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Information and Analytical Support for Decision-making in the Management of the ICT Industry in the Regions of the Russian Federation

[1] Nafisa I. Yusupova, [1] Olga N. Smetanina, [1] Ekaterina Yu. Sazonova, [1] Anna G. Ionis, [2]Andrey Morozov and [1] Tagir I. Fabarisov
[1] Ufa State Aviation Technical University, Ufa, Russia
[2] Dresden University of Technology, Dresden, Germany
E-mail: yussupova@ugatu.ac.ru, smoljushka@mail.ru, rassadnikova_ekaterina@mail.ru, solomonarmkeys@gmail.com, andrey.morozov@tu-dresden.de, flatagir@gmail.com

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Abstract: The article substantiates the relevance of the study due to the fact that innovation policy in the field of information activities has a great impact on the economic growth of the state. Implementation of the industry 4.0 concept and the digital economy of the Russian Federation program presuppose further improvement of information and communication technologies and development of ICT industry in the regions of Russia. The results of studies of the current state of the problem in the field of management of the level of development of information and communication technologies in the regions of Russia. However, when dividing the state into a large number of territorial units, there is a problem of significant differentiation for the same indicator in different regions. In this regard, the article reflects the question of the appropriateness of fuzzy logic to assess the level of development in the selected region. The use of fuzzy logic allows to take into account heterogeneous characteristics in the analysis of the industry, as well as to provide fuzzy descriptions using linguistic variables. The described model contains 35 indicators of the industry transformed into 12 linguistic variables characterizing the development of the industry at the regional level. The model contains a base of rules, which allows to identify priority areas in the development, due to the symbiosis of qualitative and quantitative indicators. Also, the problem statement for the management tools of the information and communication technologies industry is performed, the expediency of developing its own decision support system is justified. The simulation results can be used by decision makers to develop a plan of effective measures for the development of information and communication technologies in the region.

Keywords: Neural network technology, Data mining, Decision support, Factor analysis, Information and communications technology.

1. Introduction

Nowadays, the fact that information and communication technologies play a primary role for the modern person is beyond doubt. And this is connected not only with everyday life. Innovation policy in the field of information and communication activities is associated with the general recovery of the economy, the country's competitiveness. At the same time, when investigating the development of this industry, there is a problem associated with the constant emergence of new technologies and opportunities, because ICT industry is one of the fastest growing industries both in the world and in Russia. But despite the rapid growth, Russia still lags behind the level of world powers. Thanks to statistical analysis and data mining tools, it became obvious that management decision-making within this industry takes place in conditions of uncertainty, which is primarily due to the fact that Russia is divided into Federal districts, in each of which the pace of development can have a strong differentiation between the incoming regions. On the other hand, this may be due to incomplete information on the development indicators, social, political and economic factors of a particular region and the lack of applicability of the General guidelines to the country. According to statistics for 2017, there is an obvious lag in a number of indicators even within one Federal district, for example, between Moscow and the Bryansk region. Thus, there is the problem of digital inequality of the regions of Russia, associated with geographical, economic and managerial differences. One of the solutions to this problem can be the modeling of the level of ICT development at the regional level, the identification of similarities between regions, taking into account the values of indicators characterizing the level of development and building a rule base based on the interpretation results.

2. State of the Problem

All research in this area somehow affects the Solow paradox, which suggests that information technology does not affect labor productivity and attracting investment in computerization of production entails only more investment. However, after a sharp rise in productivity in the 1990s, most researchers and scientists agreed that the ICT industry was the cause of such a sharp jump. Since the middle 2000s, the results of research by many experts [1-7] show that there is a correlation between the development of information and communication technologies and the level of economic development in the country. Thus, according to the analytical service of The Economist magazine [7, 11], there is a mutual merger between ICT level and economic development in developed countries, while for developing countries this effect is not observed or is insignificant. However, all these studies have a number of significant shortcomings, which are confirmed by the results of analytical reports. One of the most successful is the empirical study of the Economist Intelligence Unit [11], which took as a basis not only the level of ICT use, but also the state of the business environment, as well as conditions conducive to the introduction of new technologies from the ICT area. The resulting model allowed not only to differentiate countries depending on the level of development, but also to explore the effects of interaction. But the question of the reasons for the influence of the ICT industry on the level of economic development in some countries still remains unresolved. In this connection, the hypothesis was proposed that the ICT industry begins to influence the country's economic growth, expressed in GDP only when the so-called critical mass, that is, the saturation point, is reached. In this case, the methods and models proposed in the works, as a rule, take into account only the relationship between the level of ICT development and the level of economic development. However, it makes sense to take into account both the contribution of the ICT industry in the country's GDP and the development of the ICT industry itself. The development of the ICT industry in each region of the country is seen as fundamental, contributing to the level of development of the country's industry as a whole. In this case, the rating of regions is determined annually.

