Automated Systems & Technologies
25-26 May 2015 • St. Petersburg, Russia

THEORETICAL AND TECHNOLOGICAL FOUNDATIONS OF COMPLEX OBJECTS PROACTIVE MONITORING MANAGEMENT AND CONTROL

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Abstract

Today the problem of complexity is one of the central one in control over modern and perspective organization-technical objects (or oversize – complex objects (CO). The problem includes a lot of aspects, such as complexity of description of both object under control and corresponding control system as a whole, complexity of modeling and prediction of their behavior, as well as complexity of decision making in the control system. As applied to complex organization-technical objects, an additional aspect of control is recognized, namely, the complexity management problem. In contrast to traditionally employed reactive control, oriented to operative response and consequent exclusion of possible extraordinary and emergency situations, the proactive control over objects presupposes prevention of the above accidents through the creation, in the control system, of fundamentally new prognostic and preemptive features of formation and realization of control actions based on methods and technologies of system modeling.

The authors proposed original dynamic multiple-model description of CO functioning at the different stages of their life cycle. Joint use of diverse models in the framework of poly-model systems, allows one to improve the flexibility and adaptability of CO, as well as to compensate the drawbacks of one class of models by

the advantages of the other. Moreover authors suggested combined methods and algorithms of models coordination and adaptation. One of the main opportunities of the proposed method of CO structure dynamic control program construction is that besides the vector of program control we receive a preferable multi-structural macro-state of CO at the end point. This is the state of CO reliable operation in the current (forecasted) situation. Now this theory is comprehensive implemented in different apply areas such as rocket-space, nuclear energetic, transport spheres.

INTRODUCTION

The main subject of our investigation is complex systems. By complex systems we mean systems that should be studied through polytypic models and combined methods. In some instances investigations of complex systems require multiple methodological approaches, many theories and disciplines, and carrying out interdisciplinary researches. Different aspects of complexity can be considered to distinguish between a complex system and a simple one, for example: structure complexity, operational complexity, complexity of behavior choice, complexity of development [1-3, 10, 16, 21-22].

Classic examples of complex systems are: control systems for various classes of moving objects such as surface and air transport, ships, space and launch vehicles, etc, geographically distributed heterogeneous networks, flexible computerized manufacturing [3-6, 13, 18-19, 25, 29].

One of the main features of modern complex technical-organizational systems (CTOS) (in our case Socio-Cyber-Physical Systems (SCPS)) is the changeability of their parameters and structures as caused by objective and subjective reasons at different stages of the CTOS life cycle. In other words we always come across the CTOS structure dynamics in practice [10].

Under the existing conditions the SCPS potentialities increment (stabilization) or degradation (reducing) makes it necessary to perform the SCPS structures control (including the control of structures reconfiguration). There are many possible variants of SCPS structure dynamics control. For example, they are [7, 20, 24, 28]: *alteration of* SCPS *functioning means and objectives; alteration of the order of observation tasks and control tasks solving; redistribution of functions, of problems, and of control algorithms between* SCPS *levels; reserve resources control; control of motion of* SCPS *elements and subsystems; reconfiguration of* SCPS *structures*.

According to the contents of the structure-dynamics control problems they belong under the class of the SCPS structure – functional synthesis problems and the problems of program construction, providing for the SCPS development.

As applied to SCPS we distinguish the following main types of structures: the structure of SCPS goals, functions and tasks; the organization structure; the technical structure; the topological structure; the structure of special software and mathematical tools; the technology structure (the structure of SCPS control technology).

By structure dynamics control we mean a process of control inputs producing and implementation for the SCPS transition from the current macro-state to a given one.

Modern informational technology (IT) market calls for reduce of costs, rapid return of investment, and increase of performance and agility. The concepts of adaptive, self-organizing information systems comply with these requirements and, moreover, introduce evolutionary modification of control paradigm and IT configurations. An automatic control loop of new information systems includes four main phases [17, 22, 27]: information gathering and filtration; analysis of information, evaluation of internal states and external situation, prediction of future states and situations via comprehensive modeling; control structuring (working out of a plan) for problem solving according to response policies; implementation of the plan, control of the plan execution.

These functions are assigned to four main subsystems, namely the monitor, the analyst, the scheduler, and the engine.

So at present time the ***fundamental problem of SCPS structure-functional synthesis*** is very *actual, interesting, and important.* The first step towards a solution of the problem is connected with ***methodological and technique approaches to comprehensive modeling of SCPS*****.** Preliminary investigation showed that traditional particular approaches to SCPS modeling and simulating are not adequacy.

THE MAIN PHASES AND STEPS OF PROACTIVE CONTROL OF SCPS STRUCTURE-FUNCTIONAL SYNTHESIS

The main aim of our investigation is to prove the need of integrated modeling for parallel structural-functional synthesis of SCPS under dynamic conditions. Moreover the main idea of our approach is to use fundamental results of structural-dynamic control theory [20] for multiple-model description of SCPS functioning and investigation. During our investigation we will describe the main classes of SCPS integrated modeling tasks. For these aims we will use SDC theory. Methodological basics of this theory include: the methodologies of generalized system analysis and the modern optimal control theory for CTOS with re-configurable structures. The dynamic interpretation of structure-dynamics control processes lets apply the results, previously received in the theory of dynamic systems stability, ability, failure tolerance, effectiveness and sensitivity, for SCPS analysis problems.

