Development, Perspectives and Application Possibilities of Situational Control of Complexes

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Abstract: The proposed paper gives a brief survey of situational control (SC) of complex systems development, also a brief survey of applications that were realized in the past period (SC of robotic - technological complexes, SC of electric network, SC in metallurgy, SC in biomedicine, situational modeling, situational classification in projecting, etc.) The paper also deals with problems of decision – making processes and classification algorithms used in situational control of complexes. We also discuss possibilities of use of situational control methodology in jet engine control.

Keywords: Complex system, situational control, decision-making processes, jet engine

1 Introduction

By control and diagnostics of complex systems the basic contradiction is a solution of contradiction between a large number of operational situations and limited number of used control strategies. The newest approaches to complex systems control (complexes, production systems, automated technological workstations, etc.), show the need of a plan preparation also for atypical operational situations (emergency, structural failures, starting and stopping of a plant, etc.). Problems related to the mentioned approaches can be overcome in the manner, that operational situations can be grouped into a finite number of classes (model classes of situations), to which certain control algorithms are assigned (strategies, functions of control regimes).

An important tool of design is a methodology of situational control that is aimed on optimal cover of vast set of situations with appropriate low number of control algorithms. The approach to creation and application of situational control methodology has been described in works of (Madarász, L. 1982; Madarász , L. 1986; Spal, J., Madarász, ., 1984; Madarász, L., Holečko P., 1994; Madarász , L.,1996).

By situational control of complex systems following problems come into our attention focus:

1. How to prepare a file of suitable and acceptable decisions (strategies of control).
2. How to classify individual situations into model classes in the way, where every class of situations would have suitable decision assigned to
3. How to realize classification of actual situations into model classes by real-time operation of a system.

In particular cases these problems are closely related with the selection of according methods of decision making, or a classification method. Most commonly appearing approach is the integrated use of several decision-making methods that are based upon these criteria: reliability, quality and efficiency.

2 Development and Further Perspectives of Situational Control of Complex Systems

2.1 Models of Situational Control Systems

Situational control of complexes as one of the alternatives of complex systems control, was invented and further developed in Russia (Ju.I.Klykov, J.M.Klimnik, A.I. Sokoľnikov, D.A. Pospelov; G.Osipov; A.N. Averkin; O. Citkin; A.A. Zenkin, L.S. Zagadskaja, V.F. Erlich, V.F. Gorjachuk, V.S. Lozovskij, V.F. Choroschevskij).

In western countries developers of situational control methods were the following scientists: J. Zaborszky, K.W. Whang, K.V. Prasad, D.R. Stinson, F.B. Vernadat, D. Howland, S. Beer, A.P. Sage.

Problems of situational control of complex systems have been also analyzed in conditions of former Czech-slovak federation by scientists as J. Beneš, J. Spal, L. Madarász and others.

Situational control was designed for the control of complex systems, where traditional cybernetic models of control weren't sufficient. The traditional cybernetic model of control is introduced for example in [27].

For systems, where it is difficult to describe their specific structure and behavior and where the presence of a human factor has an unforeseeable character and also where the system is developing by itself in time, methods of situational control have been developed. These systems can be also characterized by the following features:

- unique – an object of control has such individual structure that it is not possible to apply any traditional model of control
- dynamic – a state of the controlled object is always changing in time, so the control system has to be able to adapt to changes of controlled object
- incompleteness and uncertainty of the system description - it isn't possible to supply complete information about the controlled object;
- presence of free latitude (the presence of independent decisions) – the controlled object consists of people end technical devices (ergatic systems). A situation may occur where the controlled object has a different goal than its controller.
- ambiguity – it usually isn't possible to designate what is the optimal solution from the control point of view
- non-formality – a goal of an object existence can't be described by formal algorithms (e.g. if we look at a big city functioning it isn't practically possible to exactly formalize its aims)

One of the first models of situational control of complex systems was designed in 1960 (fig. 1; Pospelov D. A., 1986). Single components of the model have the following functions:

- analyzer – based upon the time patterns receives messages and creates a description of the current situation (e.g. the semiotic model). In the case that the analyzer finds no considerable changes being made, it doesn't undertake any action. If there are considerable changes in the system, the message is passed to the classifier.
- classifier – to actual situation assigns the model class of solutions, that consists of simple actions, that can bring the system to a desired state.
- correlator – saves all solutions in a form of logical transformation rules. It designates which solution to apply, but the exact selection is left for the extrapolation block.
- extrapolation – selects from existing several solutions applicable for given situation only one solution.
- random selection block – in the case where correlation, nor the extrapolation block haven't selected a solution, the random selection block chooses the solution that minimizes undesirable effect upon the system, or it doesn't execute any hit.

