STRUCTURE ADAPTATION OF MODELS DESCRIBING SCHEDULING PROCESSES IN COMPLEX TECHNICAL-ORGANIZATIONAL SYSTEMS (CTOS)

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ABSTRACT

In this paper, a dynamical multiple criteria model of integrated adaptive planning and scheduling for complex technical – organizational system (CTOS) is presented. Various types of CTOS are used nowadays, for example: virtual enterprises, supply chains, telecommunication systems, etc. Hereafter, we mostly interpret CTOS as the systems of the above-mentioned types. The above-mentioned CTOS peculiarities do not let produce an adequate description of control processes in existing and designed CTOS on a basis of single-class models. That is why the concept of integrated modeling and simulation that was proposed by the authors can be useful here. Possible directions of its realization were considered in their papers and books (Okhtilev et al.,2006, Ivanov et al., 2010).

Here we consider two general actual problems of the CTOS structure-dynamics investigation: the problem of selection of optimal CTOS structure-dynamics control programs at different states of the environment; the problem of structural adaptation of models describing CTOS structure-dynamics control programs.

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. There are many possible variants of CTOS structure dynamics control (Ohtilev et al., 2006).

In this paper we propose new approach to the problem of structure adaptation of models describing CTOS structure-dynamics program control. Existence of various alternative descriptions for CTOS elements and control subsystems gives an opportunity of adaptive models selection (synthesis) for program control under changing environment.

Mathematical research of control processes in CTOS can be divided into three primary approaches: optimization, simulation, and heuristics. Optimization is an analysis method that determines the best possible method of designing a particular complex system. Earlier literature presents several optimization-based approaches to CTOS operation planning and scheduling. For instance, (Ivanov et al., 2010) have applied integer programming in supporting partner selection. (Ip et al., 2004) presented a branch and bound algorithm for subcontractor selection in agile manufacturing environment.

Simulation is imitating the behaviour of one system with another. By making changes to the simulated adaptive supply chains (ASC), one expects to gain understanding of the ASC dynamics. Simulation is an ideal tool for further analyzing the performance of a proposed design derived from an optimization model. Regarding the ASC complex adaptive systems (CAS) and multi agent systems (MAS) are one of the most popular simulation techniques (Swaminanthan et al. 1998; Rabelo et al., 2002). The past research on utilization of the MAS to the ASC have been mostly dealing with agent based frameworks and software architectures. It is mostly underestimated that these paradigms offer a valuable theoretical perspective on decentralized network management. (Nillson and Darley, 2006) proposed to combine CAS and MAS and to use the CAS as theoretical approach and MAS the implementation method. (Kuehnle, 2007) considers agents as a part of the complex of interrelated models for ASC planning.

Heuristics are intelligent rules that often lead to good, but not necessarily the best solutions. Heuristic approaches typically are easier to implement and require less data. However, the quality of the solution is usually unknown. Unless there is a reason that optimization cannot be used, heuristics are an inferior approach. In the ASC settings the nature based heuristics such as genetic algorithms (Huang et al., 2005) and Ant Colony Optimization (ACO) (Teich, 2003) are usually used. For instance, (Fischer et al., 2004) elaborated an approach for optimizing the selection of partners in production networks based on an ACO-algorithm.

In this paper we present a new integrated approach to planning control process in CTOS. It accumulates three above-mentioned approaches.

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Our investigations are based on results of the CTOS adaptive control theory which is being developed now by Professor Skurihin V.I in Ukraine (Skurihin et al., 1989). The analysis of known investigations on the subject (Skurihin et al., 1989, Rastrigin, 1981, Bellman, 1972, Fleming, 1975, Nillson and Darley, 2006), confirms that the traditional tasks of CTOS control should be supplemented with procedures of structural and parametric adaptation of special control software (SCS). Here the adaptive control should include the following main phases:

- parametric and structural adaptation of structure-dynamics control (SDC) models and algorithms to previous and current states of objects-in-service (SO), of control subsystems (CS), and of the environment;
- integrated planning and scheduling of CTOS operation (construction of SDC programs);
- simulation of CTOS operation, according to the schedules, for different variants of control decisions in real situations and analysis of planning and scheduling simulation;
- structural and parametric adaptation of the schedule, control inputs, models, algorithms, and SDC programs to possible (predicted by simulation) states of SO, CS, and of the environment,
- realization of CTOS structure-dynamics control processes.

