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Computer Visualization for the Algorithmization and Programming Task of Territorial Division Based on Interactive Mapping

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Abstract

The division of the territory into regions according to some attribute is the most important factor in the effective management of spatial development at the national, macroregional and regional levels of the economy. Applying a defragmented policy on this basis makes it possible to increase both the quality of public space management and the effectiveness of strategic planning. The author's method for visualizing the task of creating a digital twin of the economic zoning grid is presented in this paper based on interactive mapping as well as on the systematization of methods for reflecting the results of territorial division. The concept of economic complexity was used as a methodological approach, which is based on an understanding of the importance of producing complex products that require a wide range of knowledge and competencies.

The basis for the visualization of economic zoning is the author's mathematical algorithm for territorial division of the country into macroeconomic regions, compiled on the basis of graph theory and implemented in the Graphviz software. The creation of a digital twin of the macroregions grid is based on the indicator "Average number of employees for the full range of organizations", according to which a single statistical database was formed for 83 regions of Russia for the period from 2009-2019 for 104 types of economic activity. The graph visualizes the strongest links between sectors of the economy by constructing a maximum spanning tree based on the Kruskal algorithm. The vertices of the industry connectivity graph are the types of activities according to OKVED, and the edges are the “distances” between them.

To automate the process of creating a digital twin of the macroregions grid and its visualization, a software tool in the Python language was used. The advantage of the proposed visualization method is that the display of simulation results using interactive mapping allows reflecting all types of economic activity and the relationships between them in an easy-to-read format. This, in turn, makes it possible to predict the behavior of economic sectors in order to enhance the development of the constituent entities of the Russian Federation and the spatial development of the country as a whole.

Keywords: spatial data, interactive mapping, data visualization, economic zoning, digital twin, industry connectivity graph.

1. Introduction

Empirical observations about "differences in the productivity of factors of production at different points in the economic space" [1, p. 14] formed the basis of the theory of international exchange by A. Smith and D. Riccardo. These differences remain relevant today. At the same time, the basic tool for improving territorial planning is the division of the state into parts according to the totality of any interrelated features in order to differentiate management mechanisms, taking into account “the maximum use of the advantages provided by the heterogeneity of space” [2, c.17].

Depending on the goals set, the parts allocated in the process of territorial division can serve both as the basis for building a public administration system, representing administrative-territorial units (for example, federal districts in Russia), and as the basis for economic development (for example, economic regions in the USSR).

In the scientific literature devoted to territorial division, both the classics of economic geography [3–5] and researchers of the current stage of economic development [6–10] use the term “zoning” as a synonym for the latter. As A. M. Nosonov and V. N. Presnyakov rightly point out, a district is a territory (water area) identified by the totality of any interrelated features or phenomena, as well as a taxonomic unit in any system of territorial division [11, p. 10]. This broad interpretation of the region will form the basis of this study in order to avoid complicating the perception of the conceptual apparatus.

Zoning methods are not just an integral part of territorial studies, but also a constructive tool for the objective identification of industrial, agricultural, transport, economic, socio-economic and other regions of different hierarchical levels. The result of zoning is the creation of a grid of socio-economic regions, which can serve as the basis for both the administrative-territorial structure of countries, regional and local self-government [12], and the basis of regional economic policy.

It is important to note that economic zoning is not just a theoretical concept, although, objectively, the division of the territory into regions according to certain characteristics facilitates the task of analyzing the corresponding statistical indicators [13]. At the same time, the territorial division solves applied managerial problems, and this explains the interest in this topic in developed countries, in particular, members of the European Union [14–17]. As a rule, a macroregion in this context is understood as "a space that includes the territory of several states or regions, united by one or more features or challenges, ...geographical, cultural, economic, etc." [17, p. 8]. As M. Bogach, who studies the economic zoning of the European Union, notes, “the creation of macroregional strategies is a new way of working in terms of European cooperation” [14, p.6].

In this context, we agree with A.N. Demyanenko is that in Russia, which economic space is characterized by a high level of heterogeneity, "state economic policy is doomed to be regional" [8, p.5]. The key zoning grids today are the division of the territory into 8 federal districts, 4 military districts and 12 economic macroregions. These grids of territorial division are the subjects of the Russian Federation united on some basis and are designed to solve various problems: representation of local authorities in order to establish administrative unification (administrative-territorial division), ensuring the country's security (military-administrative division), territorial organization of economic activities of the national economy (economic zoning).

Visualization of the results of zoning is carried out using mapping, which is a practical tool in the development of economic, social, innovation and other types of policies by the authorities. Ready-made maps, as a rule, are static images on which the selected areas are depicted in different colors. At the same time, with the development of digital technologies, static maps have been replaced by electronic interactive maps, which are “a visual information system operating in the mode of two-way interactive interaction between a user and a computer” [18]. A significant advantage of such maps is their versatility due to interactive services [19], as well as the possibility of implementing predictive analytics, implementation of virtual experiments, making forecasts of the behavior of research objects. Thus, the interactive map is a prototype of a real zoning grid, on the basis of which it is possible to analyze and predict changes in the behavior of economic sectors and individual regions in the process of implementing various tools of the state policy of spatial development. This issue is being studied by scientists and managers in the context of the so-called digital twins [20-25], the relevance of studying which is beyond doubt in the light of widespread digitalization.

In our study, we will dwell in more detail on economic zoning, by which we mean a territorial division aimed at defragmenting the economic regional policy in order to ensure the progressive development of the country. Despite the high importance of economic zoning recognized by scientists, "the scientific approach to zoning today is in some kind of stagnation, the search for a new look at the region, its essence and development prospects" [26, p.160], and "public administration is in dire need of scientific zoning, which would make it possible to differentiate the decisions made in relation to the characteristics of different parts of the country" [9, p.19].