The proposed model is efficient only in those cases, where the count of distinct situations is high, but the count of distinct considerable and usable single steps is low

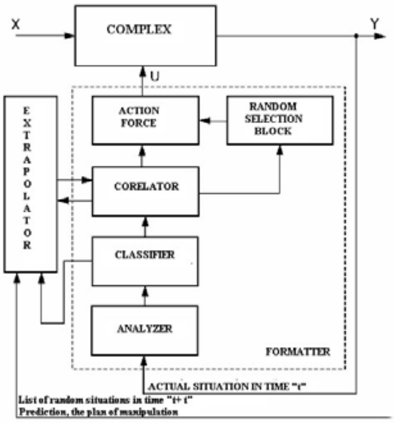

Fig. 1. Situational control model, year 1970 (Source: Pospelov, D. A. , 1986)

The first situational control system model (Fig. 1) was further developed and in 1970, a new situational control system model was presented. Following additional components are incorporated within the model:

- Block of problem solution and simulator – in cooperation with the correlator designates the solution of the problem. If the solution is known from the knowledge base, the simulator can test the found solution.
- decoder – converts the found solution from the language of situational control into the native language.

A general scheme of situational control of complex systems was proposed by L. Madarász in 1982 (Fig. 2). The control process is there composed of two basic phases, decision and a control phase, where every of them is divided into classification and an action phase. Processed situation is then analyzed in the selection part of the decision phase. According to a result of analysis a situation is then assigned to one of "N" standard situations, which are designed to process according emergency situations. Every standard situation has a certain file of algorithms which are saved in memory to its disposition.

During the action period of the decision-making phase, the most suitable file of algorithms is being activated to process the given situation.

During the selection interval of the control phase, these algorithms adapt themselves to solve the according situation (parameterization and other adaptation connected with activation). Realization of control activity occurs afterwards in the action period of the control phase (Madarász, L., 1996).

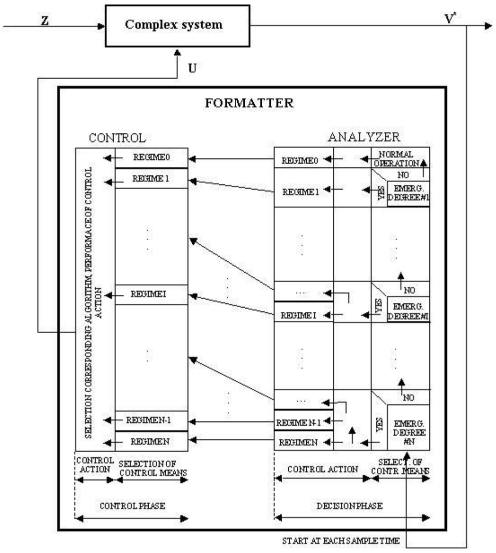

Fig. 2. Scheme of the situational control of a complex (1982) (Source: Madarász, L, 1982)

With constant development of computer capacities, also the development of techniques has occurred. Those techniques were used in the situational control model from year 1990. (Fig. 2) Relations with models from years 1960 and 1970 are following:

- the analyzer is replaced by an expert system
- as a classifier an expert system together with a domain model is used
- for extrapolation and simulation modeling and computing system is used
- instead of correlator, an expert and computing system are used

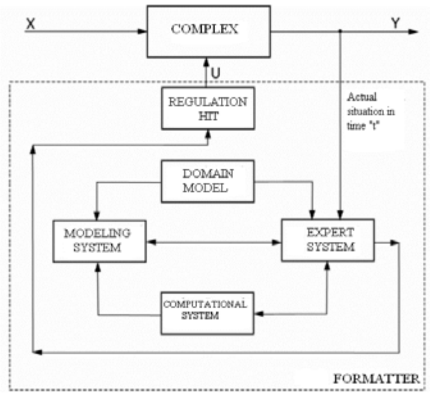

Fig. 3. Model of situational control (1990) (Source: Pospelov D.A., 1995)

Perspectives of situational control of complex systems are closely related to the development of methods of computational intelligence. As the computational intelligence part of a situational control system, a whole row of methods can be used, as are for example, neural networks, fuzzy systems, genetic algorithms, etc. One of possible perspective situational control models is shown in Figure 3.

