods, services, and skills, instead of processing them as a property.

CC helps to cope with global challenges such as excessive consumption, environmental degradation and poverty, by reducing coordination costs between online services of different communities [20]. Moreover, CC is attractive from the point of view of financial investments [3] and its influence is taken into account developing policies in different countries. Nevertheless, the features of CC are still an urgent area for researchers around the world.

Increased attention to the phenomenon of CC is primarily connected to rapid digital transformation and spread of information technology and information culture, in both developed and developing markets. For example, for the last ten years, CC in BRICS countries has covered sectors such as car rental, real estate, short-term rental, microloans and crowd funding platforms, tourism, food delivery, rental of various products and services, online education and cloud data storage. Russia is not an exclusion, as CC has become an important part of life for Russian consumers as well. According to the RAEC report, the volume of the Russian market of CC services in 2018 exceeded 500 billion rubles, showing an increase of 30% compared to the previous period [40]. Thus, Russian consumers' behavior in CC is of particular interest, but the existing research is limited to only a small number of studies [18, 30, 35], and is not covering CC adoption factors between representatives of the different generations.

According to Möhlmann [29], there is still not enough knowledge about the reasons why consumers are involved in CC or, conversely, avoid participating in it. Moreover, existing research clearly lacks a quantitative empirical research of the motivators of the younger generation, which influence consumers' attitudes and intentions toward CC [20]. It is important to mention that representatives of the younger generation will become fully fledged players in the market in the near future. Therefore, the research on the younger generation CC adoption factors is of particular interest.

Thus, the objective of this paper is to identify the typology of the younger generation customers, based on their attitude to CC adoption in emerging markets, and specifically the Russian market. The younger generations of consumers are selected for this research because of their importance and growing purchasing power. They are also quicker to respond to changing environments, globalization (and its impact on consumption), and they adopt new consumer trends faster than any other consumer group.

The paper is structured in the following way: systematization of existing approaches to understanding the theory of generations in the context of consumer behavior; identification of factors, based on the results of empirical analysis affecting younger generation CC adoption factors in Russia; development of an approach to consumer segmentation, based on the results of cluster analysis.

2 The Younger Generation as a Key Driver of the CC Adoption in Emerging Markets

2.1 Specifics of the Younger Generation CC Adoption as the Key Driver of the Sharing Economy Development

As the younger generation representatives grew up in the era of social network and cyberspace [15], CC for them seems like a natural fit [18]. An empirical study of the relationship between openness and the socio-demographic factors of consumers, has confirmed that it is precisely the representatives of Generation Z that are more open to CC. The younger generation, people aged from 18 to 35 years, more often than the other generations, use CC services and are not so sensitive to the limiting factors of CC adoption, including hygienic issues and the risk of fraud.

Table 1. Main characteristics of the Generation Y and generation Z

Title	Generation Y	Generation Z
Shopping features	39% plan shopping ahead 44% choose approved brands	44% don't plan shopping ahead 27% choose new brands and test them
Age	26–35 years old	Till 25
Field of activity Scope Sphere	64% work 12% combine studying with working 13% housekeepers	78% study at school 18% studying at college 4% working
Family	52% within marriage 31% have children	85% single
Shopping features	39% plan shopping ahead 44% choose approved brands	44% do not plan shopping ahead 27% choose new brands and test them
	Common trends	
Product reviews	55% view the product feedback before shopping 24% write feedback about the product after using	
Price	39% pay attention to the price before shopping	
Shopping features	53% trust old brands 47% prefer innovative brands 41% make shopping in Russian online stores 50% make shopping in foreign online stores	

By the younger generation in this research, we mean young people aged 18 to 35 years who have experience using CC services. Based on generation theory approach, the younger generation was divided into two age groups corresponding to generation Z (18–25) and generation Y (26–35). Despite the fact that both generations operate in a similar, constantly evolving and dynamic digital environment, they have a number of differences (Table 1).

According to a survey of the younger generation specifics conducted by McKinsey and Box1824 [17], a research agency specializing in consumer trends, a significant influence of the ethical component on the decision making to purchase goods and services was revealed. About 80% of consumers refused to buy the product if the company is not environmentally friendly, does not comply with general ethics, or has been implicated in a scandal. Francis and Hoefel also prove [17] that ethics, environmental friendliness, and a rational approach are important for the younger generation.

2.2 The Younger Generation Collaborative Consumption Adoption Factors

Despite the predominant number of works devoted to advanced economies, in recent years researchers have attempted to understand the characteristics of CC in emerging markets, with a special emphasis on differences between generations. Despite their small size, the undoubted importance of these works is that they reveal not only opportunities, but also the risks that arise with the development of a CC. Research of Kumar, Lahiri, Dogan [25] attempts to compare the factors influencing the motivation of different generations to participate in CC in emerging markets, between different generations (Baby Boomers, Generations X, Y, and Z) and on behavioral and technological factors. Results show that the Baby Boomers generation is price-sensitive, brand-loyal, values high quality and prefers to own things rather than just renting them. On the contrary, Generation X does not demonstrate such high brand loyalty as its predecessors; the optimal combination of price, quality and functionality is more important. Consumers of Generation Y (or Late Millennials – 28–37 years old) are distinguished by the fact that they use various mobile devices in everyday life, focus on the practical properties of a product, their expenses reflect their hobbies, they show concern for the environment and maintain a healthy lifestyle. The consumption of the youngest generation Z (18–20 years old), personifies the modern lifestyle and is significantly affected by the latest trends and the approval of the reference group.

In a joint study by the BSR and The Rockefeller Foundation [34], the contributions of short-term loans, crowdfunding platforms, job/work communities, and online education services for a solution of global problems such as poverty, unemployment, and low literacy, are described. Moreover, the positive social effect of the development of CC services for people with disabilities is indicated, for example, by increasing the availability of goods/services, and reducing risks when making payments. At the same time, consumers in emerging markets are concerned about gaps in legislation, security and transparency, the risks of anonymity and prejudice against different cultures. The impact of CC on local entrepreneurship is also ambiguous, as its development is accompanied by an increase in the cost of living and increased competition for traditional businesses. Main CC adoption factors for the younger generation are presented in Table 2.

Table 2. Main CC adoption factors for the younger generation: findings from the existing research

Driving factors for CC adoption	Limiting factors for CC adoption
– Financial and economic benefits [2, 7, 16, 19, 36, 45] – Benefits for the environment and sustainable development [19–21] – CC as a modern trend/lifestyle [14] – Being part of the community [10, 12, 22, 24, 26] – Maximum usefulness with spending minimum resources [11, 33]	– Difficulty of CC adoption [21] – The risk of not getting the necessary goods/services at the right time [21, 26] – Ownership as a status symbol [21, 43] – Hygienic issues [4] – Risk of fraud [28, 31, 42]
Transitional factors (may be driving or limiting for the user)	
– Social norms and approval of the reference group (friends, family members, colleagues) [1, 37] – Trust/Mistrust in CC [6, 23, 29] – Ethical issues [8, 9]	

In a global study, Accenture (2017) focuses on representatives of Generation Z, identifying specific drivers and barriers to CC adoption. As a result of a survey of 10,000 respondents representing generation Z from 13 countries, including emerging markets such as Brazil, China and South Africa, researchers identified drivers such as speed of access, ease of use, money saving, approval of the reference group and trust based on positive reviews. Unlike generation Y, representatives of generation Z are more active in using online purchases (more than 40%), are open to new services and product concepts (70%), demonstrate their willingness to pay for the temporary use of goods and services, rent personal items, electronics, and value high quality and efficiency.

The main motivation for participating in CC for them are the economic benefits [12], as participating in CC they get the maximum usefulness and are spending minimum resources [4]. Despite the fact that the representatives of the young generation have a low income, they want to get a service of the proper quality.

3 Empirical Study of the Younger Generation Collaborative Consumption Adoption Factors in the Russian Market

3.1 Research Design and Data Collection Process

The empirical stage of the study has an explorative nature and aims to identify the typology of the younger generation CC customers in the Russian market, based on their attitude to CC adoption factors. The research is focused on the Russian CC consumers of the younger generation who have experience in using CC services. To achieve the set objective, a quantitative study with a sample of 2642 respondents was conducted.

The quantitative data was collected from a survey of internet users that participated in the online course "Marketing", held on the Russian National Educational Platform "Open

Education". About 15 000 internet users took part in the course, as the survey link was sent to all participants of the course in April–September 2018. Completing the questionnaire was voluntary. With the 2642 respondents in the survey, the response rate was about 18%. The questionnaire, including 21 indicators describing CC adoption factors (based on Table 2) and 8 questions characterizing the socio-demographic characteristics of the respondents, was based on the existing research and scales and operationalizing factors affecting CC adoption factors. Questions were formulated with the use of a 7-point Likert scale: from 1 "strongly disagree" to 7 "strongly agree". All questions were tested for neutrality to get the most correct answers from respondents.

3.2 Sample Description

To ensure the quality of the answers, the respondents with less than 20% of the questionnaire fulfilment rate were deleted, resulting in 2574 valid questionnaires. To filter the respondents on their belonging to the younger generation (18–35 years old), a direct question about their age was used, decreasing the sample to 2101 respondents. Additionally, a screening question on the experience of CC services usage was used: "How often do you use CC services?" The analysis of the obtained results revealed that 63 respondents from the sample had never used CC services, thus the total sample consists of 2038 respondents. Table 3 presents the demographic information of respondents.

Table 3. Sample description (N = 2038)

Sample selection criterion	Sample characteristic	Number of respondents	Share, %
Age	18–25	949	46,6
	26–35	1089	53,4
Sex	Male	653	32,0
	Female	1380	67,7
Region	Moscow	767	37,6
	Saint-Petersburg	258	12,7
	Other regions	913	49,7
Income level	Poverty	16	,8
	Low income	70	3,4
	Lower middle	966	47,4
	Middle	613	30,1
	Upper middle class and high income	296	14,5
	High income	72	3,5
Children	Have a child/children	412	20,2
	Have no children	1614	79,2

As it is seen from the table, two age groups (18–25 and 26–35 years old) are presented in the sample representing Generation Y (Millennials) Generation Z relatively. Social and demographic characteristics of the sample, such as education, income, in general, correspond to the general population [40], as well as the place of residence as most of the users of CC services are located in large cities [13]. The percentage of female respondents in the sample is 67.7%, that is a little bit more than in previous research. However, it is worth noting that it varies in different studies: the difference in the percentage of men and women in the studies of RAEK [40] and GFK [18] is 3%. The sample bias towards female respondents may be due to the fact that the sample is limited to students of the online course.

4 Empirical Results of the Younger Generation Collaborative Consumption Adoption Factors in the Russian Market

4.1 Factor Analysis Results

In order to reveal CC adoption factors, the exploratory factor analysis (EFA) with SPSS has been applied to explore the factor structure behind the scale items. Principal Component Analysis and Varimax rotation with Kaiser normalization have been used, resulting in identifying six CC adoption factors (Table 4). EFA started on the initial pool of 21 items, that were reduced to 20 in the final version of the factor model, after deleting the items with the cross-loadings according to the EFA procedure. The indicators with high factor loadings were chosen for the further analysis while the rest of the indicators were excluded.

Table 4. Factor analysis results

Factor	Indicator	Operationalization	Cronbach's Alpha	Average variance, %	Mean	Standard deviation
F1: Difficulty of CC adoption	It takes a lot of time to adopt CC services	[21, 43]	0,829	23,012	3,374	1,379
	It is necessary for me to find new information to adopt CC services					
	It is difficult for me to adopt CC services					
	It is too complex to me to adopt CC services					

(*continued*)

Table 4. (*continued*)

Factor	Indicator	Operationalization	Cronbach's Alpha	Average variance, %	Mean	Standard deviation
F2: Risk of fraud	There are scammers in CC communities	[21, 26]	0,747	13,482	4,857	1,225
	My things can be stolen while participating in CC					
	People can rent out things that don't work well					
	The risk exists that I would not get the thing when I need it					
F3: Economic and environmental benefits	CC allows to save natural resources	[20, 21]	0,81	10,003	5,24	1,442
	CC allows to save the environment					
	CC allows to save the costs					
F4: Hygienic issues	I don't like using things that were used by strangers	[4]	0,72	8,669	4,683	1,435
	It is not hygienic to use rented goods					
	It is inconvenient when other people have access to your things					
F5: Ownership as a status symbol	People with many possessions have a high profile	[21, 43]	0,872	7,374	4,428	1,445
	Having many possessions is a status symbol					

(*continued*)

Table 4. (*continued*)

Factor	Indicator	Operationalization	Cronbach's Alpha	Average variance, %	Mean	Standard deviation
F6: CC as a modern lifestyle	CC is a tendency that keep pace with the time	[21]	0,86	5,214	4,936	1,368
	To me, CC an up-to-date life style					
F7: Social norms and approval of the reference group	My friends and family think that I need to adopt CC	[1, 36]	0,827	5,143	3,444	1,193
	My friends and family would approve of the CC option					

As a result of EFA, seven factors influencing the decision of the younger generation to adopt CC were identified, explaining 72,9% of variance. Cronbach's Alpha is above required minimum coefficient (0,7) for all the factors. The first factor (F1) describes the difficulty for the younger generation to begin to use CC services. The second factor (F2) is focused on the risk of fraud while using CC services, while the third factor (F3) is concerned about economic and environmental benefits. Further factors are connected with the hygienic issues (F4), place of property as a symbol of status (F5), CC adoption as part of a modern lifestyle, meaning consumers' desire to be trendy while using CC services (F6), and, finally, social norms and approval of the reference group on the respondent's participation in the CC. Based on the EFA analysis, seven CC adoption factors can be divided in to driving factors (F3, F6, F7) and limiting factors (F1, F2, F4, F5).

4.2 Cluster Analysis Results

Based on EFA results and seven CC adoption factors revealed, cluster analysis was carried out in order to identify the main clusters of users among the younger generation of the Russian CC customers. The cluster analysis was carried out in two steps: (1) hierarchical cluster analysis (to determine the optimal number of clusters), (2) K-means cluster analysis (to characterize the profiles of clusters). Five clusters have been identified as the optimal number. Clusters' socio-demographic characteristics are presented in Table 5.

The clusters differ in many aspects, depending on the respondents' attitude to the CC adoption. However, some factors are of the same importance for the respondents in all the clusters: "CC as a modern lifestyle" and "Economic and environmental benefits",

Table 5. Clusters' socio-demographic characteristics

Criterion	Cluster characteristic	Users with positive attitude to CC	Independent of public opinion CC users	Noncomformists	Experienced CC users	"Laggards"
Sex	Male	40,05	28,48	23,21	32,96	30,82
	Female	59,95	71,52	76,79	67,04	69,18
Age	18–25	44,43	46,15	40,77	52,36	48,24
	26–30	30,72	32	33,93	29,89	32,47
	31–35	25,87	21,85	25,3	17,75	19,29
Income level	Poverty level	1,85	0	0,3	0	1,18
	Low	3,7	2,47	2,08	4,05	4,27
	Lower middle	45,73	48,46	44,94	45,5	53,32
	Middle	29,33	31,48	32,74	32,43	26,3
	Upper middle	14,55	13,58	17,26	14,64	12,09
	High	4,85	4,01	2,68	3,38	2,84
Region	Moscow	39,51	40,52	38,27	39,39	38
	Saint-Petersburg	14,15	11,76	14,51	12,82	13,25
	Other regions	46,34	47,71	47,22	47,79	48,75

as the average values for these two factors are almost equal for all five clusters. It is not a surprise that following a modern lifestyle is a common trend for the younger generation. On the contrary, it was quite unexpected that items describing environmental and economic benefits have formed a joint factor in the Russian market, meaning that the significance of natural resources, safety and environment issues for Russian users, are as important as saving their own monetary resources. Thus, these two factors are the common characteristics of the younger generation.

From the description of the clusters (Table 5), age was treated as a control variable and didn't play a key role in the formation of the clusters. In general, the same can be said about other socio-demographic characteristics, since there are no obvious differences between the socio-demographic characteristics of all the parameters of the table. Thus, it can be argued that the CC customers of the younger generation (18–35 years) can be divided into clusters by age or based on the generation theory, meaning that the retrieved clusters can be explained better with the understanding of the physiographic characteristics of the customers, rather than sociodemographic characteristics. However, it is necessary to add that with the inclusion of other age groups in the study, the picture may change.

5 Discussion and Conclusion

Theoretical analysis of the existing research systemizes consumer behavior approach in the context of generation theory. The main objective of this study was to identify the typology of young customers based on their attitude to CC adoption factors in emerging markets and specifically the Russian market. The empirical part of the research, including both factor and cluster analysis, identify CC adoption factors in the context of young consumers in Russia.

During the factor analysis, seven factors describing the attitude of the Russian younger generation to the CC adoption were determined. Based on the factor analysis results, a cluster analysis was conducted, resulting in five profiles of the younger generation CC customers. Several researchers like Brey [9] and Botsman [8] consider ethical issues as an important factor of CC adoption. These factors may be seen both as a driving factor when the company meets the expectation of the consumer, and as a limiting factor when the company is not ethical enough, in the perception of the younger generation. At the same time, it is important to mention that empirical research conducted in the Russian market has revealed that ethical issues are not significant.

On the contrary, the younger generation of the Russian consumers pay attention to CC adoption difficulties. At the same time, the young Russian consumers fear a high risk of fraud. One more interesting finding is about the environmental and economic benefits. An unexpected result is that items describing environmental and economic benefits have formed a joint factor in the Russian market, meaning that the significance of natural resources safety and environment issues for Russian users, are as important as saving their own monetary resources. Age was considered as a control variable and as the results of the cluster analysis show, it is not the main indicator for dividing customers into clusters. The paper is based on data collected in the Russian market only. Despite the fact that empirical research is based on a representative sample, it has the limitations common for the quantitative research.

The growing ability of the younger consumers to make marketing decisions in a fast-changing environment and the globalization impact on CC model, lead to the appearance of new consumer trends. Understanding the consumer trends of the younger generation, can help companies, and indicate the best way for future development, and ensure they offer attractive products and services to them. From a managerial perspective, these findings will help to answer the question about the role of age in forming customer segments. Making a deeper analysis about the influence of determining factors such as age, sex and income on the decision to adopt CC, can help managers better understand behavioral characteristics of the younger generation. Among the areas for future research, it is necessary to conduct a more gender balanced survey, to see what influence gender plays in CC.

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References

1. Ajzen, I.: The theory of planned behavior. Organ. Behav. Hum. Decis. Process. **50**(2), 179–211 (1991). https://doi.org/10.1016/0749-5978(91)90020-T
2. Albinsson, P.A., Yasanthi Perera, B.: Alternative marketplaces in the 21st century: building community through sharing events. J. Consum. Behav. **11**(4), 303–315 (2012). https://doi.org/10.1002/cb.1389
3. Alsever, J.: The "mega trend" that swallowed Silicon Valley. CNN Money (2013)
4. Bardhi, F., Eckhardt, G.M.: Access-based consumption: the case of car sharing. J. Consum. Res. **39**(4), 881–898 (2012). https://doi.org/10.1086/666376
5. Belk, R.: You are what you can access: sharing and collaborative consumption online. J. Bus. Res. **67**(8), 1595–1600 (2014). https://doi.org/10.1016/j.jbusres.2013.10.001
6. Bhattacherjee, A.: Individual trust in online firms: scale development and initial test. J. Manag. Inf. Syst. **19**(1), 211–241 (2002). https://doi.org/10.1080/07421222.2002.11045715
7. Bock, G.W., Zmud, R.W., Kim, Y.G., Lee, J.N.: Behavioral intention formation in knowledge sharing: Examining the roles of extrinsic motivators, social-psychological forces, and organizational climate. MIS Q. **29**(1), 87–111 (2005). https://doi.org/10.2307/25148669
8. Botsman, R., Rogers, R.: What's Mine is Yours: How Collaborative Consumption is Changing the Way We Live. Collins, London (2011)
9. Bray, J., Johns, N., Kilburn, D.: An exploratory study into the factors impeding ethical consumption. J. Bus. Ethics **98**(4), 597–608 (2011). https://doi.org/10.1007/s10551-010-0640-9
10. Bucher, E., Fieseler, C., Lutz, C.: What's mine is yours (for a nominal fee)–Exploring the spectrum of utilitarian to altruistic motives for Internet-mediated sharing. Comput. Hum. Behav. **62**, 316–326 (2016). https://doi.org/10.1016/j.chb.2016.04.002
11. Buczynski, B.: Sharing is Good: How to Save Money, Time and Resources Through Collaborative Consumption. New Society Publishers, Gabriola (2013)
12. Buda, G., Pethes, B., Lehota, J.: Dominant consumer attitudes in the sharing economy – a representative study in hungary. Resources **9**(1), 1 (2020). https://doi.org/10.3390/resources9010001
13. Carsharing Market in Russia. Sberbank (2019). https://www.sberbank.ru/common/img/uploaded/files/pdf/analytics/car_28_19.pdf. Accessed 12 Jan 2020
14. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. **13**, 319–340 (1989)
15. Deal, J.J., Altman, D.G., Rogelberg, S.G.: Millennials at work: what we know and what we need to do (if anything). J. Bus. Psychol. **25**(2), 191–199 (2010). https://doi.org/10.1007/s10869-010-9177-2
16. Fornell, C., Johnson, M.D., Anderson, E.W., Cha, J., Bryant, B.E.: The American customer satisfaction index: nature, purpose, and findings. J. Mark. **60**(4), 7–18 (1996)
17. Francis, T., Hoefel, F.: True Gen: Generation Z and its implications for companies. McKinsey & Company (2018). http://innovationinsider.com.br/wp-content/uploads/2019/05/Generation-Z-and-its-implication-for-companies.pdf. Accessed 21 Dec 2019
18. GFK Rus: Global trends and Russian consumer 2017. https://www.gfk.com/fileadmin/user_upload/dyna_content/RU/Documents/Press_Releases/2017/Gfk-Global-Russian-Trends-Sep_2017_Report.pdf. Accessed 28 Dec 2019
19. Godelnik, R.: Millennials and the sharing economy: lessons from a 'buy nothing new, share everything month' project. Environ. Innov. Soc. Transit. **23**, 40–52 (2017). https://doi.org/10.1016/j.eist.2017.02.002
20. Hamari, J., Sjöklint, M., Ukkonen, A.: The sharing economy: why people participate in collaborative consumption. J. Assoc. Inf. Sci. Technol. **67**(9), 2047–2059 (2016). https://doi.org/10.1002/asi.23552

21. Hawlitschek, F., Teubner, T., Gimpel, H.: Understanding the sharing economy–drivers and impediments for participation in peer-to-peer rental. In: 49th Hawaii International Conference on System Sciences (HICSS), pp. 4782–4791 (2016)
22. Hennig-Thurau, T., Henning, V., Sattler, H.: Consumer file sharing of motion pictures. J. Mark. **71**(4), 1–18 (2007). https://doi.org/10.1509/jmkg.71.4.1
23. Josang, A., Ismail, R., Boyd, C.: A survey of trust and reputation systems for online service provision. Decis. Support Syst. **43**(2), 618–644 (2007). https://doi.org/10.1016/j.dss.2005.05.019
24. Kankanhalli, A., Tan, B.C., Wei, K.K.: Contributing knowledge to electronic knowledge repositories: an empirical investigation. MIS Q. 113–143 (2005). https://doi.org/10.2307/25148670
25. Kumar, V., Lahiri, A., Dogan, O.B.: A strategic framework for a profitable business model in the CC. Ind. Mark. Manag. **69**, 147–160 (2018). https://doi.org/10.1016/j.indmarman.2017.08.021
26. Lamberton, C.P., Rose, R.L.: When is ours better than mine? A framework for understanding and altering participation in commercial sharing systems. J. Mark. **76**(4), 109–125 (2012). https://doi.org/10.1509/jm.10.0368
27. Lanier, C.D., Schau, H.J., Muniz, A.M.: Write and wrong: ownership, access and value in consumer co-created online fan fiction. In: Advances in Consumer Research–North American Conference Proceedings, pp. 697–698 (2007)
28. Mahadevan, R.: Examination of motivations and attitudes of peer-to-peer users in the accommodation sharing economy. J. Hosp. Mark. Manag. **27**(6), 679–692 (2018). https://doi.org/10.1080/19368623.2018.1431994
29. Möhlmann, M.: Collaborative consumption: determinants of satisfaction and the likelihood of using a sharing economy option again. J. Consum. Behav. **14**(3), 193–207 (2015). https://doi.org/10.1002/cb.1512
30. Nielsen: What's next in tech? https://www.nielsen.com/apac/en/insights/report/2017/whats-next-in-tech/#. Accessed 12 Jan 2020
31. Owyang, J.: The collaborative economy: Products, services and market relationships have changed as sharing startups impact business models. To avoid disruption, companies must adopt the collaborative economy value chain. Altimeter (2013)
32. Ozanne, L.K., Ballantine, P.W.: Sharing as a form of anti-consumption? An examination of toy library users. J. Consum. Behav. **9**(6), 485–498 (2010). https://doi.org/10.1002/cb.334
33. Park, H., Joyner Armstrong, C.M.: Is money the biggest driver? Uncovering motives for engaging in online collaborative consumption retail models for apparel. J. Retail. Consum. Serv. **51**(11), 42–50 (2019). https://doi.org/10.1016/j.jretconser.2019.05.022
34. Private-Sector Collaboration for Sustainable Development (2018). https://www.bsr.org/reports/BSR_Rockefeller_Private-Sector_Collaboration_for_Sustainable_Development.pdf
35. Rebiazina, V., Shalaeva, A., Smirnova, M.: Do Russian consumers understand and accept the sharing economy as a new digital business model? In: Alexandrov, D., Boukhanovsky, A., Chugunov, A., Kabanov, Y., Koltsova, O. (eds.) DTGS 2018. CCIS, vol. 858, pp. 386–401. Springer, Cham (2018). https://doi.org/10.1007/978-3-030-02843-5_31
36. Rogers, E.M.: Diffusion of Innovations. The Free, New York (1995)
37. Roos, D., Hahn, R.: Understanding collaborative consumption to make collaboration-based organizations meaningful. In: Academy of Management Proceedings, vol. 2016, no. 1, p. 14072. Academy of Management, Briarcliff Manor (2016)
38. Schor, J.B., Fitzmaurice, C.J.: Collaborating and connecting: the emergence of the sharing economy. In: Handbook of Research on Sustainable Consumption, vol. 410 (2015)
39. Schwab, K.: Annual Report 2018–2019. World Economic Forum (2019). http://www3.weforum.org/docs/WEF_Annual_Report_18-19.pdf. Accessed 14 Jan 2020

40. Sharing economy in Russia (2018). RAEK. https://raec.ru/upload/files/riw18-sharing-gubnitsyn-ru.pdf. Accessed 25 Dec 2019
41. Shaw, D., Newholm, T.: Voluntary simplicity and the ethics of consumption. Psychol. Mark. **19**(2), 167–185 (2002). https://doi.org/10.1002/mar.10008
42. Tussyadiah, I.P., Pesonen, J.: Impacts of peer-to-peer accommodation use on travel patterns. J. Travel Res. **55**(8), 1022–1040 (2016)
43. Venkatesh, V., Thong, J., Xu, X.: Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. MIS Q. **36**(1), 157–178 (2012)
44. Wasko, M.M., Faraj, S.: Why should I share? Examining social capital and knowledge contribution in electronic networks of practice. MIS Q. 35–57 (2005). https://doi.org/10.2307/25148667
45. Young, W., Hwang, K., McDonald, S., Oates, C.J.: Sustainable consumption: green consumer behavior when purchasing products. Sustain. Dev. **18**(1), 20–31 (2010). https://doi.org/10.1002/sd.394

Driving Factors of Online Reviews and eWOM in International Hotel Industry

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Abstract. Today online client reviews (OCR) are the crucial factor in choosing the best hotel to visit. However, as the number of reviews sites is growing, tourists tend not to write feedback about their stay, especially when everything was quite good. The aim of the present work is to determine the factors compelling the publication of online reviews by Russian consumers about hotels, they have visited recently, and to suggest methods of increasing their readiness to publish feedback. Quantitative approach (online questionnaire) was applied and based on principal component analysis 9 factors were revealed. People tend to write reviews more often because of desire to help others, satisfactory/unsatisfactory performance of hotel, positive or negative experience, company's policy for reviews, whether it is easy to leave a review and some other incentives. At the end, we developed recommendations for hotels to achieve higher engagement rates for OCR publications from Russian hotel guests.

Keywords: Online reviews · eWOM · Hotels · Russian tourists

1 Introduction

Consumer reliance on online reviews is increasing from year to year. When making a buying decision, reviews are considered as trustworthy as personal recommendations. Online customer reviews are a type of electronic word-of-mouth (eWOM). The growing number of publications in the area of eWOM signifies the flourishing interest in the field [14]. eWOM is defined as consumers' communications about the product, company or service, that is believed to be free of commercial interest [19]. Online reviews have some benefits: as the information is written, easily accessible and can be viewed by people at any time, spread much faster than the traditional WOM [14]. The fact that user-generated content (UGC) on the Web is considered more credible and insightful than marketer-created content was proven by Bickart and Schindler [2]. The results of the Nielsen research [10] show that 9 of 10 people believe the reviews they get from their relatives and close friends. At the same time, 88% of consumers trust online reviews by internet users whom they don't know.

In a situation when the product cannot be assessed without trying it, like in tourism, eWOM is considered to be even more important [19]. In situations when the product is pricey, eWOM also becomes a valuable source of information [5]. Additionally, many

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studies have indicated the significance of online reviews in the process of choosing a hotel [4].

Ye, Law and Gu [32] found out that hotels with higher online ratings get more online bookings. At the first stage of the evaluation process, consumers shortlist the hotels with better ratings. Still, the ratings are only useful when they are reliable. Research by Wang [28] resulted in supporting the hypothesis that consumers are willing to pay more for hotels with a higher number of reviews and better ratings. For this reason, it is important to study ways to facilitate the generation of more reviews.

Even though eWOM has long interested professionals, there is still a gap in theoretical understanding of managing eWOM creation by hotel guests. Moreover, hotel managers and marketing teams do not have complete understanding of factors driving hotel guests to leave online reviews. They are missing opportunities for increasing the amount of eWOM about their services. They also neglect bookings, revenues and guests.

The major purpose of this work is to identify the factors that affect travelers' engagement in writing online reviews and to define the methods of increasing their participation in writing online reviews about the hotels.

The method employed in this work is a survey in the form of an online questionnaire disseminated via travel communities and travel blogs. Principal component analysis was performed in SPSS. Regression analysis was used in order to identify the influence of the established factors on frequency of leaving OCRs, Mann-Whitney and Kruskal-Wallis tests were used to check the differences between guests with different backgrounds. Based on the field research, different methods of facilitating the online reviews of Russian hotel guests were suggested, that can help hotel owners to promote and attract new visitors.

2 Literature Review

2.1 The Essence of eWOM and OCR

Word-of-Mouth (WOM) has different ways to influence consumers: it is becoming the first and most important source of information about the product it affects consumer expectations and post-purchase evaluation. Electronic word-of-mouth is a part of the traditional WOM communication, but it is associated with sharing content online. With the growing use of internet, eWOM emerged to provide much greater coverage and reach to the audience. It has been shown that eWOM can be more credible and provide more value to the customers than traditional marketer-created content on the Web [2].

eWOM can have different origins: experimental, consequential, intentional [5]. Having different forms and originating from different backgrounds, eWOM has a high impact on consumers, brands and buying intentions [22]. The eWOM effect on buying intentions has been discussed in the literature quite often. They can increase sales volumes [34]. Sparks and Browing [24] studied the impact of online reviews on tourists' booking intentions and trust. They managed to confirm that people are willing to book a hotel and they trust a hotel more when the reviews are mostly positive. Moreover, Ye et al. [32] confirmed that a 10% growth in user online reviews increase hotel booking sales by more than 5%. In a long-term perspective eWOM influences the brand equity, which

combines brand awareness, brand association, perceived quality. Vallejo et al. [27] confirmed that high quality reviews directly and positively influence repurchase intentions, increasing customer lifetime value.

Online customer reviews are one of the forms of the electronic word-of-mouth. OCRs and ratings are the most widespread and accessible type of eWOM. As the information is written, it is long-lasting and does not vanish with time. Online messages also spread much faster than the traditional WOM [14]. Online customer reviews can be defined as any positive, negative or neutral comment or ranking of a product, service or brand, presumably made by a former customer and are shared with other consumers in the form of a blog post or published on independent consumer review website (e.g. TripAdvisor.com), third-party e-commerce website (e.g. Booking.com), or corporate website (e.g. Thomson.co.uk) [8]. Consumers use online reviews at every stage of their trip planning, from getting ideas, to finally comparing their experience with others [12].

Overall, online reviews can not only influence sales, but can also provide room for improvement for a long-term success. It is important to find out which factors influence consumer decisions to express their opinions about their hotel stay experiences in order to understand suitable ways for increasing the amount of reviews.

2.2 eWOM and OCR Management

Word-of mouth includes both naturally originating online content and targeted efforts of companies to increase their online presence. Kimberly A. Whitler [30], a former CEO and CMO, suggests that marketers now have to point their attention to the three E's when addressing their customers: Engage, Equip and Empower. It is important to get in conversation with clients, which refers to "Engagement"; surprise them with the level of quality and make them talk about it, which she sees as "Equipment" and give them several ways to share their opinions, which is "Empowerment".

