The use of different types of geographic information systems for the construction of geoservices to support management of the Arctic territories

A V Vicentiy

1 Institute for Informatics and Mathematical Modeling – Subdivision of the Federal Research Centre “Kola Science Centre of the Russian Academy of Science”, Apatity, Russia
2 Apatity branch of Murmansk Arctic State University, Apatity, Russia

Abstract. The Arctic territories of the Russian Federation are characterized by a wide variety of valuable and strategic mineral resources needed for the sustainable socio-economic development of the state. Therefore, the development of the Arctic territories is one of the priorities for the development of Russia in the coming decades. On the other hand, the ecosystems of the Arctic and regions of the Far North are very fragile and sensitive to various types of anthropogenic impact. The Arctic is home to unique species of animals and plants. In order to ensure their continued safe existence, a number of measures must be taken to protect them. One of the effective measures is the creation of specially protected natural areas. Various geographic information systems are actively used to monitor and manage such areas. This work is aimed at the creation of information technology for the joint use of geographic information systems of different types to solve the problems of monitoring and territorial management support. This paper considers different types of geographic information systems from the point of view of their effectiveness in solving problems of collection, processing, storage, analysis and presentation of spatial data. For practical approbation of the proposed information technology a web-geoservice "Khibiny National Park" was developed. For information support of the web-geoservice the data on industrial activity in the area of the national park, existing and alternative transport infrastructure in this area, as well as data on the ecosystem state and biodiversity of flora and fauna were used.

1. Introduction

In recent decades, interest in the Arctic has been steadily increasing throughout the world. This interest is primarily associated with the possibility of developing rich reserves of natural resources of the Arctic territories [1]. Russia is no exception in this sense. At present, a draft strategy for the development of Russia's Arctic zone until 2035 is being developed. Transport infrastructure, the social sector, the production of local goods and services, tourism, and other businesses and industries are being actively developed in the Arctic regions. The hydrocarbons production and transportation capacities are also being increased, safe navigation along the Northern Sea Route and other areas of social and economic life are being developed.

It is important to understand that human activity in developing the Arctic and the High North has a strong impact on Arctic ecosystems. Most often, the development of new areas leads to negative consequences for local flora and fauna [2]. Various activities are being implemented to protect wildlife
in the Russian Federation. One of the most effective measures is the creation of specially protected natural areas (SPNA). Currently there are six main categories of specially protected natural areas. These are botanical gardens (dendrological parks), wildlife sanctuaries, natural and national parks, nature reserves and monuments.

Depending on the size of a particular SPNA, the best methods and means of monitoring and control are selected [3]. Modern geographic systems (GIS) are often used to monitor and manage large spatially distributed objects [4]. However, modern GIS are very different in their capabilities, functions and tools provided by users. This paper considers different types of geographic information systems in terms of their effectiveness in solving the problems of collecting, processing, storing, analyzing and presenting spatial data.

The paper describes a generalized information technology for joint use of desktop GIS and web GIS. The joint use of different types of GIS allows to use the most strengths of each of them. The web-geoservice "Khibiny National Park" is presented as a practical result of the generalized information technology use. This service allows obtaining information about the national park itself, flora and fauna, industrial activities carried out near the park borders, as well as transport infrastructure in and near the park. This web geo-service has tools that allow you to change existing information, enter new information, as well as select different modes of data visualization.

The generalized information technology for spatial data visualization based on the joint use of different types of GIS, proposed in this work, can also be used to build cognitive geointerfaces for other systems. For example, for management support systems for regional industrial and natural systems. The developed web-geoservice "Khibiny National Park" can be used for monitoring and assessment of anthropogenic impact on the ecosystem of the park, environmental monitoring and forecasting, as well as for other management tasks of the specially protected natural area.

For practical implementation of the web-geoservice "Khibiny National Park" two modern geographic information systems of different types were used. The first GIS is QGIS [5]. It is a desktop GIS. The second GIS is NextGIS [6]. It is a web GIS.