3. Statement of the Problem

The authors proposed to develop a methodology for identifying similarities between objects (regions) based on the most significant factors, which influence the industry development (considering the rating), and with using new knowledge to formulate recommendations for managing the industry development.

Problem statement can be formulated as follows: Formulate recommendations to improve the level of the development level based on analysis of the initial data presented by a set of vectors, which describes the characteristics of the regions of the Russian Federation in the ICT-industry development.

Mathematical statement of the problem of the research is formulated as follows.

Given X- a set of vectors represented by the characteristics of the regions in the region of X_i, where $X_i = \{x_{i1}, x_{i2}, \dots, x_{in}\}$, here $x_{i1}, x_{i2}, \dots, x_{in}$ - region information, where $i = \overline{1,85}$, $j = \overline{1,n}$ – j factor taken into account that influences the level of development (total n factors)

Find: $F: X_i \rightarrow Y_c$, function that maps data to knowledge. This function will make it possible to assign a region with take into account its characteristics to one of clusters that unite regions with similar characteristics, and to construct RULE rules, using which it is possible to formulate recommendations for the industry development.

4. The Technique for Solving the Problem

The technique for solving the problem (Fig. 1) includes five stages. The first two stages are aimed at preparing data for analysis. At the first stage, statistical information is collected, the characteristics of the objects are selected for further research. Thus, data from the statistical collections "Indicators of the information society" [12], "Russia in numbers" and "Regions of Russia" were taken for analysis. Socio-economic indicators" [13]. According to the structure, the data are a set of 34 indicators ranked by 85 regions of the Russian Federation, conditionally divided into 4 groups: human resources; material resources and technologies; dynamics of the number of organizations in the field of ICT use; financing, costs and key macroeconomic indicators of the ICT industry. At the second stage, preliminary data processing is carried out. Pre-processing is necessary to control the invalid values of selected indicators, as well as to detect, correct and delete erroneous records. At this stage, using the approximation functions and the means of the existing application programs, the existing gaps in the characteristic values are filled, individual criteria are standardized, for example, to normalize indicators taken in monetary terms, it is necessary to impose an index deflator. To address the question about the exception/use in the further study of anomalous observations, by means of SPSS was constructed diagram of the scope of existing indicators. During the construction it was revealed the presence of anomalous observations for the city of Moscow, explained by the concentration of key aspects of the industry: a large number of specialists, high speed of emergence and introduction of new technologies, high investment activity and attractiveness of the subject. In this connection, in the future, it was decided to include this subject in the analysis. At the third stage, a factor analysis is carried out to identify the most significant factors. The choice in favor of this method is due to the fact that the factor analysis tool allows you to: determine the data structure, reduce the dimensionality of the attribute space without losing information (relevant for data with a high level of correlation), and also highlight the most significant characteristics for regulating the process under study. As a result of the factor analysis, a compressed description of the data of small volume was obtained, which includes information on the initial data, but does not have a high level of correlation, while, due to the ranking of the obtained factors in descending variance, it becomes possible to determine the most significant indicators and assess the contribution of each factor to the overall development of the industry. The key criterion in the selection of factors was the criterion of cattle scree. To improve the quality of interpretation, the rotation procedure was applied to the obtained results. As an optimal result of this stage, the criterion of varimax was singled out, which identifies 5 main factors: material and technical resources; costs for the industry; distribution of technologies in households (separate cells of society within which the social product occurs, its consumption, as well as the reproduction of the labor force [14]); human resources; distribution of social networks and Internet technologies. The total explanatory power was 84 %. To identify similarities by clustering, the apparatus of neural networks is used, in particular, Kohonen network. In this study, clustering is necessary because it allows you to select one or more attributes as a basis for generalized groups of regions, and also to show what their similarities are and how the ranges of values are coordinated, as well as to form a characteristic of the ICT industry by territorial location. A feature of this method is also that clustering can work in "both sides".

Fig. 1. Solution Technique.

When analyzing, it can be assumed that there is a cluster at a certain point and then to test this hypothesis using the existing criteria values, on the other hand, taking into account the available input data, to identify various properties and processes occurring in the objects.

The comprehensive analytical Deductor Studio platform (steps 1-3) and the shell, which allows to realize a production system (stages 4-5) are used to implement the solution techniques.