There are many benefits to the word-of-mouth-marketing. It helps to grow sales without spending money on advertising; it builds a community of customers and increases loyalty; it increases customers' lifetime value and brings more funds to the company. However, there are a few aspects that need to be taken into consideration before trying to increase consumer involvement in eWOM. First, companies must provide a great experience with their product or service. Second, they need to have a great website with easy navigation and intuitive and fast process of purchasing. When these conditions are met, additional efforts could be used [29].

There are several ways of facilitating reviews that exist on the market. Firstly, TripAdvisor suggests adding widgets to the hotel website asking for a review. Some companies make virtual spaces on their own websites where consumers can share their brand experience [27]. The second way is distributing reminding cards to the guests at the checkout and sending personalized campaign e-mails in order to ask for the reviews [26].

There are also a few ways of increasing the amount of reviews that are not approved by some review websites but are still widely used. The most detailed insight on facilitating the reviews generation in the hotel business context was provided by Gossling [11]. He found that companies use monetary incentives in the form of free nights and discounts for a review.

It is also important to keep up with the kinds of devices that people are using. In 2018 58% of all website visits were from mobile devices. Hence, mobile-friendly review apps could possibly be of high value in increasing the number of OCRs.

All in all, the marketing methods that could be used to increase the amount of online reviews are following:

- Widgets on the hotel website
- Virtual spaces on the hotel web pages
- Reminding cards
- Reminding e-mails
- Contest
- Discounts and coupons
- Educational brochures
- Mobile applications

Even though there are many methods to increase the amount of reviews posted by the real hotel guests, there is a major trend among businesses, who understand the power of online reviews, to get mock reviews coming not from their real customers.

2.3 Fake Reviews and Responsibility

Fake reviews emerge when businesses pay people, who have never experienced a product, to write a review. These practices should be separated from increasing the amount of reviews from the real guests. This process starts with the creation of a fake identity on a review platform. The Times newspaper in the UK discovered that hotel owners were paying up to £10000 to agencies to improve their travel review rankings [21], the percentage of fake reviews is estimated to be around 15–30% [1]. These practices are deemed unlawful in many countries as they mislead the consumers [17].

Using fake reviews in promoting businesses causes information asymmetry, which can lead to lack of consumer trust about the products and services presented on the market. This increases the purchasing risks and makes the consumers buy only discounted products and services which in turn leads to the decrease in quality of the products presented on the market and overall market deficiency. Promotional reviews affect the level of consumer trust towards purchasing platforms and e-commerce as well [20]. That is why it is in the company's best interest to keep trusting relationships with their consumers and to be socially responsible.

2.4 Factors Driving People to Participate in eWOM Communications

The studies on eWOM have long investigated the will to engage in this type of communication, to leave online reviews and to spread information about the brand, product and experience, from different perspectives.

Positive Experience. The most discussed and investigated topic affecting consumers will to communicate about the brand, product and service is the user's direct experience. This research is primarily focused on assessing differences in post-usage behavior based on

the level of satisfaction with quality of service. One may assume that high-level service and positive experience leads to positive eWOM. Some scholars supported this idea [15] and researched this matter in the restaurant context. The result of the printed survey of college students indicated that superior level of food, service and atmosphere led to the will of spreading positive eWOM. Still, there is no common agreement on the positive experience leading to positive eWOM among scholars.

However, one of the recent works studied positive emotional experiences during a hotel stay as a predictor of eWOM [6]. They identified «emotional experiences» as the ones exceeding expectations and being above «average», including excitement, feeling surprised, feeling energetic. Their work also addressed the question of nationality (German and UK) mediating the positive emotional aspect and eWOM effect on loyalty and brand reputation. The results indicated very strong connection between positive emotions experienced during the stay and company reputation for both nationalities.

Negative Experience. There is more consensus among academics on the effect of negative experiences on leaving online reviews. Low level of service, resulting in dissatisfaction may lead to negative word-of-mouth. Yoo and Gretzel [12] added to the theory by claiming that "venting negative feelings" can lead to negative eWOM. It means that when people are dissatisfied, they want to get rid of the bad emotions and they need to share them. Swanson and Hsu [25] confirmed this statement. They investigated the effect of failure recovery by the service provider on further satisfaction level and eWOM intentions. When there is room for failure recovery, but the service provider ignores it, customers become more motivated to share their negative feelings with others. When the failure is resolved – their negative feelings vanish more easily. Overall, dissatisfied customers are more likely to share their negative feelings with others and warn them not to use the same service.

Performance of the Core and Facilitating Hotel Attributes. In the hotel industry, the customer experience has been studied based on the analysis of the performance of hotel attributes [33]. Slevitch and Oh [23] described core (tangible assets of a hotel: rooms, swimming pool, reservation system etc.) and facilitating (intangible assets: interpersonal connections, entertainment) attributes of a hotel. Yen and Tang [33] found that core attributes play a more significant role in consumer satisfaction and post-purchase behavior, while facilitating attributes are just additional triggers. Their research confirmed that core attribute performance affects the intention to engage in eWOM by leaving online reviews.

Personal and Social Characteristics. A great amount of studies look into different personal characteristics of consumers that influence their intention to share information online. These factors could be divided into two categories: personality-based and social factors. Personality-based factors come from inside the person and are connected with expressing interest in activity for its own sake. The question of motivation has been discussed by many other scholars, who suggested other motives for posting online: e.g. narcissism and status-seeking.

Kim, Jang and Adler [16] suggested several drivers affecting the eWOM communications. Reflected appraisal of self: the way others react to the reviews made by a user

may influence the decision to post online; conspicuous value or the effect of a "snob" – the desire to share the access to expensive goods. The other is self-image congruity when consumer tries to match with the image of a service or product.

Attitude Towards the Company. Self-relevant value, also presented by Kim, Jang and Adler [16], indicates that the feeling of personal connection with the brand results in higher will to communicate about it online. Moreover, it becomes a way of self-expression, when the experience is considered to be of personal significance. Another work examining personal connection with a brand is Hennig-Thurau [13] which established the link between the overall positive attitude to a company with the will to help promote it by spreading eWOM about it. The author called this factor "Helping the company".

Economic Incentives. However, sometimes organic factors do not lead to sufficient amount of user reviews and companies employ additional methods. There is very limited research in this perspective. Economic incentives as motivating factors were mentioned in Hennig-Thurau et al. [13], Yoo and Gretzel [12], Yen and Tang [33] which show a positive correlation between economic incentives and positive eWOM. Kim [16], however, connected the type of experience (positive/negative) with economic incentives and the results were following: consumers were more willing to share negative experiences when given economic benefits. These results contradict previous studies.

The research by Yen and Tang [33] divided the economic incentives into monetary and non-monetary (bonuses, free upgrades, reward points) in the context of two platforms: Facebook and TripAdvisor. The findings showed that economic incentives, both monetary and non-monetary, did not affect the will to post on TripAdvisor, but also had negative effect on the intention to post on Facebook. Hence, there is no common agreement on how economic incentives may influence the will to leave reviews.

Platform. Hennig-Thurau et al. [13] focused on how the platform and its attributes influence the will to post opinions on it. The research showed that only "convenience" and "problem solving support" contributed to the factor, called the "Platform assistance". Overall, we can still see that the platform-associated features influence consumer behavior.

Recognition. The report published by Power Review also showed that 55% of users do not post reviews because they want some reward or recognition in return. While rewards have already been mentioned, recognition is another important topic. In online review context, recognition can be expressed in several ways: replying to reviews, reposting them or liking them. Xie et al. [31] not only noticed that consumer satisfaction increases when the consumer gets an answer from the hotel employees, but they are also more likely to recommend it further.

Search Engine Reputation Management (SERM) is increasing in popularity nowadays. It is a means of managing company image on the Internet. It includes the dissemination of positive brand information on the Internet and addressing the negative information, including responding to the reviews. When hotel representatives respond to the 50% of user reviews, it increases the booking intentions by 24% [4]. So, recognition not only may lead to the increase in number of reviews, but also to the increase

in sales. "Recognition" can therefore be added as another factor that affects consumer behavior.

Demographic Characteristics. There are several demographic characteristics that were examined by academics as those affecting eWOM behavior: gender, age and culture. Even though the study of Duttagupta [7] showed that males are more likely to share negative eWOM and females tend to communicate more positive messages, those correlations were found insignificant. Still, the cultural aspect in this context has been emphasized in several works. Even though the most popular framework for identifying cultural aspects is the Hofstede's cultural dimensions theory, which employs six cultural characteristics: power distance, individualism, masculinity, uncertainty avoidance, long-term orientation and indulgence, the research on the national cultural differences provided ambiguous results. Fong and Burton [9] proved that collectivistic cultures are more willing to "take" online reviews (read rather than write), while individualistic ones depend on the community knowledge less, hence, they are more open to sharing their opinions and "give" eWOM. Leea and Choi [18] investigated the eWOM attitude of USA and Korean users by personal cultural values, assuming that it is wrong to apply the same cultural characteristics to the whole nation. So, they assessed every respondent's exposure to Hofsteads' dimensions. The results indicated that power distance and level of collectivism were the most significant determiners of opinion giving process.

Travel Patterns. Some researchers have found that there are some mediating roles that the hotel type can play in effects and patterns of online reviews. Higher-tier hotel bookings were found to be more affected by the review valence (the tone of the review), while low-tier ones by the volume of reviews [3]. The same pattern was noticed with independent and chain hotels. They concluded that lower level hotels should aim for the number of hotel reviews because ratings of higher-level hotels will usually be higher by default and they will be benefiting from that more. As the difference of online review significance was demonstrated by previous research, we are also interested whether the most visited hotel types influence the review activity in any way.

Overall, the factors described are summarized in the Table 1.

An overview of the literature led us to suggest that there are 9 factors that can compel hotel guests to leave online reviews (Fig. 2): positive and negative experience, core and facilitating hotel attribute performance, personal and social characteristics, economic incentives, recognition, platform and attitude to the company. Our hypotheses are:

H1. Positive experience at a hotel influences the frequency of publication of online reviews.
H2. Negative experience influences the frequency of publication of online reviews.
H3. Core hotel attribute performance influences the frequency of publication of online reviews.
H4. Facilitating hotel attribute performance influences the frequency of publication of online reviews.
H5. Personal and social characteristics of reviewers influence the frequency of publication of online reviews.
H6. Economic incentives influence the frequency of publication of online reviews.

Table 1. Factors affecting eWOM communications

Direct influence		
Factor	Sub-factors	Author
Positive experience	Positive experience, satisfaction	Jeong and Jang [15]
	Positive emotions, "Surprise" factor	Cantallops, Cardona, Salvi [6]
Negative experience	Negative experience, dissatisfaction	Swanson and Hsu [25]
	Venting negative feelings	Yoo and Gretzel [31]
Core hotel attributes performance	Core Hotel attributes performance (including: service quality, atmosphere etc.)	Yen, Tang [33], Jeong and Jang [15]
Facilitating hotel attributes performance	Facilitating hotel attributes (including: education, entertainment, aesthetics etc.)	Yen, Tang [33], Cantallops, Cardona, Salvi [6]
Personal and social based characteristics	Concern for other consumers	Hennig-Thurau [13]
	Extraversion/positive self-enhancement	Hennig-Thurau [13]
	Narcissism	Kim, Jang and Adler [16]
	Status-seeking, "snob" effect	Kim, Jang and Adler [16]
	Conscientiousness	Kim, Jang and Adler [16]
	Openness to experience	Kim, Jang and Adler [16]
	Reflected appraisal of self	Kim, Jang and Adler [16]
	Self-image congruity	Kim, Jang and Adler [16]
Attitude to the company	Self-relevant value	Kim, Jang and Adler [16]
	Helping the company	Hennig-Thurau [13]
Economic incentives	Monetary	Hennig-Thurau [13], Yoo and Gretzel [12], Yen and Tang [33], Gossling [11]
	Non-monetary (Personal request, E-mail request, Small gift, Reward, Discount, Free night)	Gossling [11], Yen and Tang [33]
Platform	Moderator-related utility: convenience, problem-solving support and power of the group	Hennig-Thurau et al. [13]
Recognition	Responses to the reviews	Xie et al. [31]

(*continued*)

Table 1. (*continued*)

Direct influence		
Factor	Sub-factors	Author
	Sharing and liking reviews	Xie et al. [31]
Demographic characteristics	Age	Duttagupta [7]
	Gender	Duttagupta [7]
	Cultural dimensions	Leea and Choi [18]
Travelling patterns	Hotel price category	Blal and Sturman [3]
	Hotel belonging to the chain	Blal and Sturman [3]

Source: compiled by the authors.

H7. The will of recognition influences the frequency of publication of online reviews.
H8. Platform features influence the frequency of publication of online reviews.
H9. Attitude to the company influences the frequency of publication of online reviews.

We also suppose that travelling patterns and demographic characteristics may influence the level of engagement in writing OCRs.

H10. Demographic characteristics influence the level of engagement in eWOM in the form of OCRs.
H11. Travelling patterns influence the level of engagement in eWOM in the form of OCRs.

3 Methodology of Research

3.1 Model Description

The 9 factors, demographic and travel pattern characteristics that may lead to writing online reviews are examined using an online questionnaire with Russian and CIS country residents, who have traveled abroad and stayed at the hotel (Fig. 1).

The questionnaire consisted of a filter question and five blocks. The filter question was implemented in order to exclude those respondents, who have never stayed at a hotel abroad for the last 2 years. The first block of questions assessed the respondents' travelling patterns and preferred hotel types. The questions were designed on the basis of the literature analysis concerning the different review pattern types for different types of hotels. Second block was dedicated to the factors that affect the will to leave online reviews about hotels abroad. It consisted of 37 total items designed to assess the presupposed factors on the basis of the literature review. Five-point Likert scale ranging from 5 (strongly agree) to 1 (strongly disagree) asking respondents to indicate the extent of their agreement or disagreement with each item was used to measure each construct; therefore, a higher motive score indicates stronger motive agreement. The third block was aimed to assess the reasons for not leaving reviews. The questions in this block were

Fig. 1. Research framework (source: compiled by the authors).

logically interpreted from the factors defined for the second block as well as formulated on the basis of the existing method of facilitating reviews in order to assess their validity. Fourth section of the questionnaire assessed the overall trust in and usage of review platforms in order to identify the most valuable platform for the hotel business, and the fifth block was dedicated to the demographic characteristics.

3.2 Respondent Profile

In total 2710 respondents were reached through online travel communities on popular Russian travel websites and travel blogs on social networks, the questionnaire was voluntary, so it was answered randomly by the participants of a special community or subscribers of a travel blog. 1906 of respondents have traveled abroad and stayed at a hotel there. 1077 of them said that they leave reviews about hotels from time to time and 829 of them never leave online reviews, so they were asked to fill only the relevant parts of the questionnaire, starting from the third block.

Those who leave reviews are predominantly females (almost 65%), two biggest group ages are 19–25 y.o. (almost 67%) and 26–35 y.o. (almost 21%), the respondents

are mainly students (around 40%) and Managers/Specialists (around 30%). Their income could be mostly defined as upper-middle class because the biggest group is represented by people who can readily afford anything except expensive cars. They mostly assign themselves to the low power distance cultural dimension (85%), collectivism/individualism was equally distributed among the respondents (50%/50%). The main reason for travelling is Tourism (97%). Most of them do not care which type of hotel to stay in (chain or individual) (77%), most of the respondents stay at hotels ranked 3* or more (96%).

3.3 Data Analysis

Kruskal-Wallis and Mann-Whitney tests were performed in order to assess whether demographic characteristics or travelling patterns influence the frequency of posting online reviews. The influence of gender was found insignificant (Sig. = 0,240), while age was a significant factor (Sig = 0,021). The results indicated that older people leave reviews more often. Low power distance was also a significant (Sig. = .000) predictor of higher frequency of reviews, while individualism was found insignificant (Sig. = .187). Among the travelling patterns, the significant one was the preferred hotel type (Sig. = .021). Those who usually stay in the non-chain hotels post reviews more frequently. Reasons for travelling (Sig. = 0.73) as well as the star ranking of the hotel preferred (Sig. = .202) did not show the influence on the frequency of posting reviews. Hence, Hypothesis 10 and 11 are partly supported.

To check the other hypotheses concerning the factors that influence the level of engagement in writing online customer reviews, the 38 items were analyzed in IBM SPSS using principal component analysis (PCA) to explore the dimensionality of the item sets. The validity of the data for this type of analysis was confirmed by the Kaiser-Meyer-Olkin (KMO) test (0.882), which is defined as acceptable level because it is higher than the threshold of 0,5 and level of significance is .000.

Based on Kaiser's eigenvalue criterion, 9 factors were extracted using the latent roots criterion and a Varimax rotation. The extracted factors explain 64,38% of variance.

The internal consistency and reliability of the factors were checked with Cronbach's α values. 3 factors demonstrate strong reliability ($\alpha > 0{,}79$) [13], 4 factors show acceptable reliability ($\alpha > 0{,}70$) while others could be accepted as their values are near .60, especially if the factor has only few items, which is the case of factor 5. So, we can conclude that factor consistency in this model is not perfect, however, highly acceptable. The factors are presented in the table (Table 2).

6 of 9 factors represent exactly the theoretically derived sub-factors: Factor 1 – Core hotel attribute performance; Factor 6 – Platform; Factor 8 – Facilitating attribute performance; Factor 9 – Negative experience, however, social and personal characteristics were divided into two factors: Factor 1 – Personal social benefits and Factor 7 – Helping others. Three other factors represent the composition of several sub-factor groups. Factor 3 – Incentives, including all the monetary incentives as well as personal request from the hotel staff; Factor 4 – Positive experience and good company attitude including overall positive experience which results in the will to help the company and Factor 5 – Company's Interest in reviews and recognition which could be described as the visible actions of the company, showing their clients that they care.

Table 2. Factor structure composition

Factor N	Factor title	Cronbach's alfa
1	Core hotel attributes performance	0,866
2	Personal social benefits	0,862
3	Incentives	0,837
4	Positive experience and good company attitude	0,728
5	Company's interest in reviews and recognition	0,678
6	Platform	0,703
7	Helping others	0,736
8	Facilitating hotel attributes performance	0,704
9	Negative experience	0,488

To understand the level of importance of the factors defined for leaving online reviews, a linear regression analysis is run with the frequency of leaving online reviews as a dependent variable. According to the model summary, the model explains 16% of the variance, the null hypothesis about the equality of the variances is rejected, since significance is <0.05 (F-value is 22,86), hence, we consider the model adequate.

All the defined factors have a significant influence (Table 3). Based on unstandardized beta coefficient the strongest positive influence on the frequency of writing online reviews have the factors: 7 – *Helping others* and Factor 1 – *Core hotel attributes performance*, as well as Factor 5 – *Company's interest in reviews/Recognition* and Factor 4 – *Positive experience*. However, the significant negative influence is shown by two Factors: Factor 3 – *Incentives* as well as Factor 8 – *Facilitating hotel attributes performance*. This indicates that the those who leave reviews less often do it mostly because of the incentives, while those who review more often, do not consider this factor important. Factor 8 consists of additional services and features of the hotels. We can only suppose that the inverse relation is due to the fact that those, who leave reviews more often, stay at the hotels with no such additional attributes or they do not pay much attention to this fact, while those who review less often are affected by this factor. The coefficients output (collinearity statistics), indicates that the VIF values obtained are equal to one, which indicates the absence of Multicollinearity (VIF should be between 1 and 10 in order to decline the multicollinearity) and confirms the adequacy of the regression analysis. Moreover, Durbin–Watson statistic is 2,02, which is between 1,5 and 2,5 and indicates lack of the autocorrelation.

Hence, we have managed to define the factors that affect the level of engagement of people who leave reviews more often and less often. Overall, hypotheses 1–9 were supported.

After determining why people leave online reviews, it is important to understand why they do not do that. The survey indicated that the main reasons are that the respondents "do not want to spend time on it" and "they forget about it". The respondents also stated that when they liked everything at the hotel, they do not see any point in writing about it.

Table 3. Factor-score regression results

Factor N	Factor title	Writing reviews frequency regression coefficient (St.)
1	Core hotel attributes performance	.164**
2	Personal social benefits	.087*
3	Incentives	−.107**
4	Positive experience and good company attitude	.123**
5	Company's interest in reviews and recognition	.151**
6	Platform	.107**
7	Helping others	.182**
8	Facilitating hotel attributes performance	−.155**
9	Negative experience	.066*
	R^2	.16

** Significant at $p < .001$, * Significant at $p < .05$.

Before running the regression analysis of the reasons for not leaving reviews, we check the interdependence of the reasons that are supposed to be used in the regression analysis. Based on the Pearson correlation coefficients, they show significant, but low influence on each other. Then, we also check the VIF values to make sure that there is no multicollinearity in the regression model. Regression analysis is run with the frequency of posting online reviews to assess the significance of the stated above reasons. The model summary indicates that the model explains 21% ($R^2 = .21$) of variance and the null hypothesis about the equality of the variances is rejected, since significance is <0.05 (F-value is 43,59), hence, we consider the model adequate. Moreover, Durbin–Watson statistic is 1,952, which is between 1,5 and 2,5 and indicates lack of the autocorrelation.

Thus, the regression equation is:

$$y = 0,06 * x_1 - 0.047 * x_2 - 0.236 * x_3 + 0.099 * x_4 - 0.107 * x_5 + 2,79 \quad (1)$$

Where:

y – frequency of writing online reviews; x1 – Forgetting about it; x2 – Platform Inconvenience; x3 – No interest; x4 – Not liking the hotel; x5 – Liking the hotel and not seeing the point.

Overall, we have identified the factors that affect the frequency of writing online reviews about hotels. We have also established the reasons for not doing so, which have significant negative influence on the frequency of eWOM in the form of OCRs.

4 Managerial Implications and Conclusions

The major findings of the present study indicate that older and younger age groups tend to leave more online reviews. Middle-age group is the least engaged in leaving online reviews. Low-power distance exposed travelers tend to leave more reviews than those with higher distance, which corresponds to the results of the studies made by Leea and Choi (2019). People, who tend to stay in the non-chain (independent) hotels post online reviews more often. Besides, those who review more often do it to help others and because of great hotel attribute performance. Positive experience, as well as understanding of company's interests in the feedback also have a great contribution. That is why it is important for the hotels to provide good service and perform their core operations in the best possible way. It should be noted that sometimes guests leave reviews only because of incentives such as bonuses and discounts, however, it can be deemed undesirable by leading review platforms.

Moreover, employee training, creating client communities, implementing mobile-friendly apps for reviews etc. can help facilitate OCRs and improve hotel brand image and number of clients.

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References

1. Belton, P.: Navigating the potentially murky world of online reviews. BBC (2015). https://www.bbc.com/news/business-33205905
2. Bickart, B., Schindler, R.M.: Internet forums as influential sources of consumer information. J. Interact. Mark. **15**(3), 31–40 (2001)
3. Blal, I., Sturman, M.C.: The differential effects of the quality and quantity of online reviews on hotel room sales. Cornell Hosp. Q. **55**(4), 365–375 (2014). https://doi.org/10.1177/1938965514533419
4. Blieva, A., Skvortsova, A.: Improving the competitiveness of hospitality enterprises based on the analysis of online complaints and customer reviews of hotel chains. Russ. Reg. A Look Into The Future **1**(6), 124–135 (2016)
5. Bughin, J., Doogan, J., Vetvik, O.J.: A new way to measure word-of-mouth marketing. McKinsey Q. (2), 113–116 (2010)
6. Serra-Cantallops, A., Ramon-Cardona, J., Salvi, F.: The impact of positive emotional experiences on eWOM generation and loyalty. Span. J. Mark. **22**(2), 142–162 (2018). https://doi.org/10.1108/SJME-03-2018-0009
7. Duttagupta, A.: To study gender as a factor impacting E-word of mouth amongst E-retail consumers in West Bengal, vol. 17, pp. 228–235 (2017)
8. Filieri, R., McLeay, F.: E-WOM and accommodation: an analysis of the factors that influence travellers' adoption of information from online reviews. J. Travel Res. **53**(1), 44–57 (2014). https://doi.org/10.1177/0047287513481274
9. Fong, J., Burton, S.: A cross-cultural comparison of electronic word-of-mouth and country-of-origin effects. J. Bus. Res. **61**(3), 233–242 (2008). https://doi.org/10.1016/j.jbusres.2007.06.015

10. Global trust in advertising and brand messages. Nielsen (2012). https://www.nielsen.com/us/en/insights/reports/2012/global-trust-in-advertising-and-brand-messages.html
11. Gössling, S., Hall, C., Andersson, A.: The manager's dilemma: a conceptualization of online review manipulation strategies. Curr. Issues Tour. **21**(5), 484–503 (2016). https://doi.org/10.1080/13683500.2015.1127337
12. Gretzel, U., Yoo, K.H.: Use and impact of online travel reviews. In: O'Connor, P., Höpken, W., Gretzel, U. (eds.) Information and Communication Technologies in Tourism (2008). https://doi.org/10.1007/978-3-211-77280-5_4
13. Hennig-Thurau, T., Gwinner, K., Walsh, G., Gremler, D.: Electronic word of mouth: motives for and consequences of reading customer articulations on the internet. Int. J. Electron. Commer. **4**, 51–74 (2003). https://doi.org/10.1080/10864415.2003.11044293
14. Huete-Alcocer, N.: A literature review of word of mouth and electronic word of mouth: implications for consumer behavior. Front. Psychol. **8**, 138–175 (2017). https://doi.org/10.3389/fpsyg.2017.01256
15. Jeong, E., Jang, S.: Restaurant experiences triggering positive electronic word-of-mouth (eWOM) motivations. Int. J. Hosp. Manag. **30**(2), 356–366 (2011). https://doi.org/10.1016/j.ijhm.2010.08.005
16. Kim, D., Jang, S., Adler, H.: What drives café customers to spread eWOM? Emerald Group Publishing Limited (2015). https://doi.org/10.1108/IJCHM-06-2013-0269
17. Lappas, T., Sabnis, G., Valkanas, G.: The impact of fake positive reviews on online visibility: a vulnerability assessment of the hotel industry. Inf. Syst. Res. **27**(4), 940–961 (2016). https://doi.org/10.1287/isre.2016.0674
18. Leea, K., Choi, H.: Predictors of electronic word-of-mouth behavior on social networking sites in the United States and Korea: cultural and social relationship variables. Comput. Hum. Behav. **94**, 9–18 (2019). https://doi.org/10.1016/j.chb.2018.12.025
19. Litvin, S., Goldsmith, R., Pan, B.: Electronic word-of-mouth in hospitality and tourism management. Tour. Manag. **29**, 458–468 (2008). https://doi.org/10.1016/j.tourman.2007.05.011
20. Mayzlin, D., Dover, Y., Chevalier, J.: Promotional reviews: an empirical investigation of online review manipulation. Am. Econ. Rev. **104**(8), 2421–2455 (2014). https://doi.org/10.2139/ssrn.2128860
21. McCracken, C.: Businesses who commission fake reviews should worry about more than just illegality. Out Law. https://www.out-law.com/page-12016
22. Saleem, A., Ellahi, A.: Influence of electronic word of mouth on purchase intention of fashion products on social networking websites. Pak. J. Commer. Soc. Sci. **11**(2), 597–622 (2017)
23. Slevitch, L., Oh, H.: Asymmetric relationship between attribute performance and customer satisfaction: a new perspective. Int. J. Hosp. Manag. **29**(4), 559–569 (2010). https://doi.org/10.1016/j.ijhm.2009.09.004
24. Sparks, B., Browning, V.: The impact of online reviews on hotel booking intentions and perception of trust. Tour. Manag. **32**(6), 1310–1323 (2011). https://doi.org/10.1016/j.tourman.2010.12.011
25. Swanson, S.R., Hsu, M.K.: Critical incidents in tourism: failure, recovery, customer switching, and word-of-mouth behaviors. J. Travel Tour. Mark. **26**, 180–194 (2009). https://doi.org/10.1080/10548400902864800
26. The TripAdvisor Incentives Policy: Why Rewarding Traveler Reviews Is Against The Rules. https://www.tripadvisor.com/TripAdvisorInsights/w591
27. Vallejo, J.M., Redondo, Y.P., Acerete, A.U.: The characteristics of electronic word-of-mouth and its influence on the intention to repurchase online. Eur. J. Bus. Manag. Econ. **24**, 61–75 (2015)

28. Wang, S., Cunningham, N., Eastin, M.: The impact of eWOM message characteristics on the perceived effectiveness of online consumer reviews. J. Interact. Advert. **15**, 151–159 (2015). https://doi.org/10.1080/15252019.2015.1091755
29. Warren, M.: Word of mouth marketing in 2019: how to create a strategy for social media buzz & skyrocket referral sales (2019). https://www.bigcommerce.com/blog/word-of-mouth-marketing
30. Whitler, K.A.: Why word of mouth marketing is the most important social media. Forbes (2014). https://www.forbes.com/sites/kimberlywhitler/2014/07/17/why-word-of-mouth-marketing-is-the-most-important-social-media/#46c1458354a8
31. Xie, K.L., Zhang, Z.: The business value of online consumer reviews and management response to hotel performance. Int. J. Hosp. Manag. **43**, 1–12 (2014)
32. Ye, Q., Law, R., Gu, B., Chen, W.: The influence of user-generated content on traveler behavior: an empirical investigation on the effects of e-word-of-mouth to hotel online bookings. Comput. Hum. Behav. **27**(2), 634–639 (2011). https://doi.org/10.1016/j.chb.2010.04.014
33. Yen, A., Tang, C.: The effects of hotel attribute performance on electronic word-of-mouth (eWOM) behaviors. Int. J. Hosp. Manag. **76**, 9–18 (2019). https://doi.org/10.1016/j.ijhm.2018.03.006
34. York, A.: 8 ways to get more reviews from your customers right now. Power Reviews (2019). https://www.powerreviews.com/blog/how-to-get-more-product-reviews
35. Zhu, F., Zhang, X.: Impact of online consumer reviews on sales: the moderating role of product and consumer characteristics. J. Mark. **74**, 133–148 (2010). https://doi.org/10.1509/jmkg.74.2.133

E-Humanities: Digital Culture and Education

Digital Museum Transformation: From a Collection of Exhibits to a Gamut of Emotions

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Abstract. Today art museum is facing the challenge of adapting it's mechanisms of keeping and presenting the works of art to spectators belonging to the communication society. Therefore, a museum gets more and more engaged in the process of digitalization using such newer technologies as internet of things, virtual reality, artificial intelligence, bid data design etc. The aims of a museum are currently shifting from traditional keeping the art pieces and studying them to—developing a scientific networks, announcing the highlights in social media and creating platforms which present digitalized pieces online allowing a viewer to collect the information through the web, moreover, an offline visit could be guided by a specified application customized to fit the necessitates of each user. An art institution today is supposed to be flexible and democratic enough to create an engaging, immersive area for a visitor to interact with, in other words, we argue that a museum armed with newer technologies is supposed not only a to secure and present the works of art but also to incorporate these pieces into the bigger flux of information, make them visible and important to viewers, to create the conditions for a lasting dialogue. We argue that this process involves not only the technical development of a museum, but also a new approach no narration of art history.

Keywords: Museum · Contemporary art · Technology · VR · AR · Internet of things · Archive · Cultural institutions · Curatorship · Multisensory environment

1 Introduction

The transition from an information society to a communication one that has taken place in recent years has led to large-scale changes in many areas of human activity, including culture. The functions of various cultural and educational institutions have changed, new formats of their interaction with the audience have appeared, brand-new platforms on which the activities of a museum, gallery, or festival can take place have emerged [1]. Communication processes related to the transfer of knowledge and information are being carried out today not only in educational institutions but also in libraries, theatres,

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archives, museums, and art spaces, as well as on their virtual "equivalents" such as web sites, social media pages, and specialized mobile applications. The explosive growth of information in the field of culture forces viewers to control and filter their news feeds more thoroughly and find relevant data. Professionals - curators, art critics, lecturers, artists, etc. – are now to develop effective communication strategies and new tools to retrieve and structure relevant information and offer the best means to report it to consumers of the cultural product.

In this study, we set out to analyze the changes taking place in art museums, spurred on the one hand by the expectations of the audience, and on the other hand, new opportunities for the development of digital technologies open up. The focus of our attention is precisely on the museum (and in some cases – galleries) of fine arts, since this is the most visited type of museum and it is here that digital transformation is proceeding at an accelerated pace, since the cultural and aesthetic demands of the audience are changing significantly due to general trends in the field of communication. Our research is based on both systematic research in the field of museology and the described experience of art museum employees directly involved in the process of digital transformation, we will argue that today there is a large-scale transformation of the idea of the museum itself. Previously, the emphasis was placed on storing and displaying exhibits, and today, the communicative aspect becomes more important [2]. One of the significant cases for our analysis will be the renewal of the Pushkin State Museum of fine arts, which is one of the critical art museums in Russia, combining ancient and modern art in its collection, as well as focused on the use of the latest technologies and following the trends adopted in the international art and Museum community. The museum is becoming a more open, flexible and interactive space, aimed not only at giving viewers access to certain items and information about them but also to captivate the viewer and form an absolute "gamut of emotions," which includes both the building itself and its virtual continuation.

