COMPLEX OBJECTS REMOTE SENSING MONITORING AND MODELING FOR PORT MARITIME MANAGEMENT

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ABSTRACT

In this paper the concept of integrated modeling and simulation the processes of the Complex Technical – Organizational System (CTOS) is presented. The main goal of the investigations consists of the practice of the predetermined modeling. The practice direction as the remote sensing ecological monitoring and inventory of the port maritime objects is proposed by the authors.

Here the methodical foundations of the integrated modeling and simulation, the process of CTOS operation, the technology of the remote sensing ecological monitoring are considered. Principal concern is attended to the continuity of the model and object solving practical issues. More over results of CTOS remote sensing monitoring make it possible to adapt models of this system to changing environment conformably to maritime port management.

Keywords: complex technical–organizational system, control process, simulation model, processing of the space, airborne and ground measurements.

1. INTRODUCTION

In practice the processes of CTOS operation are non-stationary and nonlinear. The perturbation impacts initiate the CTOS structure-dynamics and predetermine a sequence of control inputs compensating the perturbation. In other words we always come across the CTOS structure dynamics in practice. For example, monitoring of the port maritime ecological situation or actualization the port object infrastructure is considered. There are many possible variants of CTOS structure dynamics control (Ohtilev et al., 2006).

In this paper we propose the practice of the predetermined modeling where CTOS is a Remote Sensing ecological monitoring. Earlier various combinations of the analytical and simulation models were considered at the conferences with the similar theme (EUCASS 2005, Vena 2012, Aalesund 2013).

We can present the modified multiple-model multi-criteria description of CTOS problems:

$$J_\theta(\vec{x}(t),\vec{u}(t),\vec{\beta},\vec{\xi}(t),t) \to \underset{\vec{u}(t)\in\Delta_\theta}{extr}, \tag{1}$$

$$\Delta_\Theta = \left\{\vec{u}(t) \mid \dot{\vec{x}}(t) = \vec{\varphi}_\Theta(T_0,\vec{x}(T_0),\vec{x}(t),\vec{u}(t),\vec{\xi}(t),\vec{\beta}_\Theta,t)\right\}, \tag{2}$$

$$\vec{y}(t) = \vec{\psi}_\Theta(\vec{x}(t),\vec{u}(t),\vec{\xi}(t),\vec{\beta}_\Theta,t), \tag{3}$$

$$\begin{gathered}\vec{x}(T_0) \in X_0(\vec{\beta}_\theta), \vec{x}(T_f) \in X_f(\vec{\beta}_\theta),, \\ \vec{u}(t) = \| \vec{u}_{pl}^T(t), \vec{v}^T(\vec{x}(t),t) \|; \\ \vec{u}_{pl}(t) \in Q_\theta(\vec{x}(t),t); \\ \vec{v}(\vec{x}(t),t) \in V_\Theta(\vec{x}(t),t); \\ \vec{\xi}(t) \in \Xi_\Theta(x(t),t); \vec{\beta}_\Theta \in B; \vec{x}(t) \in X(\vec{\xi}(t),t);\end{gathered} \tag{4}$$

$$\vec{\beta}_\Theta = \| \vec{\beta}_0^T \vec{w}^T \|^T; \vec{w} = \| \vec{w}^{(1)T}, \vec{w}^{(2)T}, \vec{w}^{(3),T} \|^T \tag{5}$$

The formulas define a dynamic system describing CTOS structure-dynamics control processes. Here $\vec{x}(t)$ is a general state vector of the system, $\vec{y}(t)$ is a general vector of output characteristics. Then, $\vec{u}(t)$ and $\vec{v}(\vec{x}(t),t)$ are control vectors. Here $\vec{u}(t)$ represents CTOS control programs (plans of CTOS functioning), $\vec{v}(\vec{x}(t),t)$ is a vector of control inputs compensating perturbation impacts

$\vec{\xi}(t)$). The vector $\vec{\beta}_{\Theta}$ is a general vector of CTOS parameters. According to [3], these parameters can be divided into the following groups (Skurihin V.I., Zabrodsky V.A., Kopeychenko Yu.V., 1989):

