The model for computation of complex technical objects parameters based on subdefinite calculations

A V Konichenko, E O Ostrovskiy and M V Uryaseva

The Department of Computer Science, The Southwest State University, Kursk, Russia
E-mail: titov-kstu@rambler.ru

Abstract. The generalized computational model for calculation of complex technical object parameters when solving the problem of monitoring and their functioning control has been realized. The model has the following features: realization in the context of calculations of subdefinite expansion of parameters values based on assignment function and availability of consideration objects structural dynamics

1. Introduction
In the last ten years the information technology has progressed greatly and that resulted in significant growth of dynamics of complex organizational and technical systems functioning processes and in expansion of controlled parameters nomenclature. Complex technical objects (CTO) as elements of complex organizational and technical systems are managed objects of compound structure. Information about them in the form of current monitoring data is transmitted to the appropriate control system. Nowadays there is no CTO control technology that would allow to justify and generate some unitized set of software and algorithmic information processing instruments based on entire methodological approach. That is why the problem of organization of computing as a part of distributed monitoring system is not solved.

The purpose of this article is generic computational model [1, 2] development that will provide CTO parameters calculating for the improvement of formal framework for solving all-round automation of the problem of monitoring processes and for the complex organizational and technical systems control under uncertainty.

According to the research constraint programming has been developing actively and has become popular in applications recently, that is why it is one of constructive methods for the CTO parameters calculating [1, 3].

Generally, the problem of object state definition in constraint programming paradigm is formalized in the following way. Let limitations Ci (x1, x2, ..., xn), i =1, k are imposed to the object parameters x1, x2, ..., xn with codomain of sets X1, X2, ..., Xn. Value collections <a1,a2,...,an> (ai ∈ Xi) fulfilling all the limitations concurrently must be found.

This statement is called the constraint satisfaction problem and is solved by different algorithms and methods. Particularly, it may be stated as the system of equations with numerical parameters that can be solved by standard numerical methods [3]. However, these methods are often useless in the concerned subject area, because the CTO model, formalizing its technical state, involves non-numerical parameters in many cases. Furthermore, some initial data can be set approximately with capability to be dynamically specified on basis of incoming monitoring information.
That is why, Subdefinite models [1] is the most constructive approach in constraint programming for solving the stated problem. Actually, S - Models is the only technology that allows to solve the constraint satisfaction problem mostly in general definition that is appropriate for CTO parameters calculating nowadays. The fact that S - Models is marked out among the bulk of other approaches by computational power, universality and efficiency is described in a series of papers [1, 4, 5]. The capability to use the same model in solving different problems (for example, direct and inverse problems), because there is no division into input and output parameters, is essential advantage.

2. Features of usage of subdefinite calculations for complex technical objects monitoring
The features of forming of generalized calculating S – Models are described in papers [1, 5]. The analysis diagnosed that the existing mathematical apparatus applied to the concerned subject area has a number of limitations and assumptions which reduce applications solutions efficiency.

It’s worth mentioning, that the modern S – Model paradigm suggests the strict division of elements belonging to the search space for solutions. This idea is realized on basis of S – expansions structure, it determines specifics of initial data assignment and assignment functions. However, speaking about CTO the considerable part of data for modelling is fuzzy, as a result, initial data and limitations cannot be assigned appropriately on basis of the existing apparatus. The research area concerned with development of models and systems, handling subdefinite information coupled with fuzziness, ambiguity, etc. is emphasized as one of the most perspective in 13]. But such models have not been created and described in scientific literature yet.

In addition to fuzziness the significant structural CTO dynamics is an important feature of the subject area that should be concerned for modelling. It depends on the environment conditions that in conjunction can be defined with the term “system” applying to the research object. At the same time, the existing S - model apparatus being theoretical generalization suggests the availability of determined structure of modelling object. This results in the need to create a set of private S – model realizations which will formalize its structure variant depending on situation that will considerably increase resource intensity while solving applications in the area of CTO monitoring and control.

Thereby, there is the objective need of existing S – model apparatus expansion to eliminate its limitations for solving problems of CTO states prediction.

3. Formalization of the procedure of complex technical objects calculation
According to the general statement of S – model synthesis problem each CTO parameter with limited information is formalized as non-empty universe subset consisting of denotation value that is known accurate to S – value (unknown as an option) due to the lack of information at the stage of the problem statement. In the process of clarification, as monitoring data arrives, S – value becomes more and more determined and can become accurate in the limit, that means equal to denotation of this subdefined value.

As long as the constraint programming is mostly declarative and bases on the description of the problem model, but not on the algorithm of its solving, the CTO informational model is specified as a disordered aggregate of ratios, that fit relations between its parameters depending on situation. According to the requirements of the concerned problem at the initial stage a user determines which parameters are accurate, which are unknown and which are set approximately (the initial information for such parameters is limitations to the possible values set).

Let the description of CTO parameters and its modifications processes formalize as computational model:

\[ \tilde{M}(X) = \{ \{ \tilde{X}; \tilde{R}_i; \tilde{W}; C \} | A(K) \}, \]  

(1)

where \( \tilde{X} \) – set of CTO parameters; \( \tilde{R}_i \) – set of limitations for \( \tilde{X} \); \( \tilde{W} \) – set of assignment functions (defines a new parameter value as a function of current and assigned values); \( C_i \) – set of functions of correctness check (define the parameters values modifications and check the accuracy of calculated
value): \( A \) – function of model adaptation to the structural dynamics of CTO; \( K \) – set of standard situations.