In this article, we will consider examples of the use of advanced information technologies for the formation of a modern Museum exhibition space within the framework of the multisensory environment concept [3–7]. The use of virtual, augmented reality, artificial intelligence, Internet of things technologies in the formation of the museum space gives rise to a lot of interdisciplinary scientific issues that are at the intersection of design, art, museum businesses, and information technology. Thus, our research is empirical, focusing on the relationship between technological solutions and the humanitarian tasks of a modern art museum, focused on the storage of antiquities and the non-exhibition of modern art. Our analysis necessarily involves a review of the most effective digital technologies involved in transforming the traditional museum space into a multisensory, inclusive environment that is open to intensive interaction with the viewer and has a "media expansion" in the global space network. Besides, this research presupposes a systematic analysis of how digital transformation is related to the fundamental research and educational tasks of the museum, which in the XXI century require rethinking due to changes in the communication society and the place of culture in it, as well as the updated continuously requests of viewers focused on multimedia consumption of information [8].

Working on present research we are considering several key concepts that go as follows:

1. *Digitalisation of museum oeuvre and archive* – by the means of the latest technologies, museum staff apply new methods of collecting, storing and organizing information about works of art. This work is primarily related to the aims of preservation and study of cultural heritage.
2. *Digital transformation of a museum* – systematic reformation in the structure and functions of the museum under the influence of digital technologies. This process significantly affects the communication with the audience, new ways of presenting objects of the museum collection are being developed.
3. *Big data management* – a museum is not only accumulating information about the preserved objects but also is constantly monitoring both the behavior of visitors and the requests of an ever expanding audience. With the help of digital technologies, this data gets processed and later it forms the basis for the development of more effective curatorial strategies.

*еще надо как-то вот это прояснить:communicative interactions and educational/scientific activities. That is, interaction with exhibits and interaction with information are two different things

4. *Communication society* as a term reveals the features of contemporary globalized community where digital interaction and communication is structuring anew all types of social activities. Unlike to the previous period named "information society" where the usage, creation and distribution of information became a socially and economically significant activity, current communication society requires not passive recipients but participating users, digitally active citizens of a globalized world.

2 Contemporary Museums Facing Technological Challenges

A new cultural product has a hybrid character and combines traditional artistic mediums and the latest information and communication technologies [9]. Modern museums and interactive exhibitions suggest this trend most clearly and visibly. Museums' digital transformation has experienced steady progress over the last decade. These processes are now greatly intensified by improving the software and, secondly, enhancing audience requests to the technical equipment of the museum the virtual extension. Thirdly, due to the "line shock" that emerged amid the spread of a new coronavirus infection and the associated stringent security measures, suddenly forcing the museum to "virtual serve" to maintain and strengthen the connection with the audience.

In this regard, the problem of adaptation of museum mechanisms for storing and presenting art to the audience of the communication society is of particular relevance today. Therefore, the museum is increasingly involved in digitization using new technologies such as mobile applications, virtual and augmented reality, artificial intelligence, the Internet of things, and data design, which we consider the critical technologies used in a new "expanded museum."

Museum's functions are now way beyond the traditional storage of works of art, their study, and display. A museum today, as an art institution, offers a viewer new formats of communication and knowledge acquisition. Museum's scientific networks are

developing, their activities are highlighted in social media networks (short sci-fi posts about significant artifacts, exhibitions, and events appear daily on the museum's pages, lectures and workshops are broadcast online reaching a growing audience). Moreover, large-scale digital platforms are created to present digitized materials on the Internet, for example, the "Artefact" app, allowing the viewer to gather information in a virtual environment and build their collection. The concept of an "imaginary museum" described by Andre Malraux has now become a reality for every user. In addition, we offer specially designed applications created per the needs of each independent museum visitor. It primarily includes guides, which are available in the form of individual players with headphones, as well as mobile applications such as "Izitravel". Specially printed on 3D-copies of the works of art, virtual exhibitions, and tours of this digital space enable physically challenged visitors to feel and explore them.

In recent years, there has been increasing attention to digital museum transformation and the use of technology in exhibitions [9, 10]. In this article, we continue to study the problem of using innovative technologies, including information and communication technologies, as a useful tool for artistic and socio-cultural practices in the context of the development of cultural industries that require understanding the possibilities of their practical use in a communication society.

A modern art museum is supposed to be flexible and democratic enough to create a fascinating, exciting atmosphere for the visitor to interact with [11]. The immersive component comes to the foreground, since the modern viewer is no longer limited to the role of a passive recipient of a narrative, but strives for interactive communication, for understanding art through some interaction with it. This trend is manifested at a basic level in the way a museum visitor "curates" their pages in "Pinterest" and posts in "Instagram" mini-reports on the visit of a particular exhibition. However, these processes can be actively involved in the initiative of the exhibition site itself. For example, in the course of Jean-Hubert Martin's project "Carambolage" which was a large-scale visual study where works of art and material culture related to entirely different chronotypes collided. Besides, they happened to have unexpected similarities and therefore opened up new research prospects and consequently invited the viewers to participate in this process by comparing virtual "doubles" of the works presented at the exhibition and thus continuing the so-called "game" in discovering unexpected connections between different cultural layers. Taking a closer look at this case, it is a kind of billiard stroke in which the cue ball (the hit ball) makes a consecutive collision with two other shots the player is aiming at, accordingly. Jean-Hubert Martin acted as a billiard player, choosing a particular work of art and then "hitting" it with two other similar ones, but not historically related art objects. The exhibition space was designed in such a way that the viewer could see these unexpected coincidences due to the placement of art objects in the same showcase, which is a traditional, chronologically arranged exhibition that could not possibly be together. The show is supplemented with the directory, including the "threesome." However, even more, notable was the website of "Carambolage" and the eponymous mobile app, where not only curatorial idea is revealed to the audience in every detail, but also a continued dialogue is established: a visitor can find and compare art objects applying Martin's principle and may adopt this methodology to their studies.

Taking into consideration a steady interest in the format of visual research in today's humanitarian scientific field, we can assume that the web version of "carom" may end up even more resonant than the original exhibition. It is important to note that this project was not the first experiment of its kind since many art historians who specialized in iconology, structural analysis, and semiotics developed art research projects based on formal criteria, certain visual parallels, and "rhymes." The most famous of these ideas are described in the works of Andre Malraux [12], Abi Warburg [13], Erwin Panofsky [14], Ernst Gombrich [15] and other contemporary researchers [16, 17]. Jean-Hubert Martin's curatorial projects are an example of the practical implementation of these concepts in the museum halls. However, structural analysis and the creation of collections based on formal features have reached a new level thanks to artificial intelligence; thus, the Google Art Project platform is currently opening more and more sections devoted to visual research. For example, an experiment called "X Degrees of Separation" comes down to the following: the user selects two works of art as two poles, and the machine based on visual analysis selects a "palette" of similar art objects located between these two specified points. The pool of such experiments is continuously expanding. The viewer working with the Google Art Project is no longer just a consumer of a cultural product, but a user-researcher who actively studies the phenomena and contexts of art history, accordingly. The principles of curatorship are increasingly integrated into the independent work of each visitor's perception of the cultural site. In 2020, Jean-Hubert Martin is planning to hold a project at the Pushkin State Museum of Fine Arts. Structurally reminding of "carom," under the working title, "The Ancients stole all our ideas," it is very likely that the interactive component will be core here as well.

Now The Pushkin Museum pays excellent attention to working with the audience. Head of IT department, Vladimir Opredelenov, in his speech at the eNano site noted the statistics of mentioning trends in the professional literature and highlighted such technologies as virtual reality, artificial intelligence, big data processing, virtual assistants, blockchain and machine learning. Further, he revealed the results of a survey of Muscovites about what technologies they would like to see integrated into the museum space. Virtual and augmented reality, virtual assistants, mobile applications, 3D graphics, and modeling topped the list. According to the results of this survey, a specific agenda was formed including the task of integrating information about the museum and its exhibits into the systems of virtual assistants (such as "Alice" created by Yandex), which will serve as mediators for users in the future [18].

Thus, we argue that a museum armed with new technologies should not only present works of art and provide specialists with access to the maximum possible amount of information about stored objects, but also include these parts in a more abundant flow of information, make them visible to the audience, to create conditions for a lasting dialogue [19, 20]. We also state that this process involves not only the technical development of the museum but also the development of a new approach without telling the history of art.

It should be noted that the Pushkin Museum adapted to the crisis that arose in connection with the spread of new coronavirus infection in 2020. As soon as the quarantine measures were introduced in Russia, meaning that the museum was closed entirely to

visitors, not only did it keep research and educational activities, but also increased its intensity. Among the most effective measures taken by the museum are the following:

1. virtual tours on the Zoom platform, which involved the recruitment of a limited number of spectators, who were invited by the guide to evaluate a virtual copy of the Museum halls, accompanied by an interactive video with stories about the exhibits and a discussion;
2. open and free lectures on art: both Museum employees and invited specialists were involved in this project. The broadcasts were conducted in real-time and actively promoted on social networks;
3. «Ask the curator» project, which involves a series of meetings with the museum's curators, narrow-profile specialists, to whom everyone could ask questions about the most valuable exhibits;
4. Olga Viktorovna Shishko curated the project "100 ways to live a minute", in which artists, curators, and researchers of modern art recorded short analytical videos about the category of time in modern culture [21]. In parallel, a large-scale media program unfolded, during which several dozen broadcasts of works of video art and experimental cinema took place.

Due to that they have been keeping constant track of their audience's demand and expectations Pushkin Museum specialists quickly identified the growing call for educative and aesthetically entertaining content: before the "Lockdown" youtube channel of Pushkin Museum introduced 5–7 videos per month and during the spring-summer of 2020 there has been appearing 40–50 videos per month. Furthermore, on the Facebook page of the museum reveals lectures, webinars and short educative videos several times a day.

Analyzing this case, we could outline a certain trend: digitalization of museum archives and creation of online content which have been gradually performed throughout the last 15 years built up the base for a digital transformation of Pushkin Museum. Having faced the "Lockdown" art museum immediately switched all its activities to online formats – and introduces some new ones. The above-mentioned project "100 ways to live a minute" united video art and media art pieces from various collections around the globe, virtually exhibiting oeuvre that would be almost impossible to see together in any international Biennale of art fair. The team of Olga Shishko thus presented new media art – by the means of new media (and we could point out that Russian was initially not too familiar with this type of pieces). In this case the "Lockdown" turned out to be a resourceful moment. So, using creatively the newer technologies Pushkin Museum has been "holding the line" on both scientific and educative interactions with the committed viewers and reaching out for a wider audience.

Similar measures were taken in other museums and centers of contemporary art in Russia, which corresponds to international trends [22]. Museums such as the Metropolitan Museum of art, the Louvre, the Prado, the Tate, and other vital sites have strengthened their media presence during the quarantine, proving the feasibility and effectiveness of digital transformation of cultural sites.

In the course of the development of the information society, cultural and educational institutions are responsible for a vast amount of tasks. Modern people are constantly

absorbing information. It is no coincidence that today the generation of «sciensters» is viral, young people are passionate about scientific knowledge, book markets marked an unprecedented growth in sales of popular science books. More and more channels devoted to science appear on such platforms as "Youtube" and other social media networks, but with new and useful information, there is still much unnecessary random material. The current educational institutions, libraries, theaters, archives, and galleries have unique data and must present it so that the viewer-user can get valuable knowledge. The concept of "curator" in this area goes to an entirely new level in the processing of big data and their correct presentation. Among such institutions is a museum. It is necessary to continually analyze changes in the cultural field to remain relevant to the consumer, note what the museum was like, how it transforms, what trends are most suitable for its development, and how its visitor has changed.

In our world, non-traditional museums are of increasing interest to visitors. In a rapidly changing society, museums have to adapt more quickly to a new system of understanding the world. The preservation of all the material available in a traditional museum is not exactly favorable for attracting new visitors and making them want to return. In such a museum, almost nothing changes; all the items on display are in their places. However, the traditional museum has its positive aspects. In such museums, the structure is clear and understandable to the viewer, and some visitors with conservative views have a desire to return to the museum with a permanent exhibition. It is convenient for a long and detailed study of the material, natural movement through the halls among famous expositions, and employees. One must never forget that digitizing works of art and placing information about them in databases is an essential tool for inter-museum communication and a means of establishing systemic international research projects [23].

3 AR, VR, and IoT in Exhibition Space

Modern society does not exclude mixed museums with their traditions and customs, but at the same time, it is trying to "upgrade" itself. These can be various temporary exhibitions or partial changes, as well as stationary expositions, additional seminars, training programs, and further work with the visitor.

The multimedia approach to the dissemination, communication, and exploitation of cultural heritage is a recognized trend worldwide. Several studies [24–28] demonstrate that the use of new and combined media improves the perception of culture. The advantage lies in the number of people with access to information and the quality of data dissemination. In this regard, it uses augmented, virtual, and mixed reality technologies for various purposes, including education, improving exhibitions, research, reconstruction, and virtual museums. These technologies provide a user-oriented view and make cultural heritage available digitally, especially when physical access is limited. Besides, museums offer technological and digital opportunities to improve the experience of visiting.

The convergence of digital technologies such as the Internet of things, virtual and augmented reality, artificial intelligence, big data, and machine learning allows us to entirely modify the approach to the organization of the exhibition space, based on data from social networks of visitors to the exhibition space, in which users describe, evaluate

and distribute information about works of art or the exhibition itself. Information from social networks can be extracted to make recommendations for museum tours, and such judgments can be improved by combining and applying data mining from the Internet of things sensors installed in museums.

For example, the article [29] offers a generalized approach to developing recommendations for visiting museums, including the architecture of wireless sensors for local positioning of visitors to the exhibition space, including some technologies based on semantic analysis, data mining, and machine learning. This approach combines different data sources to create and recommend indoor and outdoor visualized routes for museums using augmented reality. The user route is based on opinions and ratings from social networks, semantic classification of exhibition spaces, and cultural events, as well as data received from sensors located in the exhibition space. As a result, the user receives a unique individual tour using augmented reality technologies, which contains a set of recommendations on how to visit a specific set of exhibition spaces and improve the immersiveness of the visit.

Free audio guides are currently used in museums to improve the experience of visitors. Over the past few years, some augmented reality (AR) solutions have been researched in this context, allowing for smartphones acting as additional visual and audio incentives. The unique conditions of the Casa Batlló Museum in Barcelona, where artificial markers cannot be used, and the exhibition space is a small crowded room, forced the developers to use a hybrid approach of applying augmented reality to the existing architectural framework [30] using indirect augmented reality. The issues of creating immersive museum guides utilizing the Internet of things and augmented reality technologies are discussed separately. In the article [31], the authors propose a new type of audio guide for museums, consisting of a headset equipped with a camera that takes pictures of exhibits and a computer vision device. The developed electronics can recognize works of art using functions from crucial points of accelerated segment testing and the random forest classifier and can be used throughout the day without the need to recharge batteries. The results show that the system performs better than its counterparts due to the ease of use and user preferences of the proposed method compared to traditional audio guides.

In the field of cultural heritage, wearable augmented reality devices (for example, Microsoft Hololens) are also widely used. The HoloMuse app [32] allows users to actively interact with archaeological artifacts from the museum's collection in ways that would otherwise be impossible. Such an application can be used not only in the exhibition space but also in classrooms since the spatial augmented reality technology does not impose severe restrictions on the physical area around the user. The user is provided with a wide range of interactive elements for interacting with the virtual environment. It can select, rotate, zoom, and change the hologram of the original exhibit using gestures. Similar technology for interactive holographic images was used at the Royal Ontario Museum in Toronto using the TombSeer app at the Tomb of Kitines exhibition [33].

New exhibition space undergoes digital transformation not only on the side of the visitor but also on the side of the exhibits themselves—these changes h influenced by additive technologies, programmable microelectronics, and multimedia. The need to

increase immersiveness, in this case, is bi-directional, and the existing set of technologies allows us to talk about creating a new type of exhibition exhibits - cyber-physical ones. The problem of creating such artifacts is their exceptional level of immersiveness, interactivity, and tangibility. The article [34] describes the methodological basis and tools for creating such cyber-physical exhibits on the example of the Bonobo material skull in the Darwin State Museum (Moscow) and the titanophone material skull in the Perm Museum of Antiquities (Perm). Another example of applying this methodology is the exhibition of an extinct synapsid species Dimetrodon grandis [35].

An essential factor in this context is how to organize the exhibition space and the location of various exhibits using modern digital technologies. The article [36] analyzes technological innovations to create a "smart space" in which items can communicate with visitors and with each other to generate a rich, personalized, and stimulating experience. The authors propose an architecture called "history" designed to provide the appropriate infrastructure to be used in museums and exhibition centers to support intelligent exhibits.

A reasonably important area of application of the discussed technologies is in the safety and security of exhibits and cultural heritage. The preservation of cultural heritage artifacts remains of paramount importance. Among the technological possibilities, we can highlight the regulation of microclimate parameters, such as humidity, temperature, and brightness. In connection with the digital transformation of the museum space, its systems face the problem of minimizing human interaction. The article [37] proposes a CHPC system for automatically regulating microclimate parameters and assisting employees in choosing the right exhibition halls for exhibits depending on the materials of items for reasons of different store conditions, based on the Internet of things (IoT) and artificial intelligence (AI), in particular on the Semantic Web technologies. However, exhibition space and exhibits are vulnerable not only to poor environmental conditions but also to human vandalism. It is the responsibility of humanity to preserve the content of museums. The article [38] describes a specialized system that signals suspected or unintentional attempts at vandalism and allows remote control of the environment through authorized devices with Internet access. A key distinctive aspect of the proposed system is the use of always switched on and energy-intensive sensors for comprehensive and accurate monitoring, while power provided by collecting radio is frequency (RF) energy freely available in the museum. It contrasts with the technologies proposed in the literature that use RF energy harvesting to power simple IoT devices. The authors use antenna arrays that collect radio frequency energy and convert it into electrical energy to extend the life of sensor nodes. Another essential feature of the proposed system is the use of deep learning to identify daily trends in the collected environmental data. In this way, the museum environment is further optimized, and the system becomes more resistant to failures in the detected data. Data analysis and machine learning methods are also used in the external burial grounds of the Yang Mausoleum of the Han Dynasty in China [39]. The data collection system installed in the pavilion collected more than 7,000,000 heterogeneous data. Traditional algorithms did not allow accurate prediction of various situations inside the building, so methods of training the neural network with feedback were implied. The use of machine learning for data analysis and modeling is

an effective forecasting algorithm for the preventive protection of exposition space and exhibits.

In addition, one can pay attention to the introduction of current AR and VR technologies in installations, that is, works that occupy the exhibition space almost entirely.

As for the study of virtual reality as an aesthetic phenomenon, the book by Oliver Grau, "Virtual art: from illusion to immersion" [40] plays an important role. Where the author shows that, since the Renaissance, artists have sought to create an immersive image that is, drawing the viewer, using the latest visual methods: linear perspective in painting, then panoramic photographs, cinema, television, and finally a virtual reality - the effect of immersion is becoming stronger. Grau concludes that, since immersion is the opposite of a distant view, it takes the viewer away from analytical work and offers a rather vivid bodily and emotional experience. However, this process is not just an attraction; it allows a person to have a new experience for them in its integrity, to use all the senses, and thus transform their lives.

Virtual space is a computer model of an environment whose physical properties are approximated in reality allowing the user to interact with an artificially created world and objects in it. The effect of full immersion in the program is achieved by influencing different channels of perception: now, there are high-quality versions of VR glasses and helmets that provide image and sound. Besides, VR gloves that provide tactile signals are being developed. Moreover, there is a project of VR costumes (VPL Dataset, 3rd Space Vest), with which the program could affect the entire body of the user, but now, it is clear that the critical channel of perception in virtual reality is vision. In any case, this model is currently available on the market.

What is virtual reality? On the one hand, we see the apotheosis of an opto-oriented culture, and on the other hand, being in virtual reality involves bodily experience and motor response. It means that objects in VR are seen by us as three-dimensional, having borders and weight, each of them separately is like a sculpture (it is no coincidence that one of the first commercially successful programs for VR was "Tilt Brush," a graphic editor where you need to draw three-dimensional strips). If VR is a continuation of cinema and computer games in its visual component, then the plastic principle inherent in it is related, somewhat, to minimalist sculpture and installation. The key to aesthetic impact was the viewer's sense of the materiality of the art object and in connection with it their physical presence. To explore the potential of VR technologies available to the curator of the art institute, director Alejandro Gonzalez Iñárritu creates his now-famous short film "Flesh and sand" ("Carne y Arena," 2017). This virtual installation is dedicated to the lives of migrants crossing the border between Mexico and the United States. The director has been working on this project for more than five years. As part of the project, he has talked to many people who have experienced this transition. Unfortunately, many do not manage to survive it. Alejandro gathered their experience into a series of images that strongly affect the viewer, in which elements of physical reality supplement virtual reality. When this project was brought out during the 2017 Cannes film festival, it was shown in an airport hangar. The viewer is taken to a cold "transit" room, where they are asked to take off shoes and put them next to rows of shoes that belonged to migrants, then a few minutes of uncomfortable waiting, and the viewer is provided with a heavy

backpack and a VR helmet, together with which he must make a journey in a specially designed space. Film journalist Tatyana Shorokhova described the experience inside the installation as one of the most difficult ones in her life:

> *«I found myself in the desert at dawn. A light breeze is blowing, and you can hear the tumbleweed rustling. I spin around, peering at the landscape. Suddenly, a group of people appears on the horizon. They can hardly walk straight in my direction. Men, women, and children are the same illegal immigrants that some Americans are so afraid of. Tired and exhausted. […] I am gazing at people. They are very close. I think you can reach out and touch them. However, the project has the subtitle "Present virtually, physically invisible." It can be attributed to refugees, but now I understand that it is primarily us, the guests of the installation. The feeling of presence is complete, though, I cannot see my hands and feet—this is not typical for VR projects. There are also no boundaries that are usually drawn for those immersed in virtual reality. As I retreat, a helicopter appears in the sky. It hovers above us, and the searchlight beams across the ground, illuminating the figures. Another couple of seconds and I have the border patrol behind me. American border guards with a dog jump out of two cars. I jump to the side, hitting one of the terrified Mexicans and involuntarily "look" inside him. There is a heart beating. "I look" at the border guard—the same heart. It is clear what I wanted to say to Inarritu: Yes, we are all the same, despite the walls that divide us. By the way, it is not easy to "look" at a person. People, though generated on a computer, have weight and are incredibly realistic. The word "discomfort" describes my feelings very poorly».* [41]

In terms of genre, this project is a "walker". However, the narrative component is clearly shown in everything, from the details of the appearance of migrants to the sequence of "pictures." A physically and emotionally exhausting journey across the border ends tragically for the viewer-hero: the border guard kills them. The Iñárritu project was awarded a special prize for experimenting with form and promising a new experience of cinematic perception, meaning the lesson of history in a space free from the borders of the frame, stimulating sensory cognition. Inarritu's installation is a complex involving space, objects, and people, which, undoubtedly, only enhance the effect of immersion.

Another exciting project based on virtual travel is "Psychosis" (2019), developed by the AES+F group together with Alexander Zeldovich. One part of this work was a theatrical production by Zeldovich based on the text of Sarah Kane, which described her experience of hallucinations and subsequent stay in a hospital. The second part was a VR video in which the viewer found himself in the role of a mentally ill person. The installation space in the MARS gallery was designed as a hospital corridor. The viewer had to fill out a short questionnaire, wait for an invitation, then put on a virtual reality helmet, and sit in a wheelchair. When the session started, hero identification's video took place almost instantly thanks to this wheelchair: in VR-glasses, the viewer found himself in the same hospital corridor, with his head down, saw his own body, motionless legs and hands resting on the wheels of the chair, and at the same time could feel the cold of these metal wheels. The movement inside the VR space was performed by pressing a unique

pedal, and turns were achieved by a relatively active movement of the hands turning the stroller. Thus, the body "believed" that it was in the same hospital, and hallucinogenic images floated before the eyes, and the further away, the more terrible. Huge insects, severed limbs, flying multicolored nails, giant mushrooms, and powerful explosions - all these images, elegant and at the same time repulsively textured, in the traditional spirit of AES+F, rose before viewer's eyes, and it was impossible to hide from them. This video evoked a strong sense of being in a nightmare and complete powerlessness, the inability to escape from the shroud of hallucinations, which, even though we know about their artificial nature, remain frightening.

3.1 What Else Can Virtual Reality Do?

Today, many people call VR technology a "machine for empathy" - because it enables the user to get a dose of a new subjectivity, being-with-the others or - to a certain extent-being the others. This idea forms the name of the interdisciplinary group of students BeAnotherLab from the University of Barcelona named after Pumpeu Fabra. Within the laboratory, the project "The Machine to Be Another" is being implemented. The essence of which comes down to the following: two participants (a man and a woman) put on VR glasses, and each begins to see what the other sees. For example, a man sees women's hands in front of him. The experiment participants are asked to perform simultaneous movements with their hands and feet to enhance the effect of the illusion. As a result, participants have a vivid sense of "body exchange"; they get a new experience of gender identity [42].

BeAnotherLab is not the first team of researchers to engage in such researches. It is also committing to study Thomas Metzinger and Olaf Blanke, who, together with cognitive scientists Bigna Langgenhager and Ted TEDI, created a VR system designed to evoke the experience of being outside the body, destroying the illusion of stability of its model in consciousness.

In their work, Metzinger and Blanke proceeded from the following premises: we live "inside" not only our ideas about the world, but also inside the models of our bodies, minds, and selfhood that we represent. These models, like all others, are subject to manipulation and transformation, they are not constant. When we receive new bodily changes, we gain a unique experience of subjectivity or "expand" an existing one.

From 2010 to 2015, two other researchers, Marie Sanchez-Vives and Mel Slater, worked with Metzinger and Blanke on the project "Virtual incarnation and robotic reincarnation". The project was aimed at giving the viewer the experience of "incarnation" in another body. At the moment, Marie Sanchez-Vives, along with other researchers, is developing a VR project in which perpetrators of violent crimes in the family get the opportunity to switch places with their victims.

"To be in someone else's skin", "to walk in someone else's shoes" - various modifications of this idiom must be present in most world languages. It is not accidental – because it is often difficult for us to relate ourselves to different states that we are not too familiar with, events that have never happened to us, and alternative value systems. Thanks to VR, we can be "in someone else's shoes" literally.

3.2 Multisensory Environment Problems

A brief analysis of how the Internet of things technology can be used in the cultural industry we have recently reviewed [43] gives us a track for outlining the strategy of Iot development in the context of a modernised museum. As the Internet of things is a multi-level system that includes sensors and controllers associated with specific exhibits, works of art or elements of the theater scene, means of transmitting the collected data and their visualization, powerful analytical tools for interpreting the received information, with the possibility of remote control and management in an automated mode.

In this regard, the problem of adapting museum mechanisms for storing and presenting works of art to the audience of a communication society is becoming particularly relevant. Therefore, the museum is becoming increasingly involved in the digitization process using new technologies, such as mobile applications, virtual and augmented reality, artificial intelligence, the Internet of things and data design, which we consider to be the key technologies used in the new "expanded museum". Unfortunately, now there is no integral methodology for designing the exhibition space and topologies of immersive and multisensory environment using advanced information technologies and aimed at increasing the visitor's immersion.

Usage of information technologies in multisensory environments leads to new research challenges. The goal of such research is to investigate and develop new methods for designing an exhibition space and for creating new topologies of immersive and multisensory environment using advanced information technologies to enhance the immersiveness and quality of user and audience experience.

To attain this goal, the following objectives were identified:

1. To analyze studies on designing an exhibition space and creating new topologies of immersive and multisensory environment using advanced information technologies to define the connections between the exhibition space design and advanced information technologies.
2. To create the map the technologies that enable to design spaces for immersive simulations, with strong attention for innovations and future trends.
3. To develop and investigate new methods for designing an exhibition space and for creating new topologies of immersive and multisensory environment using advanced information technologies.
4. To evaluate the effectiveness of the proposed methods using simulation.

4 Conclusion

Summing up, we can say that the process of digitalization of art museums and similar cultural institutions is now gaining momentum and becoming an integral part of the development strategies of these sites. The engine of this process is not only the needs of specialists to work with artifacts, but also the needs of viewers who expect the modern museum to actively implement innovative technologies that improve the quality of interaction with the historical heritage stored by the institution. Today, the museum is increasingly using immersion mechanisms and feedback tools to allow each viewer to get a vivid and" customized" experience of meeting art.

However, there is a need to ask to what extent modern curatorial strategies respond to the challenge of such innovations.

In the 1920-s, the first museums of contemporary art had only appeared in the USA (MOMA), Russia (State Museum of Modern Western Art), and Europe. These institutions aimed to build up not just a collection of art pieces but a narrative about the history of contemporary art, they tried to reveal a kind of genealogy of this phenomenon, to name all the art movements, to make their goals visible and to outline what the very term "art" meant at the time [44]. And their resources were classical ones: exposed artifacts, exhibition catalogs, lectures, and specialized issues. And today, a museum faces new challenges: not just the exhibition, but the whole field of information relied on it has to be curated [45].

Thus, we may conclude that the fundamental change in communication processes one sees in the work of an "expanded museum" has resulted in a substantial transformation that needs to be further reviewed in an interdisciplinary analysis. We argue that neither engineering nor humanitarian approach has to be dominant in this development of a future museum but both of them – it is crucial for technical specialists and art historians to engage in a continuing dialogue in order to build up the right track for innovations. A "smart" museum means not only attractiveness and "liveness" but also an updating of the basic narratives about art, a way of providing visitors with a set of correctly outlined concepts and facts.

If in the museum of the 20th century the guide was a human being: authors of texts posted on the walls and in catalogs, authors of scripts for audio guides and art critics who covered the exhibitions. Then today, when the viewer-user works with mobile applications, virtual assistants and other products of artificial intelligence that process big data downloaded from the museum's archive, the question of who is the "narrator" of the history of art becomes acute, who is responsible for preserving and transmitting significant narratives about the nature of art to new generations of viewers [46]. In other words, today art historians, museum employees, engineers and programmers must face the task of not only loading specific data into artificial intelligence systems and designing interfaces that make it convenient for the viewer-user to access this data, but also creating algorithms that can present information in a high-quality way. In short, an artificial intelligence working with the materials of an art museum must not only be able to "pick up pictures," but also learn to "understand" the history of art. Keeping in mind that a museum not only presents but also introduces the artefacts and builds up a storyline of aesthetic development and variation, we argue that the role of a historian/curator remains crucial in a digitally transforming institution.

Therefore, we would underline that the mission of an art museum and a gallery remains: preservation and demonstration of cultural heritage, spreading knowledge and aesthetic formation. And in order to achieve these goals specialists have been analyzing the currently changing needs and desires of their audience, introducing the newer information technologies and following the communication trends. Digital transformation of a museum is an incessant process that requires adequate tools (AI, AR, VR, social networks) to structure the great amount of content which is being curated and to make it "user friendly" for contemporary audience. Today it becomes obvious that the museum can reach its main goals only in the format of a continuous dialogue with a viewer, which

is necessarily carried out using the most up-to-date technological tools that empower both the "voice" of a curator and the "feedback" of the audience.

