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Using the integrated information technology based on GIS for marine environmental data management and creation of reference books of the hydrometeorological conditions

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Abstract

The efficiency and validity of the world ocean investigations and decisions made in the course of exploitation of marine resources depend considerably on the level of information support for this activity. This makes it necessary to treat a full technological cycle of data management, from acquisition of observational data to provision of an end-user with complex information on all environmental aspects. Now the Russian NODC is developing such technology based on modern geographical information system (GIS) to successfully support the marine environment data management and climatic research. The paper analyzes the concept, architecture and development state of information technology. The paper examines the practical samples of the specialized integrated information systems. The technology of making environmental reference books based on GIS-technology is considered in the paper. The paper discusses the results of analysis of modern electronic reference books on the Black Sea hydrology. Shown are the fragments of a new electronic guide to the Black Sea hydrology, created on the basis of GIS-technology.

Keywords: Information system; Technology; GIS; Hydrometeorology.

Introduction

Due to the requirements imposed on the information support of the world ocean investigation and exploration, it is necessary to consider a complete technological data management cycle, *i.e.* from collection of observation results to providing an end user with complex and validated information required for proper understanding of natural processes and phenomena and making correct decisions. To describe the *'end to end'* scheme of data management, the term *'integrated information technology'* (hereafter referred to as IIT) is often used (Pospelov, 1983; Fedra, 1997).

The application domain (AD) of IIT is defined by the requirements imposed on the information support for marine environment investigation and exploitation. Generally these requirements may be divided into several classes of tasks. To perform these tasks, IIT should handle data and information on a broad spectrum of various AD objects. It generates a need to create fairly complicated sets of tools to realize IIT. These tools may be divided into components and functional subsystems. The components (methods, general design decisions, data description languages, codes and codifies, instrumental software systems, etc.) form the basic level of IIT tools and comprise the environment for the development of technology functional elements. The functional subsystems are created from the components and intended to perform appropriate information activities.

The first (input) block of the technology, the archived data bank subsystem (ADB), accumulates data on marine environment, systematizes and converts them to internal information standards. Datasets formed in ADB arrive at the next block - integrated data bank (IDB). The major function of IDB is to provide integration on the basis of a more complicated and unified data model which considers both AD and functional requirements. The outcome of the IDB work consists in the complex data base (results of observations and calculations, textual data, topographical and thematic maps and others), maintained in actual conditions to be able to *'feed'* the next block – a subsystem of problem-oriented applications (POA).

In a broad sense, POA may be represented as a set of specially selected (to solve a specific task) subject – oriented data, knowledge obtained earlier and applied programmes realising methods and models of calculation of environmental characteristics. POA is oriented to obtain new information useful for selection of reasonable and economically profitable design decisions related to marine environment exploration.

The aforementioned subsystems are interconnected being developed on the basis of unified components. And whereas the ADB subsystem interacts with other subsystems on the basis of information standards (formats, metadata structure and others) only, IDB and POA subsystems have a higher level of interconnection on the basis of the client-server architecture using GIS, DBMS and WWW technologies.

In both cases the optimum organization of the data management represents the greatest complexity. In this connection when designing IIT, the aspects of representation and connections of various data types were considered, including:

- metadata - «data about data»;
- factographical data - observed, derived, calculated and modeled data;
- spatial data - electronic marine navigation and thematic maps;
- image data (graphics, figures, photo);
- textual data (documents, description, papers);
- software modules realizing particular algorithms of data processing or modeling to obtain information production.

Data management

The data management in IDB and POA subsystems is based on exchange procedures of elementary data units in client-server architecture. Thus the POA subsystem including GIS applications and certain part of the data is on the client side, and the IDB subsystem supporting the basic database is placed on the server side. The data depending on their type are placed both on the client (POA) side and on the server (IDB) side. The server side supports factographical, image and textual data as tables of DBMS or through the references to data files. The spatial data-electronic marine maps, including semantic layers of thematic maps and certain part of specialized textual and image data, are placed on the client side as an internal database of GIS applications.

