Development of models for computer systems of processing information and control for tasks of ergonomic improvements

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***Abstract*—The questions of search of ergonomic reserves of efficiency of computer systems of processing information and control are considered. A set of models of a computer system of processing information and control, describing it in the necessary sections, was developed. The results can be useful in design of information provision for Decision Support Systems, devoted to questions of programs ergonomic quality of automated systems.**

Keywords—ergonomics; human factor; computer system; system analysis; component model; morphological model.

I. Introduction

Taking into account the "human factor" becomes one of the most important questions in design and employment of automatized systems [1-4]. The effectiveness of complex computer systems of processing information and control (SPIC), which belong to the class of ergotechnical systems (ETS) [5] essentially depends on the thoroughness of ergonomic issues [6-9]. To address such concerns, the models of searching for ergonomic reserves to increase efficiently of SPIC are being developed [9-11]. Introduction of such models is constrained by the lack of information support, which makes it possible to systematically describe the subject area of activity of decision-makers and ensure optimal design and management of reliable initial data.

II. Statement of the task

To develop methodology for systemic-ergonomic analysis, which can be used as a basis for information support of decision making assistance systems (DSS) on the issues of ergonomic quality assurance of the SPIC (for the operator-supervisor, the ergonomics department staff, managers and other employees responsible for elaboration of the issues of account of the "human factor").

III. Results

A. Models for information support of DSS on issues of improving the ergonomic quality of SPIC.

We construct system models using an approach to the unified representation of information about ETS objects in the form of a list of knowledge and data bases, as described in [5].

Analysis of the list of information about SPIC, necessary for solving the problems of ergonomic support, allows us to conclude that this information can be specified using two classes of structures, namely component and morphological.

Component structures are introduced to identify the entities needed to describe the system.

Morphological structures are introduced to define connections of a different nature between entities identified in component structures. To construct a model describing individual algorithms for each operator to perform each type of application, the apparatus of functional networks of the functional-structural theory of the ETS of the school of prof. A.I. Gubinsky is used [5]. Then the complex of system models *MMS* of an information model for the operator-supervisor is represented by the scheme shown in Fig. 1 and the structural formula (1):

$$MMS =< CSs, CFs, CRs, CEs, Err, Rs, Ft, OpFt, \\ VPo, FKv, Mpl, VCo, M\,\mathrm{Pr}\,oekt > \quad (1)$$

Description of the accepted notations is shown in Fig. 1.

