Modeling and Using the Behavioral Function for Managing Multi-Control Systems

N. G. Mustafin
Saint-Petersburg Electrotechnical University "LETI"
St. Petersburg, Russia
nikolay.mustafin@gmail.com

S. V. Savosin
St. Petersburg Institute of Informatics and automation of the Russian Academy of Sciences
St. Petersburg, Russia
svsavosin@yandex.ru

P. V. Shvedenko
St. Petersburg national research University of information technologies, mechanics and optics (ITMO University)
St. Petersburg, Russia
pitk1@mai.ru

O. V. Shchekochikhin
LLC «Regul+»
St. Petersburg, Russia
slim700@yandex.ru

***Abstract*— The model of a multi-contour information-management system of an organization focused on the search for management solutions aimed at overcoming problem situations is considered. The proposed system allows you to recognize the problematic situation in the business process by rejecting the values of the indicators of the state of the organization from the target installations, to carry out a choice of the behavior model and to support the adoption of managerial decisions of the relevant management contours of the organization. An algebraic system is presented that allows to determine the type of problem situation, the behavior model, the business process and the control object. On the basis of the proposed model, a software has been developed that automatically determines the control loop that should solve the problem situation, and also define the responsibility centers for executing the management decision.**

Key words*— *information-control system; information system with behavior; contours of management; adoption of management decisions; mathematical model of multicontour control

Modern production is so difficult that a person is unable to promptly make managerial decisions with external and internal disturbing influences. Therefore, there is a tendency to apply automated data processing for analysis and formation of management objectives, search for effective management solutions to overcome problem situations. One of the methods is the creation of information systems (IP), endowed with the property of behavior [1–3]. IP with behavior provides support for making management decisions in automatic and automated modes. Automatic mode involves analyzing data, selecting the behavior model most appropriate for achieving management objectives. If the experience accumulated in the information system is insufficient to make a managerial decision, then an expert is engaged, developing a new template solution to overcome the identified problem situation while maintaining this new template in the solution base. The architecture of IP, endowed with the property of behavior, was previously considered in [4–6]. The creation of a new behavioral model was considered in [7, 8]. In this paper, we propose a formalized description of a multi-circuit IS, which allows, in the operational management mode, to use and form behavior models for the preparation and adoption of managerial decisions.

In the production system, several control loops can be identified: operational-process, operational-functional, functional-tactical, general-tactical, strategic, etc. Between the control loops, management and data are transferred to search for managerial decisions.

To find and justify management decisions, an appropriate mathematical description can be developed on the basis of set theory and first-order predicates.

In the development of a mathematical description of the management system, the composition, structures and systems of relations are introduced:

M – Multiple control loops

A lot of persons or devices that make decisions (PMD /DMD) – P

The set of functions of the PMD /DMD is PF

The mathematical system also contains a description of the business objectives tree and the management structure, which includes the decision maker with functions and a system of indicators. A plurality of PMD /DMD s through the indicators are associated with a plurality of functions performed by the PMD /DMD. A lot of applications are linked to the PMD /DMD, through executable functions.

The goal tree can have several projections – indicators of the current state of the information management system in various aspects, in which, along with the normative values f the

CRITICAL: This work was financially supported by Goverment of Russian Federation (Grant 08-08)), RFBR grants ##17-07-00327, 17-07-00328, 16-07-00463

978-1-5386-5824-6/18/$31.00 ©2018 IEEE

indicators, their actual values, the magnitude of the deviation and the degree of significance of the deviation are contained.

The projection of the target tree is represented by the following graph: $G_A = (A, T)$, where $A = \{A^0, A^1, ...A^{P-1}\}$

where Ai – is the exponent, which is a tuple:

(ID, N, NV), где

ID – the ID of the index,

N – name of the indicator,

NV – the standard value of the indicator.

T is a set of links between indicators. Each relationship defines the aggregation methods for the metric.

The indicator of the current state of the system is represented by the following graph:

GB = (B, T), where B – the state of the metric is a tuple of information:

(ID, FV, D, SD), where

ID – the ID of the figure from a graph GA,

FV-actual value of the indicator,

D-the value of the deviation of the actual value from the standard,

SD-degree of significance of deviation,

The presented mathematical structures allow to describe the interaction of control circuits of the production system.

The following mathematical structures are given to describe the information-control system:

many objects of the system – O,

set of elementary properties – H,

many types of objects To,

many types of properties – TS,

multiple business processes (BP) – BP,

set of links – L,

many applications included in the is – APP,

multiple data streams – DS.

A finite set defining the absolute and relative value of the date and time that are used in applications – DT.

Elements of the previously described sets define the basic set (Θ) of the algebraic system U and the set of constants (*C*) of the signature Σ).

The predicate describing the unique identifier of the information object (UIIO) has the following form:

uiio (O,N,H,O’,Y, DT),

$Y \subset N$, y_μ – a number of the property included in the UIIO.

The predicate is defined on the set:

$$M^u = O \times N \times H \times Y \times DT \supset \{(o_i, n, h_j, y_\mu, dt) \mid o_i \in \mathrm{O}, \mathrm{n} \in \mathrm{N}, h_j \in \mathrm{H}, y_\mu \in N, dt \in DT\}$$

The predicate takes the value 1 on a single set of arguments, thereby allowing you to define a set of properties from the set H included in the structure of the object O 'as a composite in the set of the unique identifier of the object O under the sequence number N of the set of constants Y, at time DT.

