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SYSTEM OF REMOTE MONITORING OF OBJECTS OF THE DIGITAL BROADCASTING NETWORK

Chaadaev KV
Master's student
National Research University Bauman Moscow State Technical University
vkchaadaev@gmail.com
+7 985 231 96 80
119618, Moscow, st. Glavmosstroy, house 6, apt. 225

Abstract. The article considers creation of a technological and software-algorithmic basis for a system for remote monitoring and control of technological equipment of a digital terrestrial television and radio broadcasting network, which makes it possible to improve its quality and operational characteristics. The main result of the work is the developed algorithms, information and software technology for automatic control of broadcasting objects. The formulated goal of the work and the tasks solved formed a vision of continuing research in the field of predictive analysis and big data in the field for building digital twins of broadcast objects.

Key words: broadcast object, broadcasting network, digital television, digital twin, remote control, scenario modeling, simulation modeling, software.

Introduction

The digitalization of the economy, as well as the global pandemic caused by COVID-19, are factors that have the most significant impact on all, without exception, business processes of the production life cycle. First of all, this is due to the need to increase labor productivity, reduce operating costs and the requirements to minimize manual labor. In this connection, nowadays, many companies are faced with the task of creating an effective intelligent monitoring and control system for remote engineering communications and equipment, operating in automatic mode (Chaadaev, 2018; Nikitina, Chaadaeva & Chudaeva, 2019).

Such a technology is in demand for organizing the work of enterprises that have geographically distributed technological networks. Enterprises of this type include, for example, the Russian Television and Radio Broadcasting Network (RTRN), a Russian state-owned company, the operator of the country's terrestrial television and radio transmission network, providing more than 98% of the Russian population with 20 obligatory public television channels and three radio stations in the standard DVB-T2 (Karyakin, 2020; Koz'min, Salikov & Tokarev, 2017). Among other things, the search for and implementation of innovations that enable the transition to digital production, controlled by intelligent systems in real time, is part of the Russian state policy in the field of socio-economic and scientific and technological development.

In this regard, the development of systems for monitoring the violation of the quality of telecommunication services and the operation parameters of the technical equipment of the national television and radio broadcasting network is an important scientific and practical task (Li et al., 2014; Glasman, Zelov & Glasman, 2012). The solution of this problem requires the creation and improvement of the theoretical and technical base of computer technology and mathematical algorithms that provide multi-parameter self-diagnosis of both each individual broadcast object and the entire network (Tokarev, Salikov & Muratov, 2015). At the same time, the monitoring of the state of controlled objects should be carried out based on big data analysis of equipment operation, which determines the functions of intelligent automatic control that implement automatic changes in the operating modes of objects according to scenarios specified for various life situations (Dvorkovich, Dvorkovich, 2015; Maslov, 2021).

In accordance with the above, the purpose of scientific research is the development of methodological approaches and technological solutions for intelligent automatic control of the state of a digital television broadcasting object.

The object of the study is the elements, technical means, modes and parameters of their functioning, which determine the normal operation of the digital terrestrial television and radio broadcasting facility.

The subject of scientific research is the technical, technological and software-algorithmic base of the system for remote monitoring and control of technological equipment, which allows to significantly improve the quality and operational characteristics of the digital broadcasting facility.

Methodology and data

The theoretical and methodological basis of the study are the scientific works of various authors:

– development and study of methods of intelligent decision support in the management of the technical condition of equipment (Cheng et al., 2020; Popov, 2021);

– study of methods and ways to improve the reliability of equipment (Belozertsev et al., 2018; Ermilov, 2012);

– creation of automatic control systems for complex technical systems (Karyakin, 2021; Prosviryakov, Prosviryakova & Prosviryakova, 2021).

Thus, the presence of a certain number of theoretical and practical works confirms the relevance of the topic and characterizes a certain degree of its development. However, there is a certain lack of effective methods, models and algorithms for diagnostics, as well as for predicting the technical condition and evaluating the residual life of equipment, which generally determines the need for additional research in this direction.

The circuit diagram of digital terrestrial digital terrestrial television and radio signal distribution is implemented as follows:

1. Formation of a multiplex - for each of the 11 time zones in the federal multiplexes formation center (FMFC), temporary duplicates of TV channels are formed, which, considering the time difference, are delivered to all regions of the country.