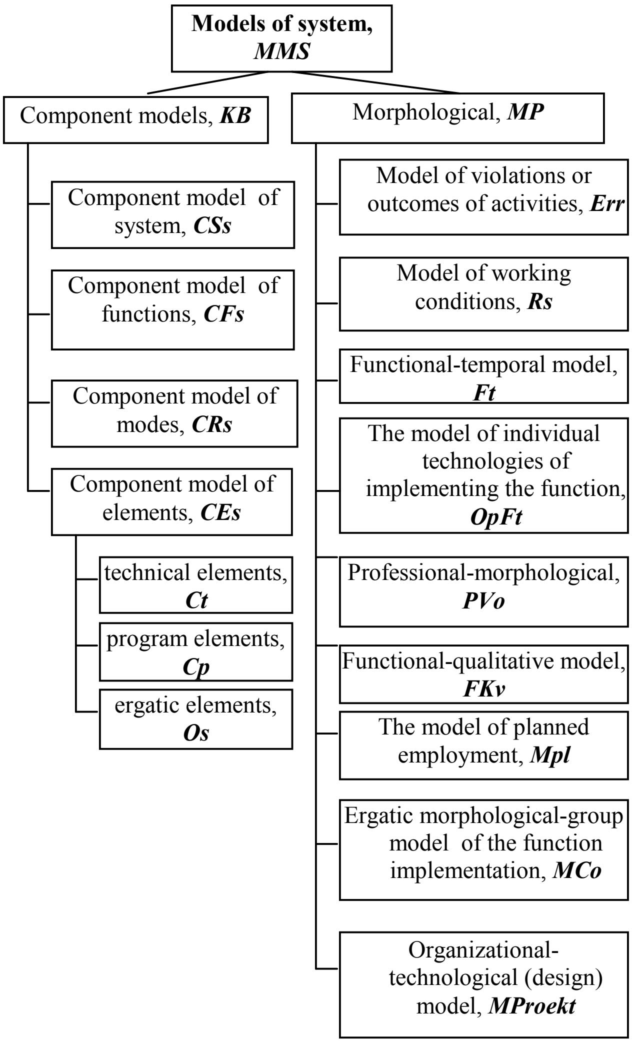

Fig. 1. Structure of the information model for computer systems of processing information and control

B. Contents of the models

Here we present several examples of the developed models.

Component model of system, *CSs*. The component-system structure reflects the location of this SPIC among the surrounding systems and the composition of its subsystems:

$$CSs =< \{LETS_l\} \mid l = 1,2,\ldots L_0 >, \quad (2)$$

where $LETS_l$ – the l-th local ETS;

L_0 – the number of local ETS systems.

Component-functional structure, *CFs*. The model represents information about the requirements for the system under study in terms of the set of realized planned functions of each LETS:

$$CFs =< \{Fpl_i; \{LETS_{l_i}\} \mid l_i \in \{1,2,\ldots L_0\}\} \mid i = 1,2,\ldots, N_{Fpl} >, \quad (3)$$

where $LETS_{li}$ – l_i-th local ETS;

L_0 – number of local ETS systems;

Fpl_i – the i-th planned function;

N_{Fpl} – the number of planned functions.

Model of violations or outcomes of activities, *Err*. The model describes possible violations when implementing functions (application) from a set given by a component-functional structure:

$$Err =< \{Fpl_i; \{Er_{ij}; U_{ij}\} \mid j = 1,2,\ldots ner_i\} \mid i = 1,2,\ldots, N_{Fpl} >, \quad (4)$$

where Fpl_i – the i-th planned function;

N_{Fpl} – the number of planned functions;

Er_{ij} – the j-th violation (error), which can be tolerated in the implementation of the i-th function;

U_{ij} – the damage caused by performing the i-th function with j-th violation;

ner_i – the number of possible violations in the implementation of the i-th planned function.

Model of working conditions, *Rs*. Displays for each workplace the values of the sanitary, hygienic and psychophysiological factors affecting the working conditions:

$$Rs =< \{RM_k; OP_k; KT_k; IBO_k; \\ \{TFak_{kj}; NFak_{kj}; ZFak_{kj}\} \mid j = 1,2,\ldots nf_k\} \mid i = 1,2,\ldots K_0 >, \quad (5)$$

where RM_k – the identification of the k-th workplace;

OP_k – the k-th operator;

KT_k – the category of gravity for the workplace RM_k;

IBO_k – the integral score in points for the workplace RM_k;

nf_k – the number of influential factors for the workplace RM_k;

$TFak_{kj}$ – the type of j factor for the workplace RM_k;

$NFak_{kj}$ – the name of j factor for the workplace RM_k;

$ZFak_{kj}$ – the value of the j-th influencing factor for the workplace RM_k;

K_0 – the number of workplace of system.

Functional-temporal model of performing functions, *Ft*. The model describes typical algorithms for performing functions (application) defined by a component-functional structure. There are several possible options for organizing activities in the implementation of the function. The model is given in the form of a formal model of a functional network:

$$Ft =< \{Fpl_i ; \{Var_{ij} , Mfs_{ij}\} \left| j = 1,2,...nv_i \} \right| i = 1,2,..., N_{Fpl} >, \quad (6)$$

where Fpl_i – the i-th planned function;

N_{Fpl} – the number of planned functions;

Var_{ij} – the j-th variant of the organization of activities in the realization of i-th function;

Mfs_{ij} – the j-th formal model of the functional network of the algorithm for the implementation of the i-th function;

nv_i – the number of variants for organizing activities in the implementation of the i-th function.

