Principles and Methods of Data Models Creation Within Automated Control Systems

Zoya Hubenova[1], Antonio Andonov[2], Vladimir Gergov [2]

Abstract – **The article addresses the problems of automating the decision making process and management of multifunctional complex (technical) objects taking into account the man – operator's availability and the informative provision of its activities. The following is referred to: the principles of analysis and synthesis of information models and the factors that influence the quality of performance of the control systems. Algorithmic method is proposed to form a pattern reflecting the key action of the operator in emergency conditions.**

Keywords – **automated systems, informational model, man – operator.**

I. TOPICALITY

The contemporary methods of complex objects control, transmitting and processing information, and the central control systems of technological processes represent complex man – machine facilities. Within these both technical appliances and staff actions are unified. The efficiency of such systems depends on the man – operator's and technics' coordination.

In this paper, the automatized control system (ACS) is examined as an aggregate of technical means and the man – operator (MO). Its main features are stability, controllability, and observability which define the system's quality. The systems stability is determined by the controllability, i.e. the aptitude for reducing the controlled object to a state previously given by means of control influence. It is also determined by the possibility of observing the controlled objects' state. Both properties controllability and observability are related to each other, i.e. the system is fully controllable if and only if the connected system is also observable and vice versa. Within the ACS there is a process of information compressing and processing while information is either being lost or distorted inevitably, [1, 2, 9].

The availability of the MO within the ACS justifies the necessity of increasing the control system efficiency on the account of heuristic capabilities inherent to the human factor in unexpected and poor formulated situations. The human activity is reduced to perception and assessment the information, making and implementing decisions, [4], the MO's availability enhances the system ability to adapt during operations under unexpected situations. Another peculiarity of its work is the reciprocal action with the information objects and the influence exerted upon the objects through a remote control, not the interaction with the real objects. One of the main factors, exerting influence on both the quality of MO's activity and therefore the system as a whole, is the *information security* of its activity.

The information model (IM), in its capacity of the most important compound of the information security, represents particular organizational cumulative information at the ACS operator's disposal, [3, 5, 10]. The state information is usually a combination of information models of the interacting objects which are perceived through information display means. The information model is defined as organized, according to a set of rules, image of the labor ways and means, the system "man-machine" (SMM), external environment, and ways to influence them. Following the model, the operator captures the image of the object, its state at any point in time and makes a decision. The information model combines two fields: sensor (sensitive), consisting of signaling devices, i.e. devices, indicators, audible signals, screens, etc., and sensorimotor, consisting of controls, i.e. knobs, levers, buttons, cutoffs, switches, and more. The information model sensing field includes all signals perceived by the operator directly from the machine.

The means of information display are part of the MO's working place meant to form the IM [6]. Thus, the information model is considered as a set of objects (phenomena, processes) data presented to the MO. The operator perceived the direct information visually (over 90%) and in acoustic way by means of information display ways and means.

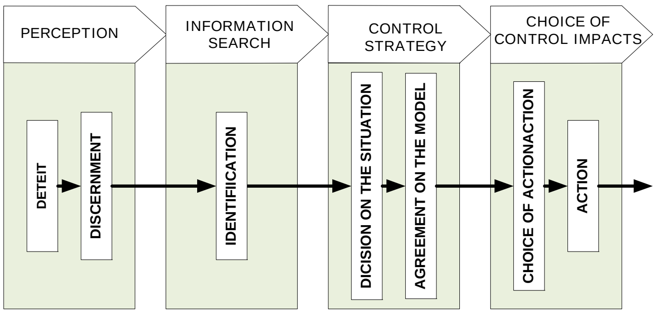

Fig. 1. Information reception by the MO within ACS.

The IM perception process, as a result of which the image of subject forms, occurs by means of information included in the *conceptual model* formed within the MO's memory. The model is a set of MO's ideas about goals and objectives of the labor activity and conditions of the ways of work, the SMM, external environment and means of influence.

The activity information security influence upon the MO's performance is determined firstly by the integrity and completeness of the IM, secondly by the organization of

[1]Space Research and Technology Institute – BAS, Acad G. Bonchev Str., Bl. 1, 1113 Sofia, Bulgaria, E-mail: zhubenova@space.bas.bg

[2]University of Transport Todor Kableshkov, 158 Geo Milev str., 1574 Sofia, Bulgaria, E-mail: andonov@vtu.bg, gergov@vtu.bg

means that convey information to the MO, and finally by the quality of the conceptual model. The IM could be described from morphological (structure of the studied system), functional (application), and organizational point of view, [9]. Basic concepts of morphological descriptions are the composition and the volume. Having considered the specifics of IM as an abstract linguistic system, its morphological and organizational descriptions might be merged. In order to establish a functional description of the IM, it is necessary to analyze the basic principles of receiving and processing information from the MO to the ACS.