Considering the foregoing, and also taking into account the scale of the territory of Russia, the possibility of obtaining a holistic visual representation of the relevant statistical data both in the context of individual subjects of the Russian Federation and in terms of entire economic macroregions becomes of particular importance in economic zoning. At the same time, it is not just about providing the option of perception, evaluation and analysis of the available information. First of all, the purpose of visual presentation of data regarding economic zoning is ***to provide the possibility of modeling the territorial organization of economic activity and predicting the behavior of economic sectors in order to increase the growth rate of the national economy and its spatial development.***

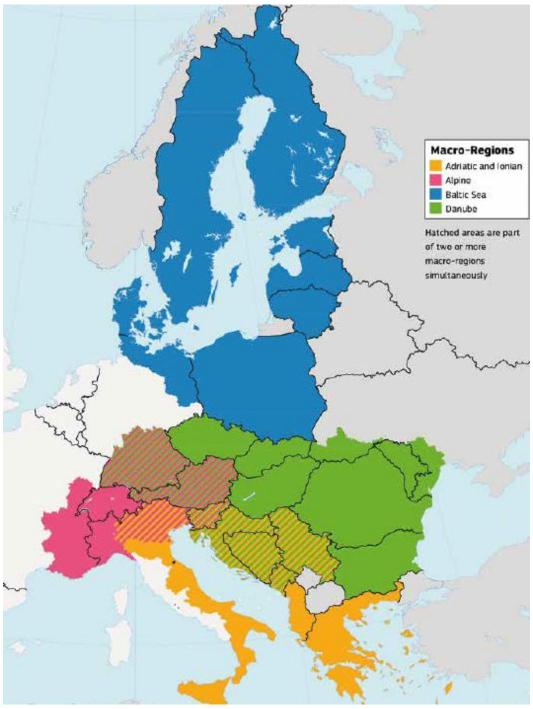
Based on the foregoing, it can be said with confidence that the visualization of the results of territorial division through interactive mapping is an essential component of the process of forming plans, forecasts and strategies for the spatial development of both individual industries and regions, as well as macroregions, and the national economy as a whole.

2. Systematization of existing methods of visualization of economic zoning

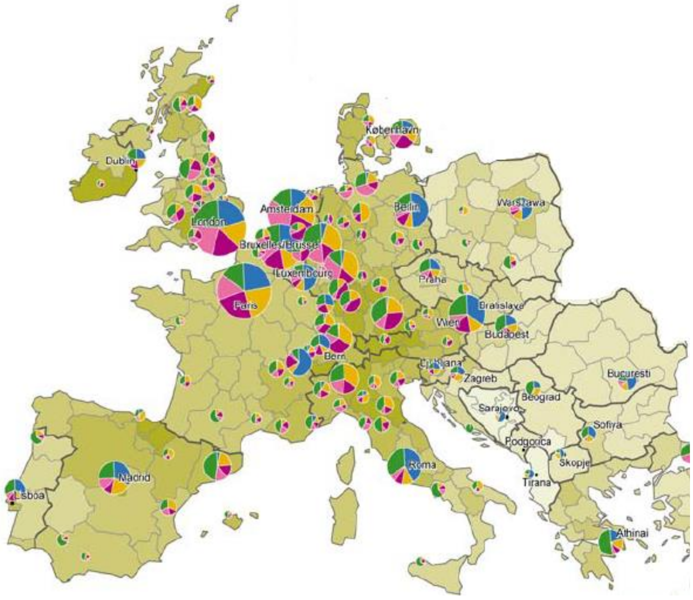
The use of visual methods for displaying the results of mapping in terms of territorial division is designed to simplify the tasks of spatial planning, forecasting, programming and strategizing. A review of scientific literature and information sources from the Internet, containing cartographic visualization of economic zoning, revealed that the solution of the problem of territorial division is carried out in practice by generating both static and interactive maps.

Let us consider the practical application of the selected types of maps in more detail. Thus, almost all territorial studies (and even more so studies in the field of economic zoning) involve cartographic visualization of the results obtained. Thus, they all contain statistical maps that display the selected areas based on preliminary qualitative or quantitative calculations.

Despite the fact that static maps can be built using various visualization tools, they have in common that they reflect specific results and do not allow obtaining additional information other than that actually shown on the geographic map [17, 27–30]. Sometimes in the scientific literature they are called "non-interactive program-dependent" [31], which, in fact, means their creation in special programs, platforms or using programming languages (CorelDRAW, Adobe Illustrator, Microsoft power BI, Stata, R and others) that support the user's operating system. The obvious disadvantage of such maps is the lack of interactivity, and the resulting problem of overloading maps with conventional signs. Examples of non- interactive software-dependent maps that visualize the results of economic zoning are shown in Figure 1.

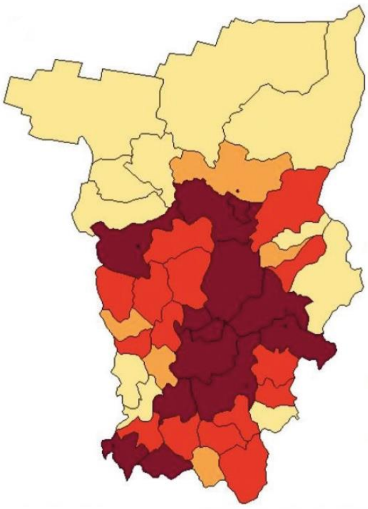


a) Macroregions of the European Union [32]



b) Clustering of European regions according to the level of production development [33, p. 53]

c) Map of strategic investment projects in Siberia [34, p. 249]



d) Clustering of municipalities Perm region by level unemployment [35, p. 407]

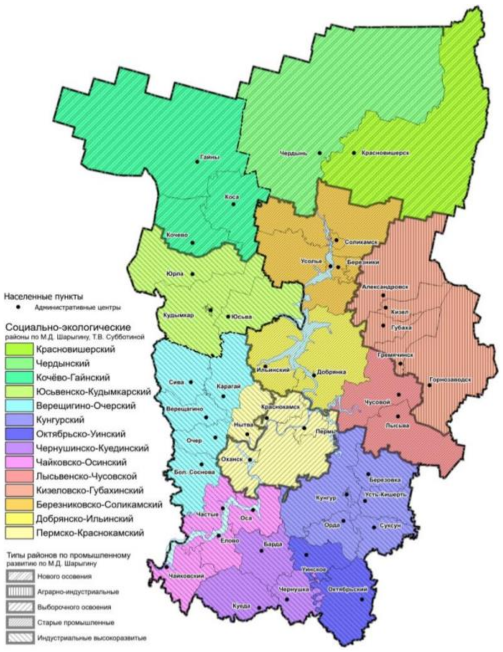
Fig. 1. Examples of non-interactive software-dependent maps visualizing the results of economic zoning

Turning to the consideration of the practical application of the second type of maps - and interactive ones, we note that we considered only maps that reflect the results of economic zoning, presented on various sites and platforms and "possessing the property of information content" [31, p.26].

