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Reconfiguration Control of the Ground Automatic Spacecraft Control Complex Based on Neural Network Technologies and AI Elements

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Abstract. The article considers the problematic issues of control of direct reconfiguration of the ground automatic spacecraft control complexes.
It is shown that main properties affecting control of the reconfiguration are controllability and observability. The proposed solution to increase the controllability and observability on base of neural network technologies are given. The necessity of creating a neural network complex to control the reconfiguration of the ground automatic control complex of spacecraft comprising an input, output, and neural network layer with four neural subnetworks having two circuits: controllability and observability is proposed.
The major advantage of this approach is using the application of self-trained algorithms of the control configuration of the ground automatic control complex of spacecraft and a possibility to create a uniform information field of dynamic contours of the control of spacecraft and carrying out the measurements.

Keywords: ground automatic control complex, spacecraft, neural algorithm, artificial intelligence, controllability, observability

Introduction

The ground-based automated spacecraft control complex (GASCC) consists of 14 individual command and measurement complexes (ICMC) and individual measurement stations (IMS) distributed throughout the country and equipped with command, measuring and telemetry means, communications and data transmission equipment, and ground control means. The ground control complex (GCC), the measurement, data collection and processing complex (MDCPC) and the ground-based measurement complex (GMC) for the rocket boosters are formed from the GASCC facilities. That is, GASCC is an integrated structure, designed to produce of a single information and communication environment, which implements the processes of the spacecraft control and telemetry of launches of space technology (ST) products.

The planning of the use of GASCC facilities, as well as the provision of the technological cycle (TC) of spacecraft control and telemetry of the launch of ST products is carried out by the Main Test Space Center of the RF Ministry of Defense named after G.S. Titov (GIKTs).

The spacecraft is controlled in accordance with the technological control cycles (TCC), that determine the sequence, order and time intervals of the spacecraft control operations. Consequently, GASCC should have an architecture that allows the formation of various types of GASCC, and ensure the implementation of their TCC. In turn, the TCC are largely determined by the capabilities of the mission control center (MCC) to establish interaction with technical objects included in the GCC. Enhancing such capabilities is one of the development goals of the GASCC.

At the moment, the GASCC control about several dozen spacecraft, and there is the tendency to expand the orbital constellations, approximately by 3-4 spacecraft per year [1].

Information support for launches of the space technology products (launch vehicles (LV) and rocket boosters (RB)) consists in receiving telemetry information (TMI) by antenna systems (AS), registering it at receiving and recording complexes (RRC), preprocessing TMI and transmitting to centers of information processing and analysis, through closed and open communication channels. The interaction of technical facilities that are part of the MDCPC and GMC, as well as the ability to control their operation, is the determining task for the development of ground-based telemetry tools.

Today, GASCC provides measurements of about 20 launches of various types of space technology products.

Control of directed reconfiguration of GASCC

The functioning of GASCC is determined by a number of important factors:

1) The increasing role of spacecraft orbital constellations (OC) in military conflicts. The wars of the late twentieth and early 21st centuries (in Afghanistan, Iraq, Syria) showed the importance and practical benefit for parties of the conflict of using OC for space reconnaissance and communications, early warning of a rocket attack, and meteorological and navigational support.

In this connection, a targeted enemy air attack on the GASCC objects in order to reduce the effectiveness of the support of the Russian armed forces from space becomes likely [2].

2) Constant increase in the number of constellations and spacecraft in constellations.

3) Trends in the unification of ground-based controls and measurements, as well as an increase in the number of means of collective use.

4) Improvement of the onboard equipment of the spacecraft and launch vehicles.

As a consequence, the role of management and coordination processes by means of GASCC is increasing. It becomes important to consider the operation of the GASCC as a process of dynamic formation of an operative configuration of the SC control facilities (GCC) and measurement facilities (MDCPC and GMC) by conducting a directed systematic reconfiguration. For each configuration of GCC, MDCPC and GMC, its own set of mission control centers (MCC), command and measurement systems (CMS), data lines (satellite, radio relay, terrestrial fiber optic, etc.) and telemetry equipment is provided.

The GASCC performs about 1000 communication sessions with spacecraft per day during its normal operation. During emergency situations, and during direct combat operations, the requirement for the time of the GASCC reconfiguration (GMC, MDCPC and GCC) increases and reaches 5–10 minutes. In this connection, a significant increase in the level of observability and controllability of the GASCC is required.

GASCC becomes an integrated multi-functional ground-space structure with a single information space, and at this stage it is advisable to move away from the concept of a static control and measurement loop and introduce the concept of dynamic control and measurement loop [3], and the GASCC will form such dynamic loops close to real time.

Controllability and observability of the GASCC facilities will become a defining characteristic, which will require expanding the capabilities of reconfiguration control using the GASCC and measurement facilities.