– $\vec{w}^{(1)}$ is a vector of parameters being adjusted through the internal adapter. This vector consists of two subvectors. The first one $\vec{w}^{(1,n)}$ belongs to the scheduling model, and the second one $\vec{w}^{(1,p)}$ belongs to the model of control at the phase of plan execution;

– $\vec{w}^{(2)}$ is a vector of parameters being adjusted through the external adapter. This vector consists of the subvector $\vec{w}^{(2,n)}$ belonging to the scheduling model and the subvector $\vec{w}^{(u)}$ including parameters of simulation model for CTS functioning under perturbation impacts. In its turn, $\vec{w}^{(u)} = \| \vec{w}^{(2,o)\mathrm{T}}, \vec{w}^{(2,b)\mathrm{T}}, \vec{w}^{(2,p)\mathrm{T}} \|^{\mathrm{T}}$, where $\vec{w}^{(2,o)}$ is a vector of parameters characterizing objects in service; $\vec{w}^{(2,b)}$ is a vector of parameters, characterizing the environment; $\vec{w}^{(2,p)}$ belongs to the model of control at the phase of plan execution;

– $\vec{w}^{(3)}$ is a vector of parameters being adjusted within structural adaptation of CTS SDC models.

The vector of CTOS effectiveness measures is described as (6).

$$\vec{J}_{\Theta}(\vec{x}(t),\vec{u}(t),\vec{\beta},\vec{\xi}(t),t) = \| \vec{J}^{(g)T}, \vec{J}^{(0)T}, \vec{J}^{(k)T}, \vec{J}^{(p)T}, \vec{J}^{(n)T}, \vec{J}^{(e)T}, \vec{J}^{(c)T}, \vec{J}^{(v)T} \| \quad (6)$$

Its components state control effectiveness for motion, interaction operations, channels, resources, flows, operation parameters, structures, and auxiliary operations (Okhtilev et al., 2010, Ivanov et al., 2010, 2012). The indices «*g*», «*o*», «*k*», «*p*», «*n*», «*e*», «*c*», «*n*» correspond to the following models: models of order progress control ($M_{<g,Q>}$); models of operations control ($M_{<o,Q>}$); models of technological chains control ($M_{<k,Q>}$); models of resources control ($M_{<p,Q>}$); models of flows control ($M_{<n,Q>}$); models of operations parameters control ($M_{<e,Q>}$); models of structures control ($M_{<c,Q>}$); models of auxiliary operations control ($M_{<n,Q>}$). In (5) the transition function

$$\vec{\phi}_{\Theta}(T_0,\vec{x}(T_0),\vec{x}(t),\vec{u}(t),\vec{\xi}(t),\vec{\beta}_{\Theta},t)$$

and the output function $\vec{\psi}_{\Theta}(\vec{x}(t),\vec{u}(t),\vec{\xi}(t),\vec{\beta}_{\Theta},t)$ can be defined in analytical or algorithmic form within the proposed simulation system; $Q_{\Theta}(\vec{x}(t),t), V_{\Theta}(\vec{x}(t),t), \Xi_{\Theta}(\vec{x}(t),t)$ are correspondingly allowable areas for program control, real-time regulation control inputs, perturbation inputs; B is a area of allowable parameters; $X(\vec{\xi}(t),t)$ is an area of allowable states of CTOS structure-dynamics. Expression (4) determines end conditions for the CTOS state vector $\vec{x}(t)$ at time $t = T_0$ and $t = T_f$ (T_0 is the initial time of a time interval the CTOS is being investigated at, and T_f is the final time of the interval). In our paper the proposed multiple-model multi-criteria description of CTOS will be used for port maritime management.

2. PROBLEM STATEMENT

Nowadays the theory, methods and techniques concerning the application of mathematical models are wide used. Nevertheless such problems as a quality estimation of multi-criteria models, an analysis and classification of applied models, as well as justified selection of task-oriented models are still not well investigated. The importance of the problem increases when a research object is described not via a single model, but with a set or a complex of multiple-models including models from different classes or combined models such as combined analytical–simulation models, logical-algebraic ones, etc.