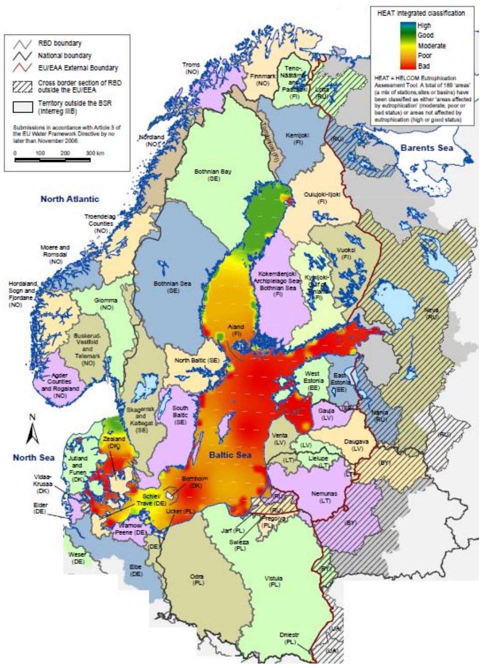
Interactive maps are conditionally divided into program-dependent and program-independent. Interactive software-dependent maps include maps generated using specialized mapping programs (MapInfo, ArcGis and QGIS, etc.). The resulting map is a file (or several files). To work with such a card, you need a computer with an operating system (mainly Windows) and the appropriate program in which it was created or a program that supports this card format. The disadvantage of these maps is the low degree of interactivity, which is understood as “an indicator that characterizes how quickly and conveniently the user can achieve his goal” [19]. This is due, first of all, to the payment of specialized cartographic programs. In addition, we note the limited possibilities in the field of integration of statistical and calculated data (for example, the user must independently find special files of map layers (shape-files), as well as limited possibilities for demonstrating the results obtained, which do not allow the mapping results to be made publicly available.

At the same time, unlike simple static, non-interactive maps, "each conventional sign on an interactive map has not only its usual informational component, but also a hidden one that is displayed as the user needs. This approach makes it possible not to overload the map with conventional signs, makes it more understandable and easier to read" [19], and also allows you to change the visual perception depending on the tasks set by the user.

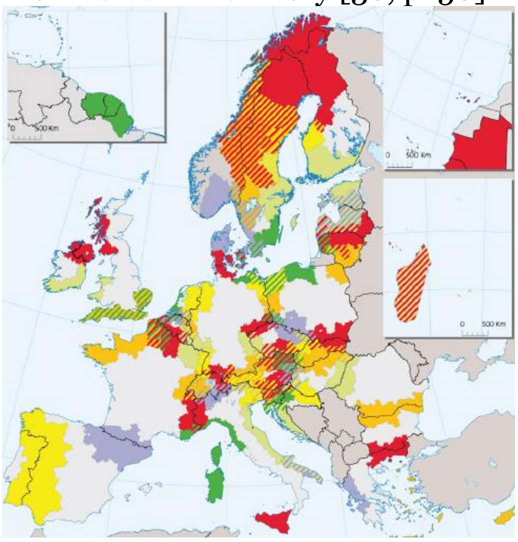
Examples of interactive software-dependent maps that visualize the results of economic zoning are shown in Figure 2.



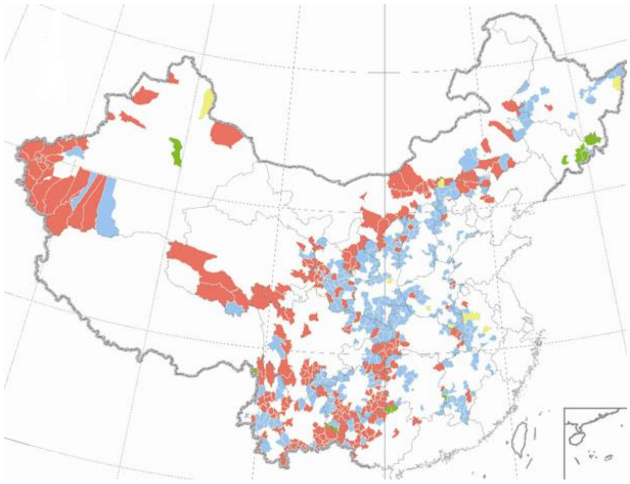
a) Economic and socio-ecological zoning of the Perm Territory [36, p. 50]



b) River basin areas in the Baltic region [15, p. thirty]



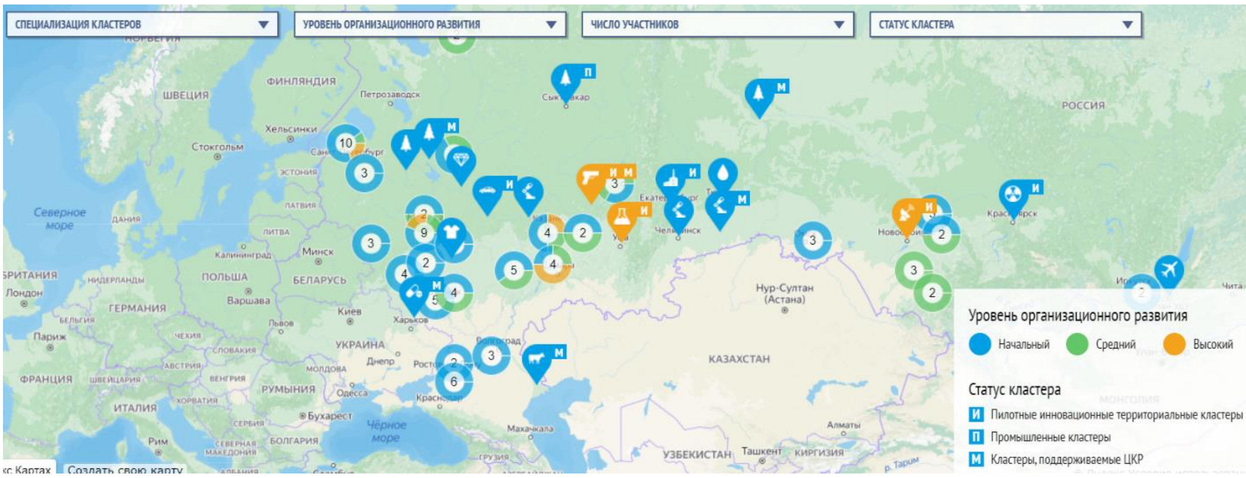
c) European Regional Development Fund cross-border cooperation program programs) [37, p. 255]