If necessary GIS application has an opportunity to contact to the basic database, which, in turn, is under management of a IDB subsystem. For this purpose, GIS application addresses to the server side of technology, where the basic data base is placed under DBMS management. To use data from the basic database, the GIS-application provides ODBC links (path, names of the users, passwords, etc.) with DBMS, which are preserved as long as a session of a GIS application is running.

The GIS application data management is carried out using a special link table. This table represents a nucleus of the standard module, which is named as Navigator and which is used in nearly all GIS-applications. The Navigator module and link table were constructed on the unified classification of marine objects and are applied in all IIT subsystems.

In this case spatial data management is provided by internal GIS application tools using attributive tables. As a result, the data present in a different form (factographical, textual, graphic, spatial) and placed in the external and internal (relative to GIS) data base are jointly used by applying a Navigator link table and an internal attributive table of GIS application. The example of the interaction of the tables mentioned is shown below:

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A key feature of the POA is attaching of user programs, which carry out calculations of various characteristics and modeling of natural marine processes. A special input and output parameter definition language was developed for the interaction between the POA shell and the user software. The language includes a number of constructs allowing parameters specification required for the user software to be set up and run. At the same time the language allows one to describe the user interface of an application (buttons, menu bar, sliders, etc.).

The practical realisation of IIT

In the last few years the considered approach to the construction of the integrated information technology has been used to develop several specialized information systems intended to support petroleum exploration and gas deposits in the Arctic seas (Odisharia *et al.*, 1997; Odisharia *et al.*, 1998). In 1999 the work on the IIT development acquired a large-scale character owing to the development of a unified system of information about the World Ocean within the framework. The essential development of IIT components, created on the basis of Web-technology was noted.

IIT methodology is also tested in the Black Sea region through the construction of IAS *'Blue Stream'*. The model of the POA subsystem of IAS related to access and visualisation of marine environmental data in the region under study has been created in GIS media using high level algorithmic languages. It includes: data base, special software environment developed for the model and standard software GIS.

The test data base consists of spatial and factographical datasets. Space-oriented data are represented by topographical and bathymetry maps (hydrometeorology, geocreology end geomorphology, biota and others) of the Black Sea and adjacent land areas. Factographical data include temperature and salinity climate sets, as well as three components of current vectors for each month of a year.

To provide a quick access to data, data visualisation, processing and analysis as well as calculation and visualisation of additional environmental characteristics, several GIS applications were realised within the IAS model. These applications contain two groups of modules: modules extending standard possibilities GIS as far as map visualisation and attributive information describing maps is concerned; and modules ensuring acquisition of new information in GIS media with the help of factographical data processing in a mode set up by a user and subsequent visualisation of results.

The following modules are included into the first group:
- module of quick positioning of a map;
- module of construction of explanatory legend for a map or a diagram;
- module of construction of a scale rule in a map window;
- module of construction of a grid for selected area of a map;
- module of search and representation of factographical data.

The second group includes the following modules:
- module of calculation and visualisation of climate horizontal water temperature and salinity fields;
- module of calculation and visualisation of vertical profiles and time series of water temperature and salinity;
- module of calculation and visualisation of climate horizontal current vectors;
- module of calculation and visualisation of trajectories of tracers released from pressing grid points at standard horizons;
- module of calculation of spatial and time statistical characteristics by factographical datasets.

The creation of reference books of the hydrometeorological conditions

One of the major aspects of a problem of researches of seas is accumulation of the information on the sea environment for the long-term period and reception of the generalized data on a mode of the sea as the various reference books distinguished by the big variety both on a set of parameters, and on scales of processing of the information.

Requirements of today have changed our representation about reference books, - convenience of use, efficiency of their preparation and a possibility of new information technologies allow to speak in the majority the about electronic reference books as all variety of handbooks can be united and unified.

The modern computer technology allows to unite at a functional level of a database, methods and models of calculations, standards and manuals, system and application programs as the integrated information media based on commercial GIS and DBMS for reception of the complex information on a condition of the natural environment. All this allows creating the reference book more mobile by way of inputting the new data and reception of the updated calculating and modeling characteristics.

