Digital environmental monitoring technology Baikal natural territory

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Abstract. An approach to digital transformation of environmental monitoring of the Baikal natural territory is proposed, using digital platforms and a service-oriented paradigm, an infrastructure approach, declarative specifications, as well as end-to-end and Web-based technologies for collecting and processing large volumes of spatial and temporal data, which improves the quality of decisions.

Keywords: Digital Monitoring, Space-time Data, Digital Platform, Service-oriented Paradigm, End-to-End and Web Technologies.

1 Introduction

Problems of ecology of the Baikal natural territory (BNT) are associated with forest fires, man-made damage, introduction of alien flora and depletion of biodiversity, bacterial diseases and insects, increased distribution zones of filamentous algae, mass extinction of Baikal sponges, etc. This justifies the need to switch to a new technological mode – the formation and implementation of digital environmental monitoring of the BNT and lake Baikal.

2 Environmental monitoring of Baikal natural territory

The Baikal natural area includes lake Baikal, its water protection area, the catchment area within the territory of the Russian Federation, adjacent protected areas, and also adjacent to the lake area width up to 200 km [1,2]. State environmental monitoring at the BNT is carried out by [3]: Federal service for Hydrometeorology and environmental monitoring, Ministry of Natural Resources and Environment, Ministry of Agriculture of the Russian Federation, Federal Forestry Agency, Federal Service for State Registration, Cadastre and Cartography, Federal Agency for Subsoil Use, Federal Water Resources Agency and the Federal Agency for Fisheries, as well as the Executive authorities of the Republic of Buryatia, Zabaikalsky territory and the Irkutsk re-

gion in the order, established by the decree of the Government of the Russian Federation [3,4]. In turn, scientific environmental monitoring is supported by institutions of the Ministry of Education and Science.

Among the environmental problems of BNT, it should be noted:

- significant changes in landscapes;
- growth of pollution of anthropogenic nature;
- decrease in the catchment area of lake Baikal, the water content of the tributaries of lake Baikal due to mass fires and economic activity;
- increase in acid precipitation, as well as pollution of the underground hydrosphere;
- decrease in forest reserves due to forest pathology, illegal logging and fires;
- abnormal development of filamentous algae, extinction of endemic Baikal sponges, increase in methane emissions, introduction of non-Baikal species;
- dangerous endogenous and exogenous geological processes, such as seismicity, landslides, mudflows, etc.

In turn, the features of environmental monitoring of BNT include:

- multiplicity of monitoring participants, as well as locality of departmental observation schemes, as well as territorial distribution of software and hardware monitoring systems;
- formation of spatio-temporal monitoring data (hereinafter data) that are not coordinated with each other, in parametric, chronological and other aspects, as well as their different formats;
- lack of comprehensive integrated monitoring systems in the mode (24/12/365), assessment and analysis of the state of the BNT ecology;
- limited access to monitoring data, which complicates management decisions, as well as interdisciplinary research.

This justifies the urgency of implementing digital transformation in the BNT environmental monitoring system, which involves the introduction of cyber-physical systems, the transition to a digital method of data transmission, as well as the use of digital platforms based on service-oriented, end-to-end technologies, cloud and distributed computing, big data, etc.

3 Digital transformation of monitoring of Baikal natural territory

The leading trend in technological development is digital transformation. this is due to the development of digital information technologies, increasing the capacity of computing clusters, creating 5G networks, and the Internet of things. The basis of the digital paradigm is the principle of "everything as a service", focused on the joint use of information resources, taking into account the requirements of interoperability and security.

This justifies the need to create a digital monitoring ecosystem (DME) of BNT as a partnership of departments, organizations (participants) that conduct it and support

open digital information and telecommunications exchange for the development and receipt of new services [5,6]. Authorized institutions of Federal and regional Executive authorities, institutes of the Russian Academy of Sciences and higher educational institutions, business and the population should act as participants in the ESM of the Baikal natural territory.

DME participants focus their efforts on their promising areas of BPT monitoring, outsourcing non-core ones. To achieve this goal, participants can combine their information resources and knowledge.