To implement the proposed concept of adaptive control let us consider two groups of parameters (Skurihin et al., 1989, Rastrigin, 1980, 1981) for CTOS SDC models and algorithms: parameters that can be evaluated on the basis of real data available in CTOS; parameters that can be evaluated via simulation models for different scenarios of future events.

The adaptation procedures can be organized in two blocks (models) (Ohtilev, 2006, Skurihin et al., 1989, Ivanov et al., 2010, 2012): external adapter of planning and scheduling models; internal adapter of planning and scheduling models.

When the parametric adaptation of SCS does not provide simulation adequacy then the structural transformations can be needed. Two main approaches to structural model adaptation are usually distinguished (Bellman, 1972, Rastrigin, 1980, 1981). The first approach lies in the selection of a model from a given set. The model must be the most adequate to SO and CS. The second approach stands for CTOS SDC model construction of elementary models (modules) in compliance with given requirements. The second approach provides more flexible adjustment of SO and CS for particular functioning conditions. However, the first one is faster and can be effective if the application knowledge base is sufficiently large.

Both approaches need active participation of system analysts and decision-makers who interact with special control software of simulation system (SIS) and consider hard-formalizing factors and dependences within the general procedure of CTOS SDC program selection.

Let us consider formal statement of structural and parametric adaptation problems for CTOS SDC models and after that we are going to investigate the problem of parametric adaptation for models describing CTOS structure-dynamics control. Adaptation of algorithms and control software does not belong to the scope of this paper.

We have implemented the conceptual model and technology of parametric and structural adaptation of models describing CTOS SDC processes via original simulation system (SIS). This simulation system consists of the following elements (Moiseev, 1974, Sowa, 2002): a) simulation models (the hierarchy of models); b) analytical models (the hierarchy of models) for a simplified (aggregated) description of objects being studied; c) informational subsystem that is a system of data bases (knowledge bases); d) control-and-coordination system for interrelation and joint use of the previous elements and interaction with the user (decision-maker).

In this paper we want to describe and to investigate concrete algorithm of structure models adaptation via integrated modeling and simulation procedures that are realized in the SIS.

PROBLEM STATEMENT

We assume that there are several variants of CTOS SDC models inscribed in the set

$$\overline{\overline{M}} = \left\{M_1, M_2, \ldots, M_W\right\} = \left\{M_\Theta, \Theta \in I\right\}, I = \left\{1, \ldots W\right\},$$

moreover the vector $\vec{\beta}$ of CTOS parameters includes the subvector $\vec{\beta}_0$ of fixed CTOS characteristics and besides of it the subvector $\vec{w} = \left\|\vec{w}^{(1)\mathrm{T}}, \vec{w}^{(2)\mathrm{T}}, \vec{w}^{(3)\mathrm{T}}\right\|^{\mathrm{T}}$ of parameters being adjusted through SS external/internal adapter or defined within structural adaptation. According to (Skurihin et al., 1989), these parameters can be divided into the following groups: $\vec{w}^{(1)}$ is a vector of parameters being adjusted through the internal adapter; $\vec{w}^{(2)}$ is a vector of parameters being adjusted through the external adapter; $\vec{w}^{(3)}$ is a vector of parameters being adjusted within structural adaptation of CTOS SDC models.

