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ADVANCEMENTS IN GEOINFORMATION MONITORING: INTEGRATING MICROWAVE AND OPTICAL TOOLS

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Abstract: The article discusses the issues of GIMS-technology that combines the methodology of GIS-technology and simulation modeling, giving it predictive functions when solving problems of environmental monitoring of the environment. The relationships between experimental data, algorithms and models of environmental processes are analyzed to implement effective operational control and diagnostics of the environment. Particular attention is paid to remote microwave sensing sensors, which ensure the implementation of the functions of GIMS-technology when solving specific problems of monitoring natural systems. For example, the use of microwave technology makes it possible to quickly obtain data on the state of soil moisture, and salinity water bodies, assess the possibility of critical hydrological situations and monitor the condition of hydraulic structures in regions with increased hydrological hazard. It is noted that GIMS-technology ensures the restoration of the spatial distribution of geo-ecosystem characteristics based on the data of route and ground measurements, which are characterized by fragmentation in space and episodicity in time. GIMS-technology makes it possible to overcome situations of irreducible information uncertainty, using the evolutionary modeling technique for this. The use of optical sensors and spectroellipsometry and spectrophotometry technologies makes it possible to calculate indicators of the quality of water resources, assessing the content of chemical elements in water and the presence of pollutant stains on the water surface.

Keywords: GIMS-technology; Remote sensing; Monitoring; Environment; Brightness temperature; Ecosystem; Spectroellipsometry; Spectrophotometry

1. Introduction

Solve modern problems of environmental protection, they require the creation of new information technologies that could provide analysis of big flows of heterogeneous data from numerous monitoring systems. The problem of synthesizing geographic information monitoring systems requires solving a huge range of problems that fall within the competence of many areas of knowledge. The complex nature of this problem is due to the combination of heterogeneous and diverse theoretical and applied research that is being conducted in many countries under national and international environmental research programs. The main goal of all such studies is to find an answer to a single basic question: what should be the structure and mode of operation of a system for monitoring environmental elements in order to provide reliable assessments of its current state and a forecast of its development for the near and future.

Due to the high cost of information about the state of environmental objects over vast territories, many researchers set the task of creating reliable and effective systems for monitoring the state of natural and natural-technogenic objects. To assess the condition of these objects, it is necessary to develop appropriate technical means for collecting, storing, transmitting data and developing methods for processing this data. The synthesis of an integrated system for collecting information about the environment, combining remote and contact measurements, is of great practical importance. These systems are called geographic information monitoring systems. They are intended for systematic observation and assessment of the state of the natural environment. Therefore, the task of studying environmental objects over vast territories is very relevant.

Among the promising directions in the creation of such systems is fiber-optic technology for the synthesis of information-measuring systems, spectroellipsometry and microwave remote sensing technology [1–7]. One of the important aspects of the functioning of these systems is the ability to predict the state of the environment and warn about undesirable changes in its characteristics. The implementation of this monitoring function is possible using mathematical modeling methods that provide a simulation of the functioning of natural complexes and, in particular, hydrophysical systems.

The experience of using mathematical modeling in solving this problem shows that solving the problem of objective environmental quality control is possible only by creating a unified monitoring system, which is equipped with a set of models of various biocenotic and biogeochemical processes in the territory occupied by the object of study. Research in recent years shows the possibility of creating such a system that can, in an adaptive mode of use, give recommendations on the monitoring structure and formulate requirements for databases. Constructive steps in this direction were made in works [1–12].

The study of the earth's landscapes, the state of vegetation, water areas and the atmosphere has become most effective with the use of aircraft equipped with remote sensing instruments capable of measuring reflected signals and recording their radiation. The problems arising here relate to the rapidly developing field of natural monitoring. Some experience in solving scientific and practical monitoring problems has been accumulated in many countries that have the technical potential to organize environmental monitoring systems.

At present, satellite or airborne multichannel monitoring systems are being widely developed in the world. Such systems allow obtaining operational information about the state of the natural environment, both on a regional and global scale. The information is accumulated in existing databases and is used on a commercial basis, in particular by agricultural producers. Remote sensing in the optical and microwave ranges has received great development [1–12]. A characteristic feature of the work carried out in these areas is the organization of data collection and their primary processing without the possibility of combining with models of the systems under study. Geophysical databases with high spatial detail for regional systems are developing with a certain lead. However, studies on their matching with models are slow and far behind due to the lack of appropriate technology. Within the framework of this work, an attempt is made to combine the capabilities of hardware, algorithmic, model and software tools for collecting and processing data with the functions of forecasting and decision-making.

