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Automated Management of Biotechnosphere of Local Urban Areas

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Abstract: The study analyzes the current problems related to the management of biotechnosphere condition and relevant environmental situation in the local urban areas. We study the approaches to the construction of the automated control systems, the structure and functions of which will ensure operational efficiency, scientific validity and effectiveness of managerial decisions in the sphere of environmental safety, a real change in the environmental situation. The structure the considered ACS contains the environmental situation center, within which the integrated subsystems of intelligent monitoring and intelligent support of decision-making function, providing immediate transformation of the monitoring data into the productive management scenarios.

Key words: Automatic control, biotechnosphere, local urban areas, support of decision-making, intelligent monitoring, forecasting

INTRODUCTION

The most important component of the national security of any of the modern states is the environmental safety of its territories of different purposes. Local urban areas should be highlighted because the quality of their natural environment has a significant impact on people's health and life-sustaining activity. Thus, the ecological situation in the yard areas of multi-storeyed residential complexes and built-up urban-rural areas determines the level of safety of the most vulnerable part of population: children, adolescents and the elderly.

Today there is no country which would neglect the problems of ecological safety. One of the main ways to reduce and prevent the occurrence and development of man-made and natural environmental risks-an active measure is the creation of effective monitoring systems, forecasting and management of environmental safety, the work of which is based on extensive use of automation and advanced methods of information technologies. However, it should be noted that even in cities where such systems with an extensive network of stationary and mobile stations provided with modern sensors and tracking devices that use GIS and aerospace technologies and simulate the spread of pollution in space operate, there is no essential improvement of the ecological situation. The main problems to be defined are:

In existing systems the issues of collection, processing, storage and transmission of data (Batzias and Siontorou, 2007; Morselli *et al*., 2002; Athanasiadis and Mitkas, 2004; Ballagour *et al*., 2012) are resolved to the fullest extent possible and the issues of decision-making support-only fragmentary. The latter should be based on appropriate forecasting (short, medium and long-term), construction and implementation of information and situational models and what is really essential on provision of possibility of the immediate transformation of environmental monitoring data into management scenarios (with their further assessment and recommendations for updating).

No integral assessment (including forecasting) of the environmental situation as a whole is carried out, i.e. of the aggregate of the various components of biotechnosphere. The models and methods used in existing systems of environmental monitoring and management allow us to estimate the change of only the individual components of the natural environment. This seriously affects the selection of controlling actions since the implementation of one and the same measure can improve the quality of one of the natural components, thus negatively affecting the others.

Tools as well as payment instruments of the systems under consideration are not used for estimation and forecasting of ecological situation development in the aforementioned local urban areas.

PROBLEMS STATEMENT

Researchers set the task of modeling the Automated Control System (ACS) of biotechnosphere condition of local urban areas. The main requirement for such ACS providing support and implementation of objective, highly efficient (in terms of operational efficiency, environmental and economic efficiency, resistance to the

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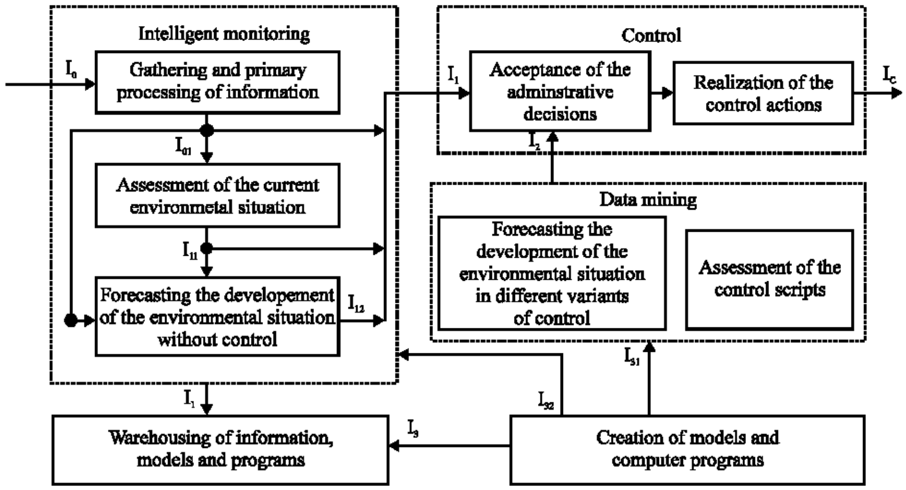

Fig. 1: Functional model of intelligent ACS of biotechnosphere condition of local urban areas

dynamics of the environment) management decisions to prevent and reduce (eliminate) the environmental risks. Basic principles of construction of the system being modeled:

- Priority ranking of environmental protection and people's life and health to the other economic and social goals and objectives
- Correspondence of the objectives of the system (all its subsystems) to the targets of upper systems for example, the objectives of the intellectual system of city management, etc.
- Versatility of the system model, the completeness and adequacy of the analyzed information, adaptability and mobility of the system, the speed of decision-making
- Scientific validity of management decisions
- Identification of causal relationships

The structure of ACS of biotechnosphere condition of local urban areas will be determined by both the above mentioned requirements and principles and the system functions which implement them. Figure 1 shows the functional model of ACS where I_0 is information about the parameters characterizing the state of the biotechnosphere condition of the considered local urban areas (yard, rural-urban, etc.) which is collected by ACS on the basis of the work of stationary and mobile control stations, the earth remote sensing instrument; I_{01} is processed information; I_1 ($I_1 = \{I_{11}, I_{12}\}$): the results of the primary evaluations (I_{11}) and forecasts (I_{12}) development of the existing biotechnosphere and related environmental situation; I_2 is results of forecasting the development of biotechnosphere condition and related environmental situation during the implementation of various control actions as well as assessment of the effectiveness of management scenarios; I_3 ($I_3 = \{I_{31}, I_{32}\}$): model generated by the system for evaluation and forecasts (I_{31} is models generated for intelligent environmental monitoring and I_{32} is for intellectual data analysis as well as formation and evaluation of effectiveness of management scenarios); I_C is management scenarios chosen for implementation.

Based on the above scientific analysis and functional model the following basic functions of the system which provide immediate transformation of the environmental information into productive control actions to reduce/eliminate the negative man-made effects on the environment, health and life-sustaining activity of the population in local urban areas are revealed:

- Automated acquisition and preliminary processing of the data
- Estimation of the parameters characterizing the biotechnosphere
- Integral assessment of the current environmental situation
- Forecasting changes in the biotechnosphere condition and related environmental situation without implementation of control actions
- Accumulation and storage of data and models
- Development of the rules how to use data and models
- Formation of situational, mathematical and information models for estimations and forecasts of various levels
- Computer programs development and simulation

- Forecasting the development of biotechnosphere condition and related environmental situation during the implementation of control actions
- Formation of management scenarios
- Development of management decisions and implementation of control actions
- Integral assessment of the efficiency of the control actions implementation
- Development of recommendations for selection of the most efficient management scenario
- Providing all interested people with the results using GIS technologies
- Management of the internal structure of the system and subsystems
- Ensuring interoperability of subsystems

The implementation of the system which corresponds to the functional model in Fig. 1 is possible on the basis of the approaches to development of environmental safety ACS on the territories stipulated by Ivashchuk *et al.* (2014a-c). However, the development of the structural model will be changed fundamentally. Thus, in the mentioned studies the environmental monitoring system is considered as a separate subsystem while in the proposed model it will be an integral part of the ACS subsystem which carries out the support of management decision-making: Environmental Situation Centre (ESC), simultaneously. The center's functioning is related to both data acquisition and mandatory data processing for their transformation into specific management scenarios.

MAIN PART

So, the basic component of ACS of biotechnosphere condition of local urban areas ESC will combine the operation of two major subsystems: intelligent monitoring and intelligent support of decision-making. Let us consider the fundamental differences of the intelligent monitoring subsystem functioning. Detailed aggregate of its functions is shown in Fig. 2.

This component of ACS is provided with both traditional functions of data acquisition and processing which similar modern systems of monitoring have and functions of preliminary evaluation which were introduced for organization of the functioning of such systems in the framework of updating ACS of environmental safety based on the methodology (Ivashchuk *et al.*, 2014a; Ivashchuk and Ivashchuk, 2013) and also the following intelligent functions: integral model assessment of biotechnosphere condition and environmental situation in general in the local urban area.

Immediate preliminary forecast of changes in the quality characteristics of the environment without the implementation of control actions which provide the intellectualization of the monitoring process and are the primary basis for the rapid development of effective control actions to reduce the negative effects of man made objects on the environment and control of biotechno sphere condition of the territory being considered. To implement these functions it is necessary to provide the monitoring subsystem with the appropriate models of assessment and forecasting which are generated in the subsystem of intelligent support of decision-making.