Thus, it is possible to define, that in modern understanding the reference book in electronic kind (ERB) can and should include not only information base (the observing, processing, modeling and help data), but also a processing and modeling set of programs of reception of regime characteristics and results hydrodynamic modeling.

Basis ERB is technological media storage, management, processing and formation of output production as cartographical, text, tabulated and graphic materials. (GIS, DBMS, Internet/intranet, etc.) problems of creation ERB various ways allow to solve development of new information technologies. The new generation electronic handbook should work both in network variant, and in the variant which has been written down on a compact disc.

ERB today is the integrated information technology of reception of a full set of characteristics of the marine environment in client-server variant for which the powerful program complex of preparation of output production on the central server is developed, it is formed full DB (a set of observational and regime materials as the tabulated, graphic, text data; metadata and the thematic maps for each type of data).

It is obvious, that development of new information technologies problems of creation ERB, as allow to solve a minimum, two various ways. The first can be named off-line or static (electronic analogue before published regime and climatic reference books), the second - on-line or dynamic (realization 'in alive' calculations and reception of statistical and modeling characteristics on the basis of an existing database).

Now two variants of basis ERB are realized: as DBMS- and GIS-applications.
Further we shall consider practical realization IIT as the information system functioning in GIS media. The system is developed as an open software product allowing for modernization and enhancement of functionality. Developments involve the modern information technologies (problem-oriented programming, DBMS and GIS) and are conducted in the distributed environment of the client–server architecture.

The basic idea of the integrated marine information system (IMIS) is to develop 'transparent' interfaces between a variety of marine environmental information resources coming from different sources such as observational networks, historical databases, analytical synthesizing, mathematical methods and models for providing access to available data and new information with a view of improving our knowledge of marine phenomena and facilitating to efficient and effective marine-related planning and decision making.

The IMIS (Batalkina *et al.*, 1999) development is based on the integration principle (sometimes it is called 'end to end' technology).

Therefore in a general form IMIS is the integrated set of subsystems designed to provide user services. Each subsystem can include several invariant functional blocks. The client-server architecture has been chosen as the basis for IMIS implementation: the server is responsible for data accumulation and integration in the distributed database and the client executes intranet applications designed to implement applied tasks (within the scope of the predetermined subject). The client is also responsible for access to data and information products under appropriate information protection conditions.

It is noteworthy, that along with specific features typical for concrete environment-related systems there are standard models typical for all types of systems. The main thing is that the system should be built on the multi-tier principle. Individual subsystems such as the integrated database subsystem can be considered as individual layers. Smaller layers such as the specialized software, the data flow management system, the ancillary software needed to ensure communications and to provide access to the functional part of the system can be further considered within individual subsystems.

The advantage of the multi-tier principle is that it allows for modifications of individual components in one layer leaving other layers unchanged and ensures formal specification of interfaces between the layers to enable independent development of information technologies and related software. In this case open standards will permit smooth replacement of software modules (*i.e.* replacement of a server or a DBMS). In addition the multi-tier approach will enhance reliability and stability of the system.

Generally when information systems are developed a number of interrelated structural elements are identified such as components, functional subsystems and workstations. In this case the base level of the system is represented by the components constituting methodical, organizational and technological environment for development of the system, and the functional level is represented by thematic subsystems responsible for specific information activities. The subsystems in their turn can be divided into functional blocks-elements implementing specific tasks. The subsystems and individual blocks are created through development of the appropriate applications on the basis of the system components ensuring the unification of the system implementation tools.

The basis of IMIS is formed by the set of components (scientific-methodical, information-linguistic, program-technological, etc.) creating environment for interaction between technological blocks and information flows. The scientific-methodological component is responsible for thematic orientation of the system determining specific features of its operation. The information component includes the information fund and data unification and encoding tools used to represent data in the databases of the system. The program-technological component ensures IMIS operation on the basis of the DBMS and GIS applications. The system components are combined in the form of several subsystems.