In the solution of problems of modeling of complex objects $Ob^{op}_{<>}$ (in our case we investigate complex objects remote sensing processes and systems), the problems of providing a required adequacy of the results and controlling the quality of models and the modeling processes is of special importance. It is obvious that, using the model (or multiple-models) $Ob^{m}_{<>}$ in practical investigations, we should evaluate its adequacy each time relative to $Ob^{op}_{<>}$. The reasons for inadequacy may be inexact source prerequisites in determining the type and structure of the models, measurement errors in testing, computational errors in processing sensor data, etc. (Ohtilev et al., 2006). The use of inadequate models may result in considerable economic loss, emergency situations, and failure to execute tasks posed for a real system.

For definiteness, following (Ohtilev et al., 2006), we consider two classes of modeled systems. By the *first class*, we refer to those systems with which it is possible to conduct experiments and to obtain the values of some characteristics by measuring. We refer to the *second class* of modeled systems, for which it is impossible to conduct experiments (according to the technique presented in Figure 1) and to receive the required characteristics. Large-scale economic and social systems and complex technical systems that function under essential uncertainty of the effect of the external environment are examples of these systems. The human factor plays an important role in these systems (organization structures).

Figure 1 presents the generalized technique for estimating and controlling the quality of models of objects of the first class.

In this figure, we take the following notation: 1, for forming the goals of functioning of $Ob^{op}_{<>}$; 2, for determination of input actions; 3, for setting goals of modeling; 4, for the modeled system (objects $Ob^{op}_{<>}$) of the first class; 5, for the model ($Ob^{m}_{<\theta>}$) of the investigated system $Ob^{op}_{<>}$; 6, for the estimation of the quality of a model (poly-model system); 7, for controlling the quality of models; 8, for controlling the parameters of models; 9, for controlling the structures of models; and 10, for changing the concept of model description.

All complex technical – organizational systems (including complex objects remote sensing processes and systems) working in an autonomous mode are examples of systems of the first class.

Let us show possible implementation proposed technique of estimation and control of models quality for applied area which is connected with Earth Remote Sensing Monitoring.

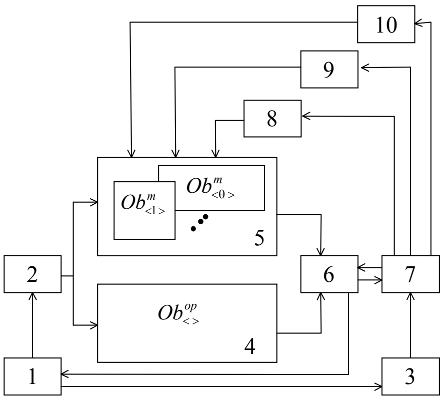

Figure 1: The generalized technique of estimation and control of the quality of models of the first class

The ecological monitoring of the environmental conditions is one of the primary ranges of the space imagery application. The monitoring of the pollutions at the three main nature environments (Water, Land surface and Atmosphere) is provided on the local, regional and global levels. The quality of the adaptations of the management decisions is increased as a result of the Remote Sensing monitoring. These adaptations are directed to the maintenance of the ecological safety of the research site and optimization of the events of the elimination of the disturbances consequence. The executor of the project aims to obtain required information with high quality and minimum cost. The effectiveness of the project depends of the source data quality (Remote Sensing data), methodical approach, software and the presentation of the project results. The integrated modeling of the basic technological processes of the Remote Sensing monitoring is realized for making the synthesis of the technical requirements for the hardware-software.

The framework of the main technological processes of the Remote Sensing monitoring is presented (fig. 1). With regard to technical characteristics of the space monitoring and facts influencing to these characteristics it demands to choose in the capacity of the source data one or some space vehicles and/or the airborne equipment complex, to choose an optimal conditions for the survey conducting base on the seasonal and daily variability of the reflectance and radiative characteristics of the landscapes and mode of operation of equipment, to organize the thematic treatment of the Remote Sensing data and the ground measurements using hardware-software, to present the results of the project in the user-friendly form permitting to make a management decisions promptly and reasonably.