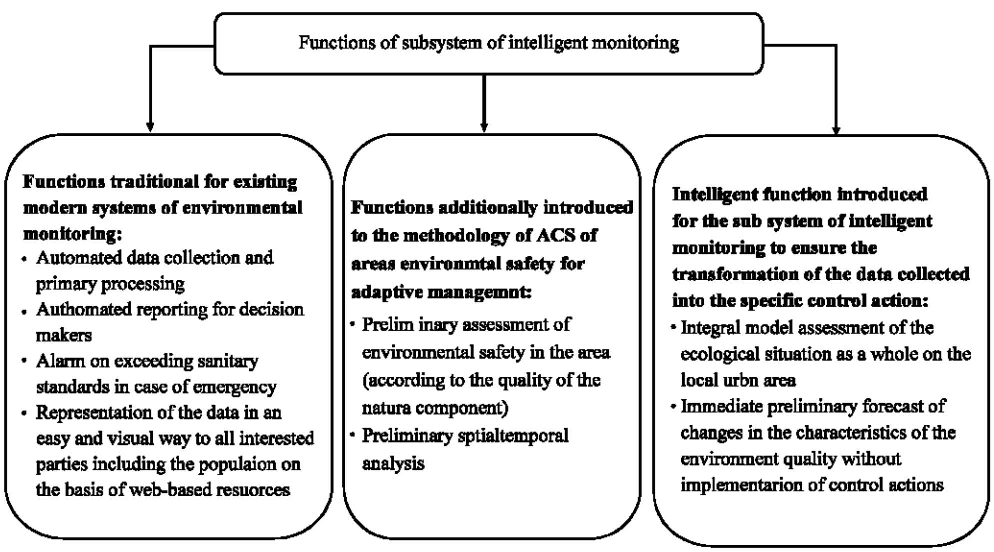

Fig. 2: Specification of functions of intelligent environmental monitoring subsystem

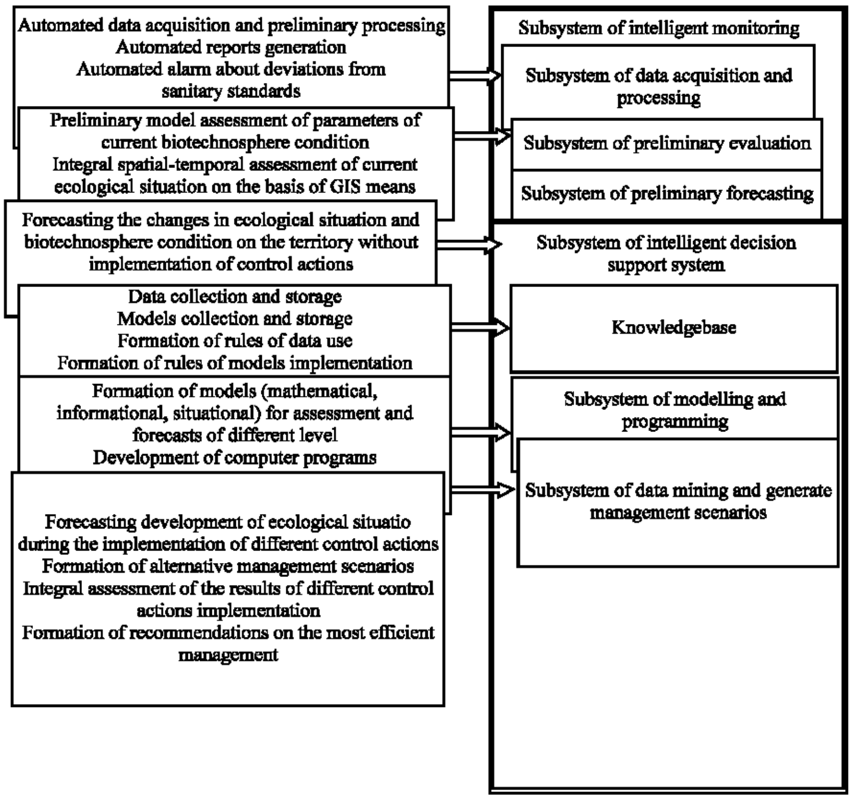

Fig. 3: Functions and ESC sub-systems updating them

Concerning the traditional functions of automated data acquisition and processing in monitoring sub-system it should be emphasized that it is necessary to use both instrumental and computational methods which are implemented with the help of specialized stationary and mobile laboratories and Earth Remote Sensing data (ERS). Earth remote sensing data can be used in the circumstances when surface methods of examination are impossible as well as for acquisition of general space-distributed picture that reflects the current environmental situation and the prospects for its development.

The resachers developed a technique of sustainable recovery of satellite images with high resolution obtained in the optical range while sharpening the images (Ivashchuk and Shcherbinina, 2014). Distinctive features of this method are as follows: increasing the contribution of the high-frequency components in the spectrum of the image with simultaneous overcoming the effects of too much contrast; implementation of evaluation of the compensation parameters of point spread function influence which is the main characteristic that describes the structure of animage transmission by optical system; adaptation of the restoring operator by defining the parameters directly on the image. For effective implementation of the functions of data acquisition on the basis of Earth remote sensing the researchers developed a specialized computer system.

Figure 3 shows the correspondence between the basic functions which are identified on the basis of the analysis of modern requirements to the process of management of biotechnosphere condition and environmental situation and the subsystems of ESC which update them. Figure 4 presentes the structual model ESC as an intellectual system of monitoring and dicission support.