2. Materials and methods
Modern geographic information systems are used in solving a wide range of tasks. Due to their processing and visualization capabilities of heterogeneous information, they are especially useful in solving problems of managing large-scale, spatially distributed bio-socio-economic systems. Such systems, in particular, include regional-scale systems, large industrial and natural clusters, as well as specially protected natural areas, including national parks, reserves and sanctuaries.

One of the classes of problems that are successfully solved with the help of modern GIS are the problems of assessing and predicting the anthropogenic load on various ecosystems. Solving of such problems with the help of geographical information systems makes it relatively easy to implement a visual representation of various scenarios for the development of the interaction of industrial objects and systems with natural and environmental systems. This visual presentation is often a more illustrative and understandable form of presentation of results for decision makers than many tables, reports and charts.

The example of the Khibiny National Park discussed in this paper is a vivid illustration of how problems between stakeholders with different objectives can arise, be discussed and solved. It is a case of industry representatives on the one hand, and the public and environmental organizations on the other. It is at the stage of searching for possible solutions, evaluating them, comparing them and choosing the most appropriate ones, that the use of geographic information systems of different types can be the most beneficial.

The generalized information technology of geovisualization proposed in the work is based on the joint use of desktop and web GIS. This approach successfully combines the diversity and power of the information processing tools available in desktop GIS with the flexibility and versatility of modern web GIS information presentation. Considering that today the most part of all information (about 60
%) has a geographical reference [7], and, consequently, can be processed by geographical information systems, it is possible to assert that subjects and problems of the given work are actual enough.

The means and methods provided to researchers by modern geographical information systems are used to solve problems in a variety of fields. In particular, we can say that in recent years there has been a boom in the use of web GIS [8]. Web GIS are widely used in such areas as tourism [9], earthquake prediction [10], radiological monitoring [11], public safety [12], development of interfaces of multi-subject information systems [13] and many others.

Desktop geographic information systems (desktop GIS) are hardware and software systems designed for collection, storage, processing and deep processing of spatial information, data presentation and analysis. These systems have powerful tools to work with geodata and transform spatial information. They also have a large number of ready-made solutions for many typical tasks of geodata processing, implemented in the form of various plug-ins and plug-in software modules.

Thus, desktop GIS is a powerful complex that implements almost all the necessary functions to work with geodata. In addition, many desktop GIS have advanced tools for intelligent data analysis. These tools are especially useful for solving territory management problems.

However, desktop GIS also has a number of shortcomings. In particular, there are some limitations on the dissemination of data processing results. These limitations are related to the problems of sharing some geographic information system functions to disseminate the results of data processing.

Web GIS is much less affected by these kinds of problems. Web GIS was originally designed to provide users with the widest possible range of options for disseminating data processing results and to provide users with tools for easy manipulation of data online. For this purpose, web GIS has a well-developed web interface.

Another important advantage when using web GIS is that the end user does not need to have on the client side any special software or pre-installed geographic information system to work with geodata. The user only needs a browser and, in some cases, plug-ins to it, which are usually distributed freely and free of charge.

Another positive factor in this approach is that all data handling, mapping, visualization and analysis tools are provided by the system directly to the user through a web interface. And since access is provided through the web interface, it is possible to implement additional extensions to the web GIS tool base by relatively simple means (HTML, CSS, JavaScript, etc.).

The cognitive imaging subsystem is also proposed to be included in the proposed generalized information technology for the joint use of GIS of different types. This subsystem is necessary for increasing the cognitive efficiency of the geointerface. The cognitive visualization subsystem interacts with GIS at the interface level and allows to adjust visualization parameters taking into account features of the concrete user. Thus, for increase of efficiency of use of GIS it is offered not simply mechanical association of their possibilities, and their expansion and enrichment by means of increase in cognitive efficiency of formed geovisual images. Increase of cognitive efficiency of geointerfaces allows to reduce labour expenses and time of the end user of system for understanding sense of the received geoimage, and, as consequence, to reduce cognitive loading.