References

1. Hezmondals, D.: Cultural industries. trans. from English I. Kushnareva, under the scientific. In: Mikhaleva, A. (ed.) National Research University Higher School of Economics. - M.: Publishing. House of the Higher School of Economics (2014). Giusti, L., Groys, B., Paul, Ch., Bishop, C.: Museums at the Post-Digital Turn. Mousse Publishing (2019)
2. Chianese, A., Piccialli, F.: Designing a smart museum: when cultural heritage joins IoT. In: 2014 Eighth International Conference on Next Generation Mobile Apps, Services and Technologies, Oxford, pp. 300–306 (2014)
3. Harada, T., Hideyoshi, Y., Gressier-Soudan, E., Jean, C.: Museum experience design based on multi-sensory transformation approach. In: Proceedings of International Design Conference, DESIGN, vol. 5, pp. 2221–2228 (2018)
4. Miotto, L.: Using scents to connect to intangible heritage: engaging the visitor olfactory dimension: three museum exhibition case studies. In: Proceedings of the 2016 International Conference on Virtual Systems and Multimedia, VSMM (2016)
5. Al Rabbaa, J., Morris, A., Somanath, S.: MRsive: an augmented reality tool for enhancing wayfinding and engagement with art in museums. In: Stephanidis, C. (ed.) HCII 2019. CCIS, vol. 1034, pp. 535–542. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-23525-3_73
6. Eardley, A.F., Dobbin, C., Neves, J., Ride, P.: Hands-on, shoes-off: multisensory tools enhance family engagement within an art museum. Visitor Stud. **21**(1), 79–97 (2018)
7. Chan, M.K., Siu, K.W.M.: Inclusivity: a study of Hong Kong museum environments. Int. J. Crit. Cult. Stud. **11**(1), 45–61 (2013)
8. Coombes, A.E., Phillips, R.B.: Museum Transformations: Decolonization and Democratization. Wiley-Blackwell, Hoboken (2020)
9. Merlo, G.: Building the Museum Experience: the role of digital technologies inside art museums. University of Westminster, MA Dissertation (2017)
10. Bekele, M.K., Pierdicca, R., Frontoni, E., Malinverni, E.S., Gain, J.: A survey of augmented, virtual, and mixed reality for cultural heritage. J. Comput. Cult. Herit. **11**(2), 36 (2018). Article 7
11. Bishop, C.: Radical Museology: Or What's Contemporary in Museums of Contemporary Art?. Walther König, Köln (2014)
12. Malraux, A.: Le Musee Imaginaire (1947). Gallimard Folio Essais, Paris (1996)
13. Warburg, A.: The great migration of images. Research on the history and psychology of the Renaissance of antiquity (1932). - Da. The alphabet-classics, (with biographical sketch Preface I. A. Doronchenkov) (2008)
14. Panofsky, E.: Studies in Iconology: Humanist Themes in the Art of the Renaissance, New York (1939)
15. Gombrich, E.: The Uses of Images. Studies in the Social Function of Art and Visual Communication. Phaidon, London (1999)
16. Didi-Huberman, G.: Devant l'image. Questions posées aux fins d'une histoire de l'art. Minuit, Paris (1990)
17. Eco, U.: La Vertigine della Lista. Rizzoli (2009)
18. Opredelenov, V.V.: Smart Museum: how modern technology works for art. Webinar within the open lecture hall of enano. https://www.youtube.com/watch?v=qMOSAh4eQig&t=3804s

19. Opredelenov, V.V., Buzina, Ju.V., Paholkova, A.Ju.: Virtual'nye tehnologii v muzee – opyt Pushkinskogo. Spravochnik rukovoditelja uchrezhdenija kul'tury № 9 (2017). https://e.rukulturi.ru/582616
20. Opredelenov, V.V.: Cifrovaja transformacija i instituty pamjati (aktual'nye IT-trendy 2016 i ih otrazhenie v sfere kul'tury). V kn.: Transformacii muzeev-bibliotek-arhivov i informacionnoe obespechenie istoricheskoj nauki v informacionnom obshhestve. Sbornik statej po materialam nauchno-prakticheskogo seminara, pp. 121–131, INION RAN (2017)
21. Project page GMII im. A.S. Pushkina «100 sposobov prozhit' minutu». https://100waystoliveaminute.pushkinmuseum.art
22. KONSPEKT IZBRANNYH SESSIJ XXII MEZhDUNARODNOGO FESTIVALJa «INTERMUZEJ». https://drive.google.com/file/d/1ckLZ_h7CZ-3eg1UqY1kJ0QgsYfbTPJkm/view?fbclid=IwAR1QTrgDVTictj8yAbZAG2j2egr-yLDSDlo2hxMji5MKUdRDPu1u-vAtE-A
23. Guk, D., Opredelenov, V., Kharitonova, T.: Integrated digital resources: organizational and technological scientific and methodological foundations and development. Collection of scientific works. Ser. "Electronic library" presidential library named after B. N. Yeltsin; Scientific editor E. D. Zhabko. Saint Petersburg (2015)
24. Li, J.-Q., Yu, F.R., Deng, G., Luo, C., Ming, Z., Yan, Q.: Industrial internet: a survey on the enabling technologies applications and challenges. IEEE Commun. Surv. Tutor. **19**, 1504–1526 (2017)
25. Chianese, A., Piccialli, F., Jung J.E.: The internet of cultural things: towards a smart cultural heritage. In: 2016 12th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS), Naples, pp. 493–496 (2016)
26. Chianese, A., Benedusi, P., Marulli, F., Piccialli, F.: An associative engines based approach supporting collaborative analytics in the internet of cultural things. In: 2015 10th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC), Krakow, pp. 533–538 (2015)
27. Mertz, J., Zapalowski, V., Lalanda, P., Nunes, I.: Autonomic management of context data based on application requirements. In: Industrial Electronics Society IECON 2017 - 43rd Annual Conference of the IEEE, pp. 8622–8627 (2017)
28. Al-Ruithe, M., Mthunzi, S., Benkhelifa, E.: Data governance for security in IoT & cloud converged environments. In: 2016 IEEE/ACS 13th International Conference of Computer Systems and Applications (AICCSA), pp. 1–8 (2016)
29. Wu, P.-W., Cheng, C.-W., Kaddi, C.D., Venugopalan, J., Hoffman, R., Wang, M.D.: Omic and electronic health record big data analytics for precision medicine. IEEE Trans. Biomed. Eng. **64**, 263–273 (2017)
30. McKee, D.W., Clement, S.J., Almutairi, J., Xu, J.: Massive-scale automation in cyber-physical systems: vision & challenges. In: 2017 IEEE 13th International Symposium on Autonomous Decentralized System (ISADS), pp. 5–11 (2017)
31. Chang, H.-L., Chin, K.-Y.: A museum guiding and learning system based on augment reality and wearable technology. In: ICCE 2019 - 27th International Conference on Computers in Education, Proceedings, vol. 2, pp. 628–636 (2019)
32. Pollalis, C., Fahnbulleh, W., Tynes, J., Shaer, O.: HoloMuse: enhancing engagement with archaeological artifacts through gesture-based interaction with holograms. In: TEI 2017 - Proceedings of the 11th International Conference on Tangible, Embedded, and Embodied Interaction, pp. 565–570 (2017)
33. Pedersen, I., Gale, N., Mirza-Babaei, P., Reid, S.: More than meets the eye: the benefits of augmented reality and holographic displays for digital cultural heritage. J. Comput. Cult. Herit. **10**(2), 1–5 (2017)
34. Ryabinin, K.V., Kolesnik, M.A.: Adaptive scientific visualization tools for a smart paleontological museum. Program. Comput. Softw. **45**(4), 180–186 (2019). https://doi.org/10.1134/S0361768819040066

35. Ryabinin, K.V., Kolesnik, M.A., Akhtamzyan, A.I., Sudarikova, E.V.: Cyber-physical museum exhibits based on additive technologies, tangible interfaces and scientific visualization. Sci. Visual. **11**(4), 27–42 (2019). https://doi.org/10.26583/sv.11.4.03
36. Poulopoulos, V., Vassilakis, C., Antoniou, A., Wallace, M., Lepouras, G., Nores, M.L.: ExhiSTORY: IoT in the service of cultural heritage. In: 2018 Global Information Infrastructure and Networking Symposium (GIIS), Thessaloniki, Greece, pp. 1–4 (2018)
37. Konev, A., et al.: CHPC: a complex semantic-based secured approach to heritage preservation and secure IoT-based museum processes. Comput. Commun. **148**, 240–249 (2019)
38. Eltresy, N.A., et al.: RF energy harvesting IoT system for museum ambience control with deep learning. Sensors **19**, 4465 (2019)
39. Jiang, H., et al.: Data mining based on Chinese traditional calendar in the Han Dynasty Yang Mausoleum Museum. Appl. Sci. **9**, 5442 (2019)
40. Grau, O.: Virtual Art: From Illusion to Immersion. The MIT Press, Cambridge (2004)
41. Shorokhova, T.: Go and watch: the cruel virtual reality of Aleoandro Gonzlez Iñárritu. https://www.kinopoisk.ru/media/article/2961433
42. Fadeeva, T., Staruseva-Persheeva, A.: Re-subjectivity: media art as a practice of identity. In: Proceedings of the 3rd International Conference on Art Studies: "Science, Experience, Education", ICASSEE 2019. «Atlantis Press», Paris, France (2019)
43. Aristova, U.V., Rolich, A.Y., Staruseva-Persheeva, A.D., Zaitseva, A.O.: The use of internet of things technologies within the frames of the cultural industry: opportunities, restrictions, prospects. In: Alexandrov, D., Boukhanovsky, A., Chugunov, A., Kabanov, Y., Koltsova, O. (eds.) DTGS 2018. CCIS, vol. 859, pp. 146–161. Springer, Cham (2018). https://doi.org/10.1007/978-3-030-02846-6_12
44. Kantor, S.: Alfred H. Barr, Jr. and the Intellectual Origins of the Museum of Modern Art. The MIT Press, Cambridge (2003)
45. Phillips, N.A.: Developing digital media for museum exhibitions: environment, collaboration and delivery: a thesis presented in partial fulfilment of the requirements for the degree of Master of Philosophy in Museum Studies at Massey University, Manawatu, New Zealand (2011)
46. Schorch, Ph., McCarthy, C.: Curatopia: Museums and the Future of Curatorship. Manchester University Press, Manchester (2019)

The Use of Virtual Reality as a Potential Restorative Environment in School During Recess

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Abstract. Previous research has found out that simulated, Virtual Reality (VR)-based forests can bring equal or even higher restorative effects than real forests. In this study, a Virtual Reality (VR)-based forest was created in order to compare whether VR-based forest can possess restorative effects in the context of primary school, and how the possible effects compare to restorative effects of a normal recess or to a situation when there is no recess at all. The effects were measured using Restorative Outcome Scale (ROS) and problem-solving tasks after the intervention. The results showed that VR-based forest had the highest restorative effect. There was a significant difference between VR-forest and no recess-groups, but no statistical difference between VR-forest and normal recess-groups. Future research avenues and implications of virtual forests are discussed.

Keywords: Virtual reality · Virtual forest · Restorative outcome scale attention restoration

1 Introduction

Learning involves multiple cognitive processes which require directed attention, such as absorbing, processing, remembering and retrieving information [9,15]. Especially in schools, students are constantly directing their attention. Maintaining directed attention is required for maintaining concentration on a task, but is effortful and drains through constant use [19]. It recovers when involuntary attention is engaged [18]. A possibility to recover during a school day is important because hard workload and time pressures cause depleted attention and stressful short-term experiences [14]. Stress has even been proposed to be one of the underlying reasons for the mental health problem of students that is an increasing concern worldwide [5].

Previous research reviewed by Tzoulas et al. [36] has shown the restorative effects of nature environments. The recent evidence of using virtual reality (VR)

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in gaining these benefits is encouraging (e.g. [2,11,42]). A recent study [23] provided information some encouraging results about university students using VR to gain benefits such as improved restoration levels and subjective vitality and improved mood. However, the study had some major limitations, including the lack of comparison groups and not measuring performance on concentration on a task. The current study was conducted to overcome these limitations by comparing three groups in a real-life situation (recess in a local primary school).

More specifically, the aim of this research was to study whether VR-based restorative environments can possess restorative effects and thus work as a recovering environment in primary school-context.

2 Literature

2.1 Attention

Jacobson [15] defines attention as the ability to focus on the stimuli which are relevant to the task at hand and as the ability to exclude stimuli which is not relevant to the task at hand [15]. Attention allows to absorb new information through various senses and select what information to pay attention to and what to ignore. For non-automated tasks, paying attention is crucial to remember, as the work memory has limits [15]. In learning, information is held in the work memory and then moved to the long-term memory [41]. Miller [28] summarises; without attention, there is no memory, and without memory, there is no learning.

2.2 Directed Attention and Directed Attention Fatigue

Directed attention is defined as a mechanism allowing the control and direct the focus of thought and perception [20]. According to Kaplan [19], any prolonged mental effort, such as attention, leads to "directed attention fatigue", DAF, and lowers one's capability to focus and learn. Especially children, who have attention deficit disorders (e.g. ADD, ADHD) may suffer more from DAF, as they need more effort to keep up their directed attention. According to Kuo and Taylor [22], symptoms of ADHD and DAF are so similar, that the Attention Deficit Disorders Evaluation scale, which is used to measure ADHD, has also been used to measure DAF.

2.3 Attention Restoration Theory

Kaplan [19] suggests that sleep is insufficient for recovering from directed attention fatigue (DAF). In order to recover from DAF, one has to find another basis to maintaining the focus. This should make the use of directed attention temporary unnecessary [19]. One way to find an another basis to maintain one's focus is to involve in restorative experiences.

Following the attention restoration theory, ART [19], a restorative experience should include four components: fascination, being away, extent and compatibility. Fascination is essentially something that fascinates people. Fascination can

arouse from content, for example an animal in a forest or from action, such as jogging in a forest. Being away refers more to the conceptual than to the physical transformation of place; a change in one's gaze away from old thoughts is required in order to achieve the conceptual shift needed for restoration. Extent is a requirement for the environment; it must be rich and coherent enough to be considered as a whole other world. In addition, the environment needs to have sufficient scope in order to engage one's mind. Lastly, compatibility refers to the connection between one's purposes and the environment; the setting needs to fit what one is trying and wanting to do [19].

According to Kaplan [17], natural environments, such as parks and forests, work well as restorative environments. They involve characteristics required for restorative experience, such as fascination (e.g. in a form of flying butterflies) and being away (e.g. physical transformation from office to a forest). In addition, they require only involuntary, effortless attention [17]. Previous research has shown that natural environments have indeed helped recover from directed attention fatigue. Moreover, it has been found out that natural environments are generally more restorative than built environments [6,7,10,12,35].

2.4 Restoration During Recess

Recess has been found out to improve classroom behaviour [1,3,8,13,16,27]. The benefits of having a recess have been studied by using multiple approaches, including observing the behaviour in the classroom [16], teacher administration [3], observing children's' gaze (inattention) [13,30], self-report measures of restorativeness, PRS [1], paper-based attention tests [1], cognitive performance (visual-spatial ability, recognition and reaction times, [27]) and sustained attention and creativity [3].

2.5 Simulated Restorative Environments

In addition to natural environments, simulated restorative environments have been found out to have recovering effects [7,38]. However, virtual reality-based environments with head-mounted-displays (HMD) have not been tested widely on the field. HMD allows full immersion in the simulated world, offering a thorough experience of the simulated environments. Some studies about the restorativeness of a VR-based forest have been conducted [23,26]. Both studies found out that the VR-based forest can possess restorative outcomes. Mattila et al. [26] also found out that the restoration level of VR-forest was higher or equal than a physical forest.

2.6 Research Questions

This research aims to fill the research gap on restorative VR environments, and its effects on problem solving ability outside VR: it is proposed that if students have restorated during recess, their problem-solving ability is higher.

The possible restorative effects of VR in educational settings are considered and compared with two other treatment groups: a normal recess between the lessons and no recess between the lessons.

Based on the research gap and previous research, we formulate our research questions as follows:

1. Do the groups differ in restoration levels?
2. Do the groups differ in problem-solving ability?

3 Data and Methods

Following the four components of a restorative experience introduced by Kaplan [19], and previous research on the topic, a VR-based virtual forest was developed. The VR environment (Fig. 1) was built using Unreal Engine [37] and shown to the participants with HTC Vive Pro-headsets [39] The VR environment included several elements, which have been found out to have a restorative effect in previous studies: warm color temperature [34], blue sky [40], flying butterflies [25], bird singing [31], and ability to see the horizon and close nature objects [19,29,33].

Fig. 1. Virtual forest environment.

Restorative effects were measured before and after the VR experience using Restoration Outcome Scale (ROS) [21], which have been used in previous studies regarding the restorativeness of both physical and virtual environments (e.g. [21, 23,26,35]). ROS scale includes six items measuring reflected relaxation, attention restoration and clearing one's thoughts [21]. Questions were answered using a Likert scale from 1 to 5.

Problem-solving ability was measured using a four page-problem solving test (Fig. 2). Both the time to complete and the scores from tasks were used to

measure the problem solving ability of the students. Results from the problem-solving task were also reviewed in order to know which way to spend the recess (VR-forest, normal recess, or no recess at all) had the highest restorative effect.

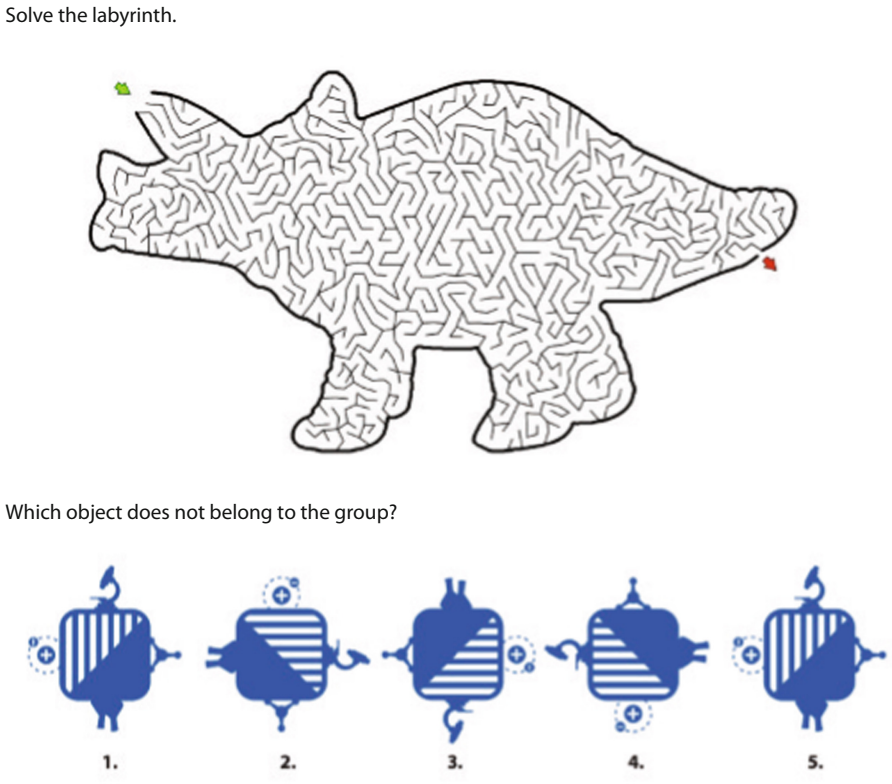

Fig. 2. Examples from the problem-solving tasks.

The research setting was as follows: at the end of a normal lesson held by the teacher of the class, all students were divided into three groups. All groups completed the first part of the ROS-questionnaire. After the questionnaire, the first group (N = 19), had a VR-based restorative experience lasting five minutes. Second group (N = 19) had a free break (15 min) and Group 3 (N = 19) did not have any break. After the intervention, all three groups completed a problem-solving task and the second part of the ROS-questionnaire. Maximum time to complete the problem solving task was 20 min. After the problem-solving task and questionnaire, all three groups attended the second lesson normally. Participants (N = 57) were all Finnish primary school students. Altogether, students from four different classes from the same primary school attended the study.

Restorativeness was measured by using a mean of all ROS items. The Cronbach's alpha of ROS was 0.94 and consistent with previous studies (e.g. [35]).

Two-way repeated measures ANOVA was used to test if there were interactions between the groups and time points on restoration levels. In addition, a non-parametric Kruskall-Wallis H-test was conducted to test whether there are differences between the groups. Analyses were completed utilizing the SPSS Statistics 25–software. For problem task completion time and scores, a one-way ANOVA was conducted [24]. In addition, multiple linear regression was applied to investigate whether gender, group, post-test ROS score had interactions to the problem task completion time or problem task scores [24].

4 Results

4.1 ROS-Questionnaire

The mean scores and standard deviations for the ROS questionnaire are presented in Table 1. The after-intervention means were highest for VR-recess followed by conventional recess, while no-recess control group showed the lowest ROS-scores.

Table 1. Scale statistics of ROS measure

Before recess (first time point)			After recess (second time point)		
	Mean	SD		Mean	SD
VR Recess	22.74	4.98		25.37	5.21
Normal Recess	21.95	5.75		22.53	6.58
No Recess	22.63	6.83		20.42	6.60

Two-way repeated measures ANOVA revealed that there was a significant interaction between time point and the treatment on the restoration levels ($F(1,54) = 6.30$, $p < .05$, $\eta p\ 2 = .19$). Kruskal-Wallis H test showed that there was no significant difference on restoration levels on the first time point $\chi 2(2) = .529$, $p = .768$, with a mean rank restoration score of 29.16 for VR Recess-group, 26.97 for Normal Recess-group and 30.87 for No Recess-group. On the second time point, there was a significant difference between the groups, $\chi 2(2) = 7.000$, $p = 0.030$, with a mean rank restoration score of 36.47 for VR Recess-group, 28.18 for Normal Recess-group and 22.34 for No Recess-group. Dunn's pairwise post-hoc tests were carried out for the three pairs of groups. Tests revealed a statistically significant difference evidence ($p = 0.025$, adjusted using the Bonferroni correction) between the VR Recess and No Recess-groups. The median restoration level for the VR group was 28.00 compared to 23.00 of the No Recess-group. There were no significant differences between the VR Recess and Normal Recess, or Normal Recess and No Recess-groups.

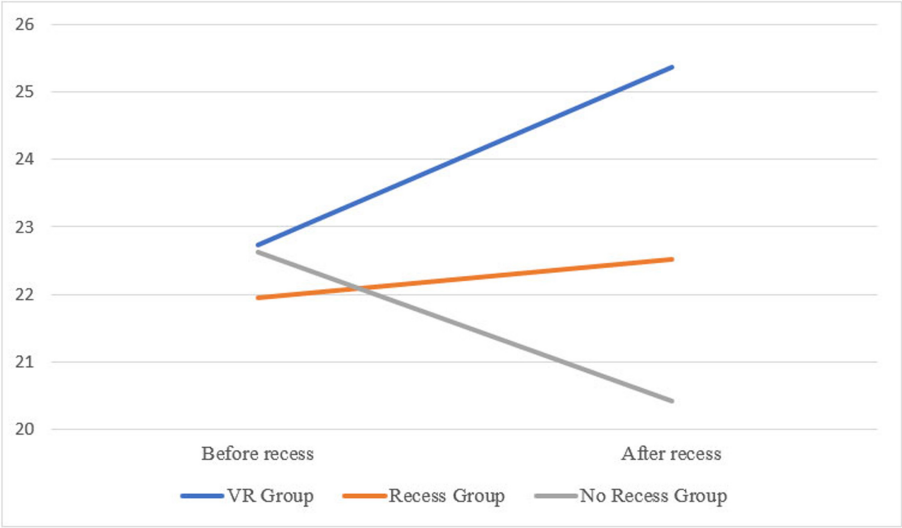

Fig. 3. Mean restoration levels before and after recess through all groups.

4.2 Problem Task and Concentration Levels

There was no statistically significant difference between groups on one-way ANOVA on problem task completion time ($F(2,54) = .181$, $p = .835$) or on problem task scores ($F(2,54) = .084$, $p = .919$) (Fig. 3).

In addition, multiple linear regression was applied to investigate whether gender, group or ROS post-test score had an effect on the problem task completion time or scores. These variables did not predict neither problem task completion time $F(3,53) = .664$, $p = .578$, $R2 = .036$ nor problem task scores $F(3,53) = 0.62$, $p = .980$, $R2 = -.003$.

5 Discussion

The aim of this research was to know whether a VR-environment can possess restorative effects in the context of primary school, and how the possible effect compares to the restorative effect of a normal recess or to a situation when there is no recess at all.

From the results of the questionnaire it can be seen that VR-environment can indeed have restorative effects on primary school context. This result was in line with previous research on restorative VR environments [2,11,23,42]. Interestingly, the group which had the VR intervention had the highest restoration levels. This is in line with the recent findings by Mattila et al. [26] who found out that a restorative VR environment can be perceived even more restorative environment than those urban forests that people usually have access to. There was a statistically significant difference to the group which had no recess at all.

However, in this research, the difference between VR Recess and Normal Recess -groups was not found to be statistically significant. Regarding traditional recess, the study results were in line with the results of previous studies regarding the restorative effects of recess [1,3,8,13,16,27].

There were challenges related to the data collection. The original idea was to have a normal lesson before the VR-intervention. This worked well, and we got good observation data about the concentration levels of the students. After the first lesson, students filled the first part of the questionnaire. Then, the students were divided into three groups. These steps worked well too. After the VR-intervention, however, it was hard to time everything so that the next lesson would start on time. Usually, the next lesson started approximately 10 min late, as the VR intervention group demanded more time. The other two groups (Normal Recess and No Recess), were already in the class waiting for the lesson to start. There is a possibility that this caused disturbance to the restoration levels of the other groups. In addition, the original idea was to have a normal lesson after the VR-intervention and second part of the questionnaire. In reality, students used approximately 9:09 min to do the problem tasks, so usually the next lesson was very short, and there was little time to observe how the concentration levels of the students from different groups differed. As we failed to get consistent data on how the concentration levels differed between the groups during the second lesson, we did not include those observations on this study.

There were no differences between the groups on problem-solving ability. It can be questioned if the tasks used in this study measured problem-solving ability well enough or if the students were tired enough so that the restorativeness of the recession would have a crucial effect on the test results. Future research is therefore invited to test new ways to study problem-solving after a recess. In addition, for future research it would be interesting to test whether better restoration during recess leads to better concentration or resilience on the lesson after the recess. Possible ways to measure this would be physiological sensors including heart rate sensors, heart rate variability sensors and electrodermal skin activity. Furthermore, it is important to validate the restorative effect to ensure that students do not just simply give high ratings to an interesting technology and intentionally creating more cognitive load (see: [4]).

Finally, the small sample size can affect the results and their significance. However, the results are encouraging and more research is needed to validate the effect of the VR environment. It is important to remember that as the technology is new and exciting, the technology itself can have positive effects, and not the environment. However, the results open both new and interesting research avenues and practical implication in e.g. letting the students with difficulties in keeping up directed attention to have a short VR break during a lecture.

References

1. Amicone, G., et al.: Green breaks: the restorative effect of the school environment's green areas on children's cognitive performance. Front. Psychol. **9**, 1579 (2018)

2. Annerstedt, M., et al.: Inducing physiological stress recovery with sounds of nature in a virtual reality forest-results from a pilot study. Physiol. Behav. **118**, 240–250 (2013)
3. Barros, R.M., Silver, E.J., Stein, R.E.: School recess and group classroom behavior. Pediatrics **123**(2), 431–436 (2009)
4. Barrouillet, P., Bernardin, S., Camos, V.: Time constraints and resource sharing in adults' working memory spans. J. Exp. Psychol. Gen. **133**(1), 83 (2004)
5. Bayram, N., Bilgel, N.: The prevalence and socio-demographic correlations of depression, anxiety and stress among a group of university students. Soc. Psychiatry Psychiatr. Epidemiol. **43**(8), 667–672 (2008). https://doi.org/10.1007/s00127-008-0345-x
6. Berman, M.G., Jonides, J., Kaplan, S.: The cognitive benefits of interacting with nature. Psychol. Sci. **19**(12), 1207–1212 (2008)
7. Berto, R.: Exposure to restorative environments helps restore attentional capacity. J. Environ. Psychol. **25**(3), 249–259 (2008)
8. Brez, C., Sheets, V.: Classroom benefits of recess. Learning Environ. Res. **20**(3), 433–445 (2017). https://doi.org/10.1007/s10984-017-9237-x
9. Myers, D.: Psychology, 9th edn. Freeman & Co., Singapore (2009)
10. Felsten, G.: Where to take a study break on the college campus: an attention restoration theory perspective. J. Environ. Psychol. **29**(1), 160–167 (2009)
11. Gromala, D., Tong, X., Choo, A., Karamnejad, M., Shaw, C.D.: The virtual meditative walk: virtual reality therapy for chronic pain management. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, pp. 521–524 (2015)
12. Hauru, K., Lehvävirta, S., Korpela, K., Kotze, D.J.: Closure of view to the urban matrix has positive effects on perceived restorativeness in urban forests in Helsinki, Finland. Landscape Urban Plann. **107**(4), 361–369 (2012)
13. Holmes, R.M., Pellegrini, A.D., Schmidt, S.L.: The effects of different recess timing regimens on preschoolers' classroom attention. Early Child Dev. Care **176**(7), 735–743 (2006)
14. Ilies, R., Schwind, K.M., Wagner, D.T., Johnson, M.D., DeRue, D.S., Ilgen, D.R.: When can employees have a family life? The effects of daily workload and affect on work-family conflict and social behaviors at home. J. Appl. Psychol. **92**(5), 1368 (2007)
15. Jacobson, M.H.: Paying attention or fatally distracted-concentration, memory, and multi-tasking in a multi-media world. Legal Writing J. Legal Writing Inst. **16**, 419 (2010)
16. Jarrett, O.S., Maxwell, D.M., Dickerson, C., Hoge, P., Davies, G., Yetley, A.: Impact of recess on classroom behavior: group effects and individual differences. J. Educ. Res. **92**(2), 121–126 (1998)
17. Kaplan, R.: Some psychological benefits of gardening. Environ. Behav. **5**(2), 145–162 (1973)
18. Kaplan, R., Kaplan, S.: A psychological perspective. CUP Archive, The experience of nature (1989)
19. Kaplan, S.: The restorative benefits of nature: toward an integrative framework. J. Environ. Psychol. **15**(3), 169–182 (1995)
20. Kaplan, S.: Meditation, restoration, and the management of mental fatigue. Environ. Behav. **33**(4), 480–506 (2001)
21. Korpela, K.M., Ylén, M., Tyrväinen, L., Silvennoinen, H.: Determinants of restorative experiences in everyday favorite places. Health Place **14**(4), 636–652 (2008)

22. Kuo, F.E., Taylor, A.F.: A potential natural treatment for attention-deficit/hyperactivity disorder: evidence from a national study. Am. J. Public Health **94**(9), 1580–1586 (2004)
23. Lähtevänoja, A., Holopainen, J., Mattila, O., Södervik, I., Parvinen, P., Pöyry, E.: Virtual reality as a recovering environment - implications for design principles. In: Alexandrov, D.A., Boukhanovsky, A.V., Chugunov, A.V., Kabanov, Y., Koltsova, O., Musabirov, I. (eds.) DTGS 2019. CCIS, vol. 1038, pp. 506–516. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-37858-5_43
24. Lewis-Beck, M., Bryman, A.E., Liao, T.F.: The Sage Encyclopedia of Social Science Research Methods. Sage Publications, New York (2003)
25. Marselle, M.R., Irvine, K.N., Lorenzo-Arribas, A., Warber, S.L.: Does perceived restorativeness mediate the effects of perceived biodiversity and perceived naturalness on emotional well-being following group walks in nature? J. Environ. Psychol. **46**, 217–232 (2016)
26. Mattila, O., Korhonen, A., Pöyry, E., Hauru, K., Holopainen, J., Parvinen, P.: Restoration in a virtual reality forest environment. Comput. Hum. Behav. **107**, 106295 (2020)
27. Mezghanni, N., Masmoudi, L., Abdallah, S.B.: Effect of play at recess on diurnal fluctuations in ability to refocus cognitively in pupils aged 11–12 years. Biol. Rhythm Res. **50**(5), 758–768 (2019)
28. Miller, G.E., Chen, E., Parker, K.J.: Psychological stress in childhood and susceptibility to the chronic diseases of aging: moving toward a model of behavioral and biological mechanisms. Psychol. Bull. **137**(6), 959 (2011)
29. Nordh, H., Hartig, T., Hagerhall, C.M., Fry, G.: Components of small urban parks that predict the possibility for restoration. Urban Forest. Urban Green. **8**(4), 225–235 (2009)
30. Pellegrini, A.D., Huberty, P.D., Jones, I.: The effects of recess timing on children's playground and classroom behaviors. Am. Educ. Res. J. **32**(4), 845–864 (1995)
31. Ratcliffe, E., Gatersleben, B., Sowden, P.T.: Bird sounds and their contributions to perceived attention restoration and stress recovery. J. Environ. Psychol. **36**, 221–228 (2013)
32. Ryan, R.M., Frederick, C.: On energy, personality, and health: subjective vitality as a dynamic reflection of well-being. J. Pers. **65**(3), 529–565 (1997)
33. Stigsdotter, U.K., Corazon, S.S., Sidenius, U., Refshauge, A.D., Grahn, P.: Forest design for mental health promotion—Using perceived sensory dimensions to elicit restorative responses. Landscape Urban Plann. **160**, 1–15 (2017)
34. Stone, N.J.: Environmental view and color for a simulated telemarketing task. J. Environ. Psychol. **23**(1), 63–78 (2003)
35. Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., Kagawa, T.: The influence of urban green environments on stress relief measures: a field experiment. J. Environ. Psychol. **38**, 1–9 (2014)
36. Tzoulas, K., et al.: Promoting ecosystem and human health in urban areas using Green Infrastructure: a literature review. Landscape Urban Plann. **81**(3), 167–178 (2007). https://doi.org/10.1016/j.landurbplan.2007.02.001
37. Unreal Engine. Accessed May 2020. https://www.unrealengine.com/en-US/
38. Van den Berg, A.E., Koole, S.L., van der Wulp, N.Y.: Environment preference and restoration: (How) are they related? J. Environ. Psychol. **23**(2), 135–146 (2003). https://doi.org/10.1016/S0272-4944(02)00111-1
39. Vive Pro. Accessed May 2020. https://www.vive.com/eu/product/vive-pro/

40. White, M., Smith, A., Humphryes, K., Pahl, S., Snelling, D., Depledge, M.: Blue space: the importance of water for preference, affect, and restorativeness ratings of natural and built scenes. J. Environ. Psychol. **30**(4), 482–493 (2010). https://doi.org/10.1016/j.jenvp.2010.04.004
41. Wickens, C.D., McCarley, J.S., Alexander, A.L., Thomas, L.C., Ambinder, M., Zheng, S.: Attention-situation awareness (A-SA) model of pilot error. Hum. Perform. Model. Avi. 213-239 (2008)
42. Yu, C., Lee, H., Luo, X.: The effect of virtual reality forest and urban environments on physiological and psychological responses. Urban Forest. Urban Green. **35**, 106–114 (2018). https://doi.org/10.1016/j.ufug.2018.08.013

Limiting Off-Task Behavior on Laptops in Classrooms Increases Student Engagement: Use It, or They Will Abuse It

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Abstract. The prevalence of technology and use thereof by part-time learners during lectures presents particular challenges to facilitators of learning. Devices used for learning can be misused for off-task activities, lowering engagement levels, and negatively impacting learning. This research investigated how learners use technology to contribute to learning, but also disengage from the learning process, and contrast it with their personal engagement to determine the potential impact. The quantitative data provides evidence of a relationship between on-task use of technology in the classroom and higher engagement levels in the learning process. Analysis reveals three insights about learning in the age of digital transformation. Firstly, the design of learning interventions should be as interactive as possible to ensure that learners do not disengage. Secondly, facilitators of learning need to ensure their learning design incorporates activities making use of the technology and thus create an environment of digital engagement and active learning. Finally, faculty that use technology to individualize learning should enable students that are working full time to become creators of media and not just consumers.