The first (input) block of IMIS - the integrated database (IDB) subsystem - accumulates the necessary data on objects of the domain, systematizes and converts them into internal standards for representation of declarative (factographic, textual and spatial) and procedural data (models) on marine environment. The IDB core is formed by the complex database (DB) updated on a regular basis to 'feed' the next block – the subsystems of problem-oriented applications (POA).

In a broad sense POA can be conceived as a set of specially selected (to solve a specific problem) thematic data, knowledge obtained previously and applied programs implementing methods and models of calculating marine environment characteristics. The POA information-technological complex is aimed to process, analyse and interpret data, and to represent information products. The separate IDB/POA block is responsible for user access to data and information as well as dissemination of information products. In terms of functionality the calculation/model block should be noted. It includes calculation procedures integrated into IDB and a number of analytical modules from POA.

Noteworthy also is the section of topographical bases, which includes marine maps of a various scale. The topographical bases are applied in thematic tasks as a basis for representation of metadata (reference information) at the maps of the areas selected.

In fact IMIS is the combination of various IDB/POA elements interconnected by information-technological interfaces when the output data flow of one source (technology) serves as a 'transparent' input data flow for the other.

Structurally the test version of IMIS includes the specialized DB, operating in the DBMS environment; the DBMS-application block performing a number of functions in the DBMS environment; the basic GIS-application, within which the user interface and basic data visualization and field construction functions are implemented.

The general framework of IMIS is shown on Fig. 1.
Data management in the system is based on the database design and on object (or logic item) management. In the system by the object of management the elementary domain component resulting from structuring is meant. It is presented in the form of an individual item, which can originally be described by:

- data kind (pollution, hydrology, etc.), groups of parameters and individual parameters within the data kind;
- data type (metadata, data on space-time distribution, outcome of observation, generalizations etc.);
- data presentation type (map-based layer, covering, graphics, textual ASCII or DOC-description, dbf-file).

Object management has three steps:

- interaction between communication tables and files-catalogs by the use of an identifier;
- file-catalog transfer by the use of an identifier;
- interaction between reference tables and catalogs.

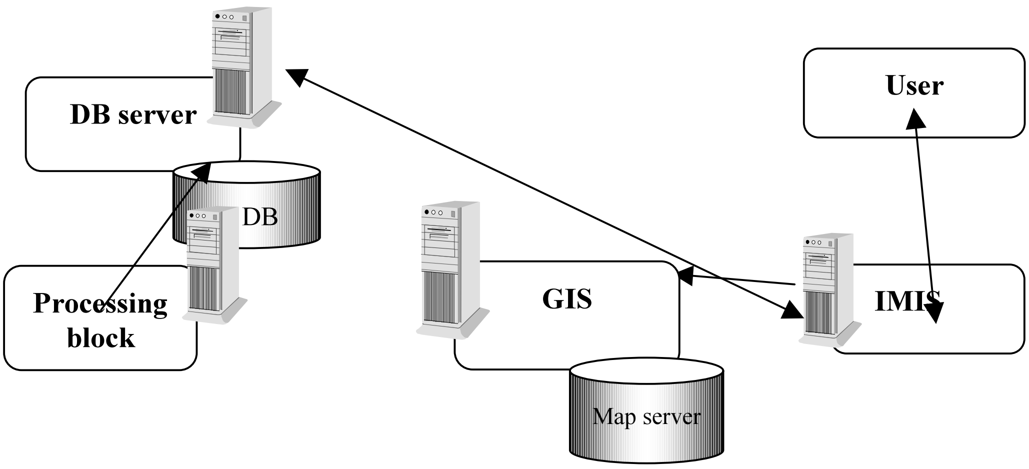

Fig. 1. The framework of IMIS.

Structurally the IDB subsystem includes a database and a set of technical and software-technological data management and processing tools. The following types of input objects should be included into IDB:

- characteristics of environmental conditions;
- data collection, accumulation and processing technologies, methods and models including calculations and modeling of environmental characteristics.