3. Results

The information technology of geovisualization described in the work is based on combining powerful tools of geodata processing of desktop GIS with wide possibilities and flexible means of representation, visualization and interactive visual analysis provided by web GIS. The essence of the proposed information technology of spatial data visualization is that the entire process of working with data, including the collection, processing, storage, analysis and presentation of data is divided into several main stages, the implementation of which is clearly divided between GIS of different types.

The first step is to implement all relatively complex processes related to data preparation by desktop GIS (search, cleaning, integration, primary processing, geocoding, etc.). As mentioned above, QGIS has been used in this paper as it is powerful enough to solve most of the real problems in
systems to support regional management. In addition, this software product is distributed under the GNU GPL 2 license, that is freely and free of charge.

The most time-consuming task was to collect and prepare data for further processing in GIS. In particular, it was necessary to process a large number of raster thematic maps covering the entire territory of the Khibiny Mountains. Raster maps were used to accurately account for the terrain, where heights are represented as horizontals or elevation lines. An example of such a map is shown in Figure 1.

![Figure 1. Raster map of the height lines of the Khibiny mountain massif](image)

In the second step, data export-import operations are performed in web GIS. For this purpose, NextGIS was used in the work. NextGIS is a modern representative of geographical information systems oriented to use in web. This web GIS provides a sufficient number of powerful and flexible tools for data processing and visualization at a free rate. It should also be noted that due to a special extension, NextGIS "seamlessly" connects with QGIS at the data level, which greatly facilitates the export process.

GeoJSON format was used for data export. This format is open, supported by a large number of information systems and is designed to store and transfer geographic data structures. The format supports storage of basic primitives (point, line, polygon) as well as their combinations.

After exporting the data, in the third step additional data preparation to the web GIS is carried out. This process is related to the additional capabilities of the web GIS and may differ for different software products. Once the operations of this step are complete, the geodata can be visualized for further analysis.

Except for the basic stages of the organization of joint use of GIS of different types, in structure of considered information technology the subsystem of cognitive visualization is entered. This system is needed to improve the effectiveness of multi-disciplinary information in web GIS. The cognitive
imaging subsystem can work with registered users. To increase cognitive visual output, it is proposed to use a user model, which is created and modified in the process of its work.

This user model is a semantic network describing the user’s interests. The user model is in the stage of continuous improvement and modification and allows setting up many parameters that affect the process of geovisualization. For example, in the model can be implemented a mechanism for remembering information about previous user sessions, set parameters of duration and priorities of remembering, taking into account the characteristics of sessions (duration, frequency and time of work with data of a certain type, the most demanded objects and attributive information, semantic interpretation, etc.). Also, the model takes into account "bursts" in user behavior, i.e. recording and analysis of sessions of activity atypical for this user, etc.

The result of the cognitive visualization subsystem is a cognitive user interface. This interface takes into account the features and preferences of the user and displays a preformed cognitive visual image of the geodata used for further visual analysis. Thus, through the use of existing geographic information systems of different types and cognitive imaging subsystems, it is possible to create relatively quickly ready-made multi-subject geoservices with a cognitive interface. The general scheme of generalized information technology of geovisualization based on the use of geographic information systems of different types for the construction of cognitive interfaces of support systems for management of territories is shown in Figure 2.

![Figure 2. Generalized scheme of geovisualization information technology.](image)

For the purpose of practical testing of the information technology described in the work, the web-geoservice "Khibiny National Park" was implemented. It should be noted that there were a number of difficulties in practical performance of this service. Most of the implementation problems were related, first of all, to data aggregation, its stylization, as well as to the complex terrain.