Keywords: Learning · Engagement · Technology · Learning design · Pedagogy

1 Introduction

The digital transformation impacts all industries and processes, and higher education is also experiencing the impact of technology [1, 23]. Fedorenko, Velychko, Stopkin, Chorna, and Soloviev [8] argued that the informatization of education is the main factor in the development of modern higher education because education's primary objective is the development and growth of each individual. The implementation of learning technologies and the development of the current and future workforce plays an essential role in the development of individual abilities and catalyzes the comprehensive informatization of society.

Current research focuses mostly on industry and organizational level transformations of education like online-, mobile, and virtual learning. However, advancements in technology have also changed students' behavior in traditional classrooms, and educators must adapt to ensure students stay engaged in the learning process [9, 11]. Positive student engagement remains a pivotal contributor to active learning [2, 26]. Engagement

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is particularly applicable to part-time adult learners in postgraduate courses, who have several years of life and work experience [11], and typically study with a high opportunity cost to attend lectures, yet have valuable tacit knowledge to contribute due to their experience.

Technology can improve learning engagement by allowing students quick access to information and engaging in activities directed by the facilitator. However, personal devices brought into the classroom can also be a distraction [15]. Learners could disengage when receiving continuous notifications from applications designed to distract the user [19] or attend to other matters deemed more relevant or enjoyable at that particular time.

Although laptop computers are widely used in many college classrooms, the debate remains about their educational value [12, 20]. Previous research determined that students engage in substantial multitasking behavior with their laptops and have non-class-related software applications active during lectures. The use of laptops in the classroom can negatively impact student attention, motivation, student-teacher interactions, and academic achievement [12, 20], and requires further scrutiny.

The objective of this study is to explore the relationship between the use of technology in the classroom and the extent of the students' engagement specifically for part-time post-experience students and to provide guidance for designers of learning engagement for these students.

2 The Impact of Technology on Higher Education

2.1 Technology and Learning

During the current technological revolution, societal development is highly dependent on the level of informatization of education. Informatization of society requires educational institutions and programs to capacitate the modern citizen to flourish in a transformed society [8]. Informatization of education is a set of interrelated organizational, socio-economic, educational, methodological, scientific, industrial, and management processes [8] aimed at providing the information technology (IT) needs of participants, facilitators, and support personnel. Informatization of education increases the efficiency and intensification of the educational process by using learning technologies and implementing new methodological developments in the learning process [8].

Lafisheva, Kudayeva, and Taisaev [13] list several challenges of education in the post-industrial society. One of these is pedagogical conservatism implying that the facilitators' competence does not meet the required norm for teaching in the current era. This leads to conflict between the traditional way of teaching and the need to switch to more technology intrinsic delivery mechanisms [13]. They argue the importance of educational systems not only adopting, but also working closely with technology providers as they reshape their execution processes [13]. Educational conservatism includes outdated assessment processes that do not embrace students' ability to use technology to create engaging products of assessment like video journals, video case studies, or even designing an educational game or simulation.

Media-multitasking is a common occurrence in the increasing presence of technologies in classrooms [24]. Students often media-multitask (social media, web browsing)

while they are supposed to be paying attention to their facilitator. Media-multitasking divides attention and leads to non-sequential task switching towards ill-defined tasks in learning situations. Activities are referred to as *on-task* when they are relevant for the learning, and *off-task* when not [10, 24]. Conversely, media-based on-task multitasking occurs when technology demands represent one component of a learning task, and additional instructional demands are present. Possible examples of on-task multitasking in the classroom include searching for the definition of a term online while listening to a lecture, or viewing an online video demonstration while engaged in face-to-face group work [24]. In addition to students using devices to support learning, media-based on-task activities can also be directed by the facilitator requesting the use of technology to support a particular learning activity.

Given the possibilities to perform on-task activities removing laptops from the classroom, to negate the off-task use as suggested by Shirkey [20], does not support learning. It may create short term attention to teaching, but it does not support long term learning. The main direction of learning must be aimed at the future possibilities of IT in education, which implies computer skills to be developed during the learning process as well [13], in support of the informatization of education.

2.2 Learning and Engagement

In the traditional classroom setting, the educator engages with the students to impart knowledge [7]. Educators make use of their years of experience to interact with students to create a social environment that promotes students' self-efficacy, trust, values, motivation, participation, and performance [1, 2, 5]. Thiyagu [22] defines the creation of knowledge in students as a five-stage process where students; (1) share their views and information, (2) explore differences of information, (3) constructively build new knowledge together, (4) adapt and test their newly acquired knowledge and finally (5) make statements and apply the new information. Following this argument, being engaged in the teaching process is critical for effective learning, and digital technologies play an essential role in each of the five phases. Limiting the use of technology in the classroom inhibits the learning process.

Student engagement refers to active engagement between the student, lecturer, and other students within a classroom or group setting [1]. Pittaway and Moss [18] emphasize that an environment conducive to learning is created when a lively and positive social environment between students and educators exists. Learning is most effective when it occurs within the right context and in the right environment and that it is the lecturers' responsibility to build and maintain this environment [11]. The pervasiveness of technology makes it more complex to create this conducive environment, yet simultaneously allows more tools to create such an environment when used correctly.

Pittaway and Moss [18] suggested an engagement framework that consists of five dimensions of engagement being social, professional, academic, intellectual, and personal. The framework (see Fig. 1) indicates how the dimensions of engagement occur in the specified environment. Personal engagement is central to an engaged learned as it links with each of the other four engagement dimensions. The engagement framework can be used to design appropriate pedagogy to ensure student engagement.

Four principles support the framework to establish the required environment [18]:

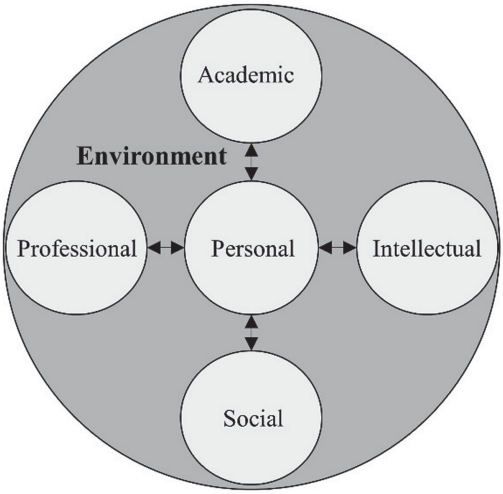

Fig. 1. The engagement framework [18]

1. The faculty is motivated and engaged to enable students to engage. This motivation is also displayed to students through the design of the learning interventions and appropriate use of technology [6].
2. Relationships built between students and educators should be respectful and supportive. Technology has enabled the relationship to start before the classroom and flourish outside lectures but also impacts classroom culture due to off-task behavior during lectures [17, 20].
3. Opportunities should be created for students to take charge of their learning. Technology allows for individualization of tasks [22] as well as accurate tracking and control of learning [3, 18].
4. Faculty members should set high standards and expectations and help students achieve milestones, which helps them achieve greater knowledge, skills, and understanding. This includes students' use of technology during the learning process [4].

Multiple authors [3, 11, 18] posit that personal engagement is the essential element of the engagement framework and argue that it happens even before the student enrolls in the course, or at least attends a lecture. Personal engagement requires the student to have self-belief and expectation that they can be successful in achieving their goal [18]. Other attributes, such as self-efficacy, persistence, and goal setting, are also part of personal engagement and will develop throughout the learning process [11].

Social engagement indicates that students' world views are challenged through interaction, leading to a deeper understanding of self and personal perceptions and beliefs [3]. Networking and social interaction between students should be encouraged, outside of the classroom, and in standard learning settings and discussions [1]. Professional engagement connects the theory and application to the working world and refers to how students will use the skills they learned [11, 18]. Academic engagement takes place when students apply themselves to become actively involved in their planning, monitoring,

and evaluation of their learning. This is achieved through knowledge and skills from past experiences [18]. Intellectual engagement occurs when students and educators take an interest in their chosen discipline and stay up to date with current affairs in their field [3]. It does not only focus on their understanding of the subject matter but also requires critical thinking and understanding of the impacts in different contextual settings such as political, social, and possible ethical issues [18].

2.3 Post Experience Student Challenges

There is a notable difference between the behavior of postgraduate and graduate students [11] and even more so when comparing these students with post-experience postgraduate programs typically offered at business schools [9]. In general, post-experience students are adult learners with work experience and potentially a family and other forms of dependencies while completing their studies [2, 4]. These students started down their chosen career paths and have a host of other responsibilities. They remain in full-time employment, which puts further strain on their limited free time [11] and increases the opportunity cost of attending lectures. Adult learners, often self-funded, do not have the same propensity for social off-task behavior and are less prone to disengage in the classroom. The challenge in keeping these students on-task is different from that required for full-time pre-graduate students.

Technological advancements assist post-experience students by allowing them to make use of the internet to stay online and connected, while also giving them the freedom to continue their studies [14, 21, 22]. However, this freedom also poses a challenge. These students often remain connected to their work environment during lectures, especially if they are not engaged in the classroom. The same technology that allows geographical freedom from the work environment to pursue further studies can also be a distraction in the classroom and negatively impact learning. For them, the work distraction is over and above the normal social distraction faced by all students using devices while in the classroom.

Digital transformation leads to the normalization of media- multitasking in the modern classroom and work environments. Research that investigates how students use laptops in the classroom and the effects of laptop usage has on student performance outcomes exist [2, 7, 12, 19]. However, there is a lack of research that focuses on the faculty-directed use of technology in the classroom. For example, some previous studies have found that postgraduate students use the internet for academic purposes more than for social engagement [21], contradicting findings for graduate students [24].

The requirement to improve the quality of higher education has led to an increased awareness of learning technologies to support the learning design [6]. A large part of this increase is directed at the creation of online learning experiences [6]. Learning design must also focus on designing online learning activities for in-class students, like simulations, desk research, gamified exercises, and similar technology intrinsic activities using devices to perform on-task activities.

Bennett, Agostinho, and Lockyer [6] argued the importance of research into university teachers' design practice in the wake of learning technologies' potential to improve learning design and shape existing design practices. There remain unanswered questions

about what shapes university teachers' design decisions and how tools can best support their design processes [6].

The purpose of the article is to emphasize the importance of introducing IT into the educational process of higher educational institutions. The focus is on 1) the relationship between on-task technology use and personal engagement, 2) understanding how to limit off-task behavior, and 3) devising mechanisms to switch from off-task to on-task behavior to guide learning designers when dealing with part-time students.

3 Research Methods

To understand the relationship between the two key constructs of engagement and on-task technology use, a research instrument that measures all the latent variables in Pittaway's [17] engagement construct (Fig. 1) was developed and validated. It formed the basis of a model to measure the relationships between social, professional, academic, and intellectual engagement and personal engagement, as well as on-task technology use and personal engagement. This paper deals with the relationships between the on-task use of technology and personal engagement, at the center of Pittaway's framework (Fig. 2), as well as drivers of on-task and off-task behavior.

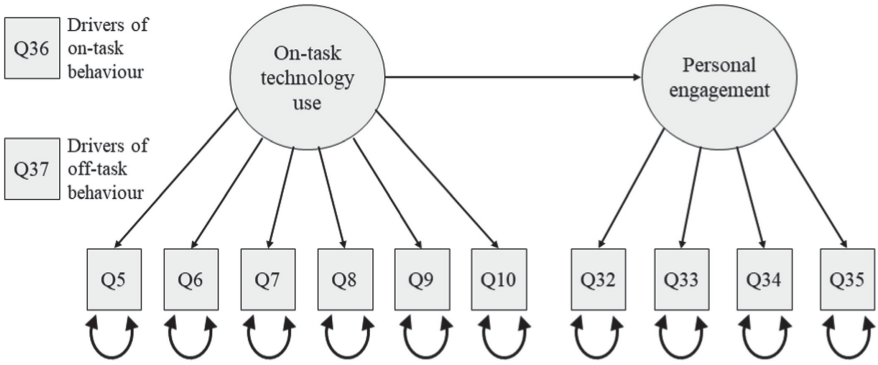

Fig. 2. The research model used to measure engagement and technology use

Making use of the engagement construct (Fig. 1) along with the definitions for each of the different engagement types as defined by various authors [3, 11, 16, 17], it was possible to set up four questions per engagement variable that measured the degree of engagement. Six questions were developed from prior research [2, 4, 11, 15, 22] to define a construct for on-task technology use. A self-reporting survey, appropriately validated, enabled the variables to be quantified. Participants were able to answer questions anonymously to accurately quantify the perceived level of engagement and their on-task technology use.

The questionnaire made use of scalar questions using a five-point grading scale from 'completely disagree' to 'completely agree' in line with recommended best practice. The questions were set up in numerical order in the first column on the left with the

five scaling options listed horizontally next to each question, on a layout without any visual stimuli to influence the respondent. It was possible to determine the relationship between personal engagement and on-task technology use through the quantified data for each variable.

Respondents were asked to comment on drivers of their on-task and off-task use of technology during lectures (questions 36 and 37). This provided qualitative data to obtain insight to contribute to the objective of guiding learning design.

4 Research Results

A total of 192 students, 50% of the sample population, started the questionnaire, of which 180 responses, 49.3% of the sample population, were valid, indicating a completion rate of 93.8%. The quantitative data was coded with scores between 0 (Completely Disagree) and 4 (Completely Agree) and vice versa for every second question asked in the negative. For appropriate technology use, participants could thus attain a 24 point maximum score (6 questions) that indicate always using technology to enhance the learning (on-task) and never for any other purpose (off-task).

For each of the engagement sections, a 16 point maximum score could be achieved (4 questions) indicating the level of engagement. This allowed for a summation of each participant's level of appropriate technology use in the classroom and their level of engagement in each of the different dimensions. Three scores (5, 7, and 24) were only recorded for a single respondent each and were omitted from the data for analyses, leaving a sample of 177 responses, as indicated in Table 1.

Table 1. On-task technology use and personal engagement data (n = 177)

On-task tech use	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Number	2	4	2	9	32	23	19	27	16	13	10	2	8	6	4
Minimum engagement	8	8	6	7	5	6	7	5	8	6	8	8	8	8	8
Average engagement	8.5	8.8	8.5	9.8	10.1	8.9	9.5	9.5	10.1	9.6	9.7	10.5	9.5	10.2	9.8
Maximum engagement	9	14	11	12	16	11	14	14	16	14	13	13	12	13	14

A correlation graph (Fig. 3) was drawn for the average level of *on-task technology use* and *personal engagement*. It is evident from the analyses that a linear relationship exists ($R^2 = 0.4614$) between the appropriate use of technology in the classroom and the level of personal engagement during lectures. It can thus be stated that learning, which benefits from student engagement, is improved when technology is used for on-task learning activities in the classroom. This direct influence of on-task technology use on

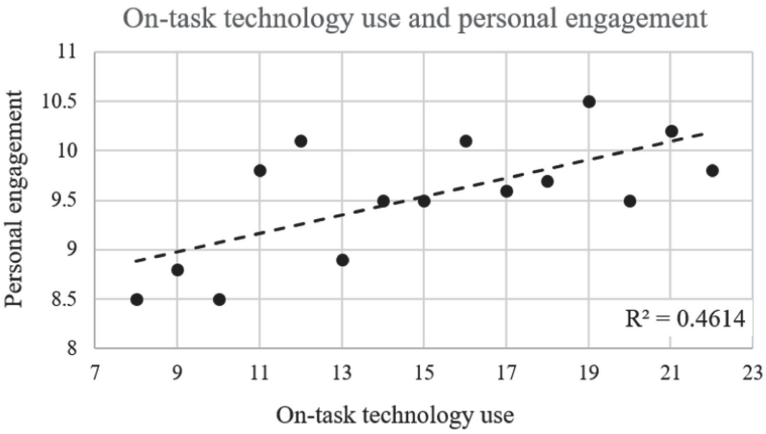

Fig. 3. Appropriate technology use and personal engagement (n = 177)

learning is not unexpected. However, it places a particular emphasis on learning design in the presence of these devices in the classroom.

At the end of each section in the questionnaire, an opportunity was provided to capture any other comments. Questions 36 and 37 also asked directly about the drivers of on-task and off-task activities. Comments were overwhelmingly positive about the on-task use of technology in the classroom and the need for students to use their devices, confirming that banning devices from class [20] is not pedagogical advisable. Many respondents admitted to making frequent use of their phones, laptops, or tablet computers to improve their learning experience.

The most common use cited in the data is making notes. Other uses were provided; for example, Respondent 54 indicated that "I will occasionally search terms and things if I do not understand them while the lecture is occurring" and Respondent 74 echoing this by indicating that "[h]aving access to [the] internet has helped me understand certain class sessions better." There seems to be a consensus that it is valuable to access terminology and additional information in a fast-paced learning environment. This was the most often cited use case, beyond taking notes.

However, of-task technology use was also evident and acknowledged confirming previous research [24]. Respondent 48 probably best summarizes the sentiments of multiple other respondents in stating that "[t]echnology is immersed in our lives … we as students need to communicate with the outside world from time to time." Many of the respondents admitted that their distraction was also dependent on the urgency of work issues. They stated that although it was not the norm to engage with work, their priorities were sometimes determined by factors outside their control.

Valuable insights emerged gained about the learning environment and learning design from the two questions asking about on-task and off-task drivers. In the words of Respondent 32, "[l]aptop use varies in the classroom context for me, hugely dependent on how engaging and interesting the lecture is." Many other respondents confirmed that they tend to wander into online distractions when not engaged by the facilitator in the learning process, and tend to pick up their engagement when prompted to engage constructively.

Respondent 132 indicated that "… there is nothing better to get my attention back in the lecture than the professor asking me to use the laptop to do something, be it an online quiz or just [to] Google some interesting facts." Respondent 117 supported this general trend and also hinted at the social environment created when stating that "I enjoy using tech during class and believe I still stay engaged in class."

Drivers of off-task behavior fall into two groups, 1) a lack of engagement in the learning process by the faculty leading to boredom, and 2) the urgency of work environment distractions that require immediate attention. However, the latter could also be perceived urgency in the words of Respondent 62 "… and then sometimes, if the lecture is not engaging, I open my work email to deal with my work activities since I feel my time in the class is a bit wasted". Respondent 18 highlighted one of the challenges the facilitators face when indicating that "…slides with lists of bullets can be read at home, I come to class to be kept busy and do not mind if this is personal interaction or the cyber-attack simulation we did. I think the 60 min simulation was the only time that all 60 students never used their laptops for non-academic activities." Respondent 44 referred to a particular group learning activity where students had to create a reflective video journal about their international academic visit; "… creating the video journal for our ISM [International Study Module] and making that part of the assessment was a great idea … to force us to learn a new skill, work together but also create something of future value".

Recognizing that students value using technology to learn, and their ability to co-create educational activities that reshape the traditional classroom, is evident from the qualitative data, supporting the work of Benitz, Pauleen, and Hooper [5] who believes that students should become knowledge creators rather than information gatherers.

5 Recommendations

Fedorenko, Velychko, Stopkin, Chorna and Soloviev [8] provided a comprehensive list of the problems associated with the informatization of education. They argue that preference should be given to the forms, methods, and techniques using learning technologies to personalize the process of learning, enrich the acquired knowledge, and allow individuals to become competent in professional activities. Recommendations to this effect, based on the data presented, are made by referencing the four principles defined by Pittaway and Moss [18] for an engaging learning environment.

Their first principle is that faculty should be motivated and engaged to enable students to engage [18]. This includes motivating faculty to use technology and integrate the use of technology by students in their pedagogy, for example, using simulations and gamified exercises performed on the very laptops that could also be a distraction. It is no longer sufficient for facilitators to only master the classroom technology; it has become essential to think about how students can use their own devices to engage in the class and design appropriate learning processes.

The second principle is a respectful and supporting relationship between students and educators, and the third principle is creating opportunities for students to take ownership of their learning [18]. This mutual respect includes knowing that students are eager to use their devices to enhance their learning experience and will assist faculty in their

part of the learning process. It requires the mindset to move away from the perception that devices take attention away from learning towards devices, providing a gateway to information and processes that enhance learning that will strengthen this relationship. The pedagogical conservatism needs to make way for flexibility and experimentation aligned with the skills required to flourish in the digitally transformed society. Students' ability to take charge of their learning using the modern tools provided by technology is unprecedented in the history of education. The same digital transformation that brought personal devices into the classroom to compete for the students' attention is also a powerful tool of learning, waiting to be unleashed by faculty that know how to utilize them.

The fourth principle of setting high standards and expectations is potentially the least appreciated environmental factor. Setting these standards could include requiring students to use technology to showcase or develop the skills valued in the modern business environment. The ability for students to become creators of content rather than consumers of content is unprecedented. Faculty do not have to be expert with a particular technology, to set high expectations for students to use the technology and create high-quality content. Faculty can assess the quality of the content created to achieve learning outcomes, not the process of using the content.

Post experience part-time students return to their workplace where they experience real-world examples of the classroom context, content, and processes. Using technology to capture and provide access to their environment to show the application of their learning and creating media content for future use, requires faculty to also move away from conservatism in assessment practices. Designing a learning process from initial exposure to displaying final competence of achieving learning outcomes requires multiple applications of technology. When faculty set an example of how to use technology themselves, educators lay the foundation for learners' efficient use of technology in their learning processes.

Wood, Mirza, and Shaw [24] established that employing relevant online activities as part of instruction leads to increased on-task behaviors for full-time students. This study confirmed their findings and indicate that it is even more relevant for part-time students with more potential distractions.

6 Limitations and Future Research

This study was limited to students enrolled at the University of Stellenbosch Business School in South Africa, where a significant amount of work has been done to facilitate the use of technology in the classroom with an emphasis on student engagement. Students who typically study in an environment where technology is omnipresent is not necessarily representative of all postgraduate and post-experienced students who may find themselves in different environments.

Noteworthy is the construct of Fig. 1 with all the multiple dimensions of engagement and the potential covariance that may be present between the dimensions. The next step of this research study is a structured equation model that analyzes the interesting construct of engagement in all its different dimensions and the use of technology in the classroom for online activities.

There was no evidence of a self-selection bias or fear-of punishment or embarrassment non-response bias by students who chose not to participate [12]. Self-reporting studies lead to specific types of bias, most notably the overestimation of own ability that should, in principle, see a consistent effect size for all levels of on-task and off-task questions. The relative data and relationship are thus used, and not the absolute values that may suffer from this bias.

The sample population is full time working postgraduate students studying part-time. To date, the vast majority of studies about media-multitasking behavior in education have been performed for full-time students. The results are thus unique to this student population and valuable within that specific context. However, the results remain specific to part-time postgraduate students.

7 Conclusion

Complex societies need highly trained individuals, and significant resources are invested in initiatives to improve university education [25]. Although they recognize the need for education, many adults are reluctant to risk unemployment by returning to higher education institutions on a full-time basis. These students study part-time and have to deal with work-related pressure in a classroom on top of the typical off-task distractions like social media faced by all students.

Student-focused approaches to teaching encourage approaches to learning that result in high-quality learning outcomes. When dealing with experienced part-time learners, a student-focused approach takes cognizance of their specific realities. It is evident from the analysis that there is a direct relationship between on-task technology use and their level of personal engagement in the learning process.

Learners will use their laptops in the classroom. There is an onus on faculty to design learning processes that are engaging to stop students from wandering off into non-academic activities. More importantly, faculty also need to design processes that require students to use these tools as part of their learning process to remain engaged in the classroom.

Educational technologies aimed at establishing knowledge and acquiring skills and abilities can be used to adapt learning to the student's individualities. Using educational technologies to extend individualization towards their place of work and including innovative forms of assessment to create knowledge is highly valued by part-time students.

The digital transformation of higher education is not only new technology intrinsic products like mobile and online learning but also an adaptation of pedagogy in physical classrooms and beyond to embrace the power of digital technologies.

References

1. Allodi, M.W.: The meaning of social climate of learning environments: some reasons why we do not care enough about it. Learn. Environ. Res. **13**(2), 89–104 (2010). https://doi.org/10.1007/s10984-010-9072-9

2. Arjomandi, A., Seufert, J., Anwar, S., O'Brian, M.: Active teaching strategies and student engagement: a comparison of traditional and non-traditional business students. J. Bus. Educ. Scholarsh. **12**(2), 120–140 (2018)
3. Baker, W., Pittaway, S.: The application of a student engagement framework to the teaching of music education in an e-learning context in one Australian university. In: 4th Paris International Conference on Education, Economy and Society, pp. 27–38 (2012)
4. Beckmann, E.A.: Learners on the move: mobile modalities in development studies. Distance Educ. **31**(2), 159–173 (2010). https://doi.org/10.1080/01587919.2010.498081
5. Benitez, E., Pauleen, D., Hooper, T.: From information gatherers to knowledge creators: the evolution of the post-graduate student. Electron. J. Knowl. Manage. **11**(2), 139–149 (2013)
6. Bennett, S., Agostinho, S., Lockyer, L.: Technology tools to support learning design: implications derived from an investigation of university teachers' design practices. Comput. Educ. **81**, 211–220 (2015)
7. Dintoe, S.: Information and communication technology use in higher education: perspectives from faculty. Int. J. Educ. Dev. Inf. Commun. Technol. **14**(2), 121–166 (2018)
8. Fedorenko, E.H., Velychko, V.Y., Stopkin, A.V., Chorna, A.V., Soloviev, V.N.: Informatization of education as a pledge of the existence and development of a modern higher education. Educ. Dimension **1**(52), 5–21 (2019)
9. Henderson, M., Finger, G., Selwyn, N.: What's used and what's useful? Exploring digital technology use(s) among taught postgraduate students. Act. Learn. High Educ. **17**(3), 235–247 (2016). https://doi.org/10.1177/1469787416654798
10. Jamet, E., Gonthier, C., Cojean, S., Colliot, T., Erhel, S.: Does multitasking in the classroom affect learning outcomes? A naturalistic study. Comput. Hum. Behav. **106**, 106264 (2020). https://doi.org/10.1016/j.chb.2020.106264
11. Johnson, E., Morwane, R., Dada, S., Pretorius, G., Lotriet, M.: Adult learners' perspectives on their engagement in a hybrid learning postgraduate programme. J. Continuing High. Educ. **66**(2), 88–105 (2018). https://doi.org/10.1080/07377363.2018.1469071
12. Kraushaar, J.M., Novak, D.C.: Examining the affects of student multitasking with laptops during the lecture. J. Inf. Syst. Educ. **21**(2), 11 (2019)
13. Lafisheva, M.M., Kudayeva, F.K., Taisaev, Dzh.M.: Informatization of education in the context of post-industrialization: the difficulties' In: 2017 International Conference 'Quality Management, Transport and Information Security, Information Technologies' (IT&QM&IS, Saint Petersburg, Russia, pp. 668–670. IEEE (2017) https://doi.org/10.1109/ITMQIS.2017.8085912
14. Li, L.Y., Lee, L.Y.: Computer literacy and online learning attitude toward GSOE students in distance education programs. High. Educ. Stud. **6**(3), 147–156 (2016). https://doi.org/10.5539/hes.v6n3p147
15. Mareco, D.: 10 reasons today's students NEED technology in the classroom. Accessed 8 Feb 2019. https://www.securedgenetworks.com/blog/10-reasons-today-s-students-need-technology-in-the-classroom
16. Onaolapo, S., Oyewole, O.: Performance expectancy, effort expectancy, and facilitating conditions as factors influencing smart phones use for mobile learning by postgraduate students of the university of Ibadan, Nigeria. Interdisc. J. E-Skills Lifelong Learn. **14**(1), 95–115 (2018). https://doi.org/10.28945/4085
17. Pittaway, S.M.: Student and staff engagement: developing an engagement framework in a faculty of education. Aust. J. Teach. Educ. **37**(4), 3–12 (2012). https://doi.org/10.14221/ajte.2012v37n4.8
18. Pittaway, S.M., Moss, T.: "Initially, we were just names on a computer screen": designing engagement in online teacher education. Aust. J. Teach. Educ. **39**(7), 8–22 (2014). https://doi.org/10.14221/ajte.2014v39n7.10

19. Santoveña-Casal, S.: The impact of social media participation on academic performance in undergraduate and postgraduate students. Int. Rev. Res. Open Distrib. Learn. **20**(1), 125–143 (2019)
20. Shirky, C.: Why I just asked my students to put their laptops away. Medium.com **11** (2014)
21. Shukla, M.D., Shinde, G.P.: Impact of student engagement in internet usage and their spending of money with special reference to smartphones. BVIMSR's J. Manage. Res. **8**(1), 64–68 (2016)
22. Thiyagu, K.: Perception towards mobile learning activities among post graduate students. I-Manager's J. Sch. Educ. Technol. **8**(1), 35–40 (2012)
23. Wilms, K.L., et al.: Digital transformation in higher education–new cohorts, new requirements? In: 23rd Americas Conference on Information Systems, Boston, 2017 AMCIS 2017 (2017)
24. Wood, E., Mirza, A., Shaw, L.: Using technology to promote classroom instruction: assessing incidences of on-task and off-task multitasking and learning. J. Comput. High. Educ. **30**(3), 553–571 (2018). https://doi.org/10.1007/s12528-018-9185-1
25. Xiao, J.: Digital transformation in higher education: critiquing the five-year development plans (2016–2020) of 75 Chinese universities. Distance Educ. **40**(4), 515–533 (2019)
26. Zilvinskis, J., Masseria, A.A., Pike, G.R.: Student engagement and student learning: examining the convergent and discriminant validity of the revised national survey of student engagement. Res. High. Educ. **58**(8), 880–903 (2017). https://doi.org/10.1007/s11162-017-9450-6

E-Health: International Workshop "E-Health: 4P-medicine and Digital Transformation"

Sign Language Recognition Based on Notations and Neural Networks

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Abstract. Automated translation from sign languages used by the hearing-impaired people worldwide is an important but so far unresolved task ensuring universal communication in the society. In the paper, we propose an original approach to recognizing gestures of the Russian Sign Language based on the combined use of the linguistic Hamburg System of Notations (HamNoSys) and OpenPose library for tracking human movements. Our software based on the specially constructed and trained artificial neural network (ANN) model performs recognition of the two main components commonly identified in gestures: handshape and location (while the hand orientation, the movement and the non-manual component are so far not considered). The recognition accuracy obtained in the experimental validation with the standard Leap Motion SDK hand tracking algorithm was 100% for adult signers and about 76% for the children. Details of the software architecture and the image recognition process with skeletal data are provided.

Keywords: Universal design · Image recognition · Artificial neural networks

1 Introduction

The 70 million deaf people worldwide who use sign languages (SLs) as their primary language of communication are represented by the World Federation of the Deaf (WFD). The Russian Sign Language (RSL) is utilized by the hearing-impaired people in the Russian Federation – 120.5 thousand users, according to the Census of 2010 – and to some extent in the former Soviet republics. Despite the significant number of users, the RSL got official backing just recently, after the amendments to the Federal Law "On the social security for the invalids in the Russian Federation" were signed by the President V. Putin in late 2012. There, the RSL is defined as "the communication language used in case of hearing and/or speaking impairments, particularly in the context of the oral use of the Russian Federation's official state language". The new version of the Law guarantees that the deaf people get free translation services for communication in federal and municipal government institutions, up to 40 h per year. However, this amount turns out to be insufficient, and the shortage of RSL translators is currently rather notable, as statistics reports that even in Moscow there's 1 translator per 500 hearing impaired people.

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1.1 Particular Features of Sign Languages

One possible classification of gestures is gesticulation, language-like gestures, pantomimes, emblems and the actual sign languages [1]. Linguistic elements of sign languages are signs (gestures), each of which can be described by as many as 5 parameters (Fig. 1): a) handshape, b) hand orientation, c) location, d) movement and e) non-manual component. A change in a single component generally alters the meaning of the whole sign.