The set X includes specific parameters that characterize the formation of certain condition of biotechnosphere and environmental situation in the local urban area under consideration. Their choice depends on the specific structure of the management object of ACS being considered.

Result parameters (components of the set Y) results of evaluation of biotechnosphere conditions and environmental situation generated under these factors of natural and man-made impact, the external environment impact as well as according to the results of the implementation of control actions; results of the forecasts

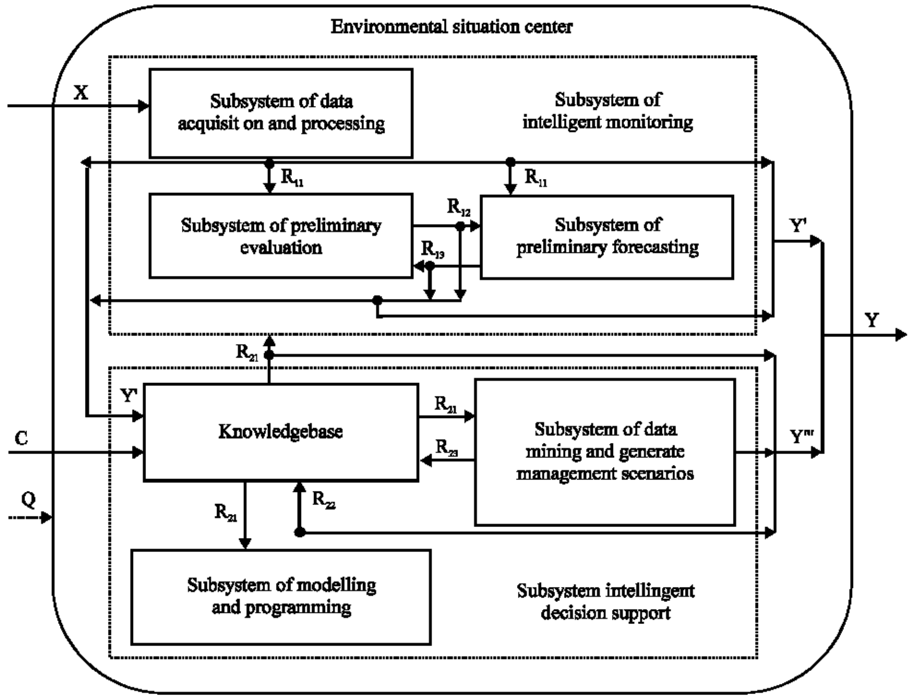

Fig. 4: Structural model of ESC

for the environmental situation development and the emergence of environmental risks; management scenarios and their evaluation.

They come from ESC to the controlling subsystem of ACS whereby the formation of management decisions and the implementation of specific control actions are carried out in the subsystem. The inner contours of management generated by them are considered above. The diagram shows the following components of the set R (parameters of ESC subsystems conditions).

R_{11} is belongs to the subset that characterize the condition of data acquisition and processing subsystem and its components the observation data and the results of evaluations and preliminary forecasts which are used for both traditional transmission of information about the current biotechnosphere condition to all interested parties and for the integrated intelligent analysis (within the monitoring subsystem and decision-making support subsystem).

R_{12} and R_{13} is belong to the subsets that characterize the condition of the subsystems of preliminary assessment and preliminary foreseeing, respectively their components-the results of integral assessment of the current environmental situation and its forecast without the implementation of control actions under varying parameters of the impact of the external environment.

R_{21} is belongs to the subset, characterizing the knowledge base in decision support subsystem. Its components-data, models, software, information which includes necessary data for intelligent monitoring and integral data analysis their results as well as formulated rules for mathematical, computer and situational modelling, program development, etc.

R_{22} is mathematical, informational, situational models, electronic maps and computer programs generated in the subsystem of modelling and mathematical programming.

R_{23} is the results of intelligent data analysis subsystem coming for storage and use: forecasting (short-medium-and long-term) of the environmental situation development during the implementation of various ways of management, the formation of management scenarios, various types of evaluations of these scenarios and their effectiveness from the point of their speed, environmental and economic efficiency, resilience, development of recommendations for their implementation. $R = \{R_{11}, R_{12}, R_{13}, R_{21}, R_{22}, R_{23}\}$, $Y' = \{R_{11}, R_{12}, R_{13}\}$, $Y'' = \{R_{21}, R_{22}, R_{23}\}$, $Y = \{Y', Y''\}$.

CONCLUSION

Synthesis of ESC comprising both monitoring subsystem (provided with traditional intellectual functions as well as the possibility to collect data on the basis of different sources, including remote sensing) and intelligent subsystem of decision-making support as their integral parts will allow us to provide an effective solution to the problem of fragmentation of monitoring data and the process of development and implementation of management. These observations will be directly transformed into possible management scenarios with the evaluation of their effectiveness.

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