2. Satellite delivery - signal transmission to regional MFCs, carried out through space communication lines to the entire territory of the country using Express and Yamal spacecraft.

3. Regionalization of multiplexes - tie-in to the federal versions of individual channels 1 of the multiplex programs of their regional studios.

4. Broadcasting of the signal to the objects of four television and radio broadcasting and its on-air distribution - satellite delivery from regional MFCs to broadcasting objects and on-air distribution of signals by terrestrial transmitters.

Each individual broadcast facility is a complex engineering structure that operates mainly in an autonomous mode without the constant presence of personnel, it consists of:

– engineering infrastructure (power supply, security systems, fire-fighting equipment, antenna-feeder devices, microclimate support, etc.);

– means and communication systems (modems, terminals, routers, cable communication lines, etc.);

– group broadcasting equipment (converter, encoder, splicer , repeater , receiver, transmitter, etc.).

Despite the reliability of the main elements and the mechanisms and technologies for reserving its most important elements embedded in the TV and radio broadcasting network, a certain number of incidents occur daily, significantly reducing the efficiency of the network as a whole and interrupting the broadcast of free-to-air TV channels.

On fig. 1 presents the graphical results of the analysis and quantitative indicators of incidents by categories of causes of their occurrence over two years of observation.

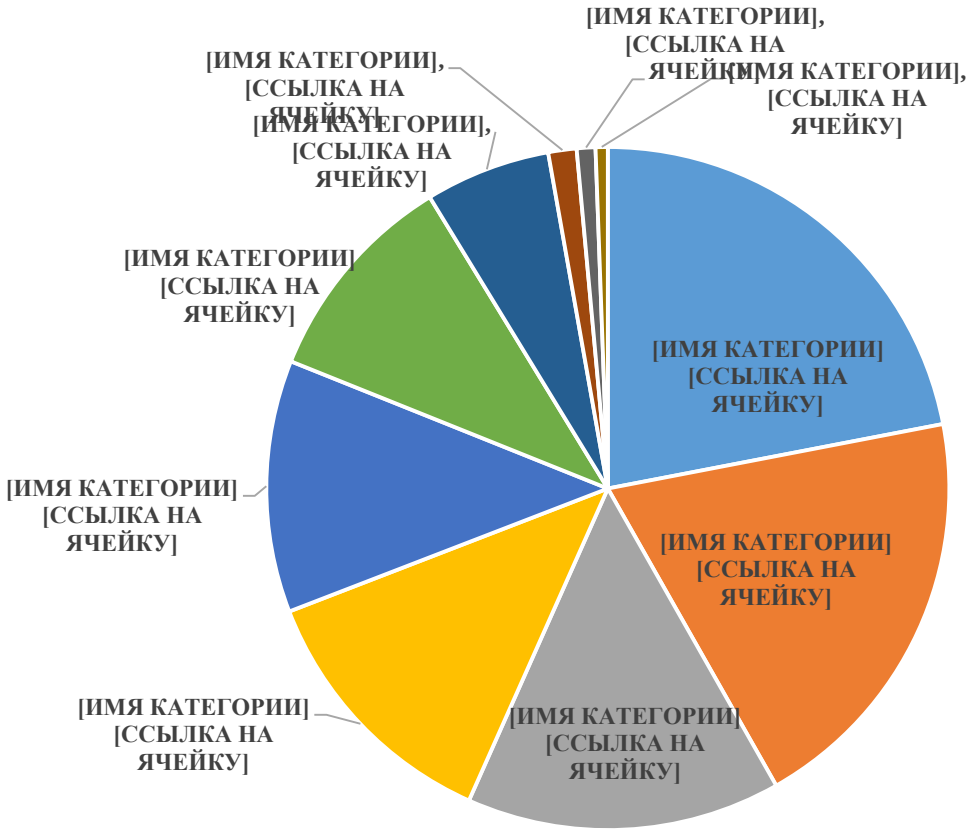


Fig. 1. Quantitative distribution of incidents by categories of causes of their occurrence for two years of observations
Source: author

At the same time, the distribution of the number of incidents by months also has an even distribution, which indicates the stability of the identified problems in the network of on-air digital television and radio broadcasting (Fig. 2).