The results of clustering show 13 clusters, most of which are heterogeneous in territorial location, but have an average or low level of use of ICT technologies and approximately one-level investment attractiveness. In the fourth stage, the revealed new knowledge in the form of characteristics of similar objects by interpreting the data makes it possible to formulate recommendations for the development of the industry in the region. At this stage of solving the problem, in addition to the results of cluster analysis, it is proposed to use the knowledge of experts, to form a knowledge base containing production rules. At the fifth stage, in order to improve the quality of decision-making, it is necessary to build development models that will be suitable for individual regions, and to work in conditions of uncertainty, helping decision-makers to obtain a more objective assessment of the proposed management decisions. Taking into account the existing heterogeneity, the authors decided to use fuzzy sets and linguistic variables for modeling. To model the ICT industry, fuzzy models are presented in the form of fuzzy production networks, the elements and sets of elements of which implement the components of the fuzzy model and the stages of fuzzy inference. For construction of fuzzy production network evaluation of the level of development of the industry of information and communication technologies it is necessary to determine the full space of preconditions $X = \{x_{1j}, x_{2j}, \dots, x_{ij}\}$, – characteristics of the industry in the region, where $i = \overline{(1,35)}$ – the number of features, $j = \overline{(1,85)}$ – the number of regions of the Russian Federation, and the total space of the conclusions of $Y = \{y_k\}$, dividing the regions into clusters, where $k = \overline{(1,13)}$ is the number of clusters. In the process of analyzing the results of factor and cluster analysis, it became possible to identify the term sets that define a group of regions with similar characteristics (Table 2):

$T1 = \{Low\ (H), Medium\ (C), High\ (B)\}$;
T2 = {Very Low (OH), Low (H), Medium (C), High (B), Very High (S)}.

And for the indicators of the industry were allocated term set:

$T3 = \{Low\ (H), Medium\ (C), High\ (B)\}$;
T4 = {Very Low (OH), Low (H), Medium (C), High (V)};
T5 = {Very Low (OH), Low (H), Medium (C), High (B), Very High (S)}.

On the basis of the proposed apparatus and the available knowledge base, it becomes possible to build an expert system for assessing the level of development of the region on the basis of fuzzy logic.

5. The Results of the Study

Interpretation of the factor analysis results allows to be drawn the following conclusions: the ICT-level and ICT-industry development in the regions is significantly affected by the organization's internal resources (the cost of research and its share of gross product; additional training for staff (human capital increase); in fixed capital; the share of computer use in the organization); the proportion employed in ICT; development of communication networks and data transmission; the share of graduates of IT areas (specialties) in the total graduation; the development level of technology; labor market index.

The obtained clustering results (Fig. 2) are interpreted and allow identifying similar objects with both high and low ratings (Table 1).

Specific values of the factors "translated into terms of the corresponding names of factors of linguistic variables" for later use in the formation of fuzzy knowledge base. At this stage of the research, interpretation results are laid down in production rules. In order to orient regions on higher rating, it is necessary to increase / decrease the values of some parameters (Table 2).

The relationship between the antecedent and the consequent is a binary fuzzy relation on the Cartesian product of the corresponding fuzzy sets. The fuzzy causal relationship between them is defined in the form of fuzzy products. The process of forming a base of fuzzy production rules is a formal representation of the empirical knowledge of the expert in the problem area under the scheme "if ..., then ...". Building a knowledge base is one of the most important tasks in creating a decision support system. Various methods and algorithms based on artificial intelligence technologies can be used to develop rules.