Existence of various alternative descriptions for SCPS elements and control subsystems gives an opportunity of adaptive models selection (synthesis) for program control under changing environment.

Therefore we considered two general actual problems of the SCPS structure-dynamics investigation. They are:

– the problem of selection of optimal SCPS structure-dynamics control programs at different states of the environment;

– the problem of parametric and structural adaptation of models describing SCPS structure-dynamics control.

In this case 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 scheduling of SCPS operation (construction of SDC programs);

– simulation of SCPS operation, according to the schedules, for different variants of control decisions in real situations;

– structural and parametric adaptation of the schedule, control inputs, models, algorithms, and SCPS programs to possible (predicted by simulation) states of SO, CS, and of the environment.

During our investigations the main phases and steps of a program-construction procedure for optimal structure-dynamics control in SCPS will be proposed.

At *the first phase* forming (generation) of allowable multi-structural macro-states is being performed. In other words a structure-functional synthesis of a new SCPS make-up should be fulfilled in accordance with an actual or forecasted situation. Here *the first-phase* problems come to SCPS structure-functional synthesis.

At *the second phase* a single multi-structural macro-state is being selected, and adaptive plans (programs) of SCPS transition to the selected macro-state are being constructed. These plans should specify transition programs, as well as programs of stable SCPS operation in intermediate multi-structural macro-states. The *second phase* of program construction is aimed at a solution of multi-level multi-stage optimization problems.

One of the main opportunities of the proposed method of SCPS SDC program construction is that besides the vector of program control we receive a preferable multi-structural macro-state of SCPS at the end point. This is the state of SCPS reliable operation in the current (forecasted) situation.

The combined methods and algorithms of optimal program construction for structure-dynamics control in centralized and non-centralized modes of CTOS operation will be developed.

Classification and analysis of perturbation factors having an influence upon operation of SCPS will be performed. Variants of perturbation-factors descriptions will be considered for SCPS SDC models. In our opinion, a integrated simulation of uncertainty factors with all adequate models and forms of description should be used during investigation of SCPS SDC. Moreover, the abilities of SCPS management should be estimated both in normal mode of operation and in emergency situations. It is important to estimate destruction "abilities" of perturbation impacts. In this case the investigation of SCPS functioning should include the following phases:

– Determining of scenarios for SCPS environment, particularly determining of extremely situations and impacts that can have catastrophic results.

– Analysis of SCPS operation in a normal mode on the basis of a priori probability information (if any), simulation, and processing of expert information through theory of subjective probabilities and theory of fuzzy sets.

– Repetition of item b for the main extremely situations and estimation of guaranteed results of SCPS operation in these situations.

Computing of general (integral) efficiency measures of SCPS structure-dynamics control.

Algorithms of parametric and structural adaptation for SCPS SDC models will be proposed. The algorithms will be based on the methods of fuzzy clusterization, on the methods of hierarchy analysis, on biological adaptation mechanisms, and on the methods of a joint use of analytical and simulation models.

CONCLUSION

Methodological and methodical basis of CTOS SDC theory is developed by now. This theory is oriented to solving three groups of tasks: CTOS structure-dynamics analysis tasks (for examples, estimation and analysis of controllability, attainability, solvability, sensitivity, stability, disaster tolerance, and etc); CTOS structure dynamics diagnosis, observation, multi-layer control tasks; tasks of dynamic structure-functional synthesis of CTOS.

It has interdisciplinary basis provided by classic control theory, operation research, artificial intelligence, theory of systems and system analysis. The dynamic interpretation of CTOS reconfiguration process provides strict mathematical fundamental base for CTOS problems decisions that have never been formalized before and have high practical importance. In the paper we propose possible ways of implementation CTOS SDC theory in the area of SCPS proactive monitoring and control and management.

ACKNOWLEDGMENTS

The research is partially supported by the Russian Foundation for Basic Research (grants 13-07-00279, 13-08-00702, 13-08-01250, 13-06-00877, 13-07-12120-ofi-m, 15-29-01294-ofi-m, 15-07-08391, 15-08-08459); grant 074-U01 supported by Government of Russian Federation; Program “5-100-2020” supported by Government of Russian Federation, Department of nanotechnologies and information technologies of the RAS (project 2.11); by the Ministry of Education, Youth and Sports of CR within the National Sustainability Program I (NPU I) (grant number LO1415); by ESTLATRUS projects 1.2./ELRI-121/2011/13 «Baltic ICT Platform» and 2.1/ELRI-184/2011/14 «Integrated Intelligent Platform for Monitoring the Cross-Border Natural-Technological Systems».

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