Testing the possibility of improving environmental objects representation adequacy, using the remote sensing data and its derivatives in a model of Geographical Information System for Biosphere Reserves

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Abstract - The development of the Information Society results in an ever increasing demand for environmental information exchange. To the best of the author's knowledge, there are not many studies concerning environmental information networks. The data collected in this way (e.g. BRIM or the systems owned by National Parks) did not respond fully to the users needs. For these reasons, the author has undertaken to put forward a model of country-wide Geographical Information System in Poland. Its basic guidelines are as follows: Taking into account the needs of the users of the GIS for Biosphere Reserves. Integrating and standardizing spatial data originating from various existing sources. The system tests proved the possibility of improving the environmental objects representation accuracy. It indicated the special information role played by the image data.

Keywords: Biosphere Reserves, Internet, GIS model, spatial information, image maps, remote sensing data, airborne data.

1. INTRODUCTION

The development of the Information Society results in increasing demand for all kinds of information. Taking it into account European Commission gave out the eEurope 2002 Action Plan and its continuation in the year 2005. It aims to develop modern public services and a dynamic environment for e-business through widespread availability of broadband access at competitive prices and a secure information infrastructure (Annoni, Smits, 2003). Increase of the need for information concerning the environment and nature protection territories, becomes more and more apparent (Boes, 2003), because of their characteristics: functional connection as a elements of spatial environmental structures; the necessity of the global environment monitoring caused by global biosphere changes; increasing need for global research and decision making; the necessity of efficient public environmental education. Mentioned above trends in the Information Society evolution and frequently expressed opinions by the members of the research, tourist and others communities, caused undertaking research concerning the matter of discussion (Adamczyk, 2004).

2. RESEARCH METHODS

The preparation stage preceding the main research was identification of the users needs. The poll was carried out during the years 2002 – 2003. The main groups of potential users taken into account during the study were the people interested in following disciplines: the environment and nature protection research; the monitoring of the environment; education; tourism; broad range of information concerning the state of the biosphere (all the people's need for information); rescue and life saving services; land and protected areas administration; enterprise administration and marketing; other needs.

The next research step was geoinformation market study, with taking into consideration the users needs and the structure and information contents of the wide range of the existing geoinformation systems. The primary objects of the research were the European- and country-wide systems, including: BRIM (Biosphere Reserves Integrated Monitoring Programme) and INSPIRE – ESDI (European Spatial Data Infrastructure) and many polish information systems. The results of analysis can be summarized as follows: None of analyzed systems could be integrally utilized as a system fulfilling the environmental information users needs. In spite of all there are some elements of the GIS in National Parks that could be used in a discussed aspect. There are some characteristics of the systems that cause this situation: not quite full response to the users needs, in particular upon the subject of describing the environmental space; in general those systems are dedicated to the administration needs; there is too high generalization level of the systems content; they are encompassing only very thin fragment of the environmental space, by means of spatial and thematic aspects – the systems were built only within the borders of propertied institution, including only numerical data or one feature of the landscape (e.g. land cover), eventually only base map information; the systems are describing environment by using administrative spatial units (even in the National Parks); there is a lack of digital spatial representation of the data; some initiatives offering only metadata, without the possibility to interactive access to the spatial information; some systems became unfinished or the initiatives don't have continuation or actualization of the database.

As a result it was established that there is a need to delve into the research concerning the methods of developing GIS systems dedicated to the representation of the structure and relationships among the landscape elements. Additional motivation for such research topic was determined by insignificant number of publications concerning this subject. The main hypothesis of the research were: there is the possibility of improving the environmental objects representation adequacy by the internet-available Geographical Information System, using the special methodological approach; such theoretical method can be implemented in a real existing system describing the protected areas in the Poland (and possibly in the other countries). The main research object was the UNESCO Biosphere Reserves Network. In

particular the transboundary area of the Poleski and Shatskyi BR was complied. The Biosphere Reserves special role in development of geographical information systems between the protected areas of the World come from some important reasons: convergence of the main objectives and functions of the MaB UNESCO programme (BRIM, 2001) and the main needs of the Information Society concerning the knowledge about the protected areas; establishing the Biosphere Reserves only for the most valuable and representative ecosystems of the World, with connection into a worldwide network ensuring fullest possible biogeographical cover; the proper, from ecological point of view, spatial organization of areas; having a major role as long-term ecological research and monitoring stations, during the conserving samples of the world's flora and fauna for the benefit of present and future generations; a big number of the biosphere reserves – 459 areas in 97 countries (30-11-2004)., and going to increase.