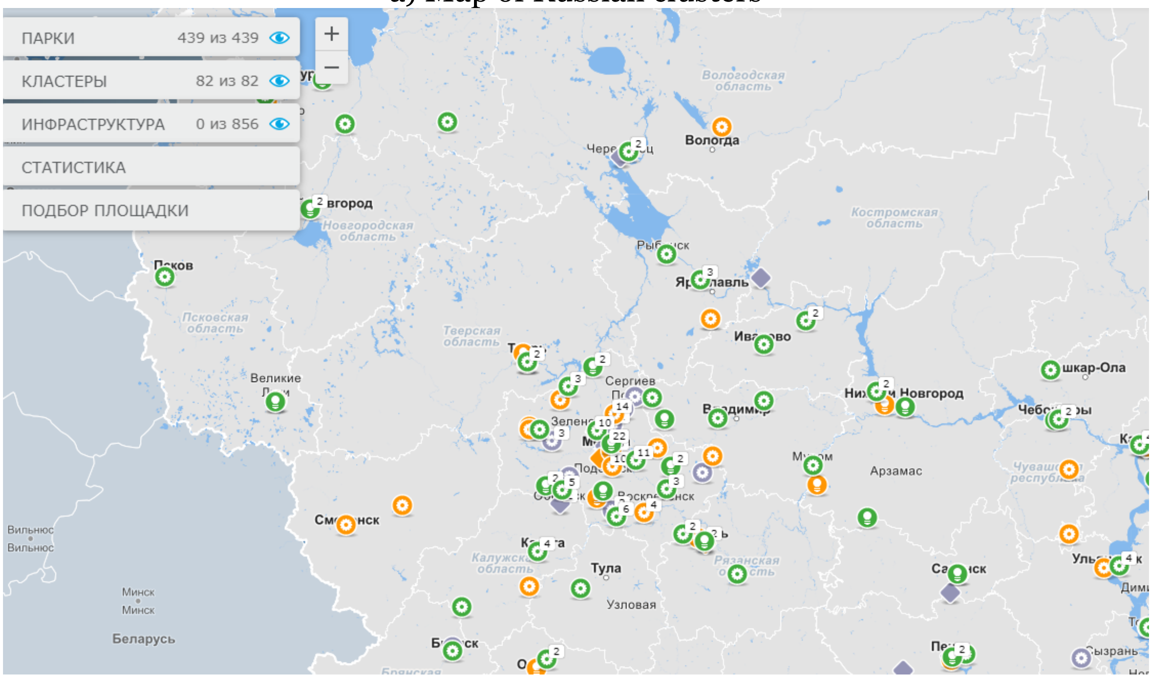
d) Clustering of Chinese regions by poverty level (Types of nation-level poverty counties) [38, p.200]

Fig. 2. Examples of interactive software-dependent maps visualizing the results of economic zoning

Interactive and software-independent maps include electronic maps that are created in special services, such as, for example, Googlemaps, Yandex maps, MapGps, etc. To work with these maps, you must have Internet access and be registered on the service. The advantages of these cards are obvious: online access to services; the possibility of creating interactive maps on remote and shared access; simple interface with the ability to integrate text, video and photos, both from a personal computer and from the Internet; the option of embedding created interactive maps on websites, blogs; free use. Examples of interactive program-independent maps by regions of Russia are shown in Figure 3 [39, 40].



a) Map of Russian clusters



b) State Information System of Industry

Fig. 3 Examples of interactive software-independent maps

We did not find examples of interactive program-independent maps that visualize the results of economic zoning in Russia. At the same time, such maps are widely used by the statistical services of many large states (for example, the USA [41], Canada [42], New Zealand [43], EU countries [44], Australia [45]) for analytical activities and for development of strategies for the development of territories of the meso-economic level.

Summing up the analysis of the visualization of the problem of territorial division, we note that it is interactive maps that fully allow predicting the behavior of economic sectors, and, therefore, make it possible to make both reasonable forecasts for the development of subjects of the Russian Federation and adequate strategies for the development of the national economy. At the same time, we did not find an accessible visual display of such calculations on the example of domestic data, which fully implements the function of convenient perception of information.

In addition, despite the numerous advantages of interactive program-independent maps, we have found that most interactive maps that reflect the processes of economic clustering of domestic regions use static data. The identified drawback is significant, since up-to-date data is the key to high-quality forecasts of territorial and spatial development. Accordingly, an interactive geographic map that embodies the digital twin of a real territory and allows automatic updating of data, recalculation of the requested indicators and changes in the visual result is an indispensable tool for qualitative modeling of the territorial organization of economic activity and forecasting the behavior of economic sectors in order to increase the growth rate of the national economy. The present study is devoted to substantiating the importance and possibility of creating such tools.

3. Algorithm for visualization of the task of territorial division based on the concept of economic complexity

In this part of the work, we describe the algorithm for the problem of territorial division based on the concept of economic complexity proposed by C. Hidalgo, B. Klinger, A.-L. Barabashi and R. Hausmann [46] in 2007 and disclosed by them in the concept of the complexity of the economy in 2009 [47]. Scientists have developed an index of complexity of the economy (hereinafter referred to as the ISE), which makes it possible to determine the level of its development through the diversification of the sectoral structure of exports and reflects the degree of interconnectedness and interdependence of enterprises, and therefore shows the "volume of knowledge mobilized by society" [48, p. 18]. Thus, the complexity of the economy is embodied in a system of knowledge that is combined to produce goods [49], and its increase is "one of the main goals of the state economic and scientific and technical policy" [50, c slide 12].

A visual assessment of the level of complexity of the economy can be carried out by analyzing the map of the product space. At the same time, the "space of all goods" is a graph, the vertices of which are the types of economic activity, and the edges are the links between related industries that complement each other based on the presence of common competencies. Thus, a complex economy is understood as a highly diversified economy, the development of which is based on the production of products that require a wide range of knowledge and competencies. The author's method of economic zoning is presented in detail in [51].