Thereafter, CTO parameters \( x \in X \) are matched to:
- their universes expansions \(*x_i, *\tilde{x}_i \), coupled subdefinition in processing of fuzzing value assignment;
- the initial value of each parameter from its universe (accurate, subdefine with strict elements division, subdefinite with fuzzy elements, great uncertainty);
- the assignment function \( \tilde{w}_i \in \tilde{W} \), that produces the intersection of fuzzy subdefine values:
  \[ \tilde{w}_i (*x_i^{old}, *x_i^{new}) = *x_i^{old} \cap *x_i^{new}; \]  
  (2)
- the function of correctness check \( C_{*x_i} \), testing \( S \) – values for non-emptiness:
  \[ corr_i(*x_i) = if (*x_i) \neq \emptyset then true else false \]  
  (3)
- the set of standard situations, influencing on parameters of the object \( S \);
- the adaptation function, providing object structural dynamics registration \( A(K) \).

The assignment function operates every time when another value is assigned to the parameter \( x \in X \) and determines the new parameter value as a function of current and assigned values. In diagram mode it can be interpreted like a fuzzy situation net [6]. It consists of a set of control decisions for CTO parameters transformations, which are characterized by a number of double vertices: the parameter \(*x_i \in *\tilde{x}_i \) - transformation operators aggregate \( \tilde{w}_i \in \tilde{W} \):

\[ \tilde{W} = \{*x_i, \tilde{w}_j\}, i = 1, I, j = 1, J \]  
  (4)

Wherein the set of operators \( \tilde{W} \) is split in functional transformation aspects:

\[ \tilde{W} = \bigcup_l^L \tilde{W}^l, \quad \tilde{W}^l = \{\tilde{w}_1, \tilde{w}_2, ..., \tilde{w}_j\} \]  
  (5)

Depending on specific problem characteristics, the transformation operators \( \tilde{W} \) can be functions, related to the following groups:
- Continuous numerical functions.
- Membership functions, based on peer review.
- Membership functions, based on automatic situations recognition with the intellectual informational technologies usage.

The summary of rules of transformation operators usage is in the table 1.

**Table 1. Rules of transformation operators of assignment functions usage.**

| No | Transformation operator group | Set of acceptable alternatives | Dimension of solution search space | Heuristic information availability |
|----|--------------------------------|---------------------------------|-----------------------------------|----------------------------------|
| 1  | Continuous numerical functions | Smooth and unimodal             | No requirements                   | No requirements                   |
| 2  | Membership functions, based on peer review | Different from item 1 | Small | No requirements |
| 3  | Membership functions, based on automatic situations recognition | Different from item 1 | Large | Required |

Binding of CTO parameters calculating values to the solution search spaces is produced due to the set of standard situations \( K = \bigcup_{r=1}^K K^r, K^r = \{*x_r', *\tilde{x}_r', ..., *\tilde{x}_q'\} \), that is divided into the set of basic
situations $K_{\text{ocn}}$ and the set of auxiliary situations $K_{\text{aux}}$, grouped by situation feature hierarchy:

$$K = \bigcup_{a=1}^{A} K_{\text{ocn}}^{a} \cup \bigcup_{b=1}^{B} K_{\text{aux}}^{b}$$

according to the constraint programming paradigm.

Each basic group (top hierarchical level group) is matched to the set of some functional packet actions of transformation operators, and each situation is matched to the subset of these actions:

$$K' \leftrightarrow A(K)' , r \in [1, R],$$

$$k' \leftrightarrow A(K)'_{q} \subseteq A(K)' , r \in [1, R], q \in [1, Q]$$

The function correctness check is a unary predicate that is executed if the parameter value has changed and checks the correctness of the new value.

The model adaptation function provides standard situations binding to the object structure and finally defines structure subset variants, and their elements are used in calculations:

$$\{X, X', W, C\} \xrightarrow{A(K)} \{X', X', W', C\}.$$  

At the interpretation level (1) is a bipartite directed graph with two vertex types: objects and functions. Arcs link functional and object vertices. Incoming function vertex arcs match it to the objects (in that case – parameters $x \in X$, their values $X_v$ are used as function input arguments), outgoing arcs denote objects in which the function results will be recorded.

By analogy with traditional S–models each object vertex is matched to type and value and the assignment functions and the functions of correctness check are bound. Each functional vertex correlates with integer that acts as priority and with benchmarking of incoming and outgoing arcs. The calculation process has a streaming character – the change of the network object vertex activates (invokes execution) function vertices, for which these object vertices are input arguments and execution of function vertices in turn may cause the result object vertices change. According to the S–model paradigm the calculations finish when there are no active function vertices or the function of correctness check yields “false” value (Figure 1).

![Figure 1. The structural scheme of calculations of complex technical object parameters.](image-url)
5. Summary

1. The generalized computational model has been announced. It provides the computation of complex technical object parameters for solving of monitoring problems and controlling their functioning.

2. Within the framework of the developed model decentralized, asynchronous, concurrent process for calculation of complex technical objects parameters has been realized. That supports organization of computations monitoring distribution system. As opposed to known generalized computational models, the control under calculations for both: data and events, has been realized. Besides, the processing of subdefinite information is made with taking into consideration its possible fuzziness and indeterminacy.

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