The task of increasing the observability of the GASCC consists in determination of the initial state of the system, namely:

- the state of technical means of the GASCC (maintenance, serviceability, currently engaged facilities);
- the presence of the necessary number of personnel to perform the tasks required to operate the GASCC;
- the state of data transmission systems (utilization of communication lines, maintenance, serviceability, currently engaged facilities).

The task of increasing the controllability of the GASCC lies is an increase in the capabilities of changing the operation states of the GASCC.

If the GASCC is maximally observable and controllable, then it is possible to create a control system that will allow to carry out a directed reconfiguration.

Thus, the directed reconfiguration of the GASCC becomes a multifactorial, intellectual task of controlling a complex technical object and requires an innovative approach to its solution.

The most promising information technology for solving multifactor tasks in complex technical systems is neural network programming and the use of artificial intelligence. The first studies of artificial intelligence were carried out with the advent of computers in the mid-twentieth century. The development of computing power, data transmission facilities, and communication lines over the past 10 years has resulted in a leap in the development of these technologies and in their application in engineering.

The use of a developed neural network complex will allow a number of improvements to be made in the methods of control of the directed reconfiguration of the GASCC. Its main difference from the ordinary software algorithms is that the task set will be solved not by direct programming, but by self-learning of a neural network component with feedback. This unique process allows minimizing the need for a direct human involvement in the formation of an operational configuration of the GASCC, and will also allow a solution to be developed based on the external data obtained by a neural network complex under rapidly changing conditions [4, 5].

The proposed neural network structure of the complex for reconfiguration of the GASCC and measurements is presented in Figure 1.

It is important to note that it is possible to distinguish two functional circuits in the structure of the neural network complex: the observability circuit and the controllability circuit. With the help of the neural network components introduced, these functional units directly solve the problem of increasing the level of observability and controllability.

The problem to be solved by the entire neural network complex is to find the optimal solution for the selection of the GASCC and measurements configuration by increasing the observability and controllability.

During the operation of GASCC, input data is formed as formalized information:

- on the technical condition of the GASCC and measurements (complex for monitoring the technical condition);
- on the analysis of the current situation (complex for situation assessment);
- on the analysis of tasks for spacecraft control and measurements (complex of analysis of tasks of spacecraft control and measurement).

The output data of the complex for monitoring of technical condition contains information about the integrity of the equipment and routine maintenance, spacecraft control and measurement operations; information about the number of personnel available to operate the GASCC equipment.

From the MCC and the ICMC command posts the complex for assessing the current situation receives information on the situation: maintaining daily activities, improving combat readiness or transition to a threatened period. This data is the output.

The task analysis complex derives data from the short-term, medium-term, long-term plans of the utilization of facilities, obtained from the mission control center and command posts.

Formed and formalized information is transmitted to the neural network component of the complex, which consists of four interconnected neural networks:

- technical means of the GASCC and measurements;
- synaptic weights and connections;
- conflict analysis;
- selection of means of the GASCC and measurements.