The research proceeded through the two iterative processes of discussing the new method of improving the environmental objects representation adequacy and creating the proposition of technical solutions, fulfilling in the practice needs of the developed method. As a result of the research Geographical Information System dedicated to the representation of the environmental objects for the Polish Network of Biosphere Reserves UNESCO and other protected areas was created. The system was designed to allow the co-operation with the other information systems on the national (e.g. Integrated System of Environmental Monitoring in Poland) and international levels.

3. THE CONCEPT OF THE BR GIS STRUCTURE

3.1 The method of environmental objects representation

The origin of the key method, determining the structure of the discussed system, is the identification of spatio-temporal and functional characteristics of the landscape. Comparing this with the method of describing and representing the reality with the computer memory, the author developed the rules fulfilling mentioned above objectives of the system and complied it during systems building process (choice from the whole text):

1. Adopting of three dimensions of data completeness: thematical – exhausting the main range of the functional components existing in the landscape; scale – ensuring the full range of representation scales, to view the landscape on different levels of the environment organization; spatial – the spatial range of the information, necessary for the full analysis of the relationships occurring between the ecosystems.
2. Distinguishing between the environmental space data (describing the processes occurring among the ecosystems) and topographical data.
3. Introducing the new concept of environmental reference data – a minimal range of data, that could be used to make full characterization of the landscape and their components.
4. The object oriented approach to elements of the environmental space – related to the integral parts of the landscape analyses in different dimensions and hierarchical levels.
5. The necessity of delivering data on the particular level also for objects too small for cartographic representation.
6. The standardization of the nomenclature describing the environmental space.
7. The visualization under the requisition of different methods, adequate to the character of represented objects and processes, especially using a wide range of image data and 3D effect – for giving the possibly real insight into the topographical situation.
8. Using time series data as a standard – data gathering process planned with comply to comparability of methods.
9. Demand for the high level of quality of GIS data.
10. Making possible to use a wide range of GIS analyses, that are accessible with the Internet interface.
11. The modular structure of the system – referring the functional heterogeneity and different ways of data handling and distribution.
12. The necessity of protecting some kinds of data about the nature objects and phenomenon's.

The presented above list determines the real construction of the BR GIS, throughout its objectives, that were divided into a two parts: ordinary and specific environmental data objectives – complying the peculiarity of the system dedicated to the environmental data meaning.

3.2 The structure of the system

The main functionality of the system is a result of two conditions: specific structure of the environmental data and the system users needs. The whole structure of the system (Fig. 1) is divided into two parts: integration; processing and distribution modules. The system architecture is based on integration of the database and functionality of GIS. The main functionality of the system is realized by the GIS server – processing data delivered by integration module and distribution of processing results. Processing and Distribution Module practically handles data and distributes it to the users by three ways: Internet access – with the personal computers and standard software (web browsers); wireless access – allowing to obtain the geographical information outdoors with the PocketPC-s, telephones and other handhelds, using the standard Web interface and LBS (*Location Based Services*); directly by the file access system – obtaining data as all kinds of files.