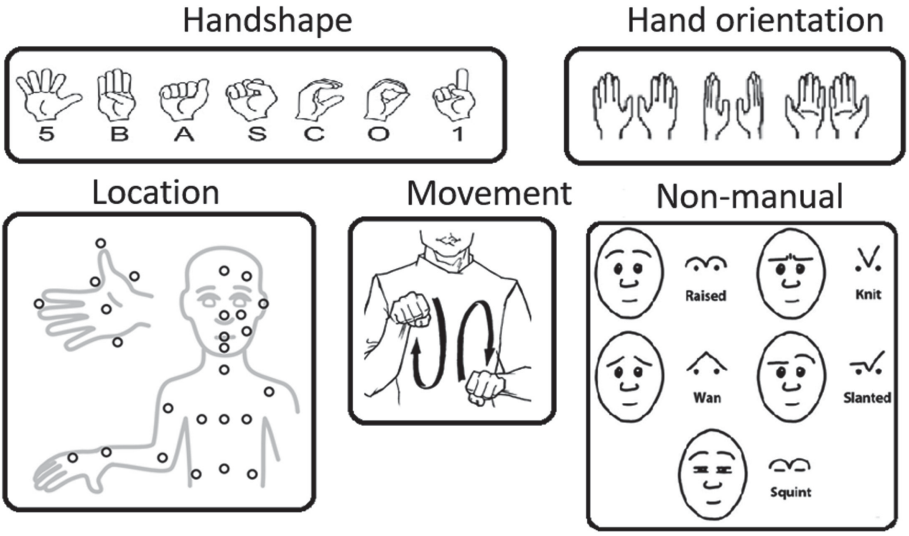

Fig. 1. The five components of signs in sign languages.

Handshape. Represents the form of the wrist when the gesture is performed. For example, in RSL the signs "Siberia" and "Novosibirsk" differ only in the shapes – S–configuration or N–configuration, while location, orientation and movements are exactly the same. Overall, the research in deaf signers' judgment of handshapes suggests that it is best predicted by positional similarity method [2], although certain alternatives have been proposed as well.

Hand Orientation. Orientation of the hand represents the position of the palm and the fingers in relation to the signer's body and the position of the hands in relation to each other. The palm can be turned up, down, right, left, towards the signer, away from the signer or edge towards the signer. The tips of the fingers can be directed up, down, right, left, towards or away from the signer, diagonally, etc. In two-handed gestures, the hands can be symmetrical, parallel to each other, one above, behind or before the other, the wrists can be crossed, the palms can touch the edges and so on. Some SL researchers see orientation not as a separate parameter, but as a sub-category of handshape. However, as noted in [3], the ability of the orientation to be the single parameter identifying the

sign's semantics (for instance, for the signs "if" and "weighting" in RSL), rather calls for considering it a distinct parameter.

Location. Includes two features: *place of articulation* and *setting*. The former refers to one of the major areas in the sign space: head, body, neutral sign space, or the passive hand. The setting further specifies the location of the gesture in these large areas: e.g. forehead, chin, nose, ear in the head area. In RSL, the signs "boy" and "girl" are both performed at the signer's head level, but the "boy" is shown at the forehead, while the "girl" is shown at the cheek.

Movement. Considered to be the most complex and internally non-uniform parameter in the gesture's structure. The two main types are path movement – moving the hand from one localization to another – and local movement. In the path movement, important features are direction, i.e. movement of the hand relatively to the vertical, horizontal and sagittal axes, and character, which can be straight, arch, zigzag, spiral, sharp, smooth, etc.

Non-manual. One of the common misconceptions regarding SLs is that they are "hand languages", i.e. that the linguistic units are articulated by hands only. Certainly, hands have the crucial role, but the other articulators – the body, head, shoulders, parts of the face – are very important nevertheless. For instance, in RSL a statement differs from a yes/no question through raised brows in the signer. Such linguistically significant components in sign speech are called *non-manual components* or *non-manual markers/signals*.

Overall, processing of SL, which has a particular temporary and spatial organization (the space in front of the signer – the sign space), is a complex task from the linguistic point of view. Naturally, it also has to be performed in real time, since the pace of SL is only marginally slower than the one of the speaking languages [4].

1.2 Automated Recognition and Translation

Automated translation between speaking and sign languages is desirable due to both shortage of human translators and abundance of contexts where their involvement is unwanted – e.g. in personal relations, in medical examinations, etc. Currently, translation from speech/text to signs is significantly better developed, achieving satisfaction level of about 80% (for instance, in Surdophone software[1]). For the reverse translation, this level is generally below 70%, due to challenges in automated recognition of signs, which is in the focus of many research projects nowadays. There is certain ambiguity in literature what exactly is recognition of hand gestures, but it commonly involves detecting positions of wrists, shoulders and finger tips, as well as identification of the configuration and the trajectory of the hand movement.

So, recognition of signs involves several complex stages: movement modeling, movement analysis, image recognition and machine learning. *Vision-based approaches* require

[1] http://сурдофон.рф.

images or videos of the signs recorded with a certain type of equipment: a simple camera, a stereo camera, a rangefinder camera, etc. *Sensor-based approaches* involve sensors and tools for motion capture, position and speed of wrist movement: inertial measurement units, electromyography, Wi-Fi and radar-based equipment, and so on. The existing algorithms for recognition can be largely divided into two categories: *appearance-based*, which focuses on analysis of the external features of the signs, and *3D model-based*, which deals with 3D model of the hand. The former has advantages in computational costs when extracting the sign features, while the latter is beneficial in the actual recognition process.

Our own research relies on model-based approaches, since we believe they have better prospects, due to the coming introduction of gesture-based devices for human-computer interaction. They are going to provide standardized resource-efficient real-time solutions for extracting the features, elimination of background, segmentation of objects in the image, including detection and monitoring the hand and the body, etc. Meanwhile, in our current work we are going to consider the sign recognition problem as two sub-tasks:

- Recognition of handshapes based on 3D skeletal data;
- Recognition of the sign location based on 2D skeletal data.

The architecture of the sign language system that we propose consists of the two interconnected modules: 1) the recognition of phonological parameters and 2) the machine translation. The former analyzes skeletal data from the video base and detects the user's body, face, hands and fingers. The machine translation module performs the final analysis of the phonological features and forms a word or a sentence (in general correspondence to how it is done for the speaking languages too). The phonological features are transformed into sign notation system based on the Hamburg Sign Language Notation System (HamNoSys[2]) phonetic transcript [5]. It was devised as early as in 1980s, but has seen several updates since then, and is currently compatible with XML version of SignML (brief examples of the signs in HamNoSys from [6] are presented in Fig. 2).

Fig. 2. "Small" and "large" signs in the Hamburg Sign Language Notation System.

Since HamNoSys is in the core of our implementation, we consider it in detail in the Methods section of our paper. With respect to specifying the components of the gestures, HamNoSys is a very robust system including over 200 sign notations, and it can be used in automated SL recognition with classifiers and linguistic models [7]. Still, it has certain related functional disadvantages: in description of fine motor movements, non-manual components in gestures, touching of various body parts (hands, body, head, etc.). Also, small number of grades available for specifying some of the gestures components, for

[2] https://www.sign-lang.uni-hamburg.de/dgs-korpus/index.php/hamnosys-97.html.

instance proximity of the palm to the body, does not allow describing the features that are significant for the automated recognition.

1.3 Research Objectives and Contribution

Automated recognition of SLs is a currently unresolved problem [8], due to both particulars of the language and the complexity imposing considerable computational costs. The objective of our work includes extension of HamNoSys with the necessary notations for more complete SL specification necessary for the computer-based translation. We see the following main contributions of our current paper:

1. The gesture model for the sign recognition task based on skeletal data and HamNoSys SL notations.
2. The principal architecture of the SL recognition system (with justification of the related advantages).
3. The algorithms for handshape recognition based on 3D skeletal data.
4. The algorithms for the gesture location recognition based on 2D skeletal data.

The remaining of the paper is organized as follows. In Sect. 2, we review some related publications and tools, detail the HamNoSys that forms the core of our approach, and outline the overall machine learning-based architecture of our solution. In Sect. 3, we describe software implementation of our algorithms and validate its performance with 10 subjects who use sign language. In Conclusions, we summarize our results, point out their limitations and lay down plans for further development.

2 Methods and Related Work

Research in SLs – the second main type of natural human languages – is currently very active in linguistics, which seeks to develop new methods for collecting and processing the language material performed in 3D space. With respect to IT, the existing vocabularies and automated translation systems for SLs are by and large work "from word to gesture". Some notable examples are Surdoserver (Moscow)[3], Surdophone mobile app (Novosibirsk), HandTalk (Brazil)[4], DELEGS[5], international SL dictionary Spreadthesign[6] and others. Software projects that allow finding a recognized sign's meaning are scarcer, not fully functional, such as Motion Savvy (USA), lack recognition of RSL, or have somehow deficient user interface (e.g. American Sign Language Dictionary[7]). Some solutions imply that the signer uses a bracelet or a colored glove, to improve the hand segmentation and lower computational costs. Overall, there are several criteria for measuring the efficiency of gesture recognition systems: scalability, reliability, real-time performance and user independence [9].

[3] http://www.surdoserver.ru/.
[4] http://handtalk.me.
[5] https://www.wps.de/en/research/delegs/.
[6] http://www.spreadthesign.com.
[7] https://www.handspeak.com/word/.

As we mentioned before, our own approach implies division of the architecture into two modules, breaking the video stream by SL parameters (just as the phonemes in speaking languages) and analyze their temporal and spatial features to extract particular words' parameters. Such separation of the phonological and the machine translation module allows two important advantages for our solution:

- Recognition of phonological gestures can be calculated in the client module (browser or mobile app) as front-end, including the engineering of features – segmentation of the user and monitoring of the hand and the body.
- Machine translation in the server module, acting as the back-end and increasing the efficiency of the computation.

The phonological module in our solution relies on the Hamburg Sign Language Notation System, while the recognition and the machine translation are performed based on machine learning methods.

2.1 The Hamburg Notation System

The Hamburg Sign Language Notation System (HamNoSys) [5] is an alphabetic system that describes signs on the nearly phonetic level. During the past 30 years, many sign notation systems were developed, and particularly HamNoSys is based upon Stokoe notation, in which alphabetic system was introduced for the American Sign Language, to describe location of sub-lexical parameters, handshape (in most cases, only for the contour) and movement. The HamNoSys for one sign includes:

1. Specification of the handshape (Fig. 3), consisting of symbols for the principal forms and diacritic signs for the position of the thumb and the flexion. Besides, it can describe departures from this general description with respect to the engaged fingers or shape of particular fingers. If necessary, intermediate forms can also be specified.

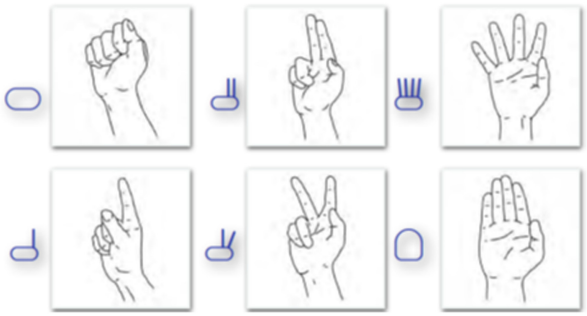

Fig. 3. The basic handshapes [HamNoSys].

2. Specification of the hand orientation, combining the two components: 1) the extended direction of the finger (i.e. indexing direction for the indexing hands) that defines the

two degrees of freedom, and 2) palm orientation, with defines the third one. Since symbols are available for both the components at 45° (Fig. 4), the 3D orientation of the hand can be specified with rather high detail.

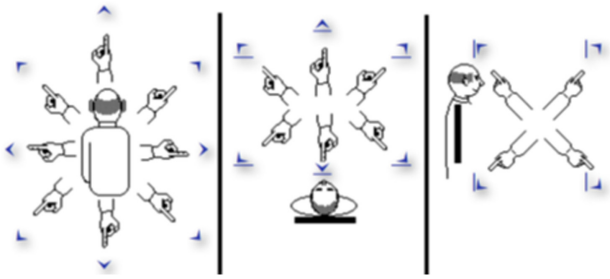

Fig. 4. The principal orientations of the hand (including the finger) [HamNoSys].

3. As with the hand orientation, the specification of the location is divided into two components: 1) defining the location in the frontal plane (x and y coordinates), and 2) defining the z coordinate. If the second component is missing, the "natural" distance of hand from the body is assumed. If both the components are missing, the notation assumes that the hand is in the "neutral space for the sign", i.e. within the "natural" distance to the upper body.
4. Actions, which are combinations of movements within the trajectory (i.e. movements that alter the hand's position) and movements of hands in place, as well as non-manual movements. Such combinations can be performed either sequentially, or in parallel.
5. Non-manual components of sign languages are not supported by the HamNoSys.

HamNoSys is not bound to a specific national orthography and can be applied internationally. Its symbols are available for free in the Unicode set for various operating systems, thus facilitating their computer-based processing.

2.2 Machine Learning Based Recognition

For visual image recognition, one can survey the object under the many possible angles of view, scales, shifts, and so on. Another well-known approach is based on edge detection, where the contours, lines' connectedness, angles, etc. are considered. Finally, arguably the most efficient method today are neural networks (NNs), which however require lots of data samples and judicious domain-specific selection of the network's architecture and the hyper-parameters. Before the emergence of deep learning, feature engineering played the key role in machine learning tasks, since the classical algorithms did not have the hypothesis space robust enough for identifying the meaningful features. The format of the data passed to the algorithm was crucial, but nowadays deep NNs can extract the features automatically from the input data.

Factors set limit the usage of the more traditional long short-term memory (LSTM) networks for SL recognition: 1) different gestures have different duration, therefore for

training the gestures it is necessary to normalize the patterns of the training set in time, and 2) sloppy gestures and epenthesis movements are extremely difficult to mark up for the training set, and therefore error (accuracy measure) deteriorates.

In accordance with the framework proposed in [10], our SL recognition software has two main parts (see in Fig. 5): the first one is to get the component representation of the sign gestures and the code table of the target set of sign gestures using the data from the reference user. In the second part, which is intended for new users, the component classifiers are learned using the training set proposed by the referenced user, and the classification of unknown gestures is performed using the comparison method. Extensibility of the gesture recognition scheme large gesture set for a new user can be implemented based on the small set that contains all the subclasses of components.

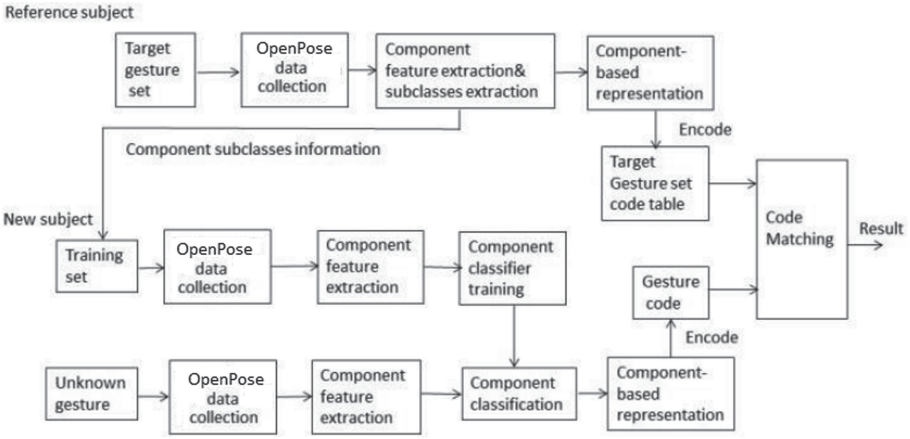

Fig. 5. The diagram process of our SL recognition framework [6].

3 Results

3.1 Implementation of the Software Framework

The handshape recognition is performed in the following steps:

1. Hand tracking using the Leap SDK.
2. Transformation of the hand joints' coordinates into angles.
3. Feature engineering for the previous points.
4. Recognition of the particular handshape.
5. Transcribing to the HamNoSys.

Leap Motion[8] is a technology based on motion capture, which is used in human-computer interaction. A small USB device is placed on a user's desktop with its working

[8] https://www.leapmotion.com/.

part facing upwards, thus creating 3D interaction area of about 227 cubic decimeters (a cube with a size of 61 cm). Inside this area, The Leap tracks movements of fingers and hands, using rangefinder, and outputs skeletal data for the hand.

The extraction of skeletal representation of the body and the hand was done according to the process described in [11]. Pre-trained VGG-19 on ImageNet up to *conv4_4* is used as the feature extractor to detect the hand skeleton, while the first 10 layers of the same network were used to detect the body skeleton. The output for the networks detecting the body and the wrist are 18 joints for the body and 21 joints for the hand, with the respective quality indexes. In this work, we use 12 out of the 18 extracted skeletal joints for the body, as shown in Fig. 6 [11]. For our purposes, we can safely ignore the leg joints, since signers usually communicate while seated and do not display them.

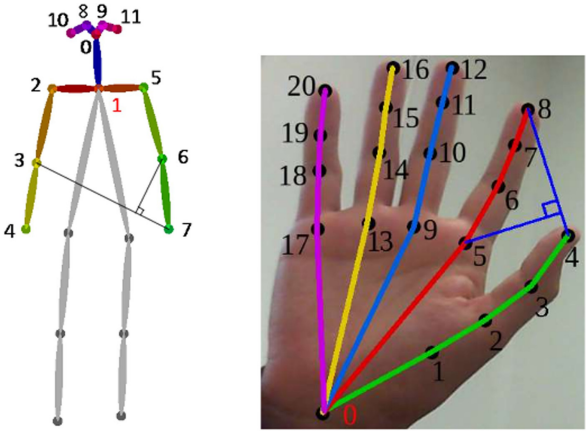

Fig. 6. The joints' points used in the recognition [11].

Another particular issue related to the classification of the features using LSA64 dataset [12] is that some of the gesture types are signed with the right hand, while the others signed with both hands. To resolve this problem, we only considered the right joints in our system. The classification in it is based on two types of spatial features and the temporal features. The first type of the spatial features is absolute coordinates of the right hand joint and the body, while the second type is the distances between the joint lines, which model distances from each joint to its projection on the lines formed by each other pair of the skeletal joints [11]. In the feature engineering, we transform the coordinates of the skeletal hand to angles for each joint in the histogram, using scalar product of vectors, as illustrated in Fig. 7.

Thus, in our approach we use 21 hand joints and 4 joints' angles, which are transcribed into the HamNoSys using SHRS [6] (see in Fig. 8). This particular transformation was chosen due to its obvious advantages:

1. no need in any supplementary equipment, such as data gloves, which can restrict movements;
2. ability to use any amounts of skeletal data for the body and the hand;
3. scalability of the solution.

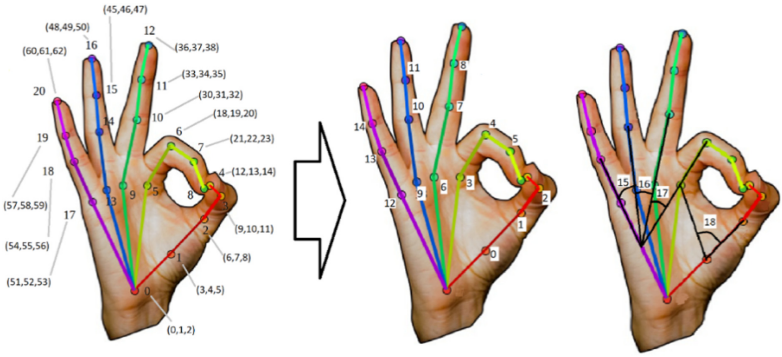

Fig. 7. Transformation of the skeletal hand's coordinates into the joints' angles.

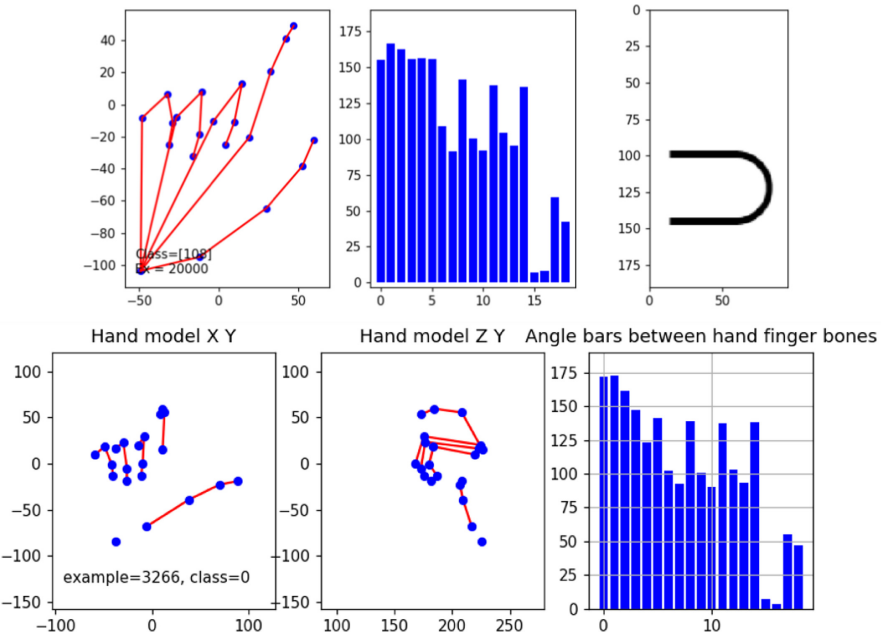

Fig. 8. Transformation of the skeletal hand's coordinates into the joints' angles and the representation of the HamNoSys transcript.

The next stage in our work was recognition of the gesture location, since it significantly affects the meaning of the signs, as we described previously. For this we used OpenPose library[9], which is the first system working in real-time for several people, jointly identifying the key points (135 in total) in human body, wrists, face and feet in individual images. The main related functionality of the OpenPose [13] is 2D detection of the key points in the real time:

[9] https://github.com/CMU-Perceptual-Computing-Lab/openpose.

- 15/18 or 25 key points for the body/feet (performance time is not affected by the number of identified points);
- 2*21 key points for the hands (performance time is affected by the number of identified people);
- 70 key points for the face (performance time is affected by the number of identified people).

After separating the layer with the points from the initial image, we obtain the points' coordinates, which are to be transformed into angles, i.e. transcribed into HamNoSys. Thus, we will have the gesture location component in the notation, as shown in the example in Fig. 9.

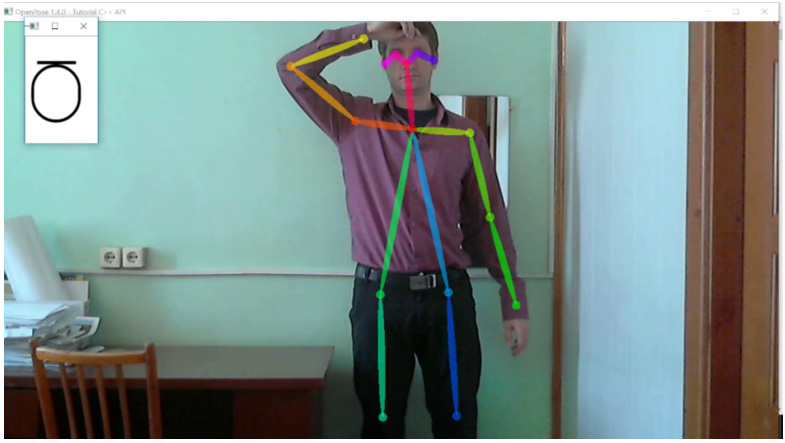

Fig. 9. Recognition of the hand's location in relation to the body.

3.2 Experimental Validation

We have collected 22042 samples with 63 features and 46 different classes of handshapes using the Leap Motion controller. They were contributed by 5 different users presenting their hands to the controller following 500 examples according to one of the labels (classes). The correspondence between the skeletal hands and the phonetic transcripts are illustrated in Fig. 10.

For the purposes of machine learning, the dataset was split into 90% training set and 10% validation set. The 63 coordinates for the hand joints were used in the feature engineering, and the output was 19 joints' angles – thus the feature set was reduced 3 times. This feature engineering provided several important advantages:

- improvement in the computational cost;
- allowing any size of the hand;
- allowing any postures to scale.

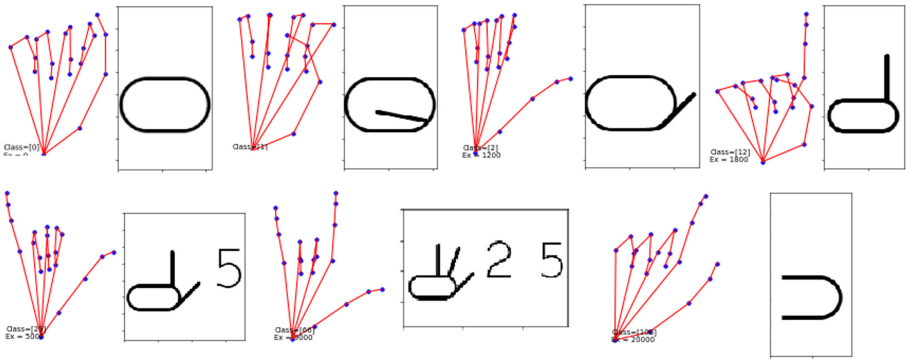

Fig. 10. Examples of 7 different classes of handshapes.

In Fig. 11 we show the 2D handshape, the angles between the joints and the finger tips, and the corresponding phonetic label. In Fig. 12 we present the 3D data.

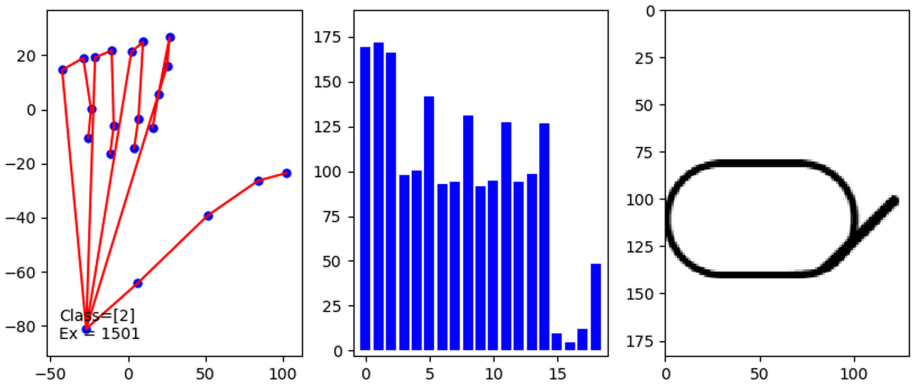

Fig. 11. The recognition: the skeletal hand, the histogram and the phonetic label.

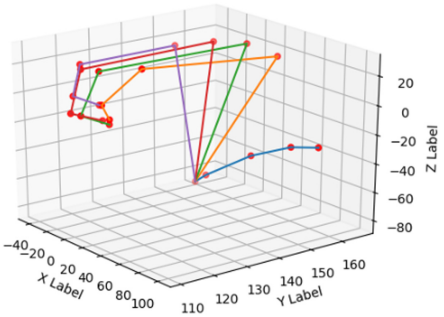

Fig. 12. The 3D representation of the hand.

In practice, such data is usually normalized: for each feature in the input data for each value the average for this feature is deducted, and the result is divided by the standard deviation. Further, the transformation of the phonetic label's number into encoding for the machine learning classification is performed.

The samples with the 19 features and the labels are used as the input for the deep learning model, for which we use Keras Sequential API. From the input, it has a simple layer with 33 neurons and RELU activation function MAX(0, x) for introducing non-linearity into the network. The last layer has 46 neurons and SOFTMAX activation function, which distributes the network's probability outputs for each class and is widely used in various multi-class classifications. The learning rate hyper-parameter was set to 0.001, and the resulting accuracy was 0.99 for the training set and 0.99 for the validation set. The loss function value was 0.3807 for the training set and 0.366 for the validation set. The results were accurate after the training, as there were no errors in 46 different classes, and the recognition rate was 100%. The outline of the saved NN model with the best recognition accuracy is shown in Fig. 13.

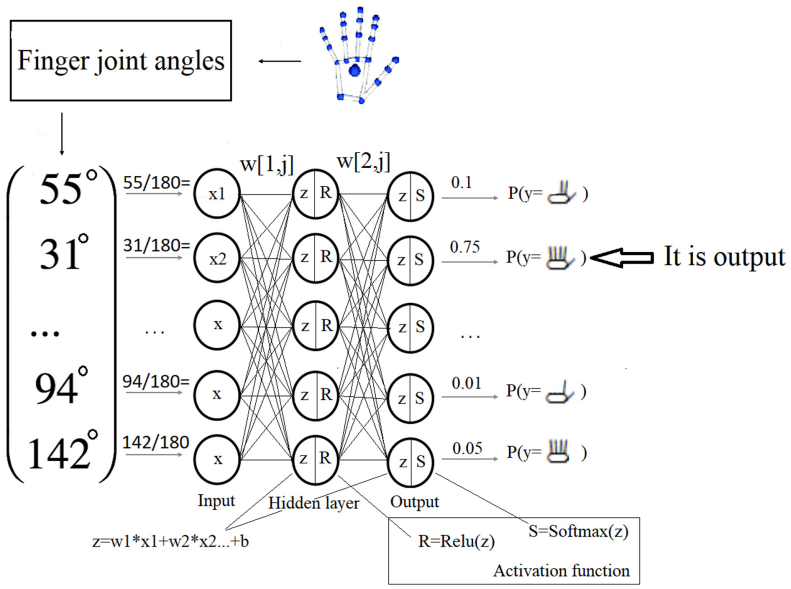

Fig. 13. Outline of the NN model for recognizing the "5" sign handshape.

The experimental validation was done with two groups of 5 subjects each – adults and children aged 8. The recognition accuracy for the adult group was perfect (100%), while for the children group it was at 75.88% (see in Fig. 14). Thus, we can conclude that our solution has certain disadvantages, as it was supposed to recognize the signs equally well for any user group. We believe this is caused by insufficiently good Leap SDK hand tracking algorithm and its design flaws, which we plan to improve in our future work.

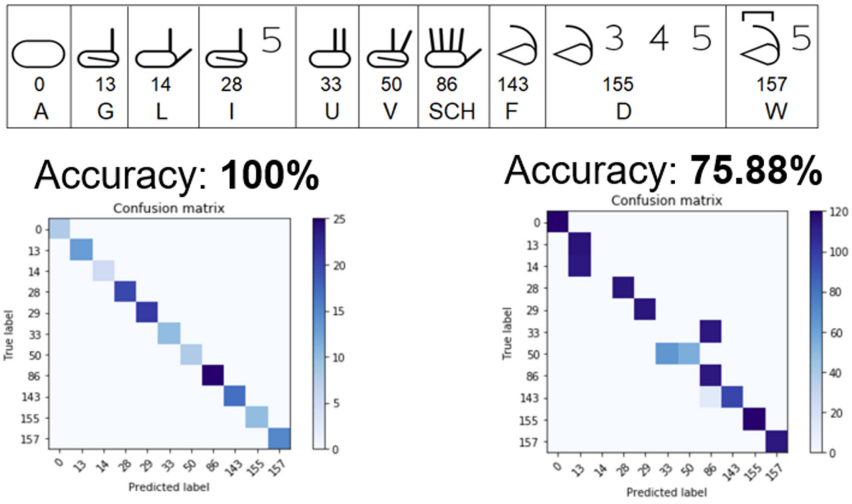

Fig. 14. The recognition results for the adults (left) and the children aged 8 (right).

4 Discussion and Conclusions

In our work dedicated to the ongoing development of SL recognition software, we proposed architecture combining the Hamburg Notation System and deep machine learning. Particularly, we implemented the neural networks-based algorithm for recognizing signs with Leap SDK adapted to the HamNoSys for handshape recognition and the OpenPose library for gesture location recognition. The latter was adapted to extract manual and non-manual markers meaningful for the sign recognition from the skeletal representation. The software is currently implemented as the scalable framework written in C++ and capable of working in real-time with various web cameras and video files. Another important advantage of our solution is that it does not require the use of any advanced equipment, such as Kinect, RealSense, data gloves, bracelets, etc.

Experimental validation of our solution's quality suggests perfect recognition (100%) for adult users, but somehow decreased accuracy (75.88%) in children. We assume that the lower accuracy found for the children is due to greater individual variability in the signs as shown by them and smaller palm, which makes recognition of the configuration more difficult. The high variance in sign language fluency in children is well documented and noted in existing research works and it calls for much more training data for the automated processing [14].

We believe that further development of our algorithm should involve improvement of the recognition accuracy through replacing the standard Leap Motion SDK with an algorithm better suited to work with the HamNoSys via the external features. The skeletal hand model, ANN models and ML used in [15] allowed achieving 90% of accuracy. Moreover, Leap Motion and Kinect sensors for hi-fi cameras can be joined in the feature extraction [16]. We also intend to consider the notation's remaining components: the hand orientation, the movement and the non-manual components, which are not covered in the current paper, but which are essential for the recognition.

In parallel, we are working on more sophisticated machine learning models – bio-inspired neural network, which is built on a convolutional neural network (CNN). In it, the first layer convolutes the frame image of the video stream with the Gabor filter. The second layer highlights the motion of the edges (linear and rotation) using MT neurons. The MT neuron receives the output values from the neurons of the first layer arranged accordingly (in a line of a certain orientation to highlight linear motion or at a point with different orientations to highlight rotation). The number of connected neurons gives the speed of movement (v), orientation – the direction of movement (alpha). Subsequent layers highlight the motion of the segments. Thus, at the output of the network it is possible to obtain a map of movements.