The digital ecosystem of BNT monitoring should have the following properties [6]:

- openness, a significant number of participants, support for their collective work to provide services;
- extensibility by attracting new participants;
- connectivity and algorithmization of interaction;
- providing real-time "on-demand" access;
- implementation of a mutually beneficial relationship strategy;
- saving resources and reducing costs.

The development and increase of the viability of DME of the BNT is carried out by establishing new relationships, using third-party solutions, services, and data. This partnership, which covers a wide range of functions of DME participants, increases the speed of service implementation and makes system components available as services. There is no need to develop a technological architecture based on services and application programming interfaces (APIs) to connect to the system. DME provides services to participants via the telecommunications backbone, a cloud environment in which participants can create their own services, applications, and offer new services, via SaaS and APIs.

At present, qualitatively new conditions have been emerged for creating a digital ecosystem for BNT monitoring based on the principles of digital platforms that accumulate the latest information and telecommunications technologies, providing participants with open access to data, services for processing them, digital tools and services.

By definition, a digital platform (DP) is an open system of algorithmic network interaction of independent monitoring participants united by a single information environment, leading to a decrease in transaction costs and to an increase in the efficiency of services due to the use of a package of digital technologies for working with data (storage, processing, analysis, etc.) and changes in the division of labor [7].

Thus, for each direction of digital environmental monitoring of the Baikal natural territory, its own digital platform of participants is created, which should include a set of digital spatial and temporal data, algorithms, services, models and tools, information and technology United by a single information environment and telecommunications infrastructure.

Using the DP monitoring of BNT will allow:

- quickly update and analyze digital profiles of the participants of the monitoring of BNT;
- to support participants access of the DP to structured information monitoring of BNT;
- integrate the necessary information technologies and services and provide all participants with spatial and temporal data and services for their processing;
- combine several services (including remote ones) provided by different participants, including third parties, and reduce the cost of receiving them.

According to the level of information processing and service provision, there are basic types of digital platforms: instrumental (IDP), infrastructure (InDP), application (ApDP), which form a hierarchy. The IDP is part of the InDP, which in turn supports the operation of application DP in various directions of BNT monitoring.

Thus, the implementation of digital transformation in the BNT environmental monitoring system involves the creation of basic types of DP for the joint use of services and data by all monitoring participants.

3.1 Instrumental digital platform

Instrumental digital platform (IDP) for monitoring BNT and lake Baikal contains instrumental software to support participants ' access to the development and debugging of applied information and hardware-software monitoring tools by providing standard functions, tool (universal) services and their interfaces for processing spatio-temporal data.

Multiple use of ready-made IDP tools allows you to reduce the time for creating infrastructure and applied IDPs, as well as providing services for organizing digital environmental monitoring of BNT.

The methodology for developing the software itself is based on the integrated application of modern service-oriented and end-to-end technologies, distributed storage and processing of spatio-temporal data, the use of declarative specifications and intellectualization using methods and technologies of deep learning. At the same time, declarative specifications provide compactness, expressiveness, and object orientation, including the ability of interpretation, transformation, and other procedures. Using SOA allows a full accounting of distributed information resources, combined with ease of testing, scaling, and the ability to reuse the created services [5] .

The IDP includes tools for creating three main types of components embedded in the shared environment:

1) development of Web Processing Services (WPS) and their compositions intended for software data processing that implement software interoperability standards;
2) creating data exchange services that support the provision and collection of thematic data;
3) deployment of geoportals that provide access to thematic data and services.