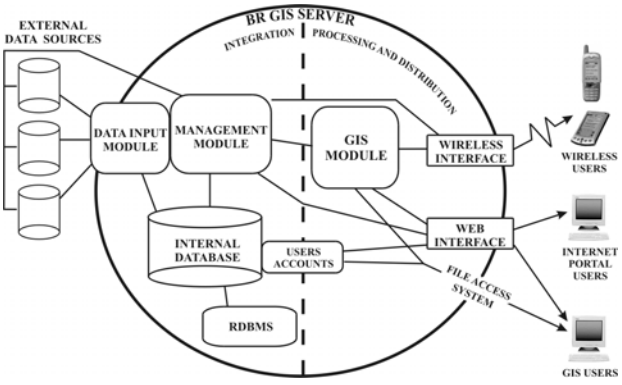

Figure 1 The overview of the Biosphere Reserves GIS structure

3.2 The method of environmental objects representation

Respecting the main topic of this article there is especially interesting method of the integration and handling of the environmental data. The system integrates data provided by a external databases, they, in the future, will serve as clearinghouse systems. The method of storing and handling information can be summarized as adopting the source data structure to the special data handling in the system. The information stored in the system is divided to the: reference- and other data. The reference data is the basis of the structure of the system and their integration into the main schemas of: the scale levels and the information content structure. The scale levels of visualization were divided respecting to the rules of landscape ecology for representation of sequential approximations of the ecosystems organization into 5 levels (Tab. A). The classification is based on the standards established by the National SDI (Bielecka, 2000).

Table A. Description of the scale levels used in the BR GIS

Level	Scale	Description
1	< 1: 1 000 000	international maps
2	1:500 000 – 1:250 000	national maps
3	1:100 000 – 1:50 000	local maps
4	> 1:50 000	particular maps
5	non cartographic level	the objects too small for cartographic representation.

The Entity Relationship Diagram was designed based on the following groups of the integrated reference data: landscape components; nature protection; tourism and recreation; typological classifications; scientific research; thematic maps; image data (satellite and airborne images, 3D visualizations); topographical maps; databases.

The internet portal provides some tools for data handling and visualization. The most important of them are tools allowing parallel visualizing of raster and vector data (examples): fast visualization of a relatively good quality raster data through the efficient compression algorithm (ECW); making any combination from thematic layers allowed by using the Layer Manager; attaching the users-layers to the visualization – making a personalized maps and analyses; personalized thematic profiles – saving results of layer choice; creating of users symbols for vector data and change display mode of raster data – the key feature, which allows parallel visualizing two kinds of data to make more visible some objects and phenomenon's; the GIS Analysis Tool – nowadays there is the possibility to make some operations using vector and attribute data; the raster data analyses seems to make too big load for the servers and takes too much bandwidth (but progress in this field is very fast); the Presentation Creator – allowing to make a printed or WWW presentations from geographical data with addition of any elements e.g. texts, photos, charts.

4. TESTING THE SYSTEM

Testing of the system was performed with a special focus on: The method of information content organization – from the point of view of fulfilling their role in improving the representation of environmental data in: integration process; realization of the main tasks; methods of access limitation.

Practical implementation of the general concept of the BR GIS. The main subject of tests was the possibility of full integration of all kinds of data. From the typological point of view the system uses groups of spatial data: vector, image and other visualization types. The vector data must be integrated into the system using the scheme based on the thematic classification and quality evaluation. The integration of the airborne and remote sensing (image) data was a more effective than the vector and attribute data. Necessary operations were possible to automate e.g. radiometric correction, transformation to the desirable reference system. Integration of the image data was free from the problems related to the transformations of the vector and attribute data – differences and errors in: schema types, symbols and nomenclature. Procedure was much more efficient when the geometric transformations were done. In account of this problems some vector and attribute data were distributed in a source format with detailed information respecting data quality.

Testing realization of the main tasks related to improving the adequacy of environmental objects representation, was performed using following applications of the system:

1. The practical applications – the need of obtaining the data indoor and outdoor for different kinds of real users needs, as e.g. tourism, research activities, forestry.
2. The considering the environmental space from the point of view of landscape components and relationships among them.
3. The possibility of following the phenomenon's in a hierarchical schema (of visualization scales) complying the different levels of the ecosystems organization.
4. Analyzing the data in a spatio-temporal aspect.
5. Visualizations in a 3D model – for obtaining a closest possible insight into a topographical situation.
6. Providing analyses of different kinds of data: statistical and about structure of the landscape.
7. Obtaining the visualization of a objects and phenomenon's on a very particular, non cartographic scale level.