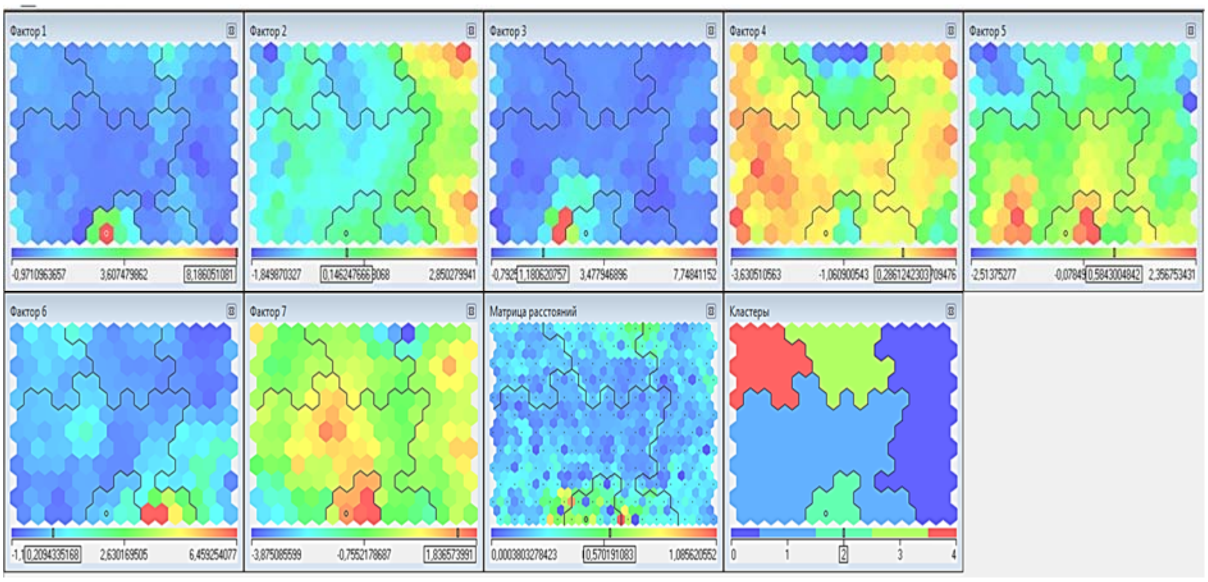

Fig. 2. Clustering results.

Table 1. The fragment of clustering results.

Cluster / Factor value	0	1	2	3	4
Factor 1	Below the average	Low	Medium and high	Below the average	Below the average
Factor 2	Average, above the average	Below the average	Medium	Below the average	Average and low
Factor 3	Low	Below the average	Medium	Low	Below the average
Factor 4	Above the average	Average, above the average	Average, above the average	Low, average	Average, above the average
Factor 5	Average	Average, above the average	Above the average and high	Average	Average and below the average
Factor 6	Average, above the average	Average, above the average	Average	Below the average	Low
Factor 7	Average and above average	Average and above average	High	Average	Average
Regions (class in rating)	Novosibirsk Oblast, Yaroslavl Oblast, Perm Territory, Mari El Republic, Chuvash Republic, etc. (2-6)	Belgorod, Omsk, Irkutsk, Arkhangelsk, Leningrad regions, Krasnodar Territory, etc. (7-12)	Moscow, St. Petersburg (1)	Tverskaya, Ivanovo regions, the Republic of Ingushetia, etc. (9, 13, 17)	Republics of Altai, Tyva, Zabaykalsky Krai, etc. (14-16)

Table 2. The fragment of characteristics of the ICT industry in the region.

Designation	Indicator	The kind of term-sets and interpretation of levels of factors
X_{1j}	the use of PC	T3. H – does not sufficiently correspond to the goals of the organization; C – corresponds to the goals with certain restrictions; C – fully corresponds.
X_{2j}	using servers	T3. H – does not sufficiently correspond to the goals of the organization; C – corresponds to the goals with certain restrictions; C – fully corresponds.
X_{3j}	local area network	T3. H – does not sufficiently correspond to the goals of the organization; C – corresponds to the goals with certain restrictions; C – fully corresponds.
X_{4j}	global information network	T3. H – does not sufficiently correspond to the goals of the organization; C – corresponds to the goals with certain restrictions; C – fully corresponds.
X_{5j}	organizations that used electronic document management systems	T5. IT – use does not meet the required level; H – satisfactory, requires updating; C – sufficient; B – good; C – excellent.
…	…	…
X_{30j}	PC households	T5. HE – the Proportion of PC households to 40; H – the Proportion of PCs in households 40-50; C – the Internet uses 50-65 % of the population; B – the Internet uses 65-85 % of the population; S – more than 85 % of the population uses the Internet.
X_{31j}	households online	T4. H – Internet is used by less than half of the population; C – Internet is used by 50-65 % of the population; B – Internet is used by 65-85 % of the population; C – over 85 % of the population uses the Internet.
X_{32j}	households broadband access	T4. H – Internet is used by less than half of the population; C – Internet is used by 50-65 % of the population; B – Internet is used by 65-85 % of the population; C – over 85 % of the population uses the Internet.
X_{33j}	Internet use by the population	T4. H – Internet is used by less than half of the population; C – Internet is used by 50-65 % of the population; B – Internet is used by 65-85 % of the population; C – over 85 % of the population uses the Internet.
X_{34j}	number of students	T3. H – does not sufficiently meet the needs of the labour market; C – meets with certain restrictions; C – fully meets.