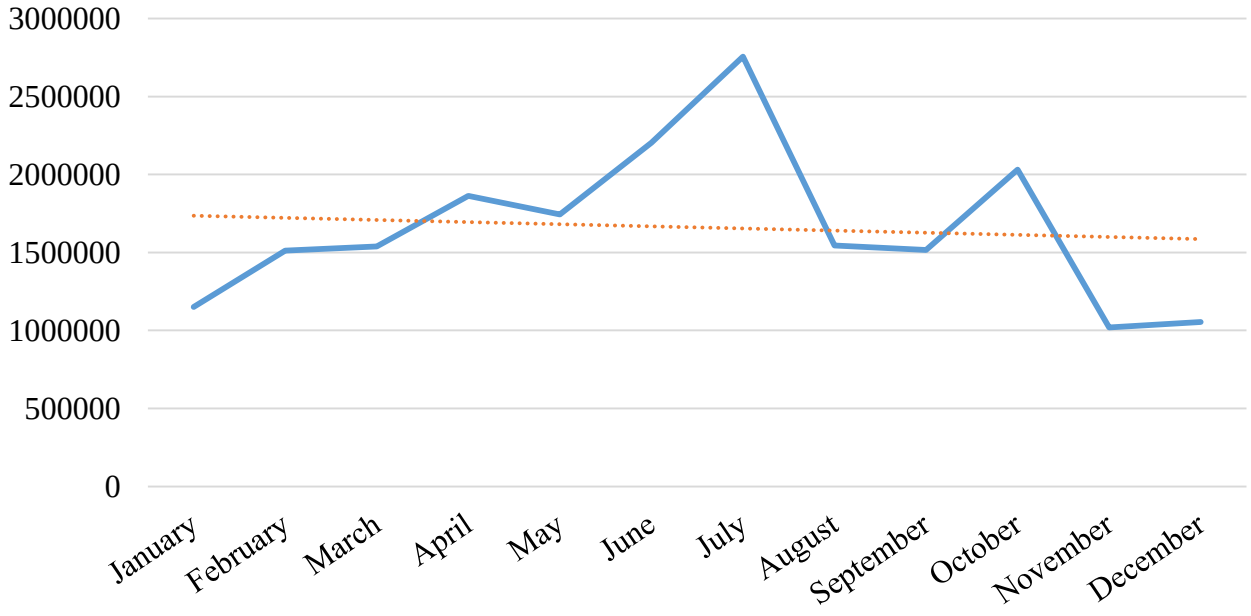


Fig. 2. Quantitative distribution of incidents by months of the year
Source: author

The above statistics confirm the necessity and usefulness of creating monitoring systems and identifying the causes of malfunctions, followed by automatic control of technical means according to specified scenarios in such a way as to return the broadcast object to normal operation or reduce the negative effects of the object being in an undesirable state.

To develop the methodological and technical base of the system for remote monitoring and control of the technological equipment of the broadcasting facility, a separate study of the technical elements was carried out and a "digital portrait" of the digital television and radio broadcasting facility was formed, which is not only the parameters characterizing the operation of individual elements, but also the rules for their processing:

– physical elements (equipment, sensors, infrastructure);

– parameters obtained by periodic measurements of physical elements in terms of their characteristics and performance;

– events automatically generated by the monitoring system based on the rules for processing parameters.

At the same time, for combinations of parameter values and rules, threshold values and their corridors were set, characterizing for each parameter the criticality of the violation and the sign of the impact on broadcasting (violated/not violated).

Results and discussion

The model for managing the flow of events of the remote-control system and automatic scenario control of the broadcasting object developed in the framework of this work is shown in Fig. 3. While processing the information flow in the model, the following main stages of its work can be distinguished:

1. Collection of measurements and fixation of preventive and emergency events (as a result of triggered rules for processing measurements) for all observed technical means as part of the broadcast object.

2. Carrying out an analysis of the total set of measurements and making a decision on whether the object is in a normal / pre-emergency / emergency state.

3. Search and activation of the necessary scenario, making the necessary information notifications of the external environment and launching the commands specified in the scenario for execution by the end devices and technical means of the object.