The experience accumulated in recent years in measuring the microwave radiation characteristics of continental covers makes it possible to obtain estimates of soil moisture, search for groundwater, determine the structure of continental glaciers and frozen soils, obtain estimates of the state of soil-vegetation formations and geological formations, as well as data on thermal processes of natural and artificial origin. Optical and microwave radiophysical measurements make it possible to estimate the radiation balance, the albedo of the earth's surface, the components of water runoff, the turbidity of the atmosphere, the concentration of aerosols, carbon dioxide, ozone, methane, and many small gaseous impurities in the atmosphere. In other words, remote operational measurements provide a wide range of applied parametric estimates with sufficient spatial resolution and accuracy to make possible a comprehensive automated assessment of a natural system, indicating significant characteristics and forecasting their trends for a given time.

Along with solving the problems of technical equipment of flying laboratories, the organization of monitoring requires the creation of a complex of computer algorithms for processing measurement data. The unconventionality of the problems arising here covers the problems of detection, delineation and territorial-temporal reference of data, as well as the formation of databases based on information that is fragmentary in space and fragmentary in time. These monitoring features are an integral part of satellite and airborne measurements.

International experience and the experience of national organizations in the field of monitoring suggest the need to synthesize integrated systems for collecting and processing environmental data. In such systems, measuring instruments, computer tools and data processing algorithms are usually combined. The specific implementation of monitoring systems requires a certain specification of these tools. As a rule, the monitoring system is implemented in the form of a specialized information modeling system of limited use with the remote transmission of part of the data in its original form to its processing center, and part of the data is processed by onboard devices and in a certain format becomes available for further use.

The most suitable method for solving the above problems is GIMS-technology (GIMS = GIS + Model) [1,2,7,8]. Systems for collecting environmental data together with artificial intelligence methods make it possible to create GIMS-technology, with the help of which many problems of microwave radiometry and optics are solved [3–6,8,10–12].

The innovation of this article is the creation of a new information technology GIMS, which will expand the functions of GIS technology by connecting algorithms and models focused on learning to recognize spectral patterns and predicting evolutionary processes in the presence of irreducible information uncertainty. The need to implement the proposed approach is determined by the requirements to increase the efficiency of the computer and other tools used to solve applied problems of object recognition based on microwave and optical remote sensing data.

2. Materials and methods

2.1 Geoinformation monitoring technology (GIMS-technology)

Geographic information systems (GIS) are one of the important and developed elements of natural monitoring. GIS technologies bring great economic benefits in many countries. GIS works closely with remote sensing, databases and computer mapping. The main elements of GIS are a system for displaying the real situation on a computer display with a close connection to a computer network and database. GIS technologies are a massive tool for monitoring the condition of an object and serve as an effective mechanism for combining multifactor information about an object. However, GIS technology has a lot of limitations for complex tasks of natural monitoring, which require the creation of a dynamic image of the environment in conditions of fragmentation of data in space and time. The main disadvantage of GIS technology is its inability to make a multifaceted forecast of the state of the monitoring object.

For the development of GIS technologies, a lot was done in works [2,6,7,10–12], where GIMS technology was theoretically substantiated and practically applied. GIMS technology eliminates many of the shortcomings of GIS technologies and allows you to synthesize monitoring systems with predictive functions. The basic concept of the GIMS technology is presented in **Figure 1**. Its key element is the remote determination, using satellite sensing, of the maximum possible number of parameters of the global model. It is this combination of the empirical and theoretical parts of the GIMS technology that makes it possible to quickly assess current and projected environmental changes on a planetary scale.

The main principles of GIMS technology are:

1) Consolidation, integration and coordination of existing state, departmental and industry systems for collecting primary information about the environment on a unified organizational, scientific and methodological basis.

2) Optimization of material and financial costs for the creation, operation and improvement of the environmental monitoring system.

3) Compatibility of information flows based on the use of a unified coordinate-time system, the use of a unified system of classification, coding, formats and data structure.

4) Centralization of access to information through international information networks with maximum expansion of the list of users.

5) Ensuring the transnational nature of global geoinformation monitoring, independent of the discrepancy between state borders and ecosystem boundaries.