The results of testing process are positive. It affirmed high level of realization above mentioned needs. Thematic schema of the system was evaluated by the users: as proper, giving a large number of possibilities and easy to use. The main thematic information come from the vector data, but it is necessary to complete the contents of the maps with a kind of background data: a layers of topographical maps – often insufficient spatial range and simplification of the information about the real appearance of the terrain; a image data – some image maps* were created. The users affirmed that the practical applications of the image maps are giving a much richer information as the topographical maps. The reason is the possibility of obtaining additional information about

* The term image map is used in the meaning of the satellite or airborne image with additional vector layers, giving together the map-like visualization.

characteristics of the objects, only symbolically represented with the traditional maps. The additional advantages of using image data instead of the topographical layers is to having following possibilities:

1. Delivering quite full information about the environment and topographical objects in spite of the lack of data in the thematic aspect or spatial cover.
2. A possibility of obtaining several kinds of information about the character of objects not covered by the environmental classifications stored by the vector data – by using different kinds of color compositions.
3. A possibility of free interpretation of the environmental space not determined by the subjective approach of the specialist preparing the data.
4. Allowing the transboundary analyses of environment because of their continuous character, also the image data can be used as a reference for data integration.
5. The cost of delivering image data is relatively low in comparison with the process of creating vector data. That advantage plays a special role in the aspect of making time series of data.
6. The more automatic process of integration can ensure a higher level of data quality (e.g. in geometrical aspect).

Despite of described above advantages of using the image data, there are some conditions and problems to solve during the process of building the system:

1. The image data is more difficult in interpretation and is recommended for advanced users. For ordinary users the system should contain a broad range of the thematic layers giving the interpretation of the objects and phenomenon's. But also in this case image data should be used as a background, supplementing the map information.
2. The parallel using of vector and raster data cause the necessity of developing the system of generating custom map symbols for vector data (changing symbols, colors and making transparent polygons).
3. The comparability of contents of the images collected in the different terms is determined by the techniques of registration and radiometric characteristics. The vector data created by stable technique are dependent from the subjectivity of interpretation done by the specialist.
4. The proper visualization of data, from cartography point of view, is easier to attain using the vector model. For creating the image map more advanced cartographic skills are needed.
5. Nowadays the main weakness of the image method is caused by a big processing power involved to a operations with a raster data, being the reason of limitations of possibility to offer the raster data analyses through the Internet. Predictions are that this factor will be less essential in the future.

It is not a main goal, of description of advantages and problems of raster and vector data systems, to make a choice between them. Fundamental role of both kinds was proved and there is essential need to use two types of data parallel in the role of: background – for images and thematic data – for vector layers.

5. CONCLUSIONS

The results of testing the functionality and capabilities of the system proved the possibility of improving environmental objects representation adequacy, using the remote sensing data and its derivatives in a model of Geographical Information System for Biosphere Reserves. The information schema and the method of data organization allow to satisfy the most users needs concerning the knowledge about environment of protected areas. The special role in fulfilling this task plays the image data. In the past this kind of data was often underestimated, but described above tests proved the usefulness of image map method. The main advantage of the image maps is making the visualization much more complete.

There are some important ways for the future research regarding to the image maps:

1. Supplementing shortage of the data by a progress in a building the vector database encompassing larger and larger areas and integration from the research documentation – possibly one of the most valuable sources of environmental data.
2. Solving the problem of Internet access to the spatial data analyses – according to the main trend in the development of the geoportals called "thick server – thin client".

Being conscious of the impossibility of giving the ideal projection of environment using the geographical information systems, author believes, that the further research and progress in the technical possibilities, will allow the continuation of improving the adequacy of the representation of environmental objects.

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