The information environment IDP includes geoportals, services for obtaining and processing spatio-temporal data based on open OGC standards [8-11]. IDP services

can be implemented on various operating systems, development environments, etc., and the problem of their compatibility is solved by using virtualization mechanisms.
To take into account the diversity of spatio-temporal monitoring data and their processing services, thematic geoportals can be created that simplify the work of participants and integrate data and services in the areas of BNT monitoring.
The IDP provides tools for the creation of standard portals and services in a cloud environment based on pre-configured templates of virtual machines. There are templates with Zoo project, 52°North Web Processing Service systems that simplify the implementation of the standard. The standard geoportal has built-in tools for creating services for entering and editing relational spatial data and providing them based on REST. To do this, the user defines the data structure, display methods, and access rights. Implemented regulated data transfer for processing by WPS services. The geoportal allows you to create new WPS services by composing existing ones using JavaScript or JSON, or the DAG specification.
For collective use, taking into account the growing number of tasks and amount of information on BNT monitoring, the IDP supports scaling of information and computing resources, their storage and data processing.

3.2 Infrastructure digital platform

The infrastructure digital platform (InDP) is created on the basis of the IDP and supports the development by participants of the BNT and lake Baikal monitoring of applied software and hardware, T-services for processing and distributed data storage based on the information environment (geoportal type), service-oriented and end-to-end technologies, the use of declarative specifications and intellectualization. A thematic service (T-service) is a service created on the basis of a digital tool platform and functioning within the framework of an InDP, which solves the tasks of a given direction of digital bpt monitoring (water bodies, forests, aquatic biological objects, atmospheric air, etc.) based on spatial and temporal data received from platform participants or external sources. The specialization of T-services is determined by the tasks of the monitoring direction, as well as the type of information processed (geospatial, navigation, biological, etc.). T-service uses functions and interfaces for processing spatio-temporal data, their services and combinations, implemented in a digital tool platform.
The structure of InDP of digital monitoring of BNT includes:
- catalogs of T-services for providing and processing participant monitoring data;
- basic spatial data and services of IDP, which support a uniform reference books and classifiers, and the work of InDP;
- scalable computing resources;
- a system for planning and executing services on distributed computing resources;
- services for publishing data in the form of maps and charts.

The “Integrated information and computing network of the Irkutsk scientific and educational complex” and the “Irkutsk supercomputer center” of the SB RAS can be used as a component of the InDP.

One of the tasks of the InDP is to support the construction of applied digital platforms, the main activity of which is to provide monitoring participants with access to T-services developed within the InDP.

3.3 Applied digital platform

The applied digital platform for environmental monitoring of BNT operates with processed data at the level of a particular type or monitoring as a whole.

The ApDP supports algorithmic exchange of services between participants using a unified information environment and information technology infrastructure. The ApDP gets its effect by combining multiple streams within a single information environment.

The applied digital platform includes the following services:

1) geoportal of digital environmental monitoring BNT;

2) services for providing BNT monitoring data (in the following areas);

3) tools for providing thematic WPS-services for detecting and evaluating changes in the environmental state of BNT based on time series of remote observation data under the influence of destructive factors.

Digital transformation of the monitoring system of the Bakal natural territory using a platform approach will allow:

- implement cyberphysical systems and sensors in BPT monitoring equipment, make the transition to digital data and its transmission methods;
- create a dynamically changing digital profile containing historical and up-to-date data on the BNT ecology, based on a large volume of spatial and temporal data;
- organize continuous (24/12/365) integration monitoring of BNT and the formation of a large volume of multi-format thematic space-time data, due to the rapid formation and updating of data, services and services;
- implement state-of-the-art BNT monitoring equipment using intelligent robotic and information and telecommunications systems;
- expand the range of services provided by monitoring participants through the effective use of remote sensing technologies, GLONASS-GPS, lidar surveys;
- implement advanced digital technologies: "end-to-end", Big Data, AI, cognitive data analysis and risk forecasting, etc.;
- implement a methodology for creating a network of distributed centers for processing and storing spatiotemporal data (data centers) for monitoring large volumes and various formats (including poorly structured ones);
- reduce the time for decision-making when assessing the operational situation, preventing and reducing the negative consequences of an emergency;
- introduce modern forms of organization of digital BNT monitoring with the involvement of scientific and educational institutions, businesses and the population.

4 Conclusions

The proposed technology for conducting digital environmental monitoring will allow participants to integrate their information and analytical resources to support interdisciplinary research and decision-making on the ecology of the Baikal natural territory.

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