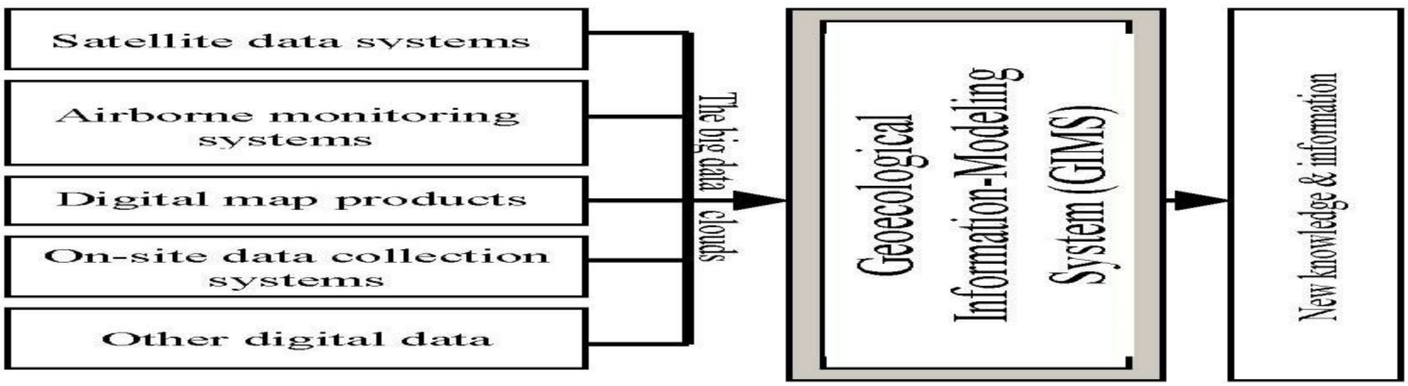

Figure 1. Conceptual block diagram of GIMS.

Natural objects are characterized by a large number of different parameters. Among them are characteristics of soil and vegetation type, water regime of the territory, salt composition of soils and reservoirs, groundwater level and many others. In principle, the necessary information about these parameters can be obtained from ground-based observation data, Earth remote sensing data, as well as from data banks of geographic information systems containing a priori information accumulated over past years. The task that needs to be solved is to obtain answers to the following questions:

- What instruments need to be used for ground-based and remote measurements;
- What financial resources should be allocated to ground-based and remote sensing;
- How to balance the number of ground-based measurements and the amount of remote data, taking into account their information content and cost;
- What mathematical models of spatiotemporal changes in the parameters of natural objects are advisable to use for interpolation and extrapolation of contact and remote observation data in order to reduce the volume (quantity) of the latter, as well as to obtain a forecast of the functioning of the observed object.

GIMS-technology allows you to answer these questions. It can be adapted to the necessary objects, such as, for example, rainfed lands, irrigated areas, flooded and floodplain areas, river-drainage systems, river-delta, canal-irrigated area, ocean waters, regional aqua-geosystem, bio-geocenosis and others [2,6,10–15].

In its structure, GIMS includes several blocks that perform the following functions:

- Collection of information about the monitoring object;
- Processing, sorting, memorizing and storing information;

- Modeling (imitation, organization of connections, training) of physical and chemical processes of various types of geo-ecosystems;
- Assessment of the current state of geo-ecosystems;
- Forecast of the state of geo-ecosystems;
- Feedback, assessment of information deficit, its optimization;
- Performing specific data processing operations within the framework of consumer requirements (assessment and forecast of the state of objects during the implementation of an anthropogenic scenario, etc.).

Any environmental subsystem is considered as an element of nature, interacting through biosphere, climatic and socio-economic connections with the Global Nature/Society System (GNSS). For a specific monitoring object, a model is created that describes this interaction and the functioning of various levels of the spatio-temporal hierarchy of the entire set of processes in the environment, which, according to preliminary estimates, influence the state of the object. The model covers natural and anthropogenic processes characteristic of a given territory and at the beginning of its development is based on the existing information base. The structure of the model is focused on the adaptive mode of its use with subsequent checks of its adequacy by comparing the measured and calculated states of the system under study. Depending on the level of discrepancy between these data, a decision is made to correct either the model or the measurement mode (frequency of measurements in time and placement of measurements in space).

As a result of combining a system for collecting information about the environment, a model of the functioning of the geo-ecosystem of a given territory, a computer mapping system and artificial intelligence tools, a unified GIMS of the territory is synthesized, providing predictive assessments of the consequences of the implementation of technogenic projects and other assessments of the functioning of the geo-ecosystem.