IMIS includes a number of tools and modules:

- the system shell in the GIS ArcView 3.2a environment responsible for IMIS operation control and maintenance of intersystem links;
- the DBMS-application for the XOZ graphs which allows the XOZ graphs to be plotted by a random sample;
- the DBMS-application for XOt graphs which allows a parameter time variation to be plotted by the data being selected;
- the XOY isoline tool in the form of the GIS-application based on Spatial Analyst 2.0, which allows fields to be constructed in a specific standard (default functions) and by the choice of a user;
- the table data visualization module – a tool to compose and display the tables of a specified type;
- the textual data visualization module – a tool to compose and display the textual data in the *.doc and *.txt format;
- the graphics visualization module – a tool to compose and display graphics of specified formats;
- the file Navigator - a tool to manage files of specified extensions (selection, viewing, processing etc.);
- the module to save data in a specified format;
- the standard GIS-function-based module to generate reports.

On Fig. 2 working panels of IMIS (managing panel, display in separate windows metadata and a thematic map) are shown.

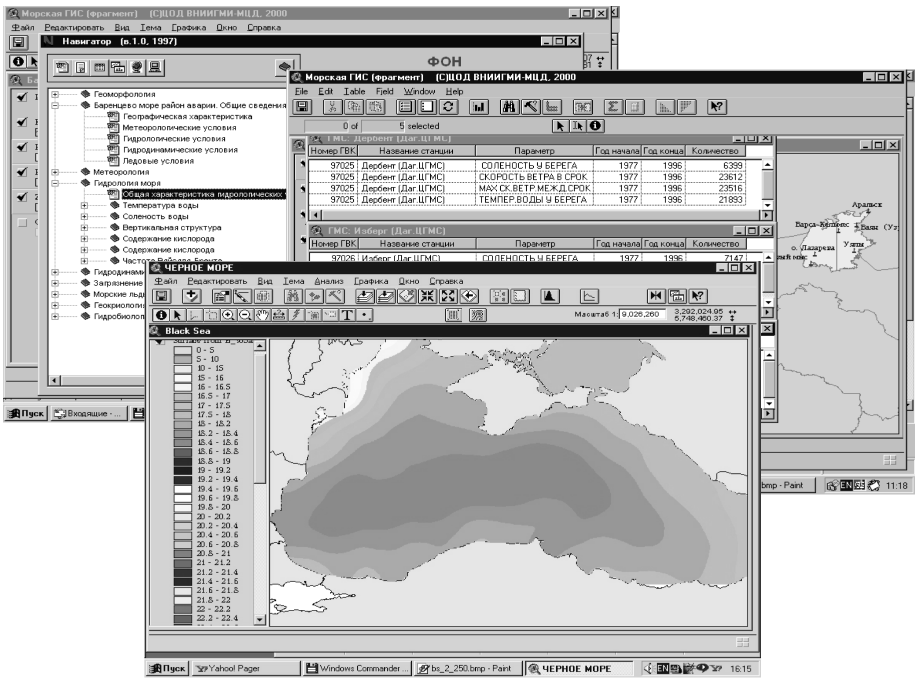

Fig. 2. Working panels of IMIS.

Conclusion

Today IMIS is in the starting model stage. The basic functional task is to visualize the initial and processing data generated in the DBMS environment and to put into operation some problem-oriented applications in the GIS environment.

In the future the full-function information system should be developed, including its ability to operate in the distributed mode. And ERB on the marine environment are realized as a complex set of the problem-oriented appendices which work should be carried out on the server of IMIS, and the user should receive only results.

One of variants of such creation of appendices is based on application of technology Taxxi - the most advanced embodiment of the concept of the objective surface offering uniform decision of problems of distributed systems connected to development. This technology provides the low traffic, minimizing volume of the sent data that comfortably allows to work with services even at access on lines with low throughput.