Algorithm for creating a digital twin of a grid of macroregions was written in the Python programming language using the BeautifulSoup, math, matplotlib, nltk, numpy, scipy, rutermextract, xlrd, xlwt libraries. The algorithm is implemented as a software tool, which is a web application - a data integrator, placed in the public domain (http://ruclusters.ru/spatial_development [52]). The digital twin synthesizes regional statistical data based on site parsing and makes it possible to build simulation models for finding the optimal variant of territorial division, taking into account promising interregional cooperation.

The scheme of interaction of subsystems of the software presented in fig. 4, includes 11 stages.

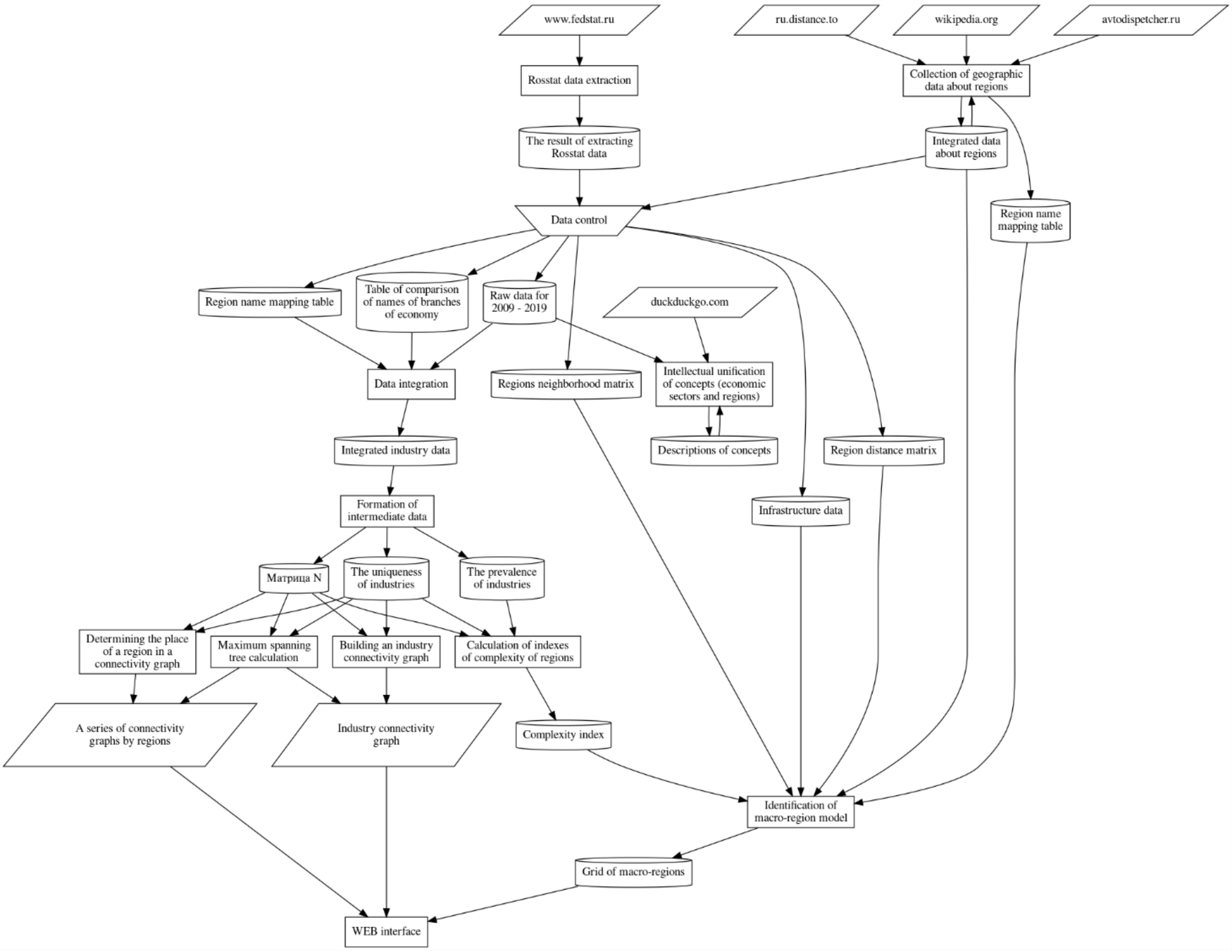


Fig. 4. Scheme of program interaction

Let us consider in more detail each of the stages of the algorithm.

Stage 1. Extraction of Rosstat data.

At the first stage, automated collection of statistical data (parsing) is carried out from open Internet sources such as: EMISS State statistics www.fedstat.ru, and the free encyclopedia wikipedia.org. The result is a structure of the following type:

"Lipetsk region": {
  "emissname": "Lipetsk region",
  "center": " Lipetsk ",
  "code": "RU-LIP",
  "vrp": "0",
  "code": "RU-LIP",
  "neighbors": [
    "Ryazan Oblast",
    "Tula region",
    "Tambov Region",
    "Oryol Region",
    "Kursk region",
    "Voronezh region"
  ],
  "yandexname": "Lipetsk region",
  color: "#ffffff"
},

The presented structure has not yet been assembled into a single database at this stage, since the database is collected at separate stages by various algorithms. In addition, the data is automatically updated after a set period of time. Due to the specifics of the statistical indicators used, data on them are updated once a year.

Stage 2. Collection of geographic data about the regions.

Calculation of distances between regions is carried out using the sites "Autodispatcher" avtodispetcher.ru and Distance Calculator ru.distance.to. As a result, a matrix of distances between the centers of regions is formed. In cases where there is no road or railway (some regions of the Far East and the Far North), the distance on the map is taken, multiplied by a coefficient selected experimentally.

Stage 3. Data control.

At the stage of data control, selective manual control of the correctness of processing web sources is performed. This is necessary because extracting data from web pages depends on their design, set by the site owner. If the design is changed significantly (for example, when a new version of the software of the data source site is released), the processing may not be correct, which will lead to errors in further calculations.

Stage 4. Data integration.