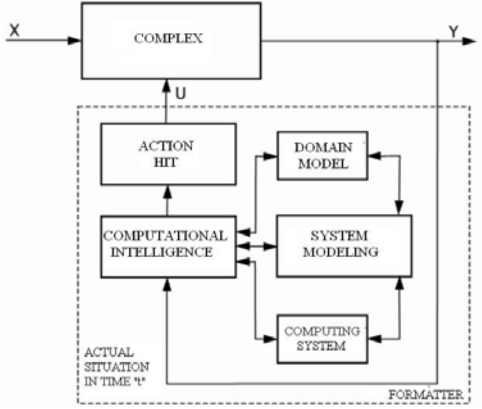

Fig. 4. Perspective model of situational control

2.2 Anytime Control of Complex Systems and Catastrophe Theory

In connection with situational control of complex systems, terms „Catastrophe theory"[24] and „Anytime Control"[23] are used. The catastrophe theory is successfully applied in the control of complex technological systems, that contain very fast, or very slow changing processes. By the control of very fast changing processes we demand quick analysis and data processing, fast units for processes with very short cycles in real-time control and powerful computing force with appropriate memory capacity. The control of very slow processes demands permanent communication due to reasons of slow changes registration, while the final and present state are discerned. Attention is also put at sampling and evaluating of fast and slow processes. Mentioned terminal situations and also their handling and control fit into the problematic of situational control.

The catastrophe theory can be applied by formalization and control of such processes that are dependant upon random factors, as thermo energetics, agricultural technological processes, environmental preservation, problems in sea and air traffic navigation, technical systems, aeronautics (stability of planes at high speeds, stability of helicopters by maneuvering), etc.

Anytime control algorithms fit into the frame of problems that are being solved with situational control methodology. According to the present definitions the anytime control algorithms are aimed only at a certain subset of situational control problems. This includes situations in control where errors in sampling rate at the system's input occur. These errors can appear due to a system overload problems or due to an erroneous function of the system itself. The anytime control algorithms can also be defined as algorithms of computing time exchange for the accuracy of results. The simplest approach to these problems solution would be the change of sampling rate upon the input. But from the accuracy point of view this approach isn't sufficient and therefore often systems that predict the missing samples upon the input are used. Traditional approaches in this area are mathematical or statistical approximation models, but those models aren't often flexible and robust to uncertainties, so there is an opening of new space for the use of computational intelligence methods, which do not require the exact mathematical model of a system. In certain cases fuzzy models are quite sufficient, but newer approaches are more aimed at adaptive an hybrid systems combining neural network algorithms and fuzzy systems and also the traditional control methods. Problems of anytime control algorithms can be generalized into three main points and these are: certainty, accuracy and particularity of obtained results. Algorithms that are hidden beneath the terms "Anytime Control" and "Anytime Processing" serve for preparation of real-time decisions. They are intelligent supervisor systems using interactive algorithms with an adaptive structure.

3 Applications of the Methodology of Situational Control of Complex Systems

The development of automation with high utilization of computational and control techniques and new information technologies is aiming at the final goal of an integrated computer controlled production (CIM systems). Nowadays this is becoming a very difficult and important task. The complexity of a fully automated production expects its economical operation. This is conditioned by preparation of program equipment also for atypical operational conditions. One of the suitable methods, which respect economical requirements for solution of such atypical conditions, is the situational control. Among areas where some basic principles of the situational control methods have been successfully implemented and tested belong:

- situational control of electric network
- situational control of a robotic technological complexes
- diagnostics and situational control of a workplace used for the planar forming,
- diagnostics and situational control of rolls,
- charging of tampering basins
- situational modeling

- biomedical engineering,
- army.

In this article we will mention further applications of methods of situational control:

3.1 Situational control of electric networks

Control of electric networks occurs in two basic stages: the firs is a decision phase and the second is a control phase, while every of them is divided into a selection phase and an action phase [9, 11, 29]. The action task of the first decision phase types a given situation into an according degree of danger. According to a degree of danger of an electric network, the action part of the decision phase selects one of the 6 control regimes to handle the situation.