The model of individual technologies of implementing the function, *OpFt*. The model describes typical technologies for the implementation of functions (application) that characterize the organization of the activity of system operators in the form of a formal model of a functional network. The model describes typical algorithms for performing functions (application) defined by a component-functional structure. There are several possible options for organizing activities in the implementation of the function:

$$OpFt =< \{Fpl_i ; OP_{ik} ; \{Var_{ij_k} , Mfs_{ij\,k}\} \left| j_k \in \{1,2,...nv_i\}\} \right| k \in \{1,2,..., K_0\} \left| i = 1,2,..., N_{Fpl} >, \right. \quad (7)$$

where Fpl_i – the i-th planned function;

OP_{ik} – the k-th operator that implements the i-th planned function;

VAR_{ijk}– the j-th variant of the organization of activity by the k-th operator when implementing the i-th function;

Mfs_{ijk} – the j-th formal model of the functional network of the algorithm for executing the i-th function by the k-th operator;

nv_i – the number of variants for organizing activities in the implementation of the i-th function.;

N_{Fpl} – the number of planned functions.

Functional-qualitative model, *FKv*. The model defines the probabilistic characterization of processes of occurrence and elimination of errors of each type to be taken into account when executing the function (application) from the set, which is specified by the component-functional structure. The set of operations of the process of performing functions is determined by the functional-temporal structure, taking into account the values of factors of the structural feature of the workplace (component-element structure), working conditions at the workplace and professional characteristics of the operator. In the case of absence of data on a particular operator, the model specifies the probabilistic characteristics of the average operator:

$$FKv = \begin{cases} FKvo, & \text{if the data on operators of system are known} \\ FKvs, & \text{if there is no data on operators of system} \end{cases} \quad (8)$$

$$FKvo =< \{Fpl_i ; OP_{ik} ; \{Var_{ij_k} ; \{Opr_{ij_k l} ; \{PK^{er_i}_{ij_k l_m} \left| m = 1,2,...,np^l_{j_k} ; \right| er_i = 1,2,..., ER_i\}$$
$$\left| l = 1,2,..., ko^i_{j_k} \} \right| j_k \in \{1,2,..., nv_i\}\}\} RM_{ik} ; KT_{ik}\} \left| \; k \in \{1,2,..., K_0\} ; \right| i = 1,2,..., N_{Fpl} > ;$$
$$FKvs =< \{Fpl_i ; \{Var_{ij} ; \{Opr_{ijl} ; \{PK_{ijl_m} \left| m = 1,2,..., np^l_{ij}\} \right| l = 1,2,..., ko^i_j\} \left| j = 1,2,...nv_i\} ; \right.$$
$$RM_{ik} ; KT_{ik}\} \left| i = 1,2,..., N_{Fpl} > ; \right.$$

where Fpl_i – the i-th planned function;

N_{Fpl} – the number of planned functions;

OP_{ik} – the k-th operator that implements the i-th planned function;

Var_{ijk} (Var_{ij}) the j-th variant of the organization of activity by the k-th operator (by the average operator) in the implementation of the i-th function;

RM_k – the identification of the k-th workplace;

KT_k – the category of gravity for the workplace RM_k;

Opr_{ijkl} (Opr_{ijl})– The l-th operation performed by the k-th (average) operator when implementing the i-th planned function in the j-th way;

$PK^{eri}{}_{ijklm}$– The m-th quality index, which takes into account the error of er_i-th type, with which the k-th operator performs the l-th operation when implementing the i-th planned function in the j-th mode;

PK_{ijlm}– The m-th quality index with which the average operator performs the l-th operation when implementing the i-th planned function in the j-th mode;

ER_i – errors of different types that can be admitted in the implementation of the i-th function.