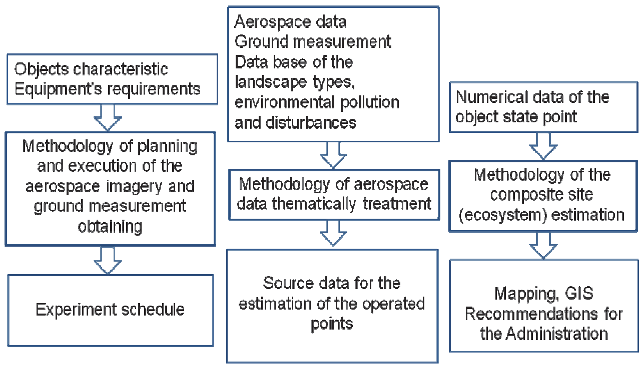

Figure 2. Framework of the methodology of the space monitoring data applying

Nowadays scientific and practical issue of the synthesis of the space monitoring components requirements is solved on the base of the modeling and simulation, the system parameters determining and expert analysis of the prospect of application solutions (see formula (2)).

The modeling and simulation of the technological processes has some uncertainty and limitations that influence to the quality of the optimization task (the vector $\vec{\beta}_{\theta}, \vec{u}_{pl}(t)$).

The CTOS has the following sources of information as space imagery in the visible, infrared and super high frequency spectral bands, airborne imagery, pilotless vehicle imagery and test ground measurements for the verification of the results of the imageries thematic treatment.

The execution of the space ecological monitoring and an actualization of the port object infrastructure consists of the some stages. Firstly, it is the planning and preparation of the works (the vector $\vec{w}^{(1,n)}$ and $\vec{u}_{pl}(t)$). This stage includes the choice of the objects, the list of controllable parameters determining and scheduling of the survey.

Secondly, it is the data acquisition. The stage includes the process of survey and ground-based measurement (the vector $\vec{w}^{(1,p)}$).

The name of the third stage is the processing of the data and presentation of the results. The treatment of the Remote Sensing data and ground measurement, creation of the thematic layer of the digital map, forming the forecast models, calculation of assessments and recommendations are executed (the vector $\vec{w}^{(u)}$).

The most convenient form of the project results presentation is the thematic layers of the digital map with the attributive information and database and photo scheme as raster image.

Moreover, it is possible to estimate the system functioning quality and the choice of the optimal monitoring conditions for the demand imagery quality obtaining. The prediction is accomplished on basis of the optical system taking into account the monitoring conditions and provides for a qualitative result. The spatial resolution of the image forms the main predictive parameter and determines as an object-background contrast value.

The movement of equipment, the Sun height, irradiance of the object, albedo of the site, physical specifications of the atmosphere is taken into account.

Accordingly, the modeling and simulation of the private elements of the space monitoring system and expert evaluations of the system functioning determine the values of the parameters of the space monitoring system functioning.

3. THEMATIC PROCESSING OF THE SPACE IMAGERY

Thematic treatment of the Remote Sensing data is the key link in the system of the space monitoring and inventory of the port objects. Generally the primary and secondary treatments are applied. The operations are done based on the modeling and simulation in automatic mode supported by the expert's knowledge.

The experience of the thematic treatment of the many and hyperspectral data with the high spatial resolution defined some important factors. One of them is the data presentation with the automatic identification of the test sites for algorithm training and adaptation. The next one is the complex treatment of the source many(hyper)spectral and temporal Remote Sensing data and ground measurements. Third factor is the data results calibration and validation and optimal application of the spectral features data base of the landscape elements with reference to seasonal and daily variability. Lastly, the organization of the distributed access to the data is exchanged on the base of the special portals, geographic informational system capability and crowd sourcing.

The informational flow rises and the necessity of the integrated modeling is determined. At that the qualitative and quantitative requirements are increased.

Commonly the main steps of the thematic treatment of the Remote Sensing data are designated for the qualitative solution of the integrated modeling task:

Phase 1. Input data array (block 3, fig.1)

- Step 1.Optimal survey parameters;
- Step 2. Change reflective and radiative settings of the landscape elements in seasonal and daily variability;

Phase 2. Data acquisition and treatment

- Step 1. Imager radiometric correction and calibration;
- Step 2. Imagery geometric correction;
- Step 3. Maintain of the system of initial data relative to the reflective and radiative characteristics of the landscape elements;
- Step 4. Combination of methods and algorithms of the thematic treatment (cluster analysis, Fourier analysis, method of principal components, classification algorithms and others) (blocks 8 and 9, fig. 1);
- Step 5. CTOS modeling and simulation on the base of the expert's knowledge (blocks 1 and 3, fig. 1);
- Step 6. Analysis of the situation dynamic based on the multi-temporal Remote Sensing data treatment (block 6, fig. 1);
- Step 7. Predictive modeling of the step 5 results influence to ecological situation (block 5, fig. 1);
- Step 8. Crowdsoursing through the geo-informational portal application (blocks 1,3 and 4, fig. 1);
- Step 9. Automatic environmental assessment in the space ecological monitoring network (blocks 6 and 7, fig. 1);

Phase 3. Creation of the thematic layers and attributive information of the monitoring.