The work of the model, in addition to detailing the stages, requires the selection of elements and entities, which were carried out using certain provisions of the theory of technical cybernetics and the theory of optimal control (Brugger, Hemingway, 2003; Ruckveratham, Promwong, 2017). As a result, the following conceptual units were identified that are necessary for further research and software and hardware implementation of the model:

– control object - a logical set of technical means operated at the broadcasting facility;

– parameter - a property or indicator of the control object, which can be numerically determined and processed by the monitoring and control system;

– measurement - the numerical value of one parameter at a certain point in time;

– rule - the pattern of processing the numerical value of the parameter to determine the normal functioning of the control object, the need to prevent an emergency or broadcast disruption;

– diagnostic map - a set of parameters and rules for processing their numerical values;

– characteristic map - a set of measurements and the result of applying the rules to them;

– emergency map - a part of the characteristic map containing only those measurements, the result of applying the rules to which is to determine the need to prevent an emergency or broadcast disruption;

– message - a part of the characteristic map containing a " human -readable " description of the parameter measurement, the result of applying the rules to which is to identify the need to prevent an emergency or broadcast disruption;

– script - execution by the object controller of a number of commands specified for a specific rule;

– command - control information consisting of an operation or a set of operations for execution by an object controller. The command is generated automatically by the object controller or manually by the operator;

– action - the result of the impact on the technical means of control information;

– mode (status) - a set of rules that reflects the various operating states of technical means at the control object.

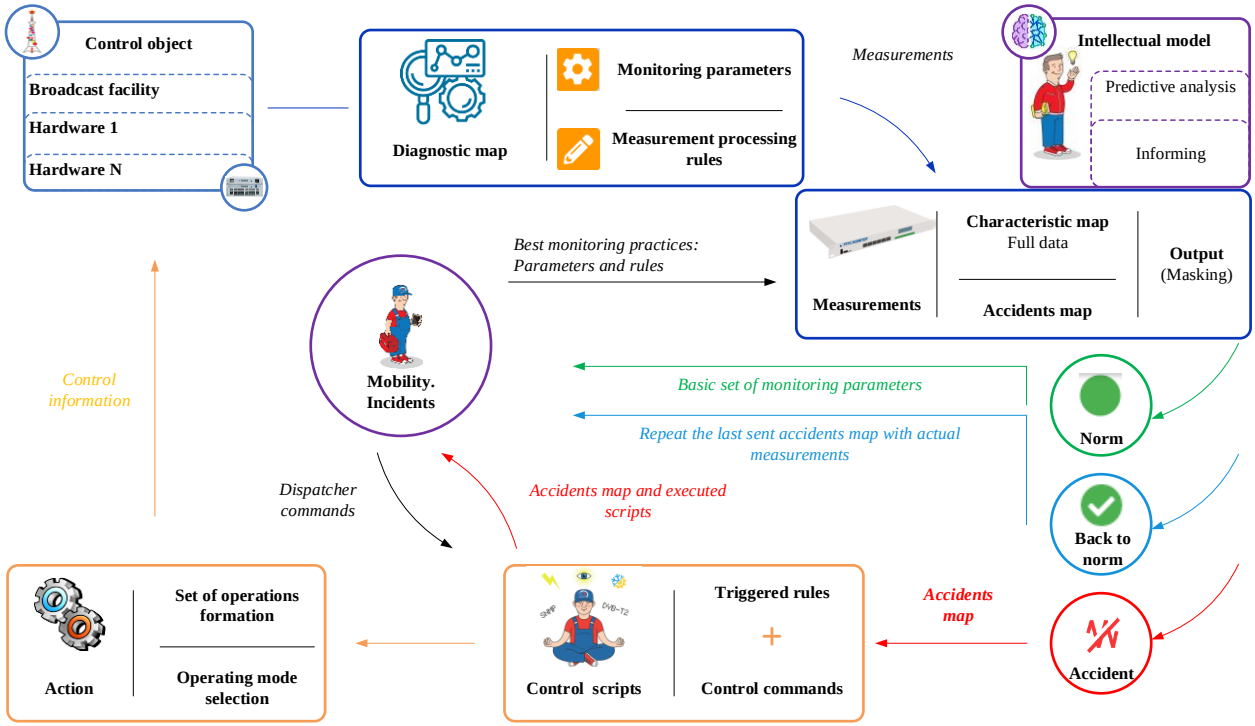


Fig. 3. The management model of the flow of events of the remote-control system and automatic scenario control of the broadcast object

Source: the author

At the same time, we emphasize that the implementation of various control actions is not a primitive sequential execution of commands, it is a complex multi-process and multi-parameter set of operations, during which all parameters and data from the entire complex of sensors and devices are constantly analyzed. As an example, the system should not start production equipment until the operation of climate technology is in normal mode, and the temperature and humidity indicators do not meet the norm.