The model of planned employment, *Mpl*. The model shows the state of employment of operators by performing routine functions. The set of functions is determined by the component-functional structure of the system. For each operator, the model specifies the start time and the completion time for each function assigned to the operator, the possibility of interrupting the function, the time of the scheduled break, etc.:

$$Mpl =< \{RM_k ; OP_k ; \{PpN_{kl} ; PpK_{kl}\} \left| l = 1,2,..., n_k ; \right. \quad (9)$$
$$\{Fpl_{ik} ; TN_{ik} ; TK_{ik} TP_{ik} ; Vyp_{ik} ; TF_{ik} ; PR_{ik}\} \left| i = 1,2,..., m_k\} \right| k = 1,2,..., K_0 >,$$

where RM_k– the identification of the k-th workplace;

OP_k – the k-th operator;

PpN_{kl} – the beginning of the l-th scheduled break of the k-th operator;

PpK_{kl} – the end of the l-th scheduled break of the k-th operator;

n_k – the number of scheduled breaks of the k-th operator;

Fpl_{ik} – the i-th planned function of the k-th operator;

TN_{ik}, – the time of start for executing the i-th planned function of the k-th operator;

TK_{ik} – the completion time of the i-th planned function of the k-th operator;

TP_{ik}, – the time of interruption of execution of i-th planned function of the k-th operator;

TF_{ik} – the actual completion time of the i-th planned function of the k-th operator;

Vyp_{ik} – the mark on the fulfillment of the i-th planned function of the k-th operator;

PR_{ik} – the priority of the i-th planned function of the k-th operator. The priority of the function is determined by a ten-point scale;

m_k – the number of planned functions of the k-th operator;

K_0 – the number of workplace of system.

Ergatic morphological-group model of the function implementation, *MCo*. Describes for each function (application) from the set, defined by a certain component-functional structure, possibility (impossibility) of organization of group activities and pairwise compatibility of the operators during implementation of the function (in case of admissibility for group activities):

$$MCo = < Fpl_i; pr_i; [\{C^i_{kl}\} | k = 1,2,..,K_0; l = 1,2,...,K_0\}] | i = 1,2,...,N_{Fpl} >, \quad (10)$$

where Fpl_i – the i-th planned function;

pr_i – a sign that determines the possibility or impossibility of organizing a group activity;

$\{C^i_{kl}\}$ – matrix, which defines pairwise compatibility of the functioning of operators OP_k and OP_l during realization of the i-th planned function. Each element of the matrix is defined by the following formula:

$$C^l_{kl} = \begin{cases} 1, & \text{if operators can be jointly involved} \\ 0, & \text{if operators can not be worked together} \end{cases} \quad (11)$$

The organizational and technological (design) model, *MProekt*. The model displays the result of solving the problem of prescribing the function for the operators and contains:

- name (identification) of the function;
- description of the technology implementation of the function (functional network of the functional-temporal model or from the model of individual technologies);
- type of organization of activities: individual or group;
- in the case of individual activities - identification of the operator who is entrusted with the execution of the application. In the case of group activities - assignment of a responsible operator for each operation.
- Prediction of the results of solution: – mathematical expectation of execution time; – variance of the execution time; – probability of error: 1-th type; 2-th type; ...n-th type; – the amount of possible damage from violations of different types..

$$M\text{Pr}oekt = < \{Fpl_{i_0}; Var_{i_0 j_0}; MFs_{i_0 j_0}; pr_{i_0 j_0}; [OP_{i_0 k_0}]; [\{Opr_{i_0 j_0 l}; OP_{l_m}\} | m \in \{1,2,...,K_0\}; \\ | l = 1,2,..ko^{j_0}_{i_0}] | k_0 \in \{1,2,...,K_0\} | j_0 \in \{1,2,..nv_{i_0}\} | i_0 \in \{1,2,...,N_{Fpl}\}\} >,$$

where Fpl_{io} – the i_0-th function, received by application for execution;