Now we can present the modified multiple-model multi-criteria description of CTOS SDC problems:

$$\vec{J}_\Theta\left(\vec{x}(t), \vec{u}(t), \vec{\beta}, \vec{\xi}(t), t\right) \to \underset{\vec{u}(t)\in\Delta_\Theta}{extr}, \qquad (1)$$

$$\Delta_\Theta = \left\{\vec{u}(t) \middle| \vec{x}(t) = \vec{\phi}_\Theta\left(T_0, \vec{x}(T_0), \vec{x}(t), \vec{u}(t), \vec{\xi}(t), \vec{\beta}_\Theta, t\right)\right\}, \qquad (2)$$

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

$$\vec{x}(T_0) \in X_0\left(\vec{\beta}_\Theta\right), \vec{x}(T_f) \in X_f\left(\vec{\beta}_\Theta\right), \qquad (4)$$

$$\vec{u}(t) = \left\|\vec{u}_{pl}^{\mathrm{T}}(t), \vec{v}^{\mathrm{T}}\left(\vec{x}(t), t\right)\right\|^{\mathrm{T}};$$

$$\vec{u}_{pl}(t) \in Q_\Theta\left(\vec{x}(t), t\right);$$

$$\vec{v}\left(\vec{x}(t),t\right) \in V_{\Theta}\left(\vec{x}(t),t\right);$$

$$\vec{\xi}(t) \in \Xi_{\Theta}\left(\vec{x}(t),t\right); \vec{\beta}_{\Theta} \in B; \vec{x}(t) \in X\left(\vec{\xi}(t),t\right);$$

$$\vec{\beta}_{\Theta} = \left\| \vec{\beta}_0^{\mathrm{T}} \vec{w}^{\mathrm{T}} \right\|^{\mathrm{T}}; \ \vec{w} = \left\| \vec{w}^{(1)\mathrm{T}}, \vec{w}^{(2)\mathrm{T}}, \vec{w}^{(3)\mathrm{T}} \right\|^{\mathrm{T}}. \qquad (5)$$

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 $\vec{v}\left(\vec{x}(t),t\right)$ are control vectors. Here $\vec{u}(t)$ represents CTOS control programs (plans of CTOS functioning), $\vec{v}\left(\vec{x}(t),t\right)$ is a vector of control inputs compensating perturbation impacts $\vec{\xi}(t)$). The vector $\vec{\beta}_{\Theta}$ is a general vector of CTOS parameters. The vector of CTOS effectiveness measures is described as (6).

$$\vec{J}_{\Theta}\left(\vec{x}(t),\vec{u}(t),\vec{\beta},\vec{\xi}(t),t\right) =$$

$$\left\| \vec{J}^{(g)\mathrm{T}}, \vec{J}^{(o)\mathrm{T}}, \vec{J}^{(k)\mathrm{T}}, \vec{J}^{(p)\mathrm{T}}, \vec{J}^{(n)\mathrm{T}}, \vec{J}^{(e)\mathrm{T}}, \vec{J}^{(c)\mathrm{T}}, \vec{J}^{(v)\mathrm{T}} \right\| \qquad (6)$$

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 $\vec{\varphi}_{\Theta}\left(T_0,\vec{x}(T_0),\vec{x}(t),\vec{u}(t),\vec{\xi}(t),\vec{\beta}_{\Theta},t\right)$ and the output function $\vec{\psi}_{\Theta}\left(\vec{x}(t),\vec{u}(t),\vec{\xi}(t),\vec{\beta}_{\Theta},t\right)$ can be defined in analytical or algorithmic form within the proposed simulation system; $Q_{\Theta}\left(\vec{x}(t),t\right)$, $V_{\Theta}\left(\vec{x}(t),t\right)$, $\Xi_{\Theta}\left(\vec{x}(t),t\right)$ are correspondingly allowable areas for program control, real-time regulation control inputs, perturbation inputs; B is a area of allowable parameters; $X\left(\vec{\xi}(t),t\right)$ 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).

General formal statements for structure adaptation of CTOS SDC modules can be written as problems of two subclasses (Skurihin et al., 1989).