Based on the results of simulation modeling, infological and datalogical models were built, and the structure of the machine information base was developed, which is the basis for software and algorithmic processing by special software.

For the software-algorithmic implementation of the developed model for monitoring and managing the broadcast object, the following functionality was defined as basic (Kuzovkova, Kuzovkov & Zhuravleva, 2018; Orlov, 2011):

1. Collection and registration of measurements in real time.
2. Enrichment of measurements with data on technical means and broadcasting services provided by them.
3. Designing in user interfaces of measurement analysis rules, control commands and automatic control scenarios.
4. Execute commands and run scripts.

An important component of the software has become a user interface that has high visibility and intuitiveness when it comes to, in fact, remote control and programming of the behavior of a complex engineering object (Grineko, Belozertsev & Glasman, 2015; Lhermitte, Chauviere & Denlau, 2013).

The number of developed interfaces for setting up commands and demonstrating the operation of the technology with comments to them are provided below.

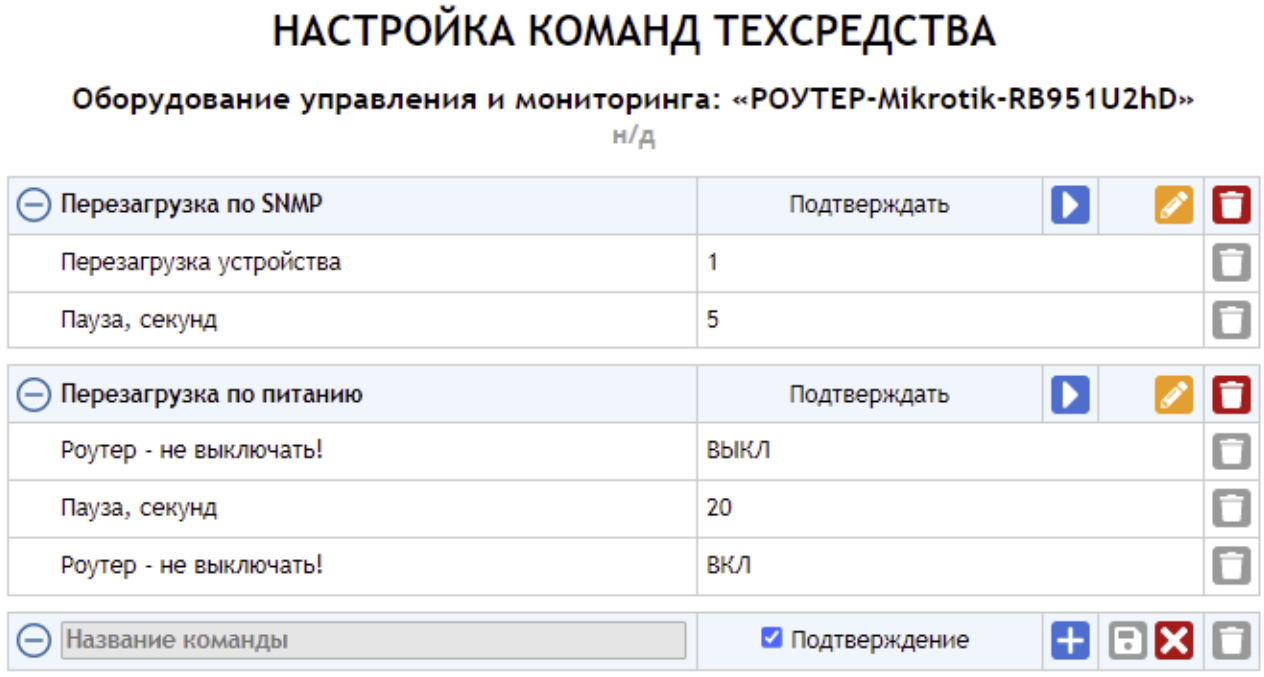
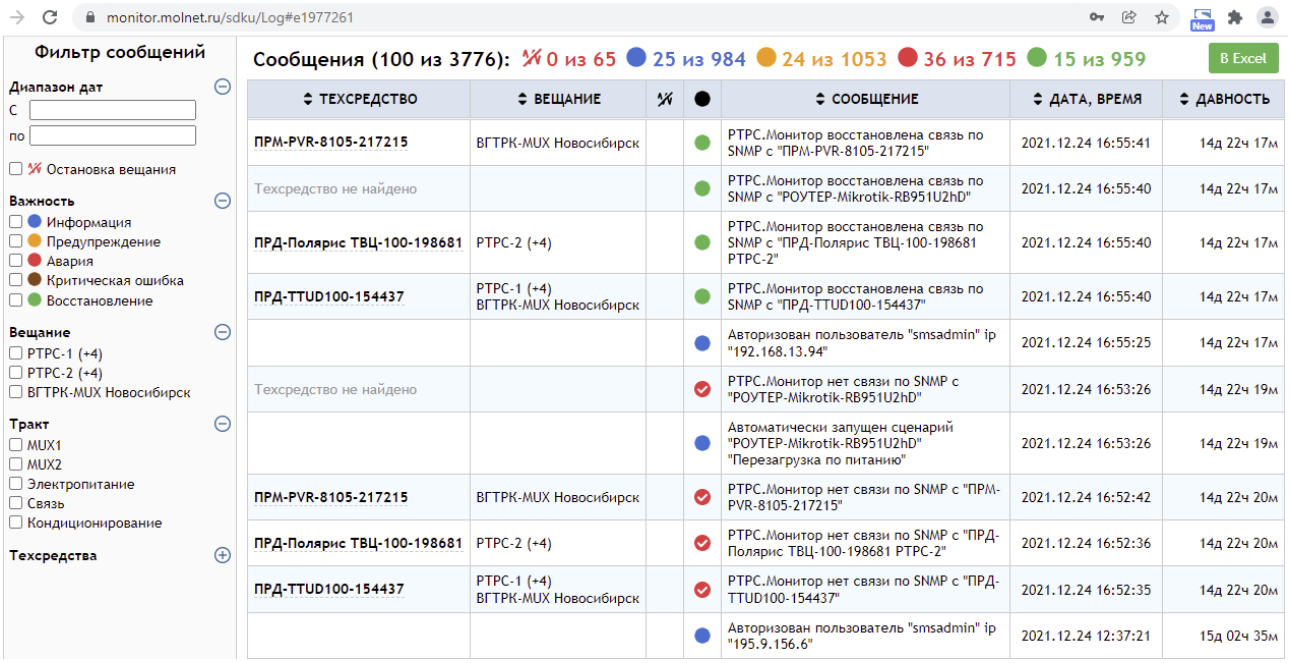