As examples, the following production rules can be given:

Rule 1: IF cluster = 0 AND 8 ≤ rating ≤ 15, THEN IT companies need to find internal resources for additional training of employees, for scientific research and for hardware upgrades.

Rule 2: IF cluster = 4 AND rating = 14, THEN IT companies need to find internal resources for additional training of employees, for scientific research, hardware upgrades, AND to increase the level of science and technology development by creating innovation centers.

Rule 3: IF cluster = 1 and 9 ≤ rating ≤ 12, THEN it is necessary to increase the proportion of people employed in IT, for example, by creating new IT companies.

Rule n: IF cluster = 0 and 1 ≤ rating ≤ 15, THEN there is need to increase the output of IT specialists in universities by attracting commercial students, working with existing students, strengthening career guidance, increasing the admission plan.

6. Conclusions

Any development strategy for the ICT industry in the region are guided by human capital; innovation potential; institutional and infrastructural environment; ICT infrastructure and access; information industry; information security; use of ICT for development, etc. The study of indicators characterizing information and communication activities, ranked by constituent entities of the Russian Federation, revealed a strong differentiation between the central part of the country and the other federal districts. The indicators of Moscow, the Moscow region are markedly different from the all-Russian (they are anomalous observations for all the ICT indicators studied).

The proposed concept is focused on identifying similar objects by conducting cluster analysis. The analysis results are interpreted according to the semantics of the application domain. Authors describes the tools develop recommendations that provide information support for decision-making. In the future, the authors propose the use of neuro-fuzzy tools to solve the problem.

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References

[1]. E. V. Presnyakov, Impact of information and communication technologies on the global economy, *Izvestiâ Sankt-Peterburgskogo Gosudarstvennogo èkonomičeskogo Universiteta*, 2011, pp. 132-134.

[2]. Abdul A. Erumban, Deb Kusum Das, Information and communication technology and economic growth in India, *Telecommunications Policy*, Vol. 40, Issue 5, May 2016, pp. 412-431.

[3]. Khakimdzhanova D. K., The ICT development and impact on the economy, *Young Scientist*, Vol. 7, 2017, pp. 290-293 (https://moluch.ru/archive/141/39836).

[4]. V. I. Ivanova, E. P. Mitrofanov, T. N. Polkanova, The importance and role of information and communication technologies in the modern economy and innovation activities, *Vestnik Chuvashskogo Universiteta*, Vol. 2, 2013, pp. 253-257.

[5]. O. Valieva, Small Innovative Business in Russia: Problems and Prospects, in *Proceedings of the XII HSE International Academic Conference on Economic and Social Development, Workshop 'S&T and Innovation Policy'*, Moscow, Russia, April 6-7, 2011.

[6]. Moskalonov S. A., Lvov A. G., Analysis of the innovative potential of the Russian economy: the method of production functions, in *Proceedings of the XII International Scientific Conference on Problems of Development of Economy and Society*, Moscow, Vol. 4, 2012, pp. 417–428.

[7]. Zimin K. V., Markin A. V., Skripkin K. G., The impact of information technology on the performance of a Russian enterprise, methodology of empirical research, *Business Informatics,* Vol. 1, Issue 19, 2012, pp. 40-48 (in Russian). http://ecsocman.hse.ru/data/2012/06/06/1271384056/6.pdf

[8]. Brynjolfsson E., Hitt L., Information, Technology and Productivity, *Brynjolfsson and Hitt*, 2005.

[9]. Brynjolfsson E., Yang S., Exploring the Relationship Between Information Technology and Business Process Reengineering, 1996.

[10]. Silja Baller, Soumitra Dutta, Bruno Lanvin, The global Information Technology Report 2016, in *Proceedings of the World Economic Forum,* 2016, http://www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf

[11]. The Economist intelligence Unit, Industry Analysis, http://www.eiu.com/home.aspx

[12]. The next level, annual report 2017. URL: https://ict.eu/wp-content/uploads/2018/03/ICT-Annual-Report-2017.pdf

[13]. Official website of the Ministry of Communications of the Russian Federation URL: http://www.mskit.ru/

[14]. Official site of the Federal State Statistics Service URL: http://www.gks.ru

[15]. Information and legal portal Garant, URL: http://base.garant.ru/12148555/

[16]. Official site of the Consultant Plus company URL: http://www.consultant.ru

[17]. Andreev V. A., Factors determining the commercial success of research and development of various levels of novelty in the real sector of the Russian economy.

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