Problem C1

$$AD\left(M_{\Theta}^{(l)},\bar{P}_{cs}\right) \to \min, \qquad (7)$$

$$t_{st}\left(\vec{w}^{(3)},M_{\Theta}^{(l)}\right) \le \bar{t}_{st}, \qquad (8)$$

$$M_{\Theta}^{(l)} \in \overline{\overline{M}}, \vec{w}^{(3)} \in W^{(3)},$$

$$M_{\Theta}^{(l)} = \overline{\overline{\Phi}}\left(M_{\Theta}^{(l-1)},\vec{w}^{(3)},\bar{P}_{cs}\right), l = 1,2,\ldots, \qquad (9)$$

where $AD\left(M_{\Theta}^{(l)},\bar{P}_{cs}\right)$ is a functional characterizing the adequacy of the model $M_{\Theta}^{(l)}$ for CTOS. The latter is described, in its turn, with a set $\bar{P}_{cs}(t) = \left\{\bar{P}_{g}^{(cs)}, \bar{g} = 1,\ldots,\bar{G}\right\}$ of characteristics; t_{st} is a total time of CTOS SDC models structure adaptation; $\bar{t}_{st}$ is a maximal allowable time of structural adaptation; $\overline{\overline{\Theta}}$ is an operator of iterative construction (selection) of the model $M_{\Theta}^{(l)}$, *l* is the current iteration number; $W^{(3)}$ is a set of allowable values for the vectors of structure-adaptation parameters.

Problem C2

$$t_{st}\left(\vec{w}^{(3)},M_{\Theta}^{(l)}\right) \to \min, \qquad (10)$$

$$AD\left(M_{\Theta}^{(l)},\bar{P}_{cs}\right) \le \varepsilon_2, \qquad (11)$$

$$M_{\Theta}^{(l)} \in \overline{\overline{M}}, \vec{w}^{(3)} \in W^{(3)}, \qquad (12)$$

$$M_{\Theta}^{(l)} = \overline{\overline{\Phi}}\left(M_{\Theta}^{(l-1)},\vec{w}^{(3)},\bar{P}_{cs}\right),$$

where ε_2 is a given constant establishing an allowable level of the CTOS SDC model $M_{\Theta}^{(l)}$ adequacy, $\overline{\overline{M}}$ is a set of CTOS SDC models.

The analysis of expressions (7)-(9) shows that the structural adaptation starts and stops according to a criterion characterizing the similarity of a real object and an object described via models (a condition of models adequacy is applied) (Sokolov et al., 2012). The adequacy of CTOS models does not mean description of all “details”. It means that simulation results meet the changes and relations observed in reality.

The main purpose of quantitative estimation of the model M_{Θ} adequacy at time *t* is to raise decision-maker’s confidence in conclusions made on real situation. Therefore, the utility and correctness of CTOS SDC simulation results can be measured via adequacy degree of models and objects.

The adequacy functional should meet the following requirements (Sokolov, 2012).

$AD\left(M_{\Theta}^{(l)},\bar{P}_{cs}\right) > 0, \forall M_{\Theta}^{(l)} \in \bar{\bar{M}}, \bar{P}_{cs} \in \bar{\bar{P}}_{cs}$, where $\bar{\bar{M}}$ is a set of CTOS models; $\bar{\bar{P}}_{cs}$ is a set of possible values of CTOS characteristics.

$AD\left(M_{\Theta}^{(l)},\bar{P}_{cs}^{(1)}\right) > AD\left(M_{\Theta}^{(l)},\bar{P}_{cs}^{(2)}\right)$, where the model $M_{\Theta}^{(l)}$ is more adequate to CTOS with the characteristics set $\bar{P}_{cs}^{(2)}$ than to CTOS with the characteristics set $\bar{P}_{cs}^{(1)}$.

$AD\left(M_{\Theta_1}^{(l)},\bar{P}_{cs}^{(1)}\right) > AD\left(M_{\Theta_2}^{(l)},\bar{P}_{cs}^{(1)}\right)$, where the model $M_{\Theta_2}^{(l)}$ is more adequate than the model $M_{\Theta_1}^{(l)}$ to CTOS with the characteristics set $\bar{P}_{cs}^{(1)}$.

It is assumed that parameters of the models are adjusted for particular CTOS.

It is important that the changes of CTOS characteristics should be observed and forecasted so that corrections of models structure and of parameters can be done in time.

The time of corrections can be determined as a compromise between an aspiration for receiving proper values of $\bar{P}_{cs}$ and necessity of a new model construction, adjustment, and preparation for use (Ivanov et al., 2010).