However, most of the problems were technical in nature. Almost all of them were solved in the process of web-geoservice implementation with the help of built-in GIS tools or specialized add-ons.
At the moment of writing this paper, the web-geoservice functions and is available at hibiny-park.nextgis.com. As an example, the screenshot of the web-interface is shown in figure 3.

![Web-interface screenshot](image)

**Figure 3.** Example of the interface of the web-geoservice "Khibiny National Park"

### 4. Conclusions

The generalized information technology considered in this paper allows to use effectively the possibilities of geographic information systems of different types for solving problems of collection, storage, processing, visualization and analysis of geodata. This work has shown the possibility and effectiveness of joint use of GIS of different types for solving tasks of monitoring and support of territory management on the example of Khibiny mountain massif.

To improve the cognitive properties of the interface, the structure of the developed information technology includes a subsystem of cognitive imaging. This subsystem allows for the synthesis of cognitive interfaces of multi-subject information systems of territory management support, taking into account the features of GIS users. Thus, it is proposed not to "mechanically combine" the capabilities of GIS of different types, but to expand their functionality by means of cognitive enhancement of formed geovisual images. The proposed approach may also find application in the construction of cognitive interfaces of other multi-subject information systems related to the processing of spatial data.

It should also be noted that for practical approbation of the proposed technology the web-geoservice "Khibiny National Park", available at hibiny-park.nextgis.com, was implemented. This geo-service has a high potential for solving applied tasks related to monitoring and management of the Khibiny National Park territories. This web-based geoservice can also be used for scientific research of flora and fauna of the Khibiny Mountains.

### References

[1] Romashkina G F, Didenko N I and Skripnuk D F 2017 Socioeconomic modernization of Russia and its Arctic Regions Studies on Russian Economic Development 28(1) 22-30

[2] Didenko N, Rudenko D, Skripnuk D 2015 Environmental security issues in the Russian Arctic Conf. Proc. of Int. Mult. Sc. GeoConf. Surveying Geology and Mining Ecology Management, SGEM 3(5) 267-274

[3] Vicentiy A 2019 Development of methods and tools to support regional management in the Arctic zone of the Russian Federation based on cognitive interfaces IOP Conf. Ser.: Earth
Environ. Sci. 302 012139

[4] Vicentiy A, Vicentiy I. 2019 The method of dynamic visualization of spatial data for cognitive interfaces of information systems supporting regional management International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM 19(2.1) 667-672

[5] The official QGIS site Available from: https://qgis.org/ru/site/ [Accessed 20 March 2020]

[6] The official NextGIS site Available from: http://nextgis.ru/ [Accessed 20 March 2020]

[7] Hahmann S, Burghardt D 2013 How much information is geospatially referenced? Networks and cognition, International Journal of Geographical Information Science 27 1171-1189

[8] Agrawal S., Gupta R. 2017 Web GIS and its architecture: a review. Arabian Journal of Geosciences 23 510-518

[9] Zerihun M E 2017 Web Based GIS for Tourism Development Using Effective Free and Open Source Software Case Study: Gondor Town and Its Surrounding Area, Ethiopia. Journal of Geographic Information System 9 47-58

[10] Gitis V G, Derendyaev A B 2017 Web-Based GIS Platform for Automatic Prediction of Earthquakes Computational Science and Its Applications - ICCSA 2018. Lecture Notes in Computer Science 10962 268-283

[11] Vicentiy A, Shishaev M, Oleynik A 2016 Dynamic Cognitive Geovisualization for Information Support of Decision-Making in the Regional System of Radiological Monitoring, Control and Forecasting Advances in Intelligent Systems and Computing 466 483-495

[12] Kurbanov O. 2015 Applied GIS: Web GIS Serving Public Safety in Central Asia International Journal of Geoinformatics 11 69-74

[13] Vicentiy A., Shishaev M., Vicentiy I. 2017 The Development of Dynamic Cognitive Interfaces for Multisubject Information Systems (on the Example of Geosocial Service) Advances in Intelligent Systems and Computing 575 449-459