Overview of New Scopes and Approaches in Situational Control of Complex Systems

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Abstract: Situational control doesn't yet have a unified definition, which would be commonly accepted and established. However this methodology is conceptually used in many applications although it is not explicitly designated. This article will be focused at our research, knowledge and newest approaches in situational control of complex (large scale) systems. The recent applications that are being researched include use of artificial intelligence approaches bound with hybrid systems of control. These applications represent control of turbojet engines and use of situational control methodology to control sampling rates in computer networks.

Keywords: situational control, turbojet engine, artificial intelligence, computer networks

1 Introduction

State of present technologies in all areas of technical, but also non-technical practice gives rise to growing complex systems. A complex system in general is a high dimensional high parametric system with complex dynamics. For effective and optimal function of such systems it is necessary to propose and implement newest knowledge from the areas of cybernetics and artificial intelligence. Present control systems are often limited to control a complex system only at some given conditions. However in real-world applications these systems find themselves in very different working conditions, what influences parameters of their operation and characteristics of behavior and may lead to errors and critical states.

It is necessary to handle all these conditions and situations in such way, the system would work economically and effectively, thus optimally. It is possible to secure this factor of optimal operation of a controlled system in all eventual states of the environment and its inner states, represented by its inner parameters with use of situational control methodology. The terms, situational, situational control intuitively tell, that they represent control of a chosen complex system in its different situational states. In an ideal case this will represent the control of a complex system in its all operational states. However such an ideal case represents existence of infinite number of operational states but we posses only a limited number of control strategies (algorithms). So we are coming to the main idea of situational control methodology. Due to limitation of number of control algorithms, it is necessary to limit the number of operational situations, so that control strategies would cover all operational situations. By declaration of this fact we are getting towards situational classification, which demands proposal of situational classes and algorithms to control a system which finds itself within states defined by these situational classes. Situational class represents then a set of similar operational states of a complex system. Usually one control strategy covers one situational class, but a case can occur where more situational classes are covered by one suitable robust control strategy.

2 The New Scopes of Situational Control

Traditional approaches to situational control of complex systems [1,2] often were often represented by fairly complex schemes which deal mostly with problems of memory and classification of the control system [1,2]. Such models however weren't sufficient to control ambiguous complex systems with unpredictable behavior and where also the presence of human factor has an unforeseeable character or the system is developing itself in time. To cope with this problem, present state of research in the area of computational intelligence brings many approaches, which can be used to solve these problems. Opposed to methods as decision tables, multicriteria analysis in their traditional form, these approaches form a robust and adaptive field of possible used algorithms. On the other hand the traditional understanding of situational control through scheme described in [5] or formatter control described in [2,4] remains actual and is also used with new approaches that will be mentioned later. Methods of control that cope with definitions of situational control nowadays mostly incline to hybrid distributed systems of control with the use of intelligent elements as neural networks, fuzzy controllers, predictive systems or intelligent diagnostic systems. The premise to use these approaches together with present traditional control systems it will be necessary to deal with the following points:

1 Use of digital technologies and elements in control with efficient transfer systems.

2 Use of algorithms with computational severity, which would allow to use them in real-time compared to the state of hardware development.

3. Resistance to noises of such electronic systems by their use in real-world applications.
4. Implementations in systems with full authority of control, where the control system could overweigh decision of human factor in situations, where such decisions would lead to destruction of whole system.
5. Implement situational control systems that would cope also with erroneous states of the control circuit itself.

The following applications that are being presently developed try to cope with these points and also traditional definitions of situational and formatter control.

3 The Present Applications of Situational Control

The later described applications are being developed at present time by authors of the article. They comprise two different areas as mentioned in the abstract, the turbojet engine control and control of sampling intervals in computer networks. Both objects in these areas comprise with definitions of complex systems and therefore need robust control mechanisms to handle them.

3.1 Situational Control in Turbojet Engines

It wouldn't be economically favourable to test technologies of situational control within expensive and also very complex normal sized turbojet engines also with regards to safety of such experiments. Therefore a special class of turbojet engines designated as small turbojet engines can be used as an ideal test-bed for differently aimed experiments in this area. Our research is headed towards three basic aims.

1. Digital measurement of turbojet engines, which means digital real-time measurement of different state and diagnostic parameters of such engines.
2. Design and implementation of new control algorithms of turbo-jet engines, especially the situational control algorithms incorporating methods of artificial intelligence.

The aim resulting from the previous points is to explore possibilities of use of alternative fuels in turbojet engines.