ALGORITHM OF STRUCTURE ADAPTATION OF MODELS DESCRIBING SCHEDULING PROCESSES IN CTOS

The proposed algorithms for structural adaptation of CTOS SDC models are based on the evolutionary (genetic) approach. As before in PROBLEM STATEMENT, let us exemplify these algorithms in the structural adaptation of a model describing structure dynamics of one CTOS output characteristic [of one element of the vector $\vec{y}\left(t_{\langle k\rangle}\right)$].

The residual of its estimation via the model M_{θ}, as compared with the observed value of the characteristic, can be expressed like this:

$$Q_{\langle k\rangle}^{\langle\theta\rangle} = \left[\psi_{\langle\theta,k\rangle}\left(\vec{x}\left(t_{\langle k\rangle}-1\right),\vec{u}\left(t_{\langle k\rangle}\right),\vec{\xi}\left(t_{\langle k\rangle}\right),\vec{\beta}_{\theta},t_{\langle k\rangle}\right)-\tilde{y}\left(t_{\langle k\rangle}\right)\right] \qquad (13)$$

To simplify formulas, we assume that the perturbation impacts $\vec{\xi}(t)$ are described via stochastic models. Thus, the following quality measure can be introduced for the model M_{Θ}:

$$\bar{Q}_{\langle K\rangle}^{\langle\theta\rangle} = \sum_{k=1}^{K} g^{(K-k)}\bar{Q}_{\langle k\rangle}^{\langle\theta\rangle}, \qquad (14)$$

where $0 \le g \le 1$ is a "forgetting" coefficient that "depreciate" the information received at the previous steps (control cycles) (Ivanov et al., 2010). If $g = 0$ then $\bar{Q}_{\langle K\rangle}^{\langle\theta\rangle} = Q_{\langle K\rangle}^{\langle\theta\rangle}$, i.e., the weighted residual is equal to one received at the last step, as the prehistory have been "forgotten". An extension of formula (13) was proposed in (Sokolov et al., 2012). The coefficient $g^{(K-k)}$ was substituted for the function $f(K)$:

$$\bar{Q}_{\langle K\rangle}^{\langle\theta\rangle} = \sum_{k=1}^{K} f(K-k)Q_{\langle K\rangle}^{\langle\theta\rangle},\theta = 1,\ldots,\Theta \qquad (15)$$

Here $f(\cdot)$ is a monotone decreasing function of "forgetting". It has the following properties:

$$\begin{aligned} &f(\alpha) > 0, f(0) = 1, \lim_{\alpha\to ?} f(\alpha) = 0, \\ &f(\alpha) \ge f(\alpha+1), \alpha = 0,1,\ldots. \end{aligned} \qquad (16)$$

Now the structural-adaptation algorithm is reduced to a search for the structure M_{Θ}, such that

$$\bar{Q}_{\langle K\rangle}^{\langle\theta'\rangle} = \min_{\theta=1,\ldots\Theta} \bar{Q}_{\langle K\rangle}^{\langle\theta\rangle} \qquad (17)$$

Thus, it is necessary to calculate the quality measures (13) for all competitive structures M_{Θ}, $q = 1,\ldots,Q$ of CTOS SDC models at each control cycle $k = 1,\ldots,K$. All quality measures should be compared, and the structure M_{Θ} with the best measure (minimal residual) should be chosen.

Another way to choose model $M_{\Theta}^{(l)}$ is probabilistic approach. In this case the following formula is used

$$p_1\left(M_{\Theta}^{l}\right) = \frac{\sum\limits_{\rho=k-d}^{k-1} J_i\left(M_i^{\langle\rho,L\rangle}\right)}{\sum\limits_{\Theta=1}^{\Theta^{\langle k-1\rangle}} \sum\limits_{\rho=k-d}^{k-1} J_i\left(M_{\Theta}^{\langle\rho,L\rangle}\right)} \qquad (18)$$

where $J_i\left(M_i^{\langle\rho,L\rangle}\right)$ – generalized quality measure value of model $M_i^{\langle\rho,L\rangle}$ functioning on previous time intervals, d – is a "forgetting" coefficient. It should be emphasized that the calculation of the quality measure is expected to carry out each time on the basis of a solution of the problem of multi-type selection. Thus, despite the random choice of the next model (multiple-model complex) greater opportunity to be chosen gets the model, which had the best value of the generalized quality measure in the previous cycle control.