Analysis of the main trends for modern systems of the space monitoring indicates their peculiarities such as: multiple aspects and uncertainty of their behavior, hierarchy, structure similarity in the detection and recognition of the landscape elements, redundancy from the source data and variety of implementations for control functions. One of the main features of modern systems of the space monitoring is the variability of their parameters and structures due to objective and subjective causes at different phases of the system life cycle. In other words we always come across the system structure dynamics in practice.

4. EXAMPLE

Example demonstrates the integrated modeling and simulation of the CTOS described as the system of the space monitoring and inventory of the port maritime objects.

The integrated modeling and simulation application to the data collection, treatment and results presentation of the space monitoring and inventory of the port maritime objects determines the source of the data requirements, the monitoring frequency and efficiency.

A waters and territory of the maritime port are the complex objects. The state of these objects is described by simulation model based on the space imagery infrastructure.

An actual practice issues are resolved based on the space monitoring: the inventory and zoning of the waters, territory and port objects; a map and scheme actualization; the turnover of goods control; the ecological monitoring of the waters and territory of the port maritime; detection of the sources of the negative impact to environment.

The maritime, airborne, space and ground measures are used during the infrastructure monitoring.

On the base of the thematic treatment of the Remote Sensing data the tasks for the port maritime management are tested. CTOS is presented as original software for oil water pollutions, the dumps and garbage contamination, the vegetation stress identification and the actualization of the port objects inventory information. CTOS consists of the input RS data (block 3, fig.1), automatic RS data processing (blocks 1,3,4,5-9, fig.1) and results. The perturbation influences are presented by the control model parameters, that can be evaluated on the real data available in CTOS and parameters that can be evaluated via simulation models for different scenarios of future events.

Evaluated model parameters from block 3 include:

- type of the satellite system, above all spectral and spatial resolutions;
- square of the analyzable part of the maritime port waters and territory;
- square of the processing area of the space image.

Evaluated model parameters from blocks 1,3,4,5-9 include:

- threshold of some vegetation indexes;
- method of the classification, furthermore number of classes, distance function;
- method of the reclassification;
- threshold of the entropy;
- minimum inventory object dimension;
- minimum water and ground pollution dimensions;
- spectral radiance values from database.

Results include oil pollution, ship bilge water (fig. 3), dumps, stress vegetation outlines and actual data base of the characteristics of the port objects (fig. 4, 5) in geographic informational system.

Consequently, the method of the estimation and control of the models organization is determined.

Examples of the Remote Sensing monitoring and inventory of the port maritime objects are being illustrated on the website of the ESTLATRUS projects 1.2./ELRI-121/2011/13.

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Figure 3. Remote sensing identification of the ship bilge water

Figure 4. Inventory of the maritime port depositories based on the remote sensing data treatment

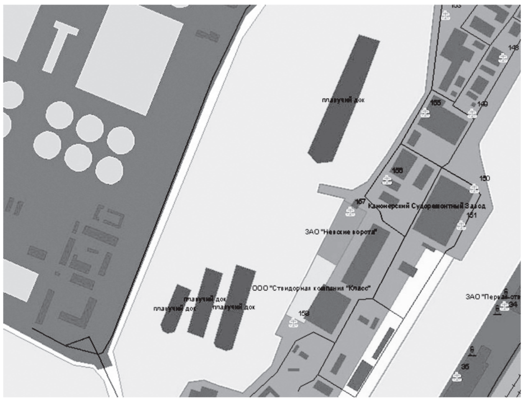

Figure 5. Inventory of the maritime port wet/dry docks based on the remote sensing data treatment and geoinformational system

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