The construction of GIMS is associated with the identification of components of the biosphere, climate and social environment characteristic of a given level of spatial hierarchy. The sequence of actions for organizing work and implementing the GIMS project is focused on the creation of the following subsystems:

- Collection and express analysis of data;
- Primary processing and accumulation of data;
- Computer mapping;
- Assessment of the state of the atmosphere;
- Assessment of the condition of soil and vegetation covers;
- Assessment of the state of the territory’s aquatic environment;
- Assessment of the level of environmental safety and risk to the health of the population of the territory;
- Identification of the causes of violation of the environmental and sanitary situation;
- Intelligent support for computer operations and decision-making tools.

3. Results and Discussion

3.1 GIMS-technology in the analysis of data from remote microwave radiometric measurements

The key element of GIMS technology is the remote determination of the maximum possible number of parameters of a controlled geo-ecosystem model. It is this combination of the empirical and theoretical parts of GIMS technology that makes it possible to quickly assess current and predicted changes in the environment on the scale of the region of its influence. Further development of GIMS technology as a constructive mechanism for geo-ecological monitoring is associated with the expansion of its algorithmic and model elements, the adaptive choice between which to solve a specific problem can reduce the information load on technical means and optimize the structure and content of its organization modes. One of the important elements of this development is the formation of an updated database with a focus on its adaptive use. All this is possible by expanding the functions of GIMS technology and developing its information interface in the direction of universalizing the range of sensors. Currently, remote technologies are being increasingly used to obtain operational information about water systems and land covers. At the same time, the synthesis of an automated system for processing multichannel measurement data involves the creation of a set of hardware, algorithms, models and software for collecting and analyzing information, taking into account the levels of reliability and completeness. The developed methods and algorithms are able to overcome such difficulties as fragmentation and non-stationarity of information, the presence of small statistically heterogeneous samples. Recently, the main trend in building large problem-oriented information systems is the use of distributed databases and knowledge, and the use of computers of various classes using local and global networks. However, there are difficulties in using information and knowledge from databases and software developed on different platforms.

In this article, these difficulties are overcome using GIMS-technology and open information systems technology using standard interfaces. From a practical point of view, it is important to create an integrated system for collecting and processing environmental information, combining remote and in-situ measurements, which form the basis of a geoinformation monitoring system.

Within the framework of the scientific cooperation program of the Russian Academy of Sciences (RAS) and the Vietnam Academy of Sciences and Technologies (VAST), theoretical and experimental research was carried out under the direction of the author on the development of methodological, algorithmic, computer and instrumental technologies for assessing physicochemical parameters (PCP) in various reservoirs and land cover. Expeditionary studies were carried out in the mid-90s and 2000s. During this time, radiometric remote sensing tools for water bodies and land were tested in Vietnam. Below are the results of processing measurements obtained in the above expeditions using the algorithms developed in this work.

In radio-physical experiments with the help of an aircraft of the laboratory AN-2, radiometers were used at wave lengths λ_1 = 2.25 cm, λ_2 = 18 cm, and λ_3 = 30 cm. The microwave radiometric complex is characterized by a sensitivity of 0.2–0.3K. The antenna part of the microwave radiometric equipment includes strip antennas aligned coaxially for waves λ_2 = 18 cm and λ_3 = 30 cm and a horn antenna for λ_1 = 2.25 cm. The electric axes of all antennas are oriented in nadir. The radiation patterns are about 30^0 wide at half power level. Antennas are attached to the lower part of the AN-2 aircraft fuselage. The flights were carried out at an altitude of 100 m and 150 m when working on ranges and when calibrating microwave radiometric equipment, respectively. The spatial resolution was 5–200m, depending on the flight altitude and the wavelength of the working radiometer (**Figure 2**). The measurements were carried out over the water surfaces of the Red River near the city of Hanoi and the coastal waters of the South China Sea in the zone of influence of the city of Vinh.

Figure 2. Several samples of microwave radiometers with a wavelength of 2.25, 6, 18/21 and 30 cm, were produced by a special design office of the Kotelnikov Institute of Radioengineering and Electronics RAS [10–12].

According to the data of trace measurements, spatiotemporal reconstruction of two-dimensional images of the radio brightness field $T_b(\phi,\psi,\lambda,t)$ was carried out and its characteristics were calculated in order to the identification problem. Some examples of the results obtained are given in **Table 1, Table 2** and in **Figure 3, Figure 4**.