Fig. 4. User interface for managing sets of scenarios when any rule for monitoring a certain technical tool is triggered
Source: author



Rice. 5. System log with a note about the lack of communication with the router and a record about the launch of the script and the commands executed: restarting the router by power
Source: author

The following technologies were used during software development: Java programming language, HTML 5.0 and XHTML 1.0 web page markup languages, CSS 3.0 style description language, the interpreted programming language (script descriptions) JavaScript ES2016, SQL 92 query language, as well as Java SE software tools, such as Java EE, Glassfish 4.1.2 SDK, IntelliJ IDEA, GitLab, Maven.

Conclusion

As a result of the work, the goal was achieved and the following tasks were solved:

– a theoretical study of the technological base of the system for the formation and distribution of digital terrestrial television and radio signal and a subsequent review of the technical elements of the local object of terrestrial terrestrial and radio broadcasting was carried out ;

– an analysis of the causes and signs of violations of the normal operation of the RRT object was carried out, on the basis of which the expediency of developing and implementing technologies for continuous self-diagnostics of the state of the RRT object and automatic control of its technical means according to specified sets of actions and scenarios was substantiated;

– methodological and technological foundations for managing the condition of a broadcasting facility have been developed;

– a digital portrait of the broadcasting object was compiled in terms of the parameters of the functioning of technical means, rules and functional operators for their processing and diagnostics of violations;

– a schematic diagram of a model of a system for monitoring and automatic control of an object was drawn up, it and its constituent elements and a theoretical description were developed.

The key result is the developed algorithms, information and software technology for automatic control of the broadcast object.

The goal set in this work and the tasks solved formed a vision of continuing research in the field of predictive analysis and big data to build digital twins of broadcast objects.

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