Our experimental engine has been derived from the TS – 20 engine, what is a turbo-starter engine previously used for starting engines AL-7F. The engine has been adapted according to [14] and used in experiments described in [14]. According to this rebuilding, the engine has been rebuilt to a state, where it represents a single stream engine with radial compressor and single one stage noncooled turbine and outlet jet. The basic scheme of the engine is shown in the Figure 1.

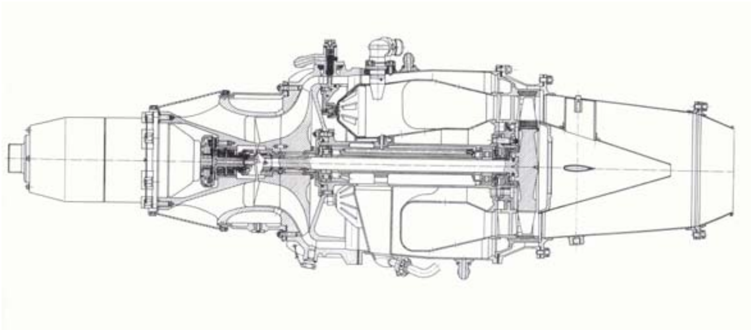

Figure 1
Scheme of the MPM 20 engine [14]

The following parameters are measured, in order to obtain a model of this engine.

- air temperature at the outlet from the difusor of the radial compressor - $\mathbf{t_{2C}}$;
- gas temperatures infront of the gas turbine - $\mathbf{t_{3C}}$;
- gas temperature beyond the gas turbine - $\mathbf{t_{4C}}$;
- static pressure of air beyond the compressor $\mathbf{p_2}$;
- static pressure of gases infront of the gas turbine $\mathbf{p_3}$;
- static pressure of gases beyond the gas turbine $\mathbf{p_4}$;
- fuel flow $\mathbf{Q_{pal}}$;
- rotations of the turbine/compressor, $\mathbf{n_1}$.

The scheme of measurement including all sensors needed is shown in the Figure 3. All sensors, except fuel flow and rotations sensor are in fact analogue which in and have voltage output. This is then digitalized by a SCXI measurement system and corresponding A/D converter and sent through a bus into computer. Every parameter is measured at a sampling rate of 1 KHz (that means acquiring 1000 samples per second). The whole scheme of measurment is shown in Figure 3.

By control of such engine, we can define three basic situational frames. The first one would represent the startup of the engine. The second regime would represent stable operation of the engine and its regulation by means of fuel flow reduction and the third one would represent cooling regime of the engine. Every situational frame needs other regulation approach.

1 **Situational frame 1** – aggressive reduction of fuel flow in order not to exceed maximal construction temperature of turbine and to diminish temperature's overshoot.

Strategy of control – control according to pressure beyond radial compressor **p_2**. At the present state this is done by means of proportional two stage regulation.

2 **Situational frame 2** – stable operation of engine. This frame represents the stable operation of the engine. The engine has to be susceptible to control inputs and respond to desired levels of rpm's, which represent the state parameter of the engine.

Strategy of control – the control has to be done with regard to desired rotations per minute of the engine and regard to temperature beyond the turbine, which cannot exceed its maximal values and also maximal rates. Fuzzy algorithms are proposed for this purpose.

3 **Situational frame 3** – cooling regime. This frame represents a regime where, the temperature T_{4c} is being lowered by at least 200 [C^0] to cool the blades of the turbine to allow their cool down. This regime is extremely important by use of alternative fuels – as the planned hydrogen.

Strategy of control – limit of the fuel input with regard to temperature beyond turbine T_4

In the basic approach, we have to be able at first classify any of the regimes in real time and according to the classified frame engage the needed regime. Therefore the following global architecture of the control system is proposed.