The selection task in the control phase selects the best solution of a given situation based upon the selection of an appropriate control algorithm, which is stored in the memory of control computer. The action task secures execution of an action hit, wile we expect that no other unfavorable situations occur during the process. The designed algorithm of situational control of electric networks has been presented in [9,11,29

3.2 Situational control of a robotic technological complex

The project which is proposed to increase the efficiency of an automated line used for production of crank-shafts comes out of an evaluation of results of modernization of the line and application of methods of situational control. In this process, the following steps were executed: designation of an algorithm of solution by the modernization, an analysis of the original structure of the subsystem, experiments with the simulation model GPSS (General Purpose Simulation System), experimental verification of operational capability using a computer simulation, proposal of a model of structure and function of the project (Petri's nets), classification and proposal of control regimes, algorithmization of regimes of control of the robotic subsystem and creation of a knowledge base and its implementation into an empty expert system FEL – EXPERT.

By classification of the error states, the following errors were taken in account:

- in the technological subsystem,
- in the manipulation subsystem,
- in the control subsystem.

At the same time errors of quality (tools errors) and errors of quantity (parallel working machines with a possibility of mutual replacements) were defined. Furthermore an absolute failure, a partial failure (lowering of the production ability), the range of a failure and time of duration of the failure were taken in account.

Considering the mentioned classification 4 degrees of danger of the complex operation and 4 regimes of control were defined [11]. A proposal of a global algorithm of situational control of the robotic technological complex was a part of the project as well as a proposal of a knowledge base for situational control of a line.

4 Situational Control Methodology Application in Jet Engine Control

Jet engines in general can be treated as very complex systems, dependant upon many parameters that influence their operation. These parameters may be of external or internal character. By external character we mean mostly the environmental conditions, by internal character we mean the inner variables of an individual engine. The outer environment represents factors as: temperatures, humidity, turbulences, airflows, etc. Inner characteristics of the engine represent factors as: inner temperatures of the engine (in front of the compressor, behind the compressor, combustion chamber, etc.), pressures within the individual parts of the engine, airflows within the engine and others. As can be seen from this brief parameters‘description control of such system may become a very complex and difficult problem. Under such high number of changing variables, an individual engine may behave very differently. Indeed nowadays control system mostly act only as stabilization systems that stabilize operation of an engine in all flight regimes. However if we want to control an engine in all its regimes, which may differ in great way, not only one classical control may be sufficient to solve all these operational states. Here comes situational control methodology into part, which is meant to control an object in general in all its operational states. Except the normal operation of an object also emergency and other exceptional situations have to be considered. By exceptional situations in an engine we mean for example start-up of the engine, or strong turbulence etc.

To handle all of these situations under all circumstances that can occur in an engine, a robust controlling system has to be used. In the following part of the article we will propose a suitable control scheme of a jet engine, which will be further implemented within the frame of the SIRIAD project. According to the proposed methodology in previous section, individual process of an engine control is composed of two main phases, a selection phase and a control phase, where every of them is further decomposed into two phases. At first we will deal with the selection phase. During this phase the control system has to classify in what state the engine is according to variables which influence its operation. Due to the mentioned quantity of variables, intelligent technologies offer such very robust solutions which don’t lead only to control and classification, but also solve problems of diagnostics, predictive control, thus failure prevention. The following figure shows a general scheme of possible control of a jet engine. This scheme is derived from [5].

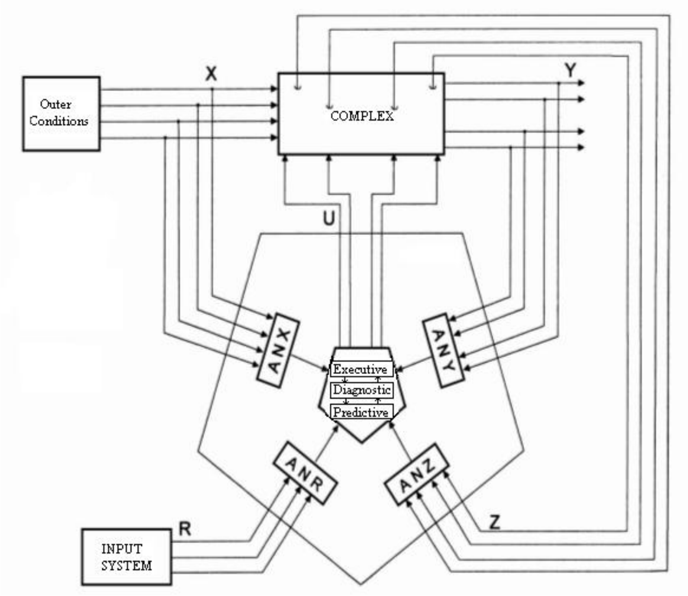

Fig. 5. General scheme of situational control system derived from [5]