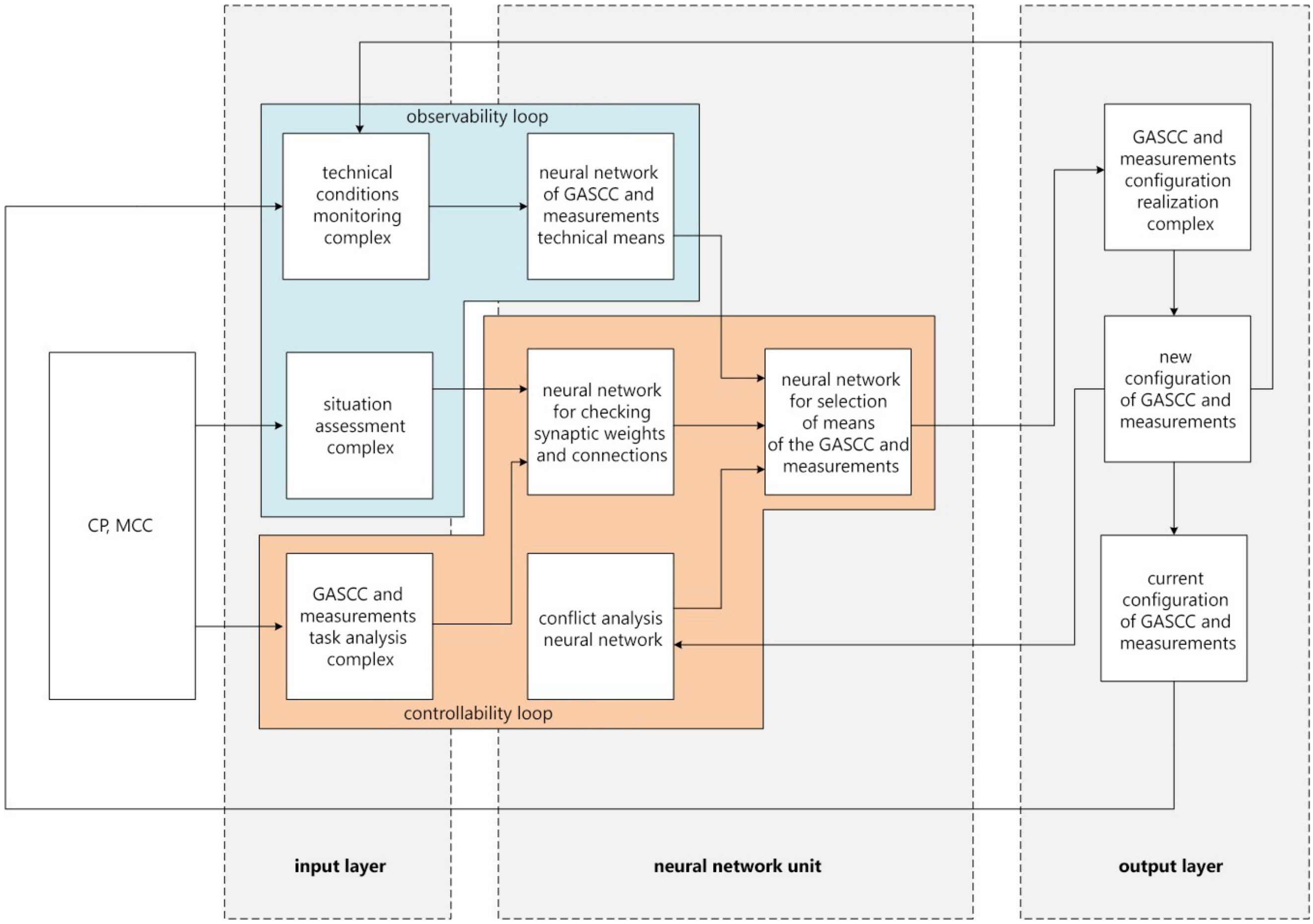

Fig. 1. Neural network structure of the control complex for reconfiguration of GASCC and measurements

The neural network monitoring the technical means of the GASCC and measurements receives information from the monitoring complex on the composition of the means ready for operation.

The neural network for synaptic weights and connections receives the assessment of the current situation from the complex and, depending on what period of the situation, the weight coefficients of connections (synapses) are determined.

The neural network of the conflict analysis is connected with the knowledge base of the output layer and checks the obtained results for conflictlessness in order to eliminate duplication of technical means of GASCC in various tasks of spacecraft control and measurements.

The data obtained as a result of the operation of the three networks mentioned above is transmitted to the neural network of means selection, where decision making takes place and in a formalized form is transmitted to the GASCC configuration and measurement implementation complex, which is the executive body of the neurocomplex output layer and directly controls the configuration of NACU KA hardware.

The output layer contains a new configuration of GASCC and measurements according to the problem being solved, the current situation and the state of technical facilities.

The structure of information obtained as a result of the work of the neural network is:

- the knowledge base of the neural network, which is used to provide feedback (recurrent structure), machine learning, creating templates and rules for further work;
- the visual component output to the display media.

Conclusion

Thus, the analysis of the current state of GASCC showed the need to manage the reconfiguration of GASCC in order to obtain a more flexible and dynamic structure in rapidly changing conditions.

As a result of the study, a variant was proposed for using the neural network complex for the task of controlling the reconfiguration of GASCC. This solution will provide a universal tool for creating dynamic spacecraft control loops and carrying out measurements close to real time, and also due to the recurrent structure of the neural network, will allow the system to learn and make decisions that are not obvious to humans based on the accumulated knowledge.

References

1. *Federal'naya kosmicheskaya programma 2016–2025* [Federal space program 2016–2025]. Moscow, Goskorporatsiya Roskosmos. (in Russian)
2. *Predlozheniya po obsecheniyu ustoychivosti upravleniya KA v osobykh usloviyakh. Nauchno-tekhnicheskiy otchet* [Offers for providing stability of spacecraft control in any conditions. Technological report]. Korolev, AO "VIKor". 2016, 50 **p**. (in Russian)
3. Okhtilev M.Yu., Sokolov B.V., Yusupov R.M. *Intellektual'nye tekhnologii monitoringa i upravleniya strukturnoy dinamikoy slozhnykh tekhnicheskikh ob"ektov* [Intellectual technologies of monitoring and control of a structured dynamics of complicated technical objects]. Moscow, Nauka, 2006, 410 **p**. (in Russian)
4. Callan R. *Neyronnye seti: kratkiy spravochnik* [The Essence of Neural Networks]. Moscow, Izdatel'skiy dom "Vil'yams". 2017, 279 p. (in Russian) (translated from English)
5. Haykin S. *Neyronnye seti. Polnyy kurs* [Neural networks. A Comprehensive Foundation]. Second edition, edited. Moscow, Izdatel'skiy dom "Vil'yams". 2006, 1104 p. (in Russian) (translated from English)