Already we believe that the results of our work presented in the current paper can be of interest to researchers and IT engineers working in the fields related to sign languages. Hopefully, they can contribute to the development of better quality software for SL automated recognition and translation.

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References

1. Kendon, A.: Current issues in the study of gesture. the biological foundation of gestures: motor and semiotic aspects. Lawrence Erlbaum Associate, pp. 23–47 (1986)
2. Keane, J., Sehyr, Z.S., Emmorey, K., Brentari, D.: A theory-driven model of handshape similarity. Phonology **34**(2), 221–241 (2017)
3. Battison, R.: Phonological deletion in American sign language. Sign Lang. Stud. **5**(1), 1–19 (1974)
4. Al-khazraji, S., et al.: Modeling the speed and timing of American sign language to generate realistic animations. In: Proceedings 20th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 259–270 (2018)
5. Hanke, T.: HamNoSys – representing sign language data in language resources and language processing contexts. In: Proceedings LREC Workshop, Paris: ELRA, pp. 1–6 (2004)
6. Grif, M.G., Prikhodko, A.L.: Approach to the Sign language gesture recognition framework based on HamNoSys analysis. In: 2018 XIV International Conference on Actual Problems of Electronics Instrument Engineering (APEIE), pp. 426–429 (2018)
7. Koller, O., Bowden, R., Ney, H.: Automatic alignment of HamNoSys subunits for continuous sign language recognition. In: LREC 2016 Proceedings, pp. 121–128 (2016)
8. Bragg, D., et al: Sign language recognition, generation, and translation: an interdisciplinary perspective. In: 21st ACM SIGACCESS Conf on Comp and Accessibility, pp. 16–31 (2019)
9. Rautaray, S.S., Agrawal, A.: Vision based hand gesture recognition for human computer interaction: a survey. Artif. Intell. Rev. **43**(1), 1–54 (2012). https://doi.org/10.1007/s10462-012-9356-9
10. Wei, S., Chen, X., Yang, X., Cao, S., Zhang, X.: A component-based vocabulary-extensible sign language gesture recognition framework. Sensors **16**(4), 556 (2016)
11. Konstantinidis, D., et al.: Sign language recognition based on hand and body skeletal data. In Proceedings 2018-3DTV-Conference, pp. 1–4. IEEE (2018)
12. Ronchetti, F., et al.: LSA64: a dataset of Argentinian sign language. In: XXII Congreso Argentino de Ciencias de la Computación (CACIC) (2016)

13. Wei, S.E., et al.: Convolutional pose machines. In: Proceedings of the IEEE conference on Computer Vision and Pattern Recognition, pp. 4724–4732 (2016)
14. Bragg, D., et al.: Sign language recognition, generation, and translation: an interdisciplinary perspective. In: Proceedings 21st International ACM SIGACCESS Conference, pp. 16–31 (2019)
15. Du, Y. et al.: Hand gesture recognition with leap motion. arXiv:1711.04293 (2017)
16. Kumar, P., et al.: A multimodal framework for sensor based sign language recognition. Neurocomputing **259**, 21–38 (2017)

Public Resources for Detecting Mentions of Medical Data in Russian Social Media

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Abstract. This paper covers the results of a comparative analysis of the effectiveness of passive and active data collection methods for the purpose of extracting mentions of adverse drug reactions (ADRs) in Russian. In terms of their effectiveness, two systems of data collection were compared: a data mining system for gathering post and comment text content from social media, and an experimental chatbot conversational survey, integrated into a thematic community and targeted at collecting ADR reports. The study was conducted on VK, a Russian social network, on a community dedicated to the discussion of user experiences with taking drugs for treating mental illnesses. A comparative analysis of the comprehensiveness of data obtained by the passive method and the chatbot was carried out. The results show that an active information collection system allows subsequent information processing to be performed more effectively. Based on the results, areas for further development of conversational surveys for medical research were identified.

Keywords: Pharmacovigilance · Social media · Data mining · Chatbot · Conversational surveys · Russian language

1 Introduction

Monitoring mentions and reports of ADRs is the main goal of pharmacovigilance. Despite there being a centralized service in Russia for gathering this information [1], it can be argued that it is not well known to the general public. According to Roszdravnadzor's report on their 2019 results, 328 messages were received by them over the course of a year, with only 35 of them reporting certain drugs being ineffective or being a suspected cause for ADRs. These numbers are likely less than what can be extracted from social media or proactive report collection within the same period.

As a result, most spontaneous reports about ADRs and drugs causing them can be found in open access on social media platforms such as specialized forums, medical question and answer websites, as well as general social networks. Due to the volume of information found online and its exponential growth, processing information from social networks for pharmacovigilance purposes is a daunting task if performed without automatization tools.

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Since every website has its own structure of discussion topics, posts, and comment branches, data extraction from forums is not a trivial task. Furthermore, most forums lack what can be considered a structured HTML for their pages that can be easily processed by most basic parsers. Lastly, unlike social networks, the majority of forum user pages, unlike social media profiles, lack information about the age and gender.

Compared to forums, social networks have great data collection potential for pharmacovigilance purposes. For its users, social media provides a platform for expression and sharing thoughts and experiences. Due to social networks' built-in functions for connecting people and encouraging discussions, they provide the development tools, such as an API, necessary for gathering user data as well as contents of what the users may post on various discussion platforms within the social network. The aforementioned reasons are why social media was chosen as a platform for data collection for this research.

There are two ways of automatic online data collection for pharmacovigilance purposes: passive, in which data from forums and other social networks, which users post without explicit prompting, is collected and analyzed, and active, in which a questionnaire or a similar system prompts the user to give feedback on ADRs they have experienced and which drugs may have been the cause.

Currently, the main method of data collection for pharmacovigilance is questionnaires on websites independent from major social networks, such as MedWatcher, or the automated Pharmakonadzor system. Automatic methods of data collection from various sources for pharmacovigilance are still in development.

Interactive dialogue systems allow for chatbots to be used as conversational surveys in many spheres of research. Being an active data collection method, chatbots allow gathering more complete and systematic information than passive methods due to the chatbot dialogue following a branching question and answer format. Furthermore, people can be more inclined to give detailed responses to a chatbot. It may be a result of users being more open to expressing their thoughts in a dialogue with a machine rather than addressing other users of a forum [2].

When collecting data on ADRs, using chatbots could allow gathering more thorough and detailed responses. An additional benefit of using chatbots for pharmacovigilance purposes is that collecting data using a chatbot can be considered convenient and natural for the respondents due to most social network users being familiar with bots and similar features.

The goal of this research is comparing the effectiveness of active and passive approaches for data collection for pharmacovigilance purposes. We offer a comparative analysis of two data collection methods for pharmacovigilance purposes: an active system using a chatbot and a passive system using a social media parser.

2 Related Work

A number of existing solutions based on machine learning and natural language processing allow identifying and extracting mentions of ADRs from social media text content and freeform survey responses. However, analysis of texts written in the Russian language can be considered complicated, making data processing difficult.

Chatbot-driven surveys, as shown in [2], provide better response results than typical online surveys. Unlike form-based surveys, the conversational nature of giving responses

to a chatbot and the novelty factor encourages users to give significantly more detailed and relevant responses. Therefore, we can conclude that conducting report collection about ADRs using a chatbot and free-text questions may lead to better results than standard surveys and forms.

In [3], the authors extract data on ADRs related to skin issues from medical forums using a neural-network based named entity recognition system. As demonstrated by that study, social networks have high utility for mining spontaneous online reports on ADRs.

Processing search results, conducted by the authors of [4], shows that any user activity, including the frequency of search engine queries and their content, can lend useful information about ADRs.

Data extraction from social media is a popular research topic with many applications and methods. In [5], the authors trained a bag-of-words model on a twitter dataset to extract slang words referencing marijuana. While in [6], the research was conducted on online health forum data to identify potential watchlist drugs using machine learning classifiers. To extract sentiment about certain drugs, the authors did not conduct extraction of ADRs. Instead, they parsed for instances of negative language or one that could be considered adverse-effect like compared to other drugs.

The articles discussed above and the findings of their authors show that while there has been a large amount of research conducted on the topic, automated extraction of ADR mentions and their subsequent processing, as well as conducting conversational surveys for that goal, is still in development and has a lot of potential for future research.

3 Methods

3.1 Using Social Media for Extracting Mentions of ADRs

According to [7], SNSs have both a range of positive and negative factors for usage in public health and medical research. Their main limitations are the following:

- frequent trolling or flaming by users,
- e-professionalism, and
- media richness.

We considered three possible data sources for extracting information about ADRs:

- specialized forums,
- Russian segment of Twitter, and
- VK, Russia's largest social network.

The main feature of using social networks for data mining is that aside from only extracting the text content from posts, it is also possible to acquire personal user data, such as their gender and age. Specialized medical forums, on the other hand, for the most part have this information restricted from open access. There also may be limitations on which topics can be viewed. Therefore, data collection from forums does not allow gathering as much useful data compared to social networks.

Table 1. Advantages and disadvantages of VK, Twitter and specialized forums for the purposes of data extraction.

	Advantages	Disadvantages
VK	Popular in the Russian segment of the Internet Large number of specialized and active communities Open-access API	API request limitations
Twitter	Search by hashtags and post text Open-access API	Posts are limited to 280 characters Little available user information
Specialized forums	Most content is text Ability to collect large amounts of information due to the majority of forums being active for longer than other social networks	Lack of API No personal user information Access limitations

To evaluate the three sources considered by us for the purposes of this research, we conducted a comparison of their advantages and disadvantages, seen in Table 1.

As a result of analyzing each social network's advantages and disadvantages, within the scope of this research, our study was conducted on VK, a Russian social network site which is considered to be the most widely used general social network in Russia [8].

VK communities are pages on the VK social network dedicated to a certain subject or topic, owned by and contributed to by users that are members of the community. Users are able to make use of numerous functions of these communities, such as posting various content, including text and images, leaving comments to them, expressing support of posts using likes, and much more. The community wall is one of the main communication channels in a VK community, where users are able to post their thoughts and respond to content posted by others. It is where most information can be passively extracted from.

There are three types of communities on VK: open, closed and private. Open communities can be viewed by anyone, closed ones are only accessible by their members be manually accepted into the community, and private communities are invite-only.

In our research, we used information gathered from a VK community [9] dedicated to the discussion of mental illnesses. The VK community considered in this research is a closed one, which allows it to be strictly moderated in terms of what content is posted. The closed format of the community and its rules allow for the most common limitations of social media for pharmacovigilance purposes to be circumvented.

All data collected for the purposes of this research was anonymized.

3.2 Passive Mining System

Currently, there are two existing main approaches to Internet data extraction [10]:

- using internal web service API,
- scraping text data from HTML pages.

Since VK has a comprehensive API, we used its methods to gather post and comment information from the VK community (Fig. 1 Overview of the module for interacting with the VK API for data gathering from a VK community Fig. 1).

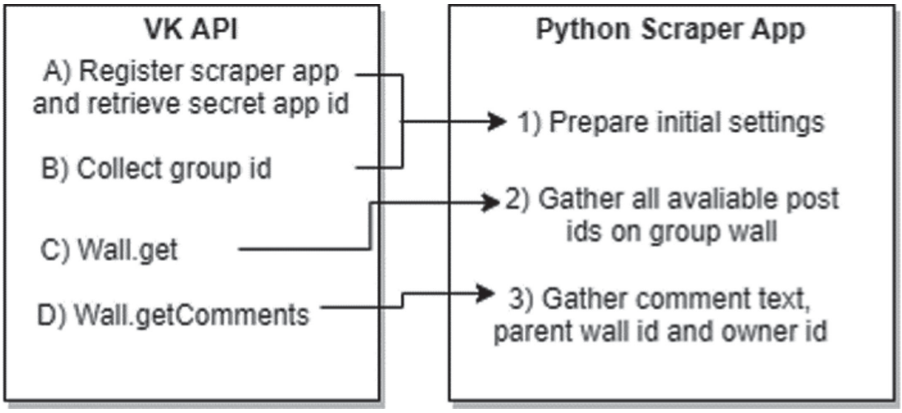

Fig. 1. Overview of the module for interacting with the VK API for data gathering from a VK community.

This method of data collection has certain complications, as the VK API limits the number of requests per second to 3. However, using API has more benefits than disadvantages, as it allows us to avoid the common issues present in parsing HTML data, such as parsing complicated tag structure and possibility of small changes to said structure rendering a scrapper ineffective.

Our first information extraction system for the purposes of detecting ADRs in social media data is a passive mining system that extracts text content from VK community posts and comments. It consists of two modules: the module for interacting with the VK API and the module for recording the extracted data and its context, such as which post or comment another comment is responding to.

The VK community that was chosen for data extraction contains information provided by users in a discussion format, where an initial topic post receives comments related to the subject. Both the post and comments may contain mentions of ADRs, which is why both were used in data extraction. While the content posted can be in any media format, such as videos or pictures, only text content was considered.

Using methods from the open VK API allowed to extract the posts and comments from the VK community chosen for the purposes of this research.

During data processing, the information was extracted in combinations of records, comments, and authors in order to expand the context of the gathered information. The data, from both posts and comments extracted from the social network, was then compiled in a.csv file.

The resulting table (Fig. 2) had the following fields:

- *parent id*, containing the VK ID of the parent post or comment (if the value is 0, then the content is a post on the community wall),

Parent Id	Id	User or group id	Text
0	7959	5077330452	кому-нибудь помогали какие-либо препараты легче переносить отмену других? отменили раздражительность и постоянно слезы на глазах. сейчас пью эглонил и атаракс. атаракс в настроение, но так эффекта не особо пока что замечаю. утром и днём адски плохо, прост становится. диагноз неуточнен. под вопросом депрессивное расстройство и неврастения.
7959	7970	5077331683	Мне врач аж Диазепам выписывал что бы я прикрывался по отмене пароксетина
7959	7971	5077330452	Атаракс наверное слабоват Как прикрытие Но я не врач это лишь мое мнение
7959	7973	5075644211	Сходи в пнд скажи что тут написала 1в1 Может изменят схему отмены или назначать прикрытие получше (не обязательно транк) Не бойся лишний раз сходить

Fig. 2. Extract from the resulting.csv file with data extracted by the parser from the VK community.

- *id*, containing the VK ID of the post or comment,
- *user or group id*, containing the VK ID of the user or community which posted the content, and
- *text*, containing the content text.

3.3 Conversational Survey Chatbot

A brief overview of the existing conversational survey systems shows that most of them are not adapted for the Russian language or are not designed to be integrated with Russian SNSs. As a result, for the purposes of this research, we decided to develop our own experimental chatbot, targeted at the members of the VK community that was also for scraping and mining text posts for mentions of ADRs. The chatbot repository can be found on Github [11].

We developed the chatbot in PHP using the Laravel framework, webhook technology (Callback API), and the VK-client package [12].

The chatbot was composed of two main modules: the conversation scenario module responsible for managing the dialogue states and recording received data and another module for interacting with the VK API.

The conversation scenario module included a component that resolved the next chatbot response depending on the flow in the state machine, and a data manipulation component for preparing responses, changing the current conversation state, and recording the user's responses. The VK API interaction module allowed the chatbot to receive information about new messages, extract basic information about the respondent, and send them responses provided by the dialog state machine. The details of the chatbot structure and the interaction between components and the user can be seen in Fig. 3.

The conversational survey collected the following data from the participants:

- gender and age,
- official diagnosis (if applicable),
- official name of the drug that is suspected to have caused an adverse reaction,
- free-format description of the experienced side effect, and

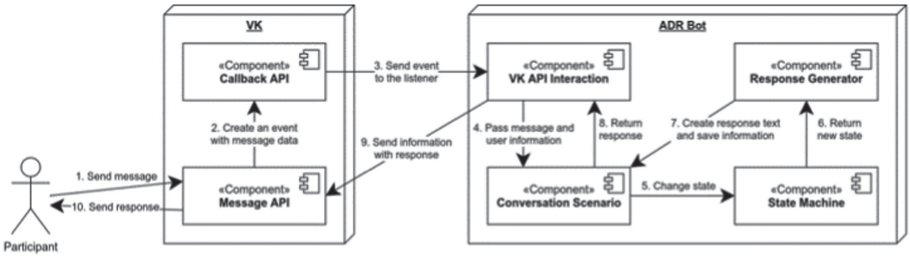

Fig. 3. Overview of the chatbot structure and interaction flow between the user, the chatbot and its components, and the VK social network API.

- information about other drugs that may have been taken at the same time and other factors.

Each participant could provide information about one drug of their choice.

When the chat is initialized, the chatbot attempts to extract information about the age and gender of the respondent from their VK profile. Then, it requests confirmation for the pre-processed data to make sure that the information retrieved from the user's social network profile is correct and up-to-date. Next, the chatbot asks questions about the user's diagnosis or its absence, the medication taken, the adverse reactions the user suspects are caused by the drug, and additional information, such as alcohol intake.

3.4 Chatbot Launch in Social Network

The designed chatbot was launched in the VK community [9] chosen for the purposes of this research. The chatbot link was posted in the community along with a short description of its purpose and an invitation for community members to take the conversational survey and share their experiences with medications and resulting ADRs.

As VK chatbots are natively integrated into the VK messaging ecosystem, the users' dialogue with the chatbot occurred without leaving the social network. We considered the convenience of taking part in the conversational survey as one of the driving factors why VK as a social network was the optimal platform for launching the chatbot.

To start the dialogue, users simply needed to follow the link to the chatbot and send the "start" command (thus launching the dialogue script) using a pre-programmed chatbot button. Then, they answered chatbot's questions with either chatbot keyboard buttons or in free-form text.

3.5 Drug Name and ADR Corpus Collection

A dictionary of relevant Russian drug names was compiled using the posts extracted from the VK community. 313 drug names were identified and added to the resulting dictionary. The same method was used for composing a dictionary of ADRs. The resulting dictionary contains 144 names in Russian.

Some of the identified ADRs can be considered to have similar meanings, but are expressed using different words.

3.6 Data Extraction

For data pre-processing, we used several tools and resources.

The NLTK package was used to pre-process all gathered data by removing stop-words and lemmatization.

Extracting ADRs from the passively collected data was performed by a Python script. The script parsed each extracted text for drug names and ADRs contained in the aforementioned custom dictionaries. If the script detected keywords each corresponding to a drug name and an ADR, then the text was considered to contain a valid ADR.

Data extraction of ADR mentions from the data actively gathered by the chatbot was conducted by a Python script in a similar fashion. The corresponding fields of the responses file were checked for mentions of drug names and adverse reactions. Same as in the parser, if keywords corresponding to a drug name as well as an ADR were detected in their respective fields, then this response was considered to contain a valid ADR.

The above methods each created a file with a dictionary containing a list of adverse reactions corresponding to a certain drug name. The full pipeline is shown in Fig. 4.

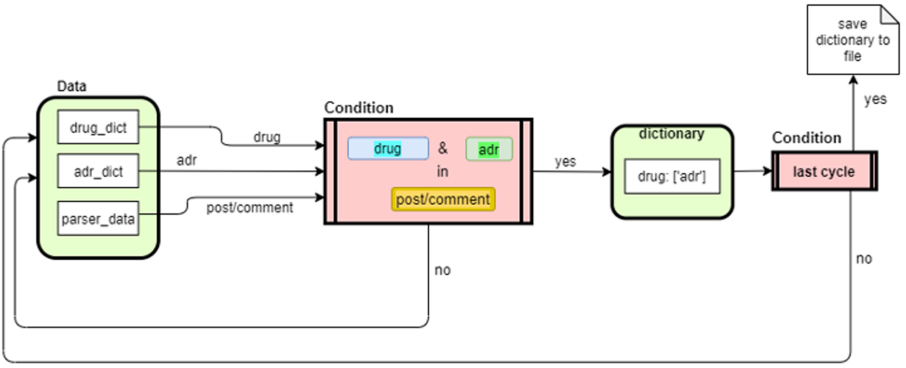

Fig. 4. Diagram of extracting ADR mentions from collected free-form text.

Data validation of detected ADRs was performed manually by checking the accuracy of ADR mentions added to the dictionary. Afterward, the occurrence rate of the most often mentioned ADRs was calculated and added to the dictionary.

The data extraction results made it possible to evaluate the relevance of collected data.

4 Results

4.1 Data Mining Results

In total, 3,821 posts and comments were extracted from the VK community and processed using the methods outlined previously.

To assess the general quality of data extracted by the mining tool and the words most frequently used in discussions by the members of the community, we composed a word cloud using Python and the wordcloud package after removing the stop words in Russian.

As can be seen in the word cloud (Fig. 5), the VK community chosen for this research contains frequent mentions of some medications (Иксел, Вальдоксан) as well as ADRs (печени (liver), вредное (harmful), проявление (manifestation), действие (effect), побочки (ADRs)).

Fig. 5. Word cloud of text content extracted from posts and comments.

The frequent mention of "в связке" (meaning taking one medication along with some others at the same time) shows that the users of this community frequently discuss taking several types of medications at the same time, as well as discuss possible ADRs caused by such combinations.

After data processing and detection of ADR mentions, only 283 posts and comments were found to contain textual data about ADRs. Therefore, only 7% of the total number of pieces of content collected using the passive system can be considered relevant for the purposes of this research.

4.2 Chatbot Results

The adverse reaction survey post received 1,100 views from the members of the VK community. In total, 357 respondents took part in the bot questionnaire, which amounted to a 32.5% response rate.

Out of all the responses received by the active chatbot system, 46% can be considered relevant in the scope of this research. Responses were marked as relevant only if the user gave comprehensive answers to questions about what adverse reaction they experienced and which drug they took. The drug name mentioned had to be contained in the dictionary of drug names.

In Fig. 6, part of the data extraction results for the chatbot is displayed. The number in percentages shows the frequency of a certain ADR occurring with its respective drug.

drug name	adverse drug reaction
adaptol	allergy, nervousness, aggression
azaleptin	weight gain, constipation, tachycardia
amitriptylinum	drowsiness(26%), fatigue(9%), weight gain(9%), tremor(9%), apathy(9%), nervousness, vomiting, dizziness, visual impairment, arrhythmia, constipation, nausea, headache, hallucinations, hypomania
anafranil	tremor(40%), libido reduction, drowsiness, tachycardia
aripiprazole	nervousness, nausea, drowsiness, akathisia
atarax	drowsiness(33%), nervousness(17%), sleeping disorder, dizziness, tremor, appetite loss, nausea, tiredness, derealization, hair loss, headache

Fig. 6. Extract from the table of drug names and their respective ADRs, identified in the data gathered by the chatbot.

4.3 Effectiveness Comparison

The results of a comparative analysis of the relevance of data obtained by the parser and the chatbot showed that an active data collection system allowed to gather 37% more accurate and detailed responses on ADRs than a passive collection system. Collected data was more complete and detailed, thus increasing its relevance for the purposes of gathering mentions of ADRs.

5 Discussion

As an active collection method, it is not unexpected that the chatbot would perform better at collecting relevant information on ADRs compared to the parser. The high response rate from the users of the VK community the chatbot was targeted at shows that the active users of the community are receptive to the idea of using a chatbot to report their experiences with ADRs and forthcoming with most of the necessary information.

In contrast, the low number of posts and comments gathered by the parser that have been found to contain mentions of ADRs shows that despite the main goal of the processed VK community being discussion of drugs and reactions to them, most content found there cannot be considered direct reports of ADRs. The number of relevant responses received by the bot was 39% higher, which allows us to conclude that chatbot, as an active data collection method, is much better than the passive collection method, the parser, at extracting information about ADRs for pharmacovigilance purposes.

6 Conclusion

Using chatbots to obtain adverse reaction reports as opposed to scraping text content from posts on general social media for detecting adverse drug reaction mentions shows

promise. Chatbots can be used for pharmacovigilance purposes as a way to actively gather information on ADRs experienced by active users of social networks, primarily the 13–25 years-old audiences due to their high engagement in using social media. We identified possible avenues for further research, such taking into consideration additional information requested by the conversational survey (alcohol intake when taking the medication or which drugs were taken at the same time when the ADR occurred) using a sophisticated ADR extraction system for receiving comprehensive and detailed results.

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References

1. Roszdravnadzor. https://www.roszdravnadzor.ru/services/npr_aism. Accessed 18 Feb 2020
2. Xiao, Z., et al.: Tell me about yourself: using an ai-powered chatbot to conduct conversational surveys (2019)
3. Nikfarjam, A., et al.: Early detection of adverse drug reactions in social health networks: a natural language processing pipeline for signal detection. JMIR Publ. Health Surveill. **5**, e11264 (2019)
4. White, R.W., et al.: Early identification of adverse drug reactions from search log data. J. Biomed. Inform. **59**, 42–48 (2016)
5. Simpson, S.S., Adams, N., Brugman, C.M., Conners, T.J.: Detecting novel and emerging drug terms using natural language processing: a social media corpus study. JMIR Publ. Health Surveill. **4**, 42–48(2018)
6. Chee, B.W., Berlin, R., Schatz, B.: Predicting adverse drug events from personal health messages. In: Annual Symposium Proceedings, pp. 217–226 (2011)
7. Benetoli, A., Chen, T.F., Aslani, P.: The use of social media in pharmacy practice and education. Res. Soc. Adm. Pharmacy **11**, 1–46 (2015)
8. Mediascope research. https://webindex.mediascope.net/top-resources. Accessed 10 Jan 2020
9. VK Community PSY.PHARMACY. https://vk.com/psy_pharmacy. Accessed 01 Feb 2020
10. Ferraraa, E., De Meob, P., Fiumarac, G., Baumgartner, R.: Web data extraction, applications and techniques: a survey. Knowl. Based Syst. **70**, 301–323 (2014)
11. Chatbot Github Repository. https://github.com/BakasaRus/ADRBot/. Accessed 18 Feb 2020
12. VK-client package. https://github.com/atehnix/vk-client. Accessed 20 Dec 2019

Ontology-Based Bibliometric Analysis of PubMed Publications Related to Cognitive Reserves

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Abstract. As the growth in the number of scientific publications keeps accelerating, exceeding 10% per year for certain booming fields, such as Neuroscience, employment of IT methods for secondary research becomes urgent. Our paper is dedicated to bibliometric text mining of PubMed databases that contain over 30 million publications, in search for the features reflecting cognitive reserves, which became an important topic particularly due to the ongoing ageing of the world population. For that end, we supplemented Entrez (EDirect) utility software tools with dedicated ontology implemented in OWL, integrating and extending several existing neuroscientific ontologies: BRCT, OntoNeuroLOG, etc. We extracted over 45 thousand publications related to cognitive functions and cognitive resources, and analyzed them per the keywords in such categories as brain structures, EEG oscillations, mental operations and activities. The results suggest that prefrontal cortex, beta range (13–30 Hz), inhibition and information load have been receiving the most attention from researchers in 1990–2019. Correspondingly, it would be practical to focus the subsequent quantitative analyses of psychometric and neurophysiological data on these factors, in order to find indicators of cognitive reserves.

Keywords: Text mining · Meta-analysis · Neuroscience research · Domain ontology

1 Introduction

The growth in the number of research publications keeps accelerating: from less than 1% annually till the XVIII century, to 2–3% up to the middle of the XX century, and to 8–9% in 2010 [1]. The previous scientific and engineering revolution is said to have started in IT, and the current one is widely believed to happen in bio technology. Correspondingly, papers relating to the latter field constitute a significant share in today's research publications, and their average annual growth is even higher – e.g., for Neuroscience literature it is well above 10% [2]. The complexity of organization in living bodies, particularly of genetic information, had led to the emergence of Computational Biology. The study of the brain is the ultimate 'know thyself' task and thus is arguably the most demanding challenge the science of humanity has ever faced. Thus, it is appropriate to believe that

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progress in this field can be ensured with application of IT for processing and analyzing the data, i.e. within the relatively novel domain of Computational Neuroscience.

One of the mainstream research directions in this field is the use of mathematical modeling, machine learning and knowledge engineering methods for conceptual interpretation of the manifold available data. Particularly, Data Mining approaches that seek for hidden patterns and regularities are increasingly applied to bio-medical data to discover the roles of various structures in the brain, the factors influencing behavior and neuropsychological phenomena, etc. The most common types of secondary research, which considers several original publications, are 1) **review** that provides mostly qualitative overview of the field, identifies the remaining gaps and the promising research directions, etc. and 2) **meta-analysis** that studies, generally using statistics, the data and results aggregated from several works that address the same research question. For instance, in [3] both systematic review and meta-analysis of 89 publications from PubMed, CINAHL, EMBASE, PsycINFO, and Cochrane Library were performed to identify significant risk factors for post-intensive care syndrome, which were older age, female sex, previous mental health problems, and so on. Indeed, PubMed search engine (https://www.ncbi.nlm.nih.gov/pubmed/) is currently the primary gateway for bio-medical data analysis, as it contains more than 30 million research publications in this field (mostly from MEDLINE database) and provides robust access capabilities.

Yet another long-established secondary research method is **bibliometrics**, which is not limited to its most popular goal – the analysis of impact, citations and ranking of publications (see e.g. in [4]). Its main other applications are in bibliomining, e.g. evaluation of reader usage, and in descriptive linguistics – for instance, the development of thesauri. Naturally, the latter implies analysis of the actual content of the publications, but with emphasis on text mining rather with data mining. For instance, in [5], they extracted publications' titles and abstracts from Web of Science and "Neuroscience" category of Journal Citation Reports (JCR) to identify 10 terms with the highest relative citation scores for each year from 2006 to 2015. We see potential use of bibliometric text mining approach in such urgent task for Computational Neuroscience as selection of important indicators (also termed as features or factors) for various cognitive functions and behavioral phenomena. Considering the continuing increase in life expectancy and the general ageing of the world population, the ones that relate to elder people currently receive particular attention.

The concept of cognitive reserves (or cognitive resources) is widely used in explaining individual differences in the changes of cognitive functions that accompany brain ageing or damage [6–8]. On the structural level, the cognitive reserves of the brain are defined by the amount of white and gray matter, as well as the particulars of the neural systems' functional connections that formed during the brain's development and the organism's adaptation to the environment. The cognitive reserves can be also seen as the limits of information processing or the inter- or intra-individual differences in resources of memory, volitional or emotional regulation of behavior. The pathologies that highlight the importance of the cognitive resources include Alzheimer's decease and other forms of dementia that accompany ageing [8, 9], tumor, traumatic, or sclerotic brain damage [10, 11] or brain hypoxia emerging due to cardiovascular diseases [12]. In all the cases,

the low level of cognitive reserves, which is generally evaluated through levels of education and professional occupation, are associated with deeper violations of cognitive functions in patients and more severe long-term effects.

So far, only a limited number of features related to cognitive reserves has been explored – e.g. in [13] they ran meta-analysis with just 3 measures for cognitive reserves, covering 135 studies, but found only modest positive association. Clearly, more potentially significant factors need to be tested, and the focus of our work is application of bibliometric text mining to PubMed databases, in order to study the dynamics of research interest towards several promising concept in the field. It is assumed that these factors should also get the highest priority in subsequent quantitative analyses of neurophysiological data. In Sect. 2 of the paper, we overview the concept of cognitive reserves and the current types of secondary research relevant for Computational Neuroscience. We also review the related publications and software tools and justify the use of ontology in the feature selection process. In Sect. 3, we describe the implementation of the cognitive reserves publications mining ontology, our software built upon Entrez (EDirect), and analyze the bibliometric data. In Conclusions, we summarize our findings on the considered factors and outline directions for future research work.

2 Methods and Related Work

2.1 Cognitive Reserves in Neuroscience

For explaining the mechanisms of the cognitive reserves' actualization, several models are commonly used. According to the Compensation Related Utilization of Neural Circuits Hypothesis (CRUNCH) model, elder people employ comparatively greater amounts of neural resources to solve their tasks – i.e. more brain structures are engaged [14]. Whereas the Hemispheric Asymmetry Reduction in Older Adults (HAROLD) model [15] considers engagement of the other hemisphere to be such a resource. According to the Scaffolding Theory of Aging and Cognition (revised-version – STAC-r) [16], the brain neurodegeneration processes in aging, their acceleration or deceleration, the specifics of distribution and compensation are inextricably linked with behavioral activity, e.g. levels of education, social interaction, intellectual stimulation, physical activity, health status, and quality of life.

Taking into account the data obtained in research of neurophysiological mechanisms of ageing as the model for successful adaptation due to cognitive reserves, we need to note the commonly recognized deceleration of information processing in nervous system and the weakening of inhibitory processes in the selection of relevant information [17]. The compensation of these processes that are caused by the atrophy of neurons and impaired myelination of nerve fibers [18] is ensured by the reorganization of brain structures and neurogenesis, which in turn is associated with stimulation of cognitive and social activity and the preference for rational nutrition [6, 19]. Correspondingly, the promising directions in the search for informative predictors of the cognitive reserves are in various levels of the brain's activities: structural-functional, problem-oriented and social-behavioral organization.

We pay particular attention to finding justifications for the use of the intelligence and emotional regulation indicators as predictors for cognitive reserves. Particularly, it

is supported by the previously published results of epidemiological and psychometric studies suggesting that intelligence can be an integral indicator of socio-economic status and public health, as well as individual self-assessment of quality of life [20]. The ratio between the positive and negative emotions in the regulation of behavior that manifests the degree of optimism in assessment of the life situations is widely discussed and calls for quantitative proofs of emotional intelligence and/or emotional stress features' significance as indicators of cognitive reserves.