At this stage, the results of processing various sources are combined, such as the Initial data of Rosstat for 2009 - 2019, a table for comparing the names of economic sectors and a table for comparing the names of regions. The merging takes place on the basis of fuzzy algorithms for comparing textual data, which makes it possible to avoid discrepancies in the names of regions and industries, which are characteristic of semi-structured data posted on the Internet.

Stage 5. Intellectual association of concepts (sectors of the economy and regions).

At this stage, fuzzy data processing occurs for use in subsequent stages. A fuzzy linguistic portrait of concepts is compiled using the duckduckgo.com search engine. As a result, for example, it is possible to automatically establish a connection between such concepts as "kozhuun" and "municipality".

Stage 6. Formation of intermediate data.

For each region, the types of economic activities that have a comparative advantage are determined based on the calculation of localization coefficients:

$$LQ_{ri} = \frac{empl_{ri} / \sum_i empl_{ri}}{\sum_r empl_{ri} \,/ \sum_i \sum_r empl_{ri}} \tag{1}$$

where r – region index, $empl_{ri}$ – total number of employees by type of economic activity i in region r, $\sum_i empl_{ri}$ – total number of employees in region r, $\sum_r empl_{ri}$– total number of employees by type of activity i, $\sum_i \sum_r empl_{ri}$– total employment.

Next, a matrix M is formed, the rows of which are the regions, the columns are the types of economic activity. The matrix element is equal to 1 if the industry localization coefficient in the region is greater than 1, and equals 0 otherwise:

$$m_{ri} = \{1, \text{если } LQ_{ri} > 1 \ 0, \text{если } LQ_{ri} \leq 1 \tag{2}$$

An additional binary matrix S *is also formed,* the element of whichs_{ri} is equal to 1 if the number of people employed in the region in a certain industry is included in 90% of the employed in the country. The need to introduce an additional matrix is justified by the fact that those industries where there are very few employed are excluded from consideration for a particular region. Next, the Final matrix N *is formed* by element-by-element multiplication of the elements of two matrices:

$$n_{ri} = m_{ri} * s_{ri} \tag{3}$$

Based on the data of the final matrix N, vectors of diversity $d_r = \sum_i N_{ri}$ (how many industries of specialization are in each region) and ubiquity $u_i = \sum_r N_{ri}$ (how many regions specialize in each of the industries) of the distribution of industries among regions are formed.

Stage 7. Calculation of indices of complexity of regions.

For each region, the index of economic complexity is calculated by finding the sum of the elements of the complexity matrix $\widetilde{N}$ by row. The complexity matrix is obtained as a result of matrix multiplication of the inverse diagonal matrix formed from the industry diversity vector

D, and the matrix Bcalculated based on the final matrix and the diversity and ubiquity vectors:

$$\tilde{N} = D^{-1}S \qquad (4)$$

in this case, the matrix element B *is* calculated by the formula: $b_{rr\prime} = \sum_i \frac{n_{ri}n_{r\prime i}}{u_i}$

Stage 8. Calculation of the maximum spanning tree.

Graph visualization is implemented according to the following principles: firstly, all industries must be interconnected, i.e. there should not be isolated activities in the graph, and secondly, the graph should not be “overloaded” with a large number of edges. The first principle is implemented by constructing the maximum spanning tree, i.e. a set of connections that connects all the vertices of the graph using the minimum number of edges and the maximum possible value of the connection strength between the vertices. The maximum spanning tree is constructed using the Kruskal algorithm. The second principle is implemented by imposing a limit on the average number of edges per vertex of the graph: there should be no more than 5 of them. Thus, we avoid excessive visual complexity of the graph. Otherwise, the graph may overlap the most relevant connections.

Stage 9. Construction of the industry connectivity graph.

After calculating the complexity index, a graph of connectivity of sectors of the national economy is constructed. The graph visualizes the strongest links between sectors of the economy. The vertices of the industry connectivity graph are the types of activities according to OKVED, and the edges are the “distances” between them. The “distance” between sectors is measured on the basis of the output matrix N and is calculated as a minimum between the conditional probability of having a comparative advantage in activity i, given that the region has a comparative advantage in activity j, and the conditional probability of having a comparative advantage in activity j, given identified comparative advantage in activity i:

$$\varphi_{ij} = (P(n_{ri} = 1|n_{rj} = 1), P(n_{rj} = 1|n_{ri} = 1)) \qquad (5)$$

The higher the value of "distance" between industries, the stronger they are interconnected. As a result, taking into account the above principles, a graph of connected industries is constructed using the “neato” algorithm of the Graphviz software [53] (Fig. 5).

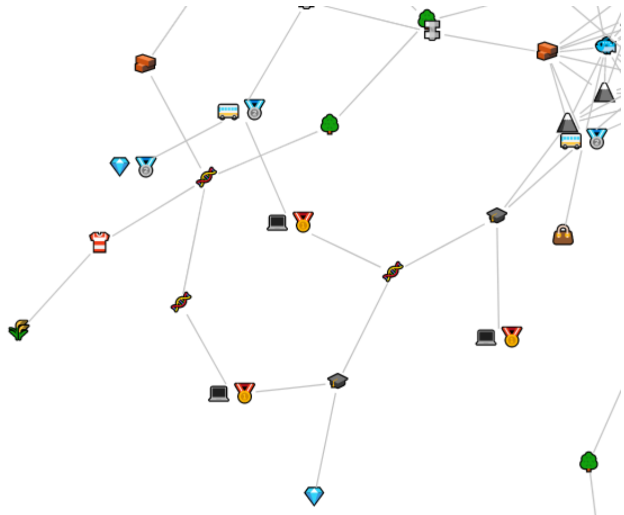


Fig. 5 - Fragment of the industry connectivity graph

Stage 10. Determining the place of the region in the connectivity graph

The place of the region in the industry connectivity graph is determined based on the data of the Final Matrix and is visualized by highlighting those industries - graph vertices in which the region specializes (Fig. 6).