Convenience of application of the given technology is caused also by that the user computer is protected from the non-authorized access, as from network Taxxi Communicator (client part) receives only passive XML-descriptions, instead of active Java-applets. It means, that there is no basic opportunity of automatic installation of another's executed code.

The complex of appendices for preparation of output production as ERB on marine environmental now is created as the separate project.

The basic components are:

- the control service of access;
- the managing center;
- the set of application;
- the local database;
- service of auto updating of the data.

For an example on Fig. 3 panels of the managing centre and the application for sample of the data are shown.

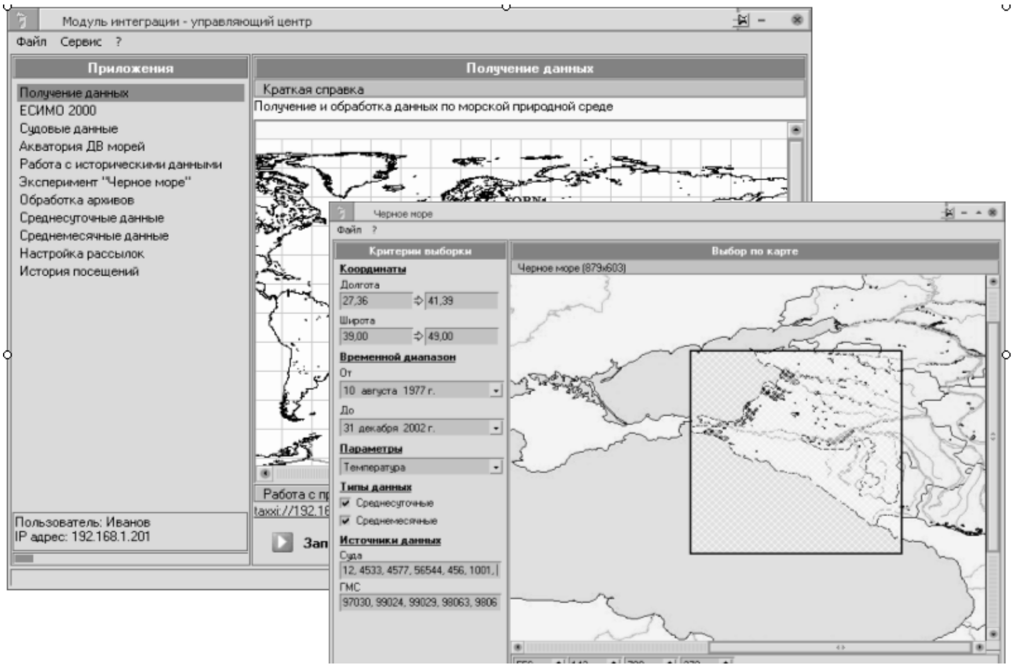

Fig. 3. Managing centre and the appendix for sample of the data.

References

Batalkina S., N. Mikhailov, V. Tuzhilkin and A. Vorontsov. 1999. Marine Information System in Oceanography and Meteorology of the Black Sea. p.234-236. In: Proc. International Conf. Oceanography of the Eastern and Black Sea, 22-26 February, 1999, Athens, Greece.

Fedra K. 1997. Integrated environmental information systems: from data to information, p.367-378. In: Integrated approach to environmental data management systems. Kluwer Academic Publisher, Dordrecht.

Odisharia G.E., L.V. Shershneva, A.S. Tsvetsinsky, N.N. Mikhailov, B.V. Arkhipov, A.A. Vorontsov, S.A. Batalkina and V.S. Tuzhilkin. 1998. On application of GIS technologies for design of Jamal gas production and transportation sites, ArcReview, 1998, 4(7):12-13.

Odisharia G.E, A.S. Tsvetsinsky, N.N. Mikhailov and G.I. Dubikov. 1997. Specialized information system on environment of Yamal Peninsula and Baydaratskaya Bay. Proc. Int. Offshore and Polar Eng. Conf. (ISOPE-97), Honolulu, USA, 1:574-581.

Pospelov G.S. 1983. Artificial intellect: modern information environment - Vestnik AN USSR 6:31-42.