The parametric adaptation of the model M_{Θ} (Ivanov et al., 2010, 2012) should follow the structural one.

It is important to determine a proper "forgetting" function under the perturbation impacts $\vec{\xi}(t)$. The higher is the noise level in CTOS, the slower decrease of the function should be implemented. However, if CTOS highly changes its structure then the function $f(\alpha)$ should be rapidly decreasing in order to "forget" the results of the previous steps (Ivanov et al., 2012). It can be show that the structural-adaptation algorithms based on model construction (synthesis) of atomic models (modules) are rather similar to the algorithms of the CTOS structure-functional synthesis (Okhtilev et al., 2006). These algorithms only differ in the interpretation of results.

EXAMPLE

Example demonstrates a structural adaptation of CTOS containing the plurality of realization and multifunctional character.

CTOS is presented as an original software for the remote sensing (RS) data treatment for the forest cuts identification. CTOS consists of three main blocks: input RS data (block 1), automatic RS data processing (block 2) and results (block 3). The perturbation influences are presented by the control model parameters, $\vec{w}^{(3)}$, that can be evaluated on the real data available in CTOS (block 1) and parameters that can be evaluated via simulation models for different scenarios of future events (block 2).

The problem consists of the structure adaptation of CTOS models to perturbation influences. According to mentioned in the paper algorithm it is necessary to choose the model for sceduling of CTOS functioning under perturbation influences.

Evaluated model parameters from block 1 include:

− type of the satellite system, above all spectral and spatial resolutions;

− square of the processing area of the space image.

Evaluated model parameters from block 2 include:

− threshold of the Normalized Differentiated Vegetation Index;

− method of the classification, furthermore number of classes, distance function;

− method of the reclassification;

− threshold of the entropy;

− minimum forest cut dimension;

− spectral radiance value from Database.

Evaluated model parameter from block 3 includes forest cuts outlines.

The following global optimization problem is considered: $AD\left(w_1^{(3)},w_2^{(3)},\ldots w_n^{(3)}\right)\to\min$, (see formula (7)) where the arguments $w_1^{(3)},w_2^{(3)},\ldots w_n^{(3)}$ are model parameters from blocks 1-3 to be varied in order to receive the minimal (the best) value of function *AD*. It is possible to recognize clearly forest cuts due to the vector of program control based on the evaluated model parameters.

The general algorithm is suggested:

Step 1: *Input RS data.* The spectral and spatial resolutions are marked. The part of the space image area for processing is indicates.

Step 2: *Processing RS data. The first phase.* The feature space of the image splits up two classes by means *NDVI (Normalized Vegetation Differencial Index)* values – the vegetation and the rest. *NDVI* values can vary between 0,2 to 0,9.

Step 3: *Processing RS data. The second phase.* The feature space of the vegetation class splits up *k*-classes by means of the *m*-method of classification (m=1..δ) for the forest cuts extraction. Simultaneously the reclassification and texture are computed. The polygons agglomeration is carried out according to minimum desired value of the forest cut. In current program implementation δ=5.

Step 4: *Processing RS data. The third phase.*The feature space of each polygon on the image is created per *NDVI* and *NIR/RE* values. The classification of the polygons to identify the range of the forest cuts resumption is accomplished. These result is automatically transmitted to geoinformation system.

Step 5: *Processing RS data. The fourth phase.* The model forest cuts outlines are compared with the reference outlines of the digital map. Function *AD* should be taken the best value, otherwise decision about new control model parameters, $\vec{w}^{(3)}$ is make.

Consequently, the probability of the model parameters choice based on the task solution is determined (expression (18), where *J* is the forest cut square).

Examples of the various results of the forest cuts identification conditionally of the subvector of model parameters are being illustrated on the website of the ESTLATRUS projects 1.2./ELRI-121/2011/13.

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