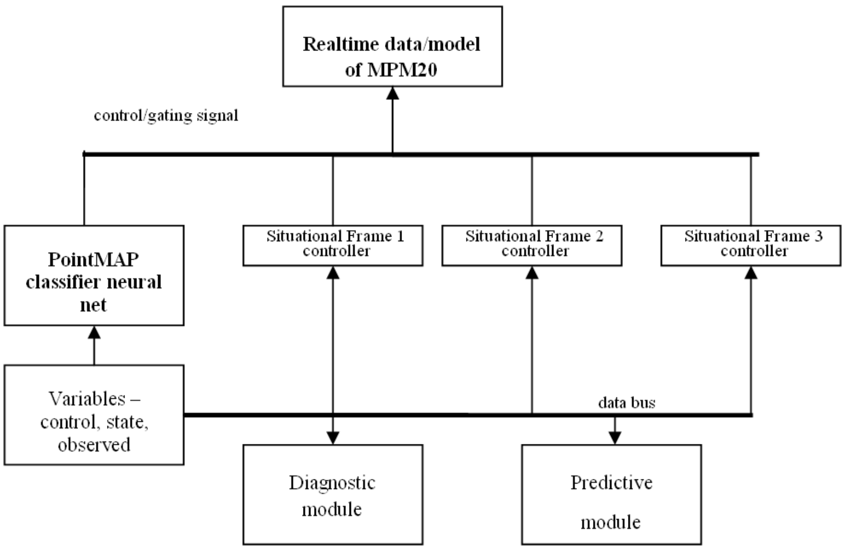

Figure 2

Sheme of situational control of the MPM 20 engine

The neural network of PointMAP architecture is used as the classifier [13]. It represents a progressive memory based learning system that continuously evaluates the information value of each of its coding nodes and that uses the information value to prune nodes both during and after training. It transforms the multi dimensional space of engine's parameters into control signal which engages the individual controlers according to actual state of engine. Situational frame controller is in the present state designed as a distinct electro-mechanical system. Controllers 2 and 3 are proposed as software fuzzy controllers.

3.2 Situational Control in Control of Sampling Intervals in Computer Networks

To monitor, diagnose and state evaluation of computer networks it is necessary to measure bandwidth. This is done by taking samples of network's bandwidth in certain time moments, what is called sampling. However it is necessary to make the sampling intervals as short as possible, but secure that they would represent changes in the network's bandwidth. This is needed to save resources, because with fixed sampling rate, the amount of gathered data would be too big and also such fixed sampling could miss the trends in the network's load by too long or too short sampling intervals. Methods that deal with changing of sampling intervals are usually designated as adaptive sampling methods. Situational control methodology is suitable for solution of this problem, which can also be transformed as a problem of control of sampling intervals. The size of sampling interval depends upon the situation, in which a computer network or a part of it can be found, eg. night operation, video-conference, etc.

There are many methods to control sampling intervals, which can be combined within the frame of situational control methodology. Among other approaches the use of fuzzy logic controller to adaptively control sampling intervals in a computer network may be used [15]. The whole scheme of the sampling control circuit with a fuzzy logic controller and situational classification controller is shown in the following figure.

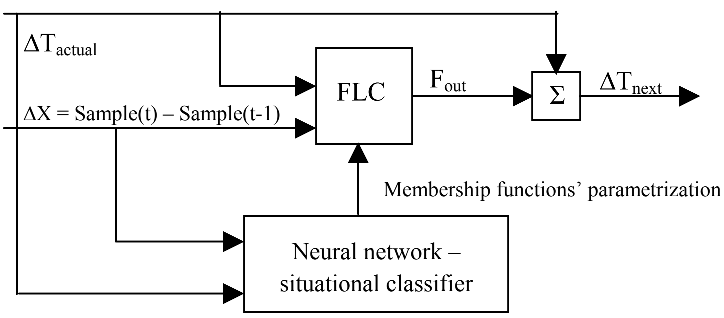

Figure 3
Sheme of situational control of sampling interval in computer network

Neural network situational classifier parameterizes coefficients of individual membership functions of fuzzy logic controller according to the network's load. The situational frames in this case can be expertly set, as for example in the simplest manner a video-conference and normal operation. But present experiments are aimed at division of whole operation of a network into situational frames via clustering analysis, which we designated as situational clustering. After such analysis, division into finer frames could be achieved, because network's load is often mainly dependant upon time, e.g at night the sampling intervals would become much longer than daylight, or during weekends, etc. This brings a whole new area of problems to solve. Another problem which lays in front is the problem of combination of more controllers of sampling interval according to their suitability for different situational frames, as are linear prediction or conventional sampling (systematic, random, stratified random sampling, etc.). These different control algorithms might be incorporated into the whole system of control similarly as shown in the Fig. 2.

Conclusions

The article shows two different areas of present use of methodology of situational control. Both of these areas show use of elements of artificial intelligence in situational control systems. The new approach in situational control that is presented in the application of sampling rate control is the situational clustering by use of neural networks. This approach would be complementary to the traditional expert designation of situational classes as is used by control of the turbojet engine in the article. Both systems represent hybrid architecture of neural networks and fuzzy logic controllers. However, methodology of situational control in its scope isn't limited to such fixed architectures, as both presented architectures are modular and different control mechanisms can be used in different situations where the controlled systems can find themselves.

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