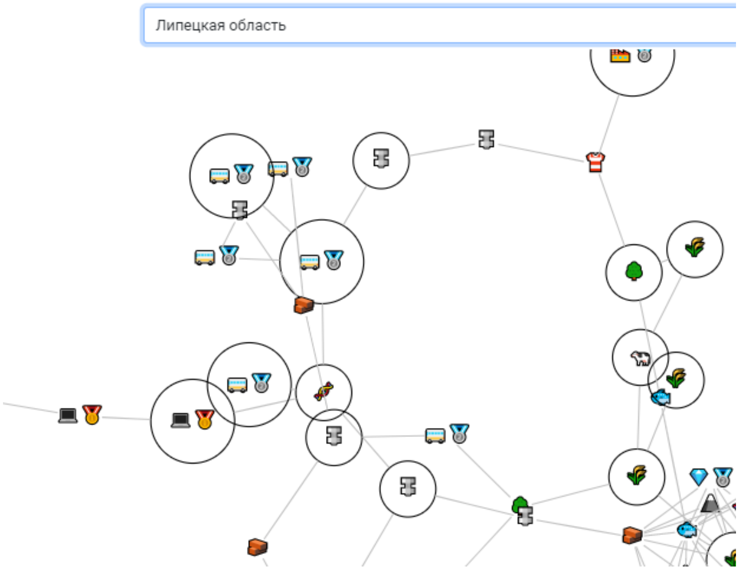


Fig. 6 - Connectivity graph for the region (fragment)

On the connectivity graph for a region, those vertices are tagged that correspond to the sectors of the economy expressed in this region. These vertices are circled, for which the shape=circle tag is added to the top of the graph in Graphviz notation.

Stage 11. Simulation modeling of the process of identification of macroregions

Conducting a simulation experiment to find the optimal grid of macroregions implies the fulfillment of the following conditions:

1. The value of the Theil index is minimal (i.e., heterogeneity is minimal between regions within a macroregion and between macroregions themselves);
2. Each of the regions included in the macroregion has a common border with at least one region from the given macroregion;
3. When a region is added to a macroregion, the economic complexity index of the macroregion does not decrease;
4. On the territory of the macroregion, there are certain objects of social and engineering infrastructure based on the author's methodology [54]. This condition will guarantee at least the preservation of the existing population and, as a maximum, its positive reproduction.

The experiment is carried out on the basis of an analysis of the geographic connectivity of regions obtained from Internet sources. Also used are the distances between the centers of the regions, the calculated indices of the economic complexity of the regions and the infrastructure facilities included in them (the presence of a port, a major highway, healthcare facilities, etc.). The conditional core of the macroregion is chosen as the next region of Russia in the list not included in the macroregions, and having the most pronounced infrastructural complexity. It is joined by regions that a) border it, b) increase the infrastructural and economic complexity of education, and c) do not increase the value of the Theil index. The process is iterative. As a result, such macroregion layout options are selected for which the indicators of economic and infrastructural complexity are maximum, but the Theil index is minimum.

In some cases, situations may arise when the approach described above does not find potential candidates for inclusion in the macroregion, and a “pseudo-macroregion” is formed, consisting of one region. Then the second stage of the search and elimination of "pseudo-macroregions" is implemented. At the same time, all possible options for “pseudo-macroregions” and already formed macroregions are considered, adding a “pseudo-macroregion” to a macroregion occurs provided that the Theil index for a macroregion does not increase when it is combined with a “pseudo-macroregion”. This also takes into account the geographical proximity of the regions.

Based on the numerical values of the index of complexity of the economies of the regions that form the macroeconomic region, and the place of the region in the graph of connectedness of sectors of the national economy, the potential for the emergence of related industries and their further development in the macroregion is determined. This, in turn, provides objective prerequisites for determining the prospect of macroregion specialization.

As a result of the simulation experiment, the optimal structure of economic zoning is determined, which is a digital twin of the grid of Russia's macroeconomic regions.

4. Visualization of the task of economic zoning based on interactive mapping

Approbation of the algorithmization and programming of territorial division based on interactive mapping was carried out on the basis of statistical data of the constituent entities of the Russian Federation, taking into account promising areas of interregional cooperation. In the work, complexity indices were calculated for each subject of the Russian Federation; a graph of connectivity of sectors of the national economy was built and the place of each subject of the Russian Federation on the graph was determined; the optimal structure of macroregions was determined on the basis of the author's methodology. The approbation results are available in the public domain (http://ruclusters.ru/spatial_development [52]).

The digital twin of the optimal grid of macroeconomic regions, based on interactive mapping, includes the following elements: a drop-down list with the ability to select a region for analysis, a graph of connectivity of sectors of the national economy, and an interactive geographical map (рис.Fig. 7).