Table 1. Statistical characteristics of radio-brightness temperature of the sea surface in the region of Vinh. Designation: W-mean value, D-dispersion, S-rms ratio, A-asymmetry coefficient, K-kurtosis, V-coefficient of variation.

Channel, λ	**W**	**D**	**S**	**V**	**A**	**K**	**Type of probability distribution**
2.25 cm	90	21	4.6	5.2	0.9	5.2	Gamma distribution
18 cm	120	145	12.1	22	0.8	3.2	Gamma distribution
30 cm	140	48	6.9	3.1	1.2	1.8	Gamma distribution

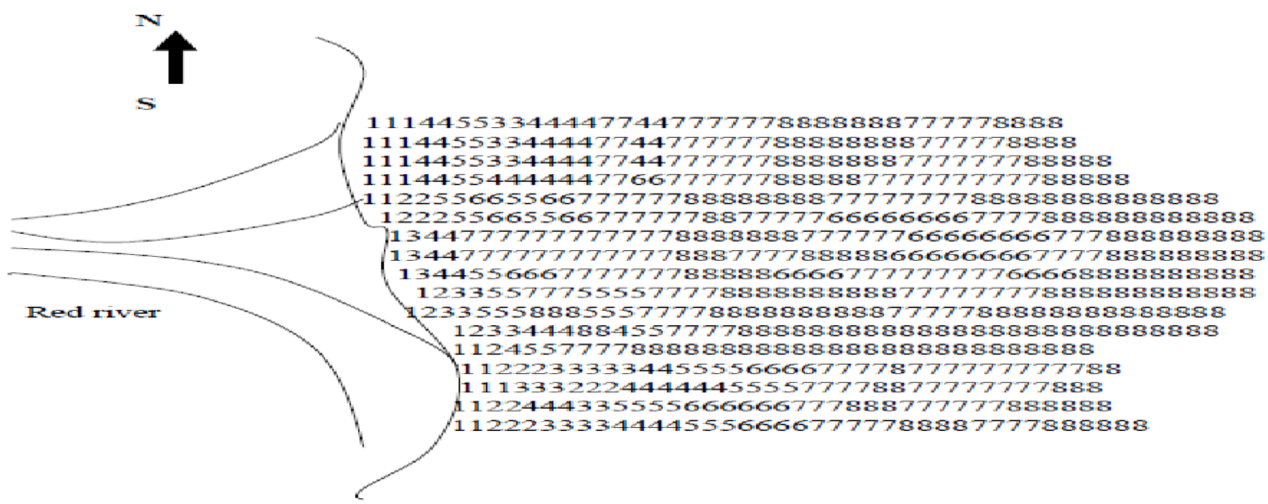

Figure 3. An example of restoring the distribution of radio brightness temperatures of the sea surface in the area of the city of Vinh (Vietnam). Scale: 8–(100–110) °K; 7–(11–120) °K; 6– (121–130) °K; 5–(131–140) °K; 4–(141–150) °K; 3–(151–160) °K; 2–(161–170) °K; 1–>171°K.

Table 2. Statistical characteristics of radio brightness temperatures in the Red River region (near Hanoi). Designation: W-mean value, D-dispersion, S-rms ratio, A-asymmetry coefficient, K-kurtosis, V-coefficient of variation.

Channel, λ	**W**	**D**	**S**	**V**	**A**	**K**	**Type of probability distribution**
2.25 cm	172	36.6	6.2	6.7	0.85	2.4	Exponential Distribution
18 cm	180	81.2	9.1	4.7	0.7	3.5	Exponential Distribution
30 cm	196	104	10.2	6.3	0.9	7.8	Exponential Distribution

Figure 4. An example of a reconstructed map of the distribution of radio brightness temperatures in the zone of influence of the Red River (Vietnam) according to microwave radiometric measurements. Scale: 1-(170-180) °K, 2-(181-190) °K, 3-(191200) °K, 4-(201-210) °K, 5-(211-220) °K, 6-(221-230) °K, 7-(231-240) °K, 8- >241°K.

Microwave monitoring makes it possible to measure the PCP distribution on the surface of the aquatic environment. To obtain more complete estimates of the state of a water body, it is required to use a model of the PCP dynamics, which certainly requires a lot of a priori information. Obtaining this information is possible using an Adaptive Identifier (AI) (see point 3.2, **Figure 5**). Without this information, microwave measurements give fairly complete estimates of water surface spotting. As demonstration examples, **Table 3** and **Table 4** give the results that make it possible to evaluate the efficiency of the algorithm for calculating spotting characteristics [9].