This allows you to uniquely identify the instance of the object in the information system at a time and all the data that accompanies it.

Further in the model, constructs describing the structure of processes are identified. A construct is understood as a speculative construction, introduced hypothetically (theoretically) or created about observable events or objects (empirical) according to the rules of logic with rigidly defined boundaries and precisely expressed in a specific language.

struct_SBP (BP, N,$\overline{O}$,$\overline{O}$,$\overline{O}$,…) – the predicate describing the BP version N.

The predicate is defined on the set:

$$M^{sbp} = BP \times N \times \overline{O} \times \overline{O} \times \overline{O} \times ... \times \overline{O} \supset \{(bp_j, n, \overline{o_1}, \overline{o_2}, ...) | bp_j \in BP, n \in N, \overline{o}_i, \in \overline{O} \land o_i \in O + A\}$$

Since the process has a stage structure, a predicate is introduced that specifies for the nth stage of the process a set of a single information object, a control loop, a decision maker, a corresponding control loop that processes incoming information and converts it into data of one or more indicators:

step_SBP(BP,N, N, M, P, APP,$\overline{O}$,$\overline{O}$,$\overline{O}$,…)

The set of truths of the predicate has the form:

$$M^{ssbp} = BP \times N \times N \times M \times P \times APP \times \overline{O} \times \overline{O} \times \overline{O} \times ... \times \overline{O} \supset \{(bp_j, n, \overline{o_1}, \overline{o_2}, ...) | bp_j \in BP, n \in N, n', \in N, \exists!\, o_i \in O\}$$

The interaction of applications operating at the BP stages is ensured by data streams in a multilayer bus.

The predicate of the unique identifier of the data stream in the bus has the following form:

Data_stream (BP, N, O, APP, DT)

The set of truths of the predicate has the form:

$$M^{ds} = BP \times N \times APP \times O \times DT \supset \{(bp_j, n, o_i, app_k, dt) | bp_j \in BP, n \in N, \exists!\, o_i \in OM \land o_q \in F, i \neq q, app_k \in APP, dt \in DT\}$$

The scheduled execution time of processes is analogous to the relationships in the relational database – by the predicate formula you can understand how the data in the flows are related.

The behavior model is determined on the basis of the analysis of sets of indicators and their deviations from the given normative values.

Behavior model predicate:

Behavior_model (A, B, PF, DS)

The set of truths of the predicate has the following form:

$$M^{ds} = A \times B \times PF \times DS \supset \left\{ (a_j, b_i, pf_k, ds_m) \middle| a_j \in A, b_i \in \exists!\, pf_k \in PF, ds_m \in DS \right\}$$

The behavior model allows defining a subset of management decisions. The degree of significance of the deviation of the indicator is related to the control loop. Depending on the degree of significance of the indicator, the management decision is automatically executed with the launch of the relevant BP and the control of their execution or automated with the participation of the SDP. The indicators are related to the control loop of the degree of significance of the indicator for one-to-many communication.

The proposed solution allows to simulate the operation of the information and control system, flexibly configure sets of indicators, determine the behavior patterns and control loops, depending on the degree of detail in the representation of the problems solved in the system.

REFERENCES

[1] Madraky A. Hair-oriented data model for spatio-temporal data representation. A. Madraky, Z.A. Othman, A.R. Hamdan. Expert Systems with Applications. No. 59. 2016, pp. 119-144. DOI: 10.1016/j.eswa.2016.04.028

[2] Vasin Y.G., Yasakov Y.V. Object-oriented system transfer management of spatially-distributed databases. Pattern Recognition and Image Analysis, 2016, No.26 (4), pp. 734-741. DOI: 10.1134/S1054661816040180

[3] Khakpour N. Synthesizing structural and behavioral control for reconfigurations in component-based systems. N. Khakpour, F. Arbab, E. Rutten. Formal Aspects of Computing, 2016, No.28(1), pp.21-43. DOI: 10.1007/s00165-015-0346-y

[4] Shvidenko V.N. Architecture for management information systems for problem-solving in the enterprise. V.N. Shvidenko, O.V. Schekochikhin, P.V. Shvidenko. Information control systems No. 5, Pp. 86-90 2016. doi:10.15217. 2016. (In Russian).

[5] Schekochikhin O.V. Object-process data model in management information systems. O.V. Schekochikhin. Scientific and Technical Journal of Information Technologies, Mechanics and Optics, 2017, vol. 17, No. 2, pp. 318-323 (in Russian). doi: 10.17586/2226-1494-2017-17-2-318-323

[6] Shvedenko V.N., Shchekochikhin O.V. The architecture of the integrated information system, providing the property of behavior. Journal Scientific and technical of information technologies, mechanics and optics. 2016. Vol. 16. No. 6. Pp. 1078-1083. doi: 10.17586/2226-1494-2016-16-6-1078-1083

[7] Shchekochikhin O.V., Shvedenko V.N. Methodological support of training and management decision-making in information systems with the property of behavior . Informatization and communication. No. 3 2017. Moscow. ANO "Editorial Board Informatization and communication". 2017.

[8] Sakharov N. Analysis of information support of business processes with the use of a group of queries of the metadata model. Scientific-technical Vestnik of the Volga region, 2015. No. 5. Pp. 272-274. (In Russian).