II. PRINCIPLES OF OPTIMAL ORGANIZATION OF THE IM.

The man's paradigm as a section of information processing is based on the general laws of control processes within living and non-living systems: the equivalent unit paradigm is based on the MO's specific actions depending on its personal characteristics and information security of its activities; the IM paradigm are not limited to the MO's interaction with the object, rather with its IM; the operational paradigm reflects the MO's adaptability to the conditions and the means necessary for its activities in accordance with its task previously assigned.

Having unified these paradigms, we are allowed to form the general principles of analysis and synthesis of the IM.

Target compatibility principle: non-discrepancy of the objectives of the man and entire ergatic system (ES) and, therefore, MO's ways of interaction (material, energy and information resources by means of which the man implements its activity) with the entire system. The realization of this principle implies assessment of the IM in terms of man's conformity and complexity of the problem being solved [7].

Possible formalization can be done by assuming that S_i^g is one of the target functions of the ES (i $\in$ N, where N is the number of activities functions being considered) and S_j^c is one of the target functions concerning the entire ES. Then the principle of target compatibility will be determined by:

$$(\forall i \in N)(\exists j \in M)(S_i^g \cap S_i^c \neq \varnothing) \qquad (1)$$

This principle can be refined further. Firstly, by means of identifying the need to link the indicators of the quality of the business resources and the quality of human activity itself enabled by these means.

$$\begin{aligned}&(\forall y_{ij} : i \in N_j, j \in L)(\exists f_{ij} : K^j = \\ &= f_{ij}(y_{ij}, y_{kj} = i\,dem),\end{aligned} \qquad (2)$$

where y_{ij} is a quality indicator of the j^{th} mean od activity in terms of the i^{th} property; N_j is the set of relevant properties of the j^{th} mean; L is the set of means of activity; K^j is quality of the operator's activity through the j^{th} mean; f_{ij} is function of the quality of the activities carried out by the operator in terms of the j^{th} mean in terms of the i^{th} property.

Secondly, it is necessary to perform a possibility to explicitly include the quality indicator in terms of the j^{th} activity mean of the ES quality indicator.

$$\begin{aligned}\bar{Y} &= \{\bar{y}_1, \bar{y}_2, \ldots, \bar{y}_j, \ldots \bar{y}_l, \bar{x}_1, \bar{x}_2, \ldots, \bar{x}_k, \ldots, \bar{x}_m\} \\ \bar{Y}_j &= \{y_{1j}, y_{2j}, \ldots, y_{ij}, \ldots y_{nj}\}(1) \\ \bar{X}_k &= \{x_{1k}, x_{2k}, \ldots, x_{ik}, \ldots x_{rk}\},\end{aligned} \qquad (3)$$

where $\bar{Y}$ is the ES quality indicator; y_i are quality indicator of the ES j_{th} component related to the MO's means of activity; L is a set of the ES elements related to the manufacture ways and means; N_j is a set of j^{th} mean properties under consideration ($j=\overline{L;1}$); $\bar{X}$ is the quality indicator of the ES k^{th} compound that is not related to the manufacture ways and means; R_k is a set of ES elements which are not related to the MO's activity manufacture ways and means $k=\overline{M;1}$.

Implementing this principle provides development of indicators for selecting the most rational option as regards the MO's ways of activity as well as optimization within the entire system in order to synthesize the whole set of means of MO's information security.

Optimality principle: it determines possible approaches toward IM optimization, both in terms of the best solution from many possible and in the sense of bringing IM into an optimum condition. Among the entire possible set (T) of IM, each element of which is distinguished by a certain quality indicator vector $Y_{<m>}(T_j)$, the optimal T^{opt} is this one which is distinguished by such vector $Y_{<m>}(T^{opt})$ so that the last vector component is less than the relevant component of another arbitrary vector $Y_{<m>}(T' \in T)$, i.e.

$$\begin{aligned}&Y_{\langle m\rangle}(T_i \in T) = \{y_1(T_i), y_2(T_i), \ldots, \\ &y_i(T_i), \ldots, y_{\langle m\rangle}(T_i)\}\end{aligned} \qquad (4)$$

$$Y_i(T^{opt}) \geq Y(T'), [i = \overline{1, M}] \qquad (5)$$

Implementing this principle defines the possible approaches toward IM optimisation, i.e. the best option selection among the other possible as well as putting IM into its optimal condition.