3.2 GIMS technology and optical means for monitoring the aquatic environment

The joint use of GIMS technology and technical means of operational monitoring of the aquatic environment is poorly developed. The tasks of algorithmic and informational combination of a monitoring system are quite complex. For environmental monitoring of aquatic environments, various compact polarization optical and microwave devices are required. At the same time, the effectiveness of solving the assigned problems strongly depends on the sensitivity and accuracy of the instruments. Spectral measurements provide an informative basis for the use of Data processing methods, spectroellipsometric and methods and algorithms for the recognition and identification of pollutants in the aquatic environment spectrophotometric measurements were first combined. in the adaptive identifier (AI) [4,5] (**Figure 5**).

Table 3. Statistical characteristics of spotting of the water and earth surface of the Red River region, obtained from the results of remote measurements from the aircraft-laboratory AN-2 at a wavelength of λ = 30 cm.

Threshold °K	**Average spot diameter, km L**	**Dispersion, (m) D**	**Asymmetry coefficient A**	**Kurtosis K**	**Correlation coefficient *ρ***
180	11.3 2.6	420.2 5.5	2.87 2.14	7.6 4.2	–0.14
190	5.3 3.4	135.9 15.5	4.02 2.1	15.7 3.2	0.06
200	4.06 6.16	123.6 71.7	4.3 3.1	16.6 8.6	0.15
210	4.7 10.5	164.9 184.7	3.4 2.1	9.05 3.3	–0.24

Table 4. Statistical characteristics of water surface spotting in the region of Vinh, obtained from the results of remote measurements from the AN-2 laboratory aircraft at a wavelength of λ = 30 cm.

Threshold °K	**Average spot diameter, km**	**Dispersion, (m)**	**Asymmetry coefficient**	**Kurtosis K**	**Correlation coefficient *ρ***

	L	D	A		
180	28 3.3	260 27	1.4 1.4	0.25 0.25	–0.32
190	18 5	58 33.2	0.9 1.8	-1.2 2.02	–0.21
200	10 8.6	180.3 31.2	2.2 2.4	4.3 4.6	–0.03
210	2.4 16.4	3.6 174.8	1.6 2.2	1.3 3.2	–0.02

Figure 5. AI for the study of aquatic environment characteristics in real-time laboratory and field conditions.

Training the AI consists of the following procedures: 1) measuring the spectral characteristics of the aquatic environment; 2) simultaneous independent measurements of the content of chemical elements in the aquatic environment. After this, a bank of standards is formed in the knowledge base. The identification problem is solved after comparison with standards located in the bank. One of the comparison options may be to calculate the standard deviation of the measured physical image of an object from the standards available in the bank. To solve this problem, various algorithms are introduced by AI software. These algorithms include cluster analysis and discriminant analysis.

The applications of AI can be varied. It can be used to assess the quality of an aqueous solution, as well as to identify various chemical elements in the aquatic environment. AI can be used in continuous monitoring of the aquatic environment. There are 2 options here: 1) stationary measurements, allowing you to monitor the dynamics of water quality in the stream; 2) placement on board the vessel, allowing - to measure the characteristics of a water body along the route. The capabilities of AI are expanding by increasing the volume of standards in the knowledge base.

AI was tested in the mid-90s and 2000s in Vietnam in joint Vietnamese-Russian environmental expeditions, and in 1995 in Russia as part of Russian-American expeditions in Siberia. A recently modified version of AI was used to monitor natural waters in Siberia (Baikal-Angara-Yenisei). Currently, AI is used to measure PCP in natural and wastewater in the area of the city of Fryazino, Moscow region.

When solving the problem of object recognition based on measurement data using AI, several approaches are possible, the choice among which depends on the required recognition accuracy. A rough method for determining water quality can be based on a direct comparison of the light scale with the water quality scale. The calculation of such an identification scheme according to Goody and Young [13] is based on the attenuation of light with depth according to the exponential law $I(Z) = I(0) \exp(-\beta Z)$, where the coefficient β is a direct indicator of water quality and is determined by its values, the content in the water layer Z of suspended or dissolved matter. Note that this approach does not give a clear estimate if β is the same for different substances.