Var_{iojo}– selected the j_o-th variant of the organization of activities in the implementation of the i_o-th function which has been received with the application for execution;

Mfs_{iojo} – selected the j_o-th formal model of the functional network of algorithm implementation of the i_o-th function;

OP_{ioko}– selected the k_o-th operator for the implementation of the application of the i_o-th function in the case of the impossibility of group activity;

$\{Opr_{iojol}\}$ – the set of operations of the activity algorithm for the selected j_o-th variant of the organization of activities for implementation of the i_o-th function which has been received with the application for execution;

ko^{jo}_{io}– the number of operations of the activity algorithm for the selected j_o-th variant of the organization of activities for implementation of the i_o-th function which has been received with the application for execution;

nv_{jo}– the number of options for organizing activities in the implementation of the i_o- function;

$\{OP_{lm}\}$ – the group of operators assigned to execute l_m-th operations j_o-th variant of the organization of activities in the implementation of the i_o-th function which has been received with the application for execution. To implement the function, group activities are allowed.

The symbols "[ ]" in the models mean that optional elements are enclosed in parentheses.

For example, this model (structure) can demonstrate the "relationship" of different models in the process of solving tasks for ensuring ergonomic SPIC on a model example tasks of ergonomics, which is distribution of functions between operators.

It is obvious that the task of distributing functions can be represented as a task of forming a new organizational and technological structure which satisfies the requirements to the quality of the application and a variety of ergonomic standards and requirements (figure.2)

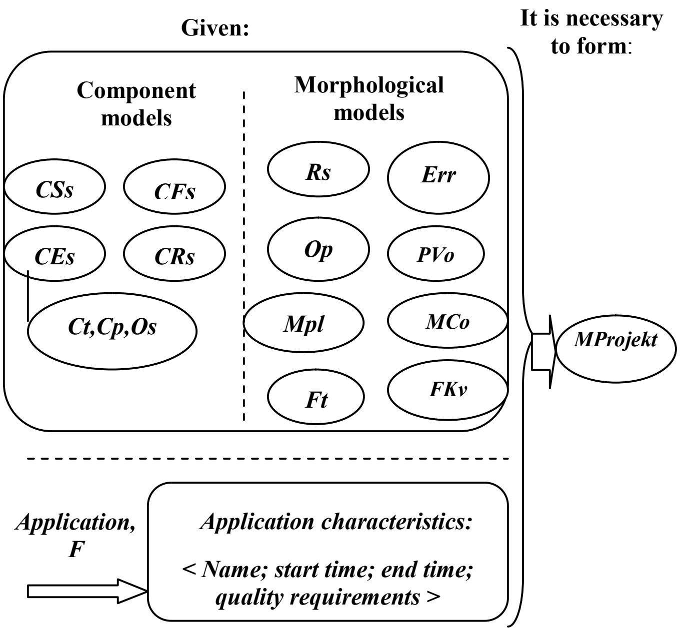

Fig. 2. Illustration for the meaningful estasblishment of the task of assigning functions to operators using the technology of component and morphological analysis of SPIC

APPROBATION. USING OF RESULTS AND THEIR PRACTICAL SIGNIFICANC

The approach was used in the development of the modeling qualimetric complex of ergotechnical systems [11-16].

The results were used in solving the following problems:

- Development of information models for a human operator [14,15];
- Development of algorithms for operators [16];
- Distribution of functions between operators [12,13];
- Distribution of functions between a human and automation devices [11].

The results are used in the design and utilization of systems for various purposes (automated control systems, payment centers, contact centers, e-learning systems, etc.).

CONCLUSION

The complex of models makes it possible to determine the structure of information support for the management system of ergonomic quality of information processing and control systems.

The results allow for making decisions on the use of ergonomic reserves to increase the efficiency of human-machine interaction.

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