Particular principles characterizing the specific requirements that the IM should meet and determining the man's role into the automated system are following:

1) Principle of minimum operating effort – the MO has to perform the work required and this part of work that cannot be performed by the system at that.

2) Principle of maximum mutual understanding - the system provides maximum support to the MO, i.e. the information provided should not require / allow interpretation and recoding.

3) Principle of minimum volume of user RAM - the person is required to memorize as little as possible.

4) Principle of maximum control done by MO – the operator must be able to control the sequence of work and if necessary, modify it.

5) Principle of optimal load – an allocation of functions is recommended such that the operator, in accordance with the rate of incoming data, either does not run short of sensors (loss of activity) or is not in excess of sensors (missing signals).

6) Principle of responsibility – the MO is assigned a number of important functions, even if full automation is available.

III. ALGORITHMIC MODELS MEANT TO DESIGN THE IM.

The algorithmic methods allow for forming patterns reflecting the operator's algorithm of action taking into account the peculiarities of work under a variety of conditions, [4, 8]. Such conditions may be rosters, emergency conditions, etc. The operator's activity is a set of several activities $A = \{Act_i\}$, where Act_i is the i^{th} activity so that each activity could be considered as a set of precedents P_{ij}, i.e. consecutive actions taken to work out problems.

The informational volume included in the model and the rules of its organization must comply with the control process objectives and methods. Physically, the IM is implemented by means of the display information devices, while the most significant feature of the MO's activity with the IM is the need of information consistency obtained through the control and measurement devices and the monitors, both between as well as the real controllable objects. Indeed, the overall MO's activity is built upon the basis of information compliance.

An exemplary organizational chart of the MO's activity is shown in Fig. 2, while the informational interaction between the operator and the machine is generally divided into the following stages.

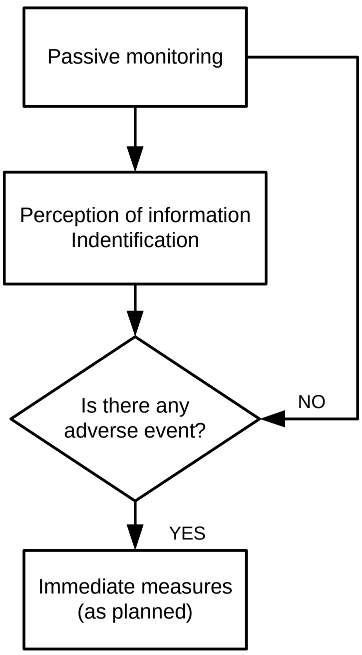

Fig.2. Structural scheme of human activity operator.

1) Information perception. It is a process including following qualitatively different operations: a process, including the following qualitatively different operations: the detection of the object by perception during close monitoring of the production process, or instrumentation monitoring reflecting the parameters of the current processes, selection individual signs within the objects rising to the operator's challenges, introduction with individual signs and the very object of perception. The perception is carried out by means of sense organs from which point it is transmitted to the central nervous system.

2) Processing of the information obtained, i.e. assessment, analysis, and summary on the basis of previously defined or set up criteria and assessments. The assessment is made based on a comparison between the data model and the designed within the operator internal conceptual model of the situation (the control system) and leads to making a decision. The conceptual model is a product of understanding the operator's situation considering the forthcoming task. Unlike the IM, it refers to internal man's psychological – mental abilities and the operator's ways and means of action. Thus, the operator's decisions are influenced not only by the external information but also the internal one.

3) Implementation of the decision taken by means of the actuators. In the EU, this is the control through which changes to the current processes are implemented in case of control devices influence.

VI. CONCLUSION.

Within the ACS the operator performs a wide spectrum of functions through utilizing a variety of technical ways and means. The main problem of the human – machine optimization is the agreement between psychological, psychophysiological, anthropometrical, and physiological characteristics and abilities, and the technical properties of the means of automation, the environmental parameters and the staff working place. Moreover, the information models should commonly meet the following five quality criteria:

1. Degree of adequacy of the generated indexing alongside the actual state and behavior of the object. The expertize methods are estimated (digital images).
2. Reliability of reproducing and reading the information. The error probability and the error size during measurements and necessary information adoption is estimated.
3. Time required for observing the information field and making a decision – the input-output characteristics are estimated.
4. Correspondence between the spatial components of the system (controls) and the optimal location in the workspace – spatial characteristics.
5. Speed (intensity) of information flows reproduction as well as IM informativeness and intensity (informativeness = intensity per unit area).

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