Table 5 shows an example of solving the identification problem using this method. Knowledge of such assessments makes it possible to identify the type of pollutants in the aquatic environment. As can be seen from the example in **Table 6**, detailing the β coefficient estimates by spectral channels significantly increases the effect of pollutant classification. Here, the effect of selective light absorption is manifested [14]. By putting into the database samples of

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vectors $\beta^*(\lambda i)$ (i =1,7), characteristics for each type of substance in the aquatic environment and comparing the obtained measurement $\beta(\lambda i)$ with these samples, we determine the type of pollutant. As test measurements show, the reliability of such identification does not exceed 70% and drops sharply when there are many pollutants in the water in similar concentrations. In the field measurements carried out here in the water bodies listed in **Table 5**, according to the data in **Table 6**, the selected substances were detected on average with a probability of 0.72. At the same time, the presence of oil products was detected with a probability of 0.81, and biogenic elements—with a probability of 0.69. This is because a noticeable characteristic heterogeneity is observed in the spectrum of oil products, and the spectrum of biogenic elements (as well as pure water), such inhomogeneities are smoothed out. Increasing the efficiency of the classification of chemicals present in the aquatic environment is achieved through the use of cluster analysis based on training clusters in the space of statistical parameters calculated for each spectral range [10,15]. An example application of this procedure is shown in **Figure 6**. Here, characteristic clusters are identified at a depth of 1 m in the Angara River within Irkutsk. It can be seen that in the spectral channel space, the cluster positions are well separated even in cross-sections. Expanding the space by including measurements with statistical parameters makes it possible to distinguish between the PCP indicated in **Table 5** with up to 89% confidence.

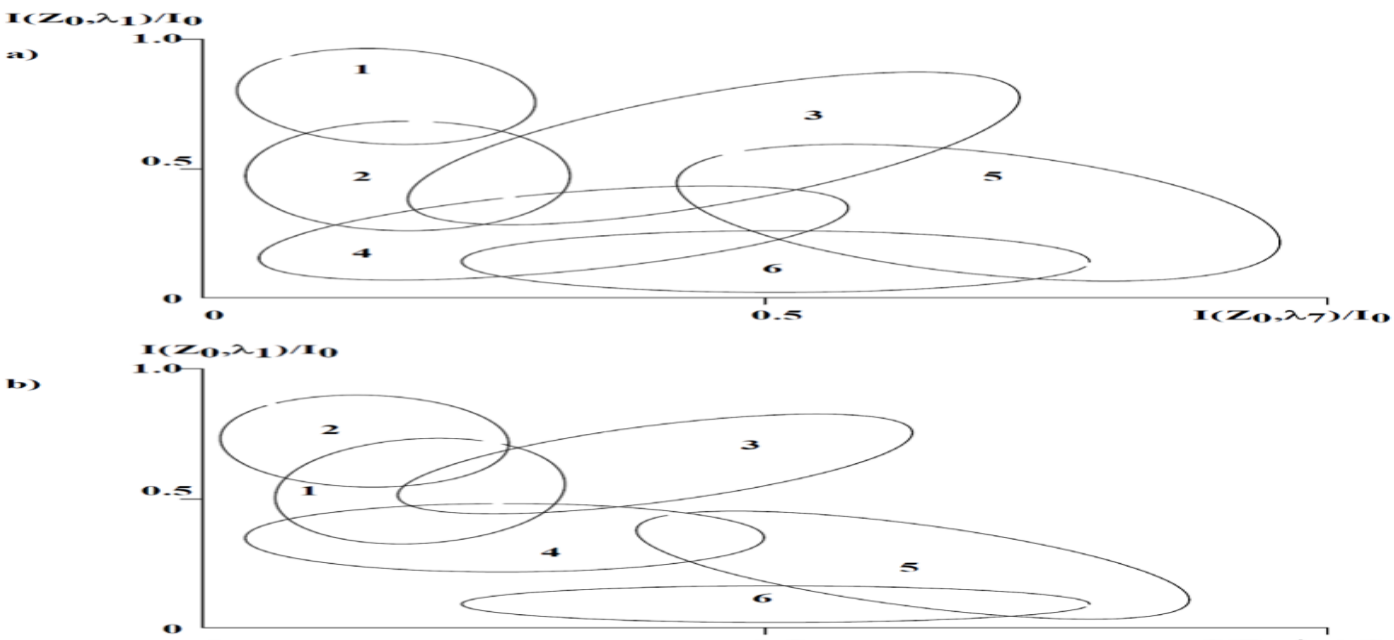

Table 5. Integral indicators of vertical light attenuation β (m^{-1}) according to measurements at a depth of 1 m.