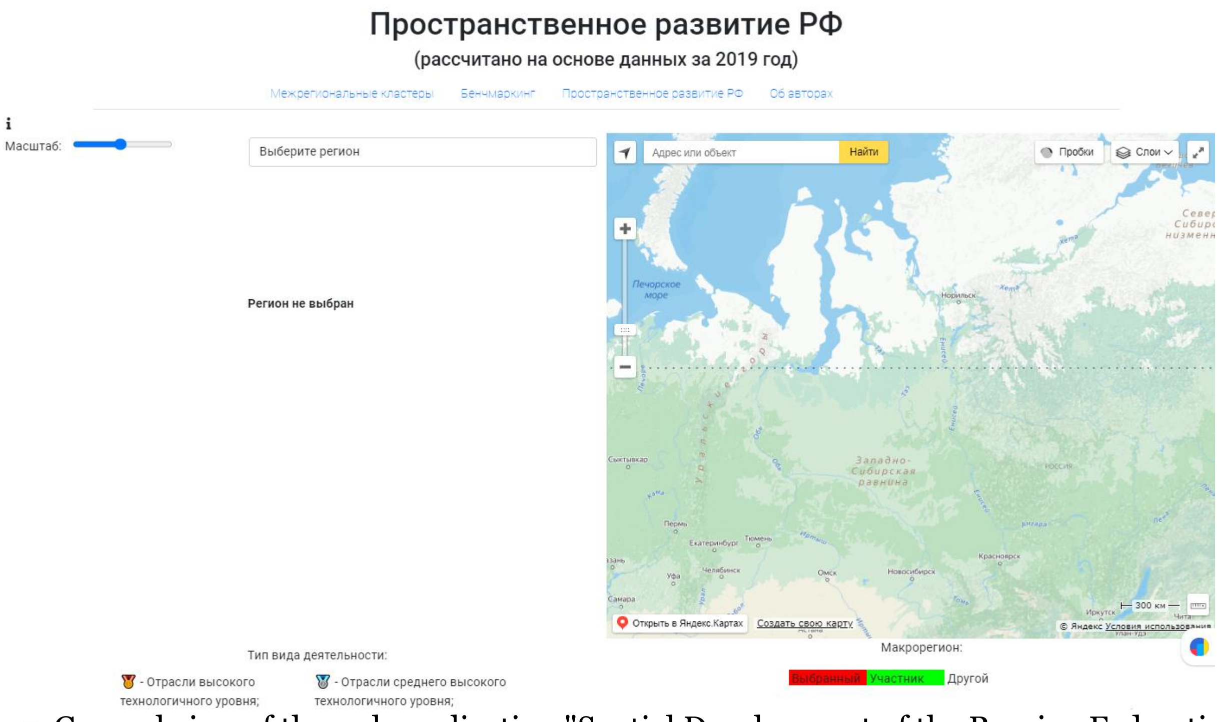


Fig. 7. General view of the web application "Spatial Development of the Russian Federation"

After selecting a region for analysis, the graph of connectivity of sectors of the national economy of the Russian Federation is displayed in the left part of the application window. The graph displays those types of activities in which the analyzed region has a comparative advantage (localization coefficient is greater than 1).

The calculation was based on the indicator "Average number of employees for the full range of organizations", according to which a single statistical database was formed for 83 regions of Russia for the period from 2009 to 2019 for 104 types of economic activity (94,952 values in total).

Thus, the graph contains 104 vertices that have at least one connection with a neighboring vertex. In the center of the graph are the most "difficult" industries. In the right part of the web application window, a geographic interactive map is displayed, on which the analyzed region is highlighted in red, and the regions of the macroregion that includes the analyzed region are highlighted in green (Fig. 8).

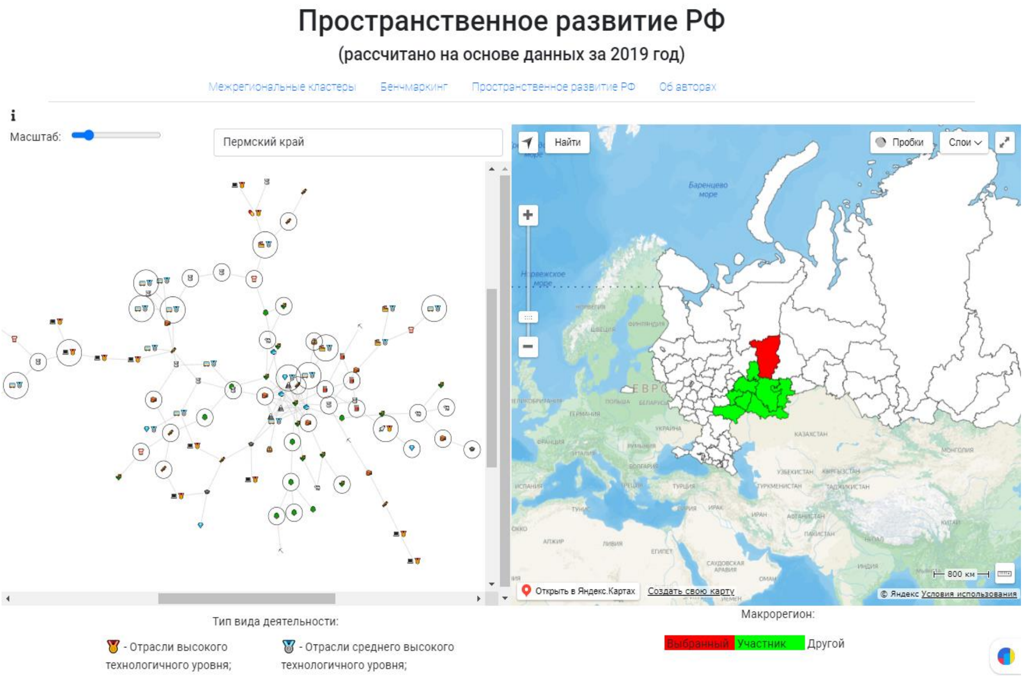


Fig. 8. Appearance of the web application when choosing a region in the drop-down list

In addition, when you hover over any of the vertices of the graph, a tooltip appears with the name of the type of activity, and when you click on the vertex of the graph (selecting the type of activity), the geographic interactive map displays in real time enterprises that specialize in this type of activity (Fig. 9).

Fig. 9 Appearance of the web application when choosing the type of activity on the graph of connected industries.

Based on the analysis of the location of the regions of the Russian Federation in the graph of connectivity of industries, it is possible to determine promising specializations of macroregions in the national and global economy, the development of which is carried out by embedding economic entities in the value chains of the regions of the macroregion.

5. Conclusion

The paper presents a technique for computer visualization of the problem of algorithmization and programming of economic zoning based on interactive mapping. The methodology was based on the results of systematization of existing methods for visualizing various grids of economic zoning and the creation of digital twins, as well as the author's simulation model for finding the optimal variant of territorial division, taking into account promising interregional cooperation.

The basis for creating a digital twin of the macroregion grid is a mathematical algorithm for the problem of territorial division, compiled on the basis of the concept of economic complexity and graph theory. At the same time, graph visualization is implemented by constructing a maximum spanning tree using the Kruskal algorithm.

The advantages of the proposed visualization method are, firstly, that the results of economic zoning in the form of macroregions fully allow predicting the behavior of economic entities, and therefore make it possible to make both reasonable forecasts for the development of economic sectors and to form adequate strategies for spatial development; secondly, the visual display of modeling results using interactive mapping allows you to reflect all types of economic activity and the relationships between them in an easy-to-read format, i.e. in a format that is easy to understand for a wide audience.

The practical significance of the web-application "Spatial Development of the Russian Federation" is due to the potential for its use by the executive authorities of the federal and regional levels in determining the directions of interregional interaction in order to model the spatial organization of economic activity and predict the behavior of the economic sectors in the national economy in order to increase its growth rates. In addition, it is planned to use the evil approach to visualization of economic zoning as the basis for the development of a test bench of the RegScienceGRID digital research platform, aimed at working with large regional data and using the most promising open solutions from the machine learning technology stack.

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