However this model differs from works of Beneš in a way where mutually interconnected modules are incorporated into the control system:

- Executive module – the actual set of control systems, that execute the final action hit to the complex
- Predictive module – makes decisions prior to actual situations, that are based upon the conditions given by ANX, ANR, ANZ variables. This module influences actual parameters of controllers of the executive module. For example it may change characteristics of the control to prevent an emergency situation.
- Diagnostic module – observes variables of the actual object (a jet engine) and evaluates if an emergency situation has occurred and according to such situation makes a direct hit (e.g. shutdown, or influencing the executive module through controller parameters)

This is a general approach to control of a complex system like a jet engine is. In the following part we will try to propose architecture of a model of the executive module of situational control. There are many possible ways how to realize the actual classification of actual situations into situations frames. We selected a connectionist neural network to do the actual classification. Here many approaches may be selected and tested to obtain the best results. This network will work as the gating network, which will then set gates for the individual controllers used in the system, which create NARA like architecture.

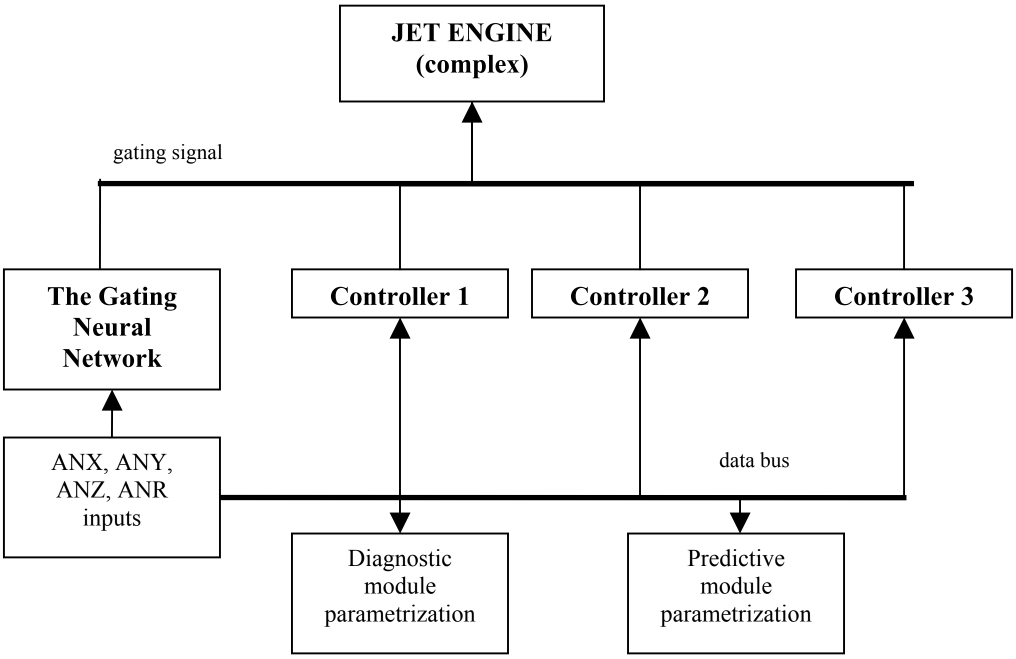

Fig. 6. Simplified scheme of possible control system of a jet engine

This scheme has to be considered as a simplified one, because in reality more than just 3 controllers, which represent only 3 situational frames, may be needed. As controllers classical parametric control mechanisms may be used, but also fuzzy controllers or other types may be used within this scheme. Proposal of suitable controllers will be part of further development. Application of such control system expects also use of full authority electronic control system in jet engines [28].

Conclusions

Situational control of complex systems is based mainly on the situational classification, situational estimation and situational recognition of the actual situation and assignment of an appropriate control regime, which has to provide the return of a complex into its normal operational state. Together with mentioned problematics, questions of a general architecture of control systems definition are coming into foreground. Also questions of validity of decision-making processes based upon the principles of artificial intelligence, questions of preparation of working processes in off-line mode and of real-time control arise.

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