Substance	Water body				
	Lake Baikal	The source of the Angara River near Baikal	Angara River within the Irkutsk	The mouth of the Angara River	Yenisei River near the Yenisei
Pure water	0.019	0.023 0.028 0.041	0.035	0.049 0.088	0.138 0.152
Oil	0.022	0.053 0.055 0.027	0.131	0.171 0.234	0.179 0.277
Dissolved organic	0.035	0.038	0.111	0.143 0.145	0.085 0.123
matter	0.044		0.155 0.093	0.056	0.079
Suspended matter	0.049		0.031		
Chlorophyll “a”	0.008		0.047		
Yellow substance	0.029				
Biogenic elements					

Table 6. Indicators of vertical light attenuation β (m^{-1}) according to measurements at a depth of 1m in the Angara River in the city of Irkutsk.

Substance	Spectral channels						
	1	2	3	4	5	6	7
Pure water	0.118	0.101	0.038	0.127	0.129	0.138	0.031
Oil	0.351	0.389	0.288	0.253	0.218	0.089	0.063
Dissolved organic matter	0.033	0.029	0.024	0.171	0.228	0.256	0.199
Suspended matter	0.117	0.212	0.236	0.296	0.263	0.242	0.235
Chlorophyll “a”	0.095	0.153	0.102	0.092	0.093	0.113	0.097
Yellow substance	0.053	0.072	0.091	0.076	0.054	0.084	0.066
Biogenic elements	0.067	0.083	0.088	0.111	0.127	0.108	0.118

Figure 6. Sections of the spectral space with characteristic clusters selection according to measurements at a depth of Z_0=1m in the Angara River within the Irkutsk. a) $\lambda = \lambda_7$; b) $\lambda = \lambda_5$. 1-Oil; 2-Organic matter; 3-Suspended matter; 4-Chlorophyll “a”; 5-Yellow substance; 6-Biogenetic elements.

From the above, it follows that the methodology for calculating the PCP incorporated in the AI is stable with respect to the reliability of the input information and does not lead to a significant increase in errors in the assessment of the PCP. It is clear that accuracy can be improved if AI is applied locally in a controlled information environment. Of course, the transition to larger spatial scales will inevitably lead to an increase in errors. A more complete assessment of the reliability of the proposed methodology, taking into account all possible aspects of monitoring hydro-physical objects, requires special studies covering a diverse range of water bodies. Model and experimental assessments of PCP prove the possibility of joint use of AI and computer technologies to assess the dynamic characteristics of complex water bodies.

4. Conclusions

This article discusses the basic principles of GIMS - technology and its specific applications. These principles make it possible to jointly use mathematical methods and corresponding technical means when solving problems of geoinformation monitoring. These principles of geoinformation monitoring when processing data make it possible to effectively use joint hardware, algorithmic and software tools for collecting and analyzing information.

When monitoring water systems, a large number of laboratories analyzes are required to evaluate it. This significantly degrades the functionality and performance of the monitoring system. The results of this article when assessing the quality of the aquatic environment allow us to eliminate the stage of laboratory analysis. The laboratory analysis stage is transferred to the beginning of the identification algorithm adaptation procedure. This result is fundamental and differs sharply from the approach of other authors. In this work, effective information technologies based on multichannel measurements in the optical and microwave ranges are used to solve problems of classification and identification in water bodies and land covers.

In the article, specific examples of the application of the developed GIMS technology for water bodies and land covers based on microwave radiometric and optical measurements show the effectiveness of the developed technology.

The development and application of the ideas of GIMS technology, which involves combining methods and algorithms of mathematical modeling with ground-based and remote measurements of the characteristics of the natural environment, as experience shows, is possible based on the synthesis of flying and mobile laboratories. In the future, it is precisely such complexes that will solve the following main tasks:

- Forecasting the start time and degree of danger of natural disasters, emergencies and man-made disasters.
- Monitoring the dynamics of accidents and disasters, including in adverse weather conditions, and providing information for decision-making.
- Assessment of the consequences of accidents and disasters for cities, agricultural and forest-wetlands, marine and coastal flora and fauna.
- Issuing target instructions to rescue services during search and rescue operations.

GIMS technology will allow solving problems of monitoring the territories of large industrial centers.

Conflict of Interest

The author declares no conflict of interest.

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