The influence of social environment as the cognitive resource factor is highlighted in the multiple indicators multiple causes (MIMIC) model [21]. According to this model, cognitive resources are represented by such latent variables as:

- Cognitive Assets: Intellectual Functioning, Education, Occupational Prestige;
- Cognitive Activity: Health Literacy, Lifetime Leisure Activity, Parental SES;
- Non-Cognitive Activity: Physical Activity, Spiritual/Religious Behaviors.

The use of this model further extends the space of the potential predictors of cognitive reserves, in which we can identify three levels of quantitative characteristics that describe 1) structure and functions of the brain, 2) cognitive activity and 3) social-economic status and the quality of life. The increase in life expectancy and the associated aging of the population combined with increasing requirements towards acquisition of new knowledge and skills due to the extended usage of information technology emphasizes the relevance of the search for indicators of cognitive reserves at all these levels. The proofs of the dynamics of their purposeful enhancement, particularly through the use of computerized cognitive training programs [6, 22], suggest both theoretical and practical value in studying the neural and behavioral mechanisms of the cognitive resources organization.

2.2 Secondary Analyses of PubMed

PubMed text and data mining especially gained in popularity about a decade ago, with the development of interfaces for accessing the MEDLINE database. Even while the querying was limited to keyword-based Boolean search engine, in [23] the authors developed MedlineRanker for finding distinguishing terms for certain topics and further scoring and ranking of publications' abstracts. The implementation was based on linear naïve Bayesian classifier and split-Laplace smoothing scheme to counteract class skew. The latter was also employed in a functionally similar, but non-domain-specific tool, MScanner, which sought to extend the somehow unsatisfying search capabilities of PubMed for better relevance-based filtering [24]. Another example of the time is RefMed – a multi-relevance feedback software, employing machine learning methods to train relevance function for information search. First it extracted results in the search by user-specified queries, and then supplemented them with feedbacks on the corresponding publications, with the RankSVM algorithm [25].

As the capabilities of PubMed's own interfaces kept improving, most of such tools that emerged in the beginning of the 2010s do not see wide usage nowadays, or are just plainly unmaintained. One notable exception is Quertle, which has since grown into full-scale search engine for biomedical and life sciences literature. Lately there is less

emphasis on the development of dedicated software for the mining, due to the trend towards reliance on existing platforms and packages. For instance, PubMed MineR [26] was implemented in R environment, while in [27] they relied on Biopython Entrez and the Neopython Neo4j APIs. Indeed, Entrez is arguably the most widely used search and retrieval system for bio-medical information databases, which also has rich capabilities to support automated access.

Entrez (E-utilities) are the set of 9 server-based programs that provide interface into the Entrez query and database system at the National Center for Biotechnology Information (NCBI). They use the fixed URL syntax translating a standard set of input parameters into values that various NCBI software components can use for searching and extracting the required data. Of the instruments included in the set of E-utilities, the following ones are particularly relevant with respect to the focus of our research (extract from the documentation[1] follows):

- `EInfo` – retrieves the number of records indexed in each field of a particular database, the date of the last database update, and available links from the current database to other Entrez databases.
- `ESearch` – responds to a text query, returning the list of matching publications identifiers (UIDs) in a given database, for later use in `ESummary`, `EFetch` or `ELink`.
- `EFetch` – responds to a list of UIDs in a given database with the corresponding data records in a specified format. Currently, it does not support all the 38 Entrez databases.
- `ESummary` – responds to a list of UIDs from a given database with the corresponding document summaries (DocSum). It functions for all Entrez databases, and a text search in web Entrez is equivalent to `ESearch-ESummary`.
- `ELink` – responds to a list of UIDs in a given database with either a list of related UIDs and relevancy scores in the same database or a list of linked UIDs in another Entrez database.

For the purposes of our work, we are using Entrez supplemented with domain ontology.

2.3 Feature Selection and Ontologies

Feature selection methods that consider relationships between the potential factors are actively studied nowadays, since they have shown advantages over conventional "flat" approaches. E.g. in [28] hierarchical feature selection has shown better predictive accuracy and robustness on a substantially imbalanced bioinformatic data. In that work, Gene Ontology terms were used as hierarchical features, and indeed ontologies are increasingly employed for storing normalized features and the contextual information [29]. In yet another large-scale study [30], 21000 protein features were extracted from Gene Ontology plus some other databases, in the machine learning-based search for ageing-related factors, of which 36 were selected. Overall, it is recognized that ontologies can be very helpful in organization of the somehow segmental knowledge related to theories of brain and cognitive functions, and that they should enjoy wider usage [31]. For

[1] https://www.ncbi.nlm.nih.gov/books/NBK25497/#chapter2.The_Nine_Eutilities_in_Brief.

instance, in [32] the authors derived a cognitive ontology and used it for evaluation of predictive ability of several psychological metrics, related to self-regulation, which allowed identification of consistent individual differences. Ontology-based hybrid approach was recently applied for organization of concepts in the domain of mental disorders, extending the DSM-5 manual [33].

Truly, the current mainstream in ontological engineering is integration of existing ontologies, so applied domain ontologies are rarely created from scratch [34]. According to classical definitions, ontology is a formal specification of a shared conceptualization, whose main elements in the popular Web Ontology Language (OWL) include **classes** (concepts) and various types of **relations** between them. Classes generally have **properties** (attributes), and when **instances** of classes are created, specific values are assigned to the properties. When ontology is supplemented with instances, it turns into knowledge base, although in practice drawing a sharp line between the two is often problematic. Further technical details on ontologies and particulars of different sublanguages of the OWL family can be found in one of our previous works [35].

Ontologies are now widely used as AI method, particularly for study and organization of concepts in dynamically developing domains, such as bio-medicine. So, it is not by accident that the most popular ontology editor, Protégé, has been created and maintained by the Stanford Center for Biomedical Informatics Research. In our particular work we rely on ontology for structural representation of the keywords – particularly because our goal is to analyze frequency and dynamics in groups of factors on the same level of generality. In other words, comparing popularity of e.g. such EEG-specific term as "delta" to such universal and widespread term as "memory" would make little sense and could lead to biased conclusions. So, in the subsequent Section we describe ontology engineering for the keywords related to cognitive reserves and its use in PubMed publications mining.

3 Results

3.1 The Keywords for the Factors

The variety of approaches to specification of cognitive reserves and the types of cognitive functions, their characteristics and the approaches to testing, require organization and classification of the findings presented in research publications. According to the two-factor model of the reserves, one can identify:

1. structural and functional indicators of the brain's reserves: for example, the volume or functional activity of the prefrontal cortex or hippocampus, or indicators of cerebral blood flow and metabolism;
2. the actual cognitive reserves, which are in turn formed within the framework of the complex mental activities (education, professional features, social environment), the intellectual abilities, velocity characteristics of information processes and memory capacity, and the executive control functions of mental operations.

Considering the above model and the previously developed conceptual model of the frequency-spatial organization of brain's activity reflecting the cognitive reserves

[36], for the pilot stage of our analysis we chose the following keywords reflecting the corresponding indicators, to be sought in titles and abstracts of PubMed publications:

- brain structures: *prefrontal, parietal, temporal cortex*;
- EEG oscillations (reflecting the brain's functional activity): *delta, theta, alpha, beta*;
- the relevant mental operations: *processing speed, inhibition, attention, memory*;
- complex mental activities (are mostly shaped by determined by social attitudes and cultural preferences, which are rapidly changing in modern social conditions): *education*, *profession*, plus *information load*.

We show the outline of the related concepts in Fig. 1. For all the above indicators, we expect rapid dynamics in publications related to cognitive reserves. Correspondingly, our analysis is to include the temporal dimension, considering the changes by decades within the relatively recent period of 1990–2019.

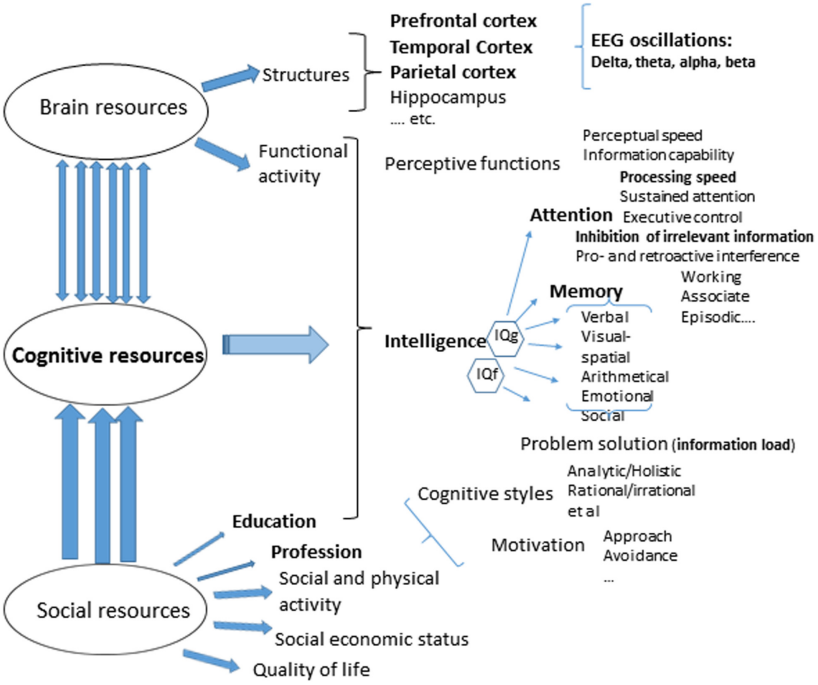

Fig. 1. Diagram of concepts related to cognitive resources.

For the benefit of our analysis and since many of these concepts are rather general in Neuroscience, we decided to implement the search process in two stages: 1) selecting publications with keywords *cognitive resources* and *cognitive functions*, and 2) counting the number of publications in the set obtained in the first stage, for each keyword drawn from the ontology.

3.2 The Cognitive Reserves Mining Ontology

In construction of the integrated ontology used in the PubMed information analysis, we relied on several existing OWL bio-ontologies (since we perform bibliometric search for the past 30 years, we are not limited to the most up-to-date ontologies):

- Brain Region & Cell Type terminology (BRCT)[2] – organizing the knowledge domain of brain anatomy with a top-down granularity.
- OntoNeuroLOG (ONL)[3] – ontological framework integrating Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) and several core ontologies, particularly for neuroimaging domain.
- Mental State Assessment (ONL-MSA)[4] – a module of the OntoNeuroLOG ontology that covers instruments, instrument variables, assessments, resulting scores, etc. in the field of mental state assessments.
- eNanoMapper (ENM)[5] – terminology related to support research into nanomaterial safety, which also covers some electroencephalography-related concepts.

The brain structures from the BRCT ontology (Fig. 2) were supplemented with additional `annotation property`, named *search keyword*, as sub-property of already existing *Synonym* property (see in Fig. 3). Then, the values of this property for *Frontal cortex*, *Parietal cortex* and *Temporal cortex* classes were specified according to the list of keywords in the *Brain Structures* category.

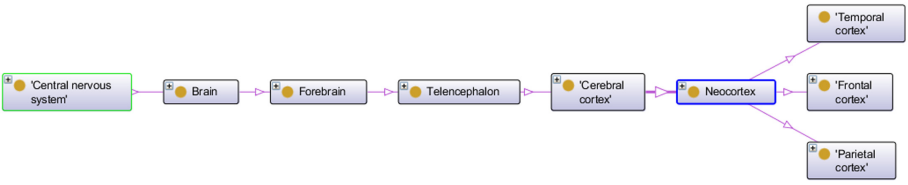

Fig. 2. The relevant brain structures from the BRCT ontology (with the hierarchy of concepts).

For the *EEG Oscillations* category of keywords, we extended the *composite-instrument* class in the OntoNeuroLOG ontology with the relevant classes from the eNanoMapper ontology, as shown in Fig. 4. The alpha, beta, delta and theta wave measurements correspond to the frequencies of electric potential between parts of the brain: 8–13 Hz, 13–30 Hz, 0.1–4 Hz and 4–8 Hz respectively. The relevant keywords from the above list were similarly added as the values of the *search keyword* property. Further, the *Synonym* property of the *EEG measurement* class got the values from the ENanoMapper ontology: "electroencephalogram traits", "brain waves", "brain oscillations" and "brainwaves".

[2] https://bioportal.bioontology.org/ontologies/BRCT.
[3] http://neurolog.i3s.unice.fr/neurolog.
[4] https://bioportal.bioontology.org/ontologies/ONL-MSA.
[5] https://bioportal.bioontology.org/ontologies/ENM.

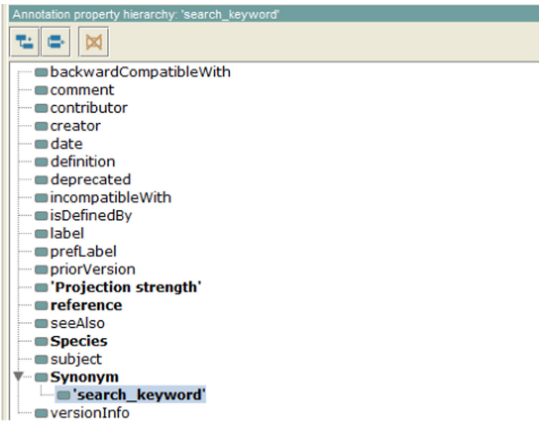

Fig. 3. Annotation properties (BRCT): *search keyword* as sub-property of *synonym.*

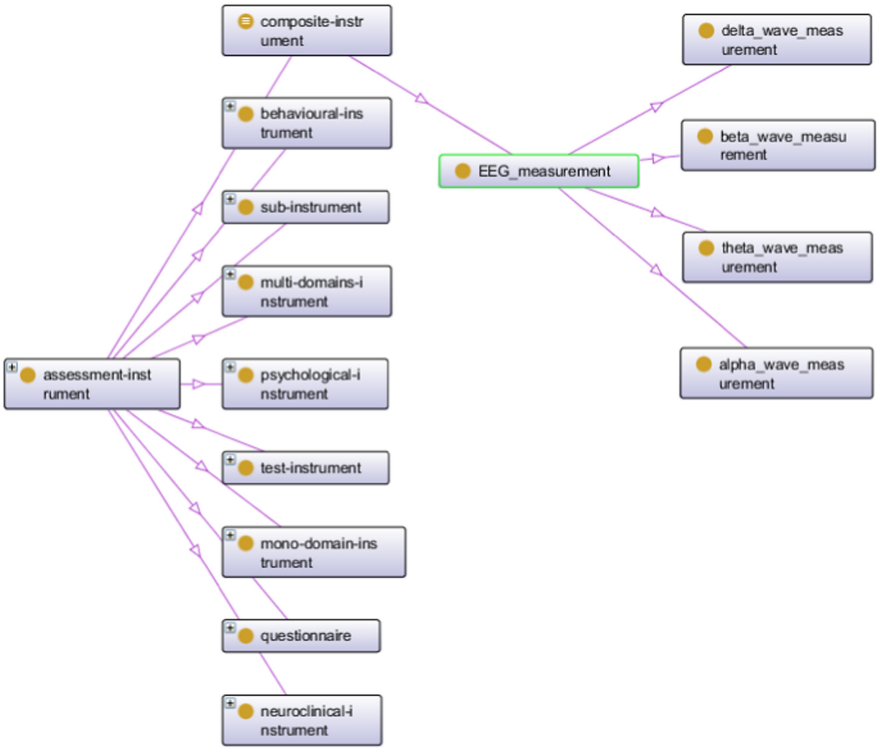

Fig. 4. Assessment instruments in the OntoNeuroLOG ontology supplemented with the *EEG oscillations*-related classes.

3.3 Software Implementation

With respect to search functionality, PubMed accepts natural language-based queries as the input and outputs matching publications. In its search strategy, it adds logical operators to the queries and uses Automated Term Mapping (ATM)[6] by default. The latter implies that PubMed automatically compares and matches keywords from the query to its lists of pre-indexed terms. If the query is considered relevant to one or several of these terms, they are added to the initial keywords. As the result, the output is formed with consideration of these additional PubMed indexing terms.

In our work, we relied on utility tools provided by PubMed – in particular, Entrez Direct (EDirect) that we described previously, which allows accessing the set of interconnected NCBI databases from UNIX terminal window. We have installed EDirect on a virtual server under Debian operating system and used the following functions for our data mining task. For instance, the following terminal query was used for data search and filtering:

```
esearch -db pubmed -query "****" | efilter -query "****" | efetch
-format docsum | xtract -pattern DocumentSummary -element Id Sort-
FirstAuthor Title FullJournalName /-block PubDate -sep " " -element
Year > output.csv
```

The result of the query – the publications that contain a certain keyword (marked as "****" in the above example) in their title or abstract – is saved to the output file in the structured format for further analysis. Particularly, `efetch -format docsum` and `xtract -pattern DocumentSummary -element` specify that the output data are transformed from EDirect XML into data table compatible format, which allows subsequent import of `.csv` file into MySQL. The corresponding table named `Filtered_Publication` in the database includes the following fields:

```
Article_ID (int)
First_Author (text)
Article_Title (text)
Journal_Name (text)
Pub_Full_Date (varchar)
Pub_Year (int)
Keyword (varchar)
```

The last field was added since for the purposes of our analysis, we extracted just the publications year (`Pub_Year`) from the full publication date provided by PubMed (`Pub_Full_Date`). Correspondingly, the following query would be used to obtain the number of publications for one of the periods used in our analysis (1990–1999):

```
SELECT count(*) FROM 'Filtered_Publication' WHERE 'Keyword' =
'****' and 'Pub_Year' BETWEEN '1990' AND '1999'
```

.

[6] https://www.nlm.nih.gov/bsd/disted/pubmedtutorial/020_040.html.

3.4 Bibliometric Data Analysis

In the first stage, publications were selected from PubMed and saved to our database: 36984 containing *cognitive functions* and 8600 containing *cognitive resources* keywords in their titles or abstracts (as of Feb 2020). There were 570 duplicates across these two categories, which were removed, so the resulting set included 45014 publications, of which 43419 fit within the period of our analysis: 1990–2019 (see their annual numbers in Fig. 5). For the sake of comparison, the number of all saved publications prior to 1990 was 923 – about 21% of publications in the year 2019 alone. We further constructed the exponential regression equation ($R^2 = 0.997$, $F_{1,28} = 9048$, $p < 0.001$), which suggests that the annual growth rate was approximately 10.9%:

$$Number\ of\ publications = 179e^{10.9x} \tag{1}$$

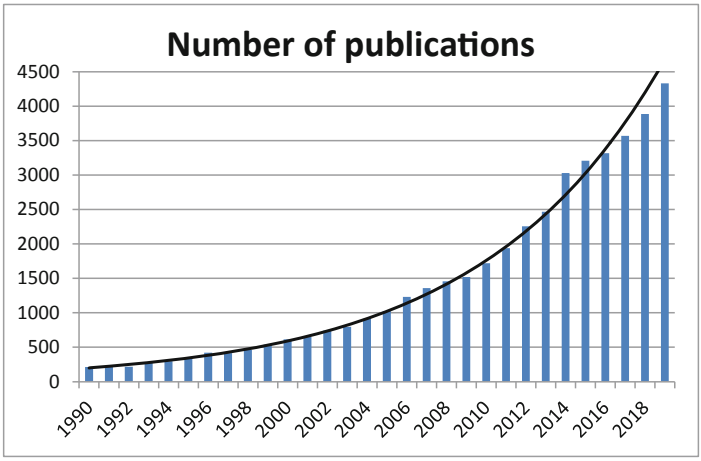

Fig. 5. The annual increase in the number of cognitive reserves-related publications.

For each individual keyword, we calculated the relative growth rates (RGR) for the periods of 10 years, using the following well-known formula [2]:

$$RGR = \underset{i=1}{\overset{3}{average}}(\ln N_i - \ln N_{i-1})/10 \tag{2}$$

where i is period in the analysis, N_i is the number of publications in the period. The absolute numbers of publications and the growth rates are presented in Table 1. The Total column reflects the keyword's growth in the relative number of cognitive reserves-related publications (i.e. it is adjusted for the growth in the total number of publications), and we marked the highest value in each category in bold. In the RGR column, we used the color coding to indicate whether the growth is considerably higher (green) or lower (red) compared to the cognitive reserves-average of 10.9%.

The results presented in Table 1 suggest prevalence of researchers' attention towards the cortex functions in the prefrontal area (49.5%) compared to its other regions. This is

Table 1. Number of publications and growth rates per the keywords

Category	Keyword	Period			Growth	
		1990-1999	2000-2009	2010-2019	Total	RGR
Brain Structures:						
	Prefrontal cortex	168	876	2195	**49.5%**	12.8%
	Parietal cortex	70	290	792	29.5%	12.1%
	Temporal cortex	115	379	907	-9.7%	10.3%
EEG Oscillations:						
	delta	14	73	203	65.9%	13.4%
	theta	25	91	410	87.7%	14.0%
	alpha	82	305	1029	43.6%	12.6%
	beta	68	381	1639	**175.8%**	15.9%
Mental Operations:						
	Processing speed	69	329	1340	122.2%	14.8%
	Inhibition	95	604	2239	**169.7%**	15.8%
	Attention	749	2609	6390	-2.4%	10.7%
	Memory	1317	4189	11102	-3.5%	10.7%
	Intelligence	298	718	1697	-34.8%	8.7%
	Emotional regulation	28	136	565	130.9%	15.0%
Mental Activities:						
	Information load	9	41	186	**136.5%**	15.1%
	Education	295	930	3662	42.1%	12.6%
	Profession	12	17	68	-35.2%	8.7%
Total number of publications:		**3400**	**10308**	**29711**		

consistent with the increasing research interest towards inhibition processing (175.8%), whose functional organization is the result of the activities of the neural networks in the prefrontal cortex [17]. The mental activities associated with cognitive reserves are foremost represented by the *information load*. On the neurophysiological level, this fact is consistent with the intensive growth in the number of publications that analyze the low-frequency theta and high-frequency beta oscillations in neuronal systems as indexes of their functional interaction in the context of information load. The data reflecting the relatively weakening interest towards *intelligence* and *profession* may suggest the shift of attention towards studying the dynamic processes shaping the mechanisms of cognitive resources instead of their integral static indicators.

4 Discussion

The relative growth rate of 10.9% found in our study for the overall number of publications related to cognitive reserves is consistent with the one reported in other research works for the field of Neuroscience (see e.g. [2] or [5]). The number of publications we considered, about 45000, is higher than in most meta-analyses on cognitive reserves (e.g. 135 articles in [13]) and in some bibliometric analyses in adjacent fields (e.g. 2627 articles in [37]). As for our main findings, to the extent of our knowledge no other works had focused on identification of the influential factors for CRs based on bibliometric analysis, so we are unable to make a comparison.

Whereas the scope of our study was substantial, the mining methods that we applied were rather unsophisticated, which we see as its primary limitation. We did not rely on topic modeling, semantic proximity or other natural language processing method that see increasing use in AI-based brain research [38], nor extracted the meaning or relations in the data. The secondary limitation we see is that the validation of the publication selection was performed rather informally by a Neuroscience expert, who however recognized them as mostly relevant. So, our plans for further research work involve validation of the identified factors' effects and possibly employment of more advanced semantic information search tools.

5 Conclusions

The exponentially growing number of research publications leads little choice but the wide application of IT for secondary analysis, particularly in the booming field of Computational Neuroscience. In our paper, we performed bibliometric data mining of PubMed databases to identify the potential indicators of the cognitive resources, which are considered very relevant not just in normal and pathological aging, but also for purposeful increase of the cognitive activities efficiency, particularly in neuropsychological rehabilitation after surgery. This suggests high practical importance of differentiating the informative values for the different predictors of the cognitive resources for various groups of citizens.

The analysis of the publications dynamics suggests steadily increasing research interest in the EEG oscillatory activity of the brain cortex. This is apparently due to the fact that synchronization/desynchronization of brain biopotentials reflects a wide range of changes in the functional activity of its individual regions and the degree of their interaction and, accordingly, presents the basis for resource involvement in cognitive activity. Our analysis results suggest that among the different EEG frequencies the high-frequency *beta* range attracts the most attention, while among the main cortex regions the research interest is most focused on the *prefrontal cortex*.

The absolute number of publications with the keywords *attention* and *memory* is the highest compared to any other cognitive processes-related term, in each decade that we considered. However, the relative increase is the highest for the *processing speed*, *inhibition* and *emotional regulation*, whereas *inhibition* is leading not just among all the mental operations, but also among all the considered terms. The particularly intensive growth in the number of publications mentioning *information load* should be noted as well. In conjunction with the discovered sharp increase for the *inhibition* and *processing speed* keywords, this fact can be regarded as evidence of a rising interest towards the study of information selection processes for understanding the mechanisms of cognitive reserves formation.

As for the analysis of the complex mental activities with respect to the cognitive reserves, the research works mentioning the *education* keyword are prevalent. Despite the general growth in the number of publications mentioning intelligence and profession, these terms seem to be less attractive for researchers, among all the considered indicators of cognitive reserves.

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References

1. Bornmann, L., Mutz, R.: Growth rates of modern science: a bibliometric analysis based on the number of publications and cited references. J. Assoc. Inf. Sci. Technol. **66**(11), 2215–2222 (2015)
2. Chitra, V., Jeyshankar, R.: Growth of literature in neuroscience: a scientometric study (1972–2011). J. Adv. Libr. Inf. Sci. **1**(4), 201–210 (2012)
3. Lee, M., Kang, J., Jeong, Y.J.: Risk factors for post-intensive care syndrome: a systematic review and meta-analysis. Aust. Crit. Care **33**(3), 287–294 (2020)
4. Iftikhar, P.M., et al.: A bibliometric analysis of the top 30 most-cited articles in gestational diabetes mellitus literature (1946–2019). Cureus **11**(2), e4131 (2019)
5. Yeung, A.W.K., Goto, T.K., Leung, W.K.: The changing landscape of neuroscience research, 2006–2015: a bibliometric study. Front. Neurosci. **11**, 120 (2017)
6. Razumnikova, O.M.: Patterns in brain ageing and the ways for activation of its cognitive reserves. Usp. Fiziol. Nauk **46**(2), 3–16 (2015). (in Russian)
7. Anthony, M., Lin, F.: A systematic review for functional neuroimaging studies of cognitive reserve across the cognitive aging spectrum. Arch. Clin. Neuropsychol. **33**(8), 937–948 (2018)
8. Stern, Y.: What is cognitive reserve? Theory and research application of the reserve concept. J. Int. Neuropsychol. Soc. **8**(3), 448–460 (2002)
9. van Loenhoud, A.C., et al.: Cognitive reserve and clinical progression in Alzheimer disease a paradoxical relationship. Neurology **93**(4), e334–e346 (2019)
10. Brochet, B.: Neuroprotection and cognition in multiple sclerosis: effects of cognitive and brain reserve. In: DeLuca, J., Sandroff, B.M. (eds.) American Psychological Association, pp. 321–343 (2018)
11. Gil-Pagés, M., et al.: A positive relationship between cognitive reserve and cognitive function after stroke: dynamic proxies correlate better than static proxies. J. Int. Neuropsychol. Soc. **25**(9), 910–921 (2019)
12. Gayda, M., et al.: Cognitive function in patients with stable coronary heart disease: related cerebrovascular and cardiovascular responses. PLoS ONE **12**(9), e0183791 (2017)
13. Opdebeeck, C., Martyr, A., Clare, L.: Cognitive reserve and cognitive function in healthy older people: a meta-analysis. Aging Neuropsychol. Cogn. **23**(1), 40–60 (2016)
14. Reuter-Lorenz, P.A., Cappell, K.A.: Neurocognitive aging and the compensation hypothesis. Curr. Dir. Psychol. Sci. **17**(3), 177–182 (2008)
15. Cabeza, R.: Hemispheric asymmetry reduction in older adults: the HAROLD model. Psychol. Aging **17**(1), 85–100 (2002)
16. Reuter-Lorenz, P.A., Park, D.C.: How does it STAC up? Revisiting the scaffolding theory of aging and cognition. Neuropsychol. Rev. **24**(3), 355–370 (2014). https://doi.org/10.1007/s11065-014-9270-9
17. Razumnikova, O.M., Nikolaeva, E.I.: Braking functions of the brain and age-related features of the organization of cognitive activity. Usp. Fiziol. Nauk **50**(1), 75–89 (2019). in Russian
18. Zatorre, R.J., Fields, R.D., Johansen-Berg, H.: Plasticity in gray and white: neuroimaging changes in brain structure during learning. Nat. Neurosci. **15**(4), 528–536 (2012)
19. Razumnikova, O.M., Vol'f, N.V.: Reorganization of the association between intelligence and the characteristics of attention and memory on aging. Neurosci. Behav. Physiol. **48**(4), 453–462 (2018). https://doi.org/10.1007/s11055-018-0586-4
20. Razumnikova, O.M.: Creativity and intelligence as predisposing factors of mental, social, and physical health. In: Proceedings of the International Conference on Medical Psychology (PHYSIOLOGY 2010). Advances in Biomedical Research, UK, pp. 205–214 (2010)

21. Ikanga, J., Hill, E.M., MacDonald, D.A.: The conceptualization and measurement of cognitive reserve using common proxy indicators: testing some tenable reflective and formative models. J. Clin. Exp. Neuropsychol. **39**(1), 72–83 (2016)
22. Ball, K., et al.: Effects of cognitive training interventions with older adults: a randomized controlled trial. JAMA **288**(18), 2271–2281 (2002). Advanced Cognitive Training for Independent and Vital Elderly Study Group
23. Fontaine, J.F., et al.: MedlineRanker: flexible ranking of biomedical literature. Nucleic Acids Res. **37**, W141–W146 (2009)
24. Poulter, G.L., et al.: MScanner: a classifier for retrieving Medline citations. BMC Bioinform. **9**(1) (2008). Article number: 108. https://doi.org/10.1186/1471-2105-9-108
25. Yu, H., et al.: Enabling multi-level relevance feedback on PubMed by integrating rank learning into DBMS. In: Proceedings of the 3rd International Workshop on Data and Text Mining in Bioinformatics, pp. 43–50 (2009)
26. Rani, J., Ramachandran, S.: pubmed.mineR: an R package with text-mining algorithms to analyse PubMed abstracts. J. Biosci. **40**(4), 671–682 (2015). https://doi.org/10.1007/s12038-015-9552-2
27. Drakopoulos, G., Kanavos, A.: Tensor-based document retrieval over Neo4j with an application to PubMed mining. In: 7th IEEE International Conference on Information, Intelligence, Systems & Applications (IISA), pp. 1–6 (2016)
28. Wan, C., Freitas, A.A.: An empirical evaluation of hierarchical feature selection methods for classification in bioinformatics datasets with gene ontology-based features. Artif. Intell. Rev. **50**(2), 201–240 (2017). https://doi.org/10.1007/s10462-017-9541-y
29. Zhang, B., et al.: EEG-based automatic sleep staging using ontology and weighting feature analysis. Comput. Math. Methods Med. **2018** (2018). Article ID 6534041. https://www.hindawi.com/journals/cmmm/2018/6534041/
30. Kerepesi, C., et al.: Prediction and characterization of human ageing-related proteins by using machine learning. Sci. Rep. **8**(1) (2018). Article number: 4094. https://www.nature.com/articles/s41598-018-22240-w
31. Poldrack, R.A., Yarkoni, T.: From brain maps to cognitive ontologies: informatics and the search for mental structure. Ann. Rev. Psychol. **67**, 587–612 (2016)
32. Eisenberg, I., et al.: Uncovering the structure of self-regulation through data-driven ontology discovery. Nat. Commun. **10** (2019). Article number: 2319. https://www.nature.com/articles/s41467-019-10301-1
33. Amoretti, M.C., Frixione, M., Lieto, A., Adamo, G.: Ontologies, mental disorders and prototypes. In: Berkich, D., d'Alfonso, M.V. (eds.) On the Cognitive, Ethical, and Scientific Dimensions of Artificial Intelligence. PSS, vol. 134, pp. 189–204. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-01800-9_10
34. Norris, E., et al.: A scoping review of ontologies related to human behaviour change. Nat. Hum. Behav. **3**(2), 164–172 (2019)
35. Kurcheeva, G., Rakhvalova, M., Rakhvalova, D., Bakaev, M.: Mining and indexing of legal natural language texts with domain and task ontology. In: Chugunov, A., Misnikov, Y., Roshchin, E., Trutnev, D. (eds.) EGOSE 2018. CCIS, vol. 947, pp. 123–137. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-13283-5_10
36. Razumnikova, O.M., Bakaev, M.: Ontology of frequency-spatial organization of brain activity reflecting the cognitive reserves. In: International Multi-Conference on Engineering, Computer and Information Sciences (SIBIRCON), pp. 950–954 (2019)
37. Liu, F., et al.: Worldwide tendency and perspectives in traumatic dental injuries: a bibliometric analysis over two decades (1999–2018). Dent. Traumatol. **36**, 489–497 (2020)
38. Chen, X., et al.: Topics and trends in artificial intelligence assisted human brain research. PLoS ONE **15**(4), e0231192 (2020)

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