Multi-agent modeling of the control system of space-time states of man-made objects

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Multi-agent modeling of the control system of space-time states of man-made objects

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Abstract. The article discusses the development of a multi-agent system for solving problems of determining, controlling, and predicting the space-time states (STS) of objects. A generalized scheme of a multi-agent approach to solving the problem of determining the STS of an object is given. The article describes an algorithm “decision trees” on the example of the decomposition of the object in order to monitor and predict the STS of the structural parts of the object.

1. Introduction
Currently, the development and implementation of automated monitoring systems (AMS) for the safety of man-made objects is actively underway. Mainly, it relates to especially dangerous, unique, technically-complex construction objects, representing a threat to human life and health, and the environment. The relevance of such work is confirmed by the requirements of the Government of the Russian Federation on the need to develop a single basic system for monitoring critical facilities.

The main advantage of automated systems is the automation of the process of collecting data from the sensors installed in the object’s body, which allows determining the state of an object with any degree of discreteness at any time of the day, in any weather conditions. However, the data processing algorithms incorporated in these systems are not unified, they are not capable of solving the complex problems of determining the space-time state of the entire object as a whole [1-4].

2. Materials and Methods
Each object is unique in its own way, it has its own design features, it is subject to the influence of various external factors, often with elements of uncertainty. Therefore, the task of creating such a system of control STS arises, which would work in conditions of uncertainty, make decisions based on available data, be able to adapt to changes in goals, have the ability to make management decisions independently. If the uncertainty is higher, the decision-making processes are more distributed in nature and the more unplanned events happen. In turn, it lowers efficiency in the existing systems, which are unable to make decisions independently and automatically rebuild to changes in the environment.

A multi-agent technology can solve this problem. They are implemented on the basis of multi-agent systems, using a large flow of information flows, when working with a large amount of data of diverse nature.
3. Results and Discussion

An multi-agent system is based on the interaction between intelligent agents capable of communicating with each other and making decisions together. Each agent includes solving a problem of analysis, forecasting and diagnostics, identifying hidden dependencies and supporting optimal decision making based on the methods and algorithms incorporated in it. Similarly, each agent in the system is an “expert” in his field who is able to solve a specific task, thereby contributing to the achievement of a common goal. Figure 1 shows the enlarged structure of a typical intelligent agent. At the entrance, an agent is given the characteristics of the environment, and at the output, information about the state of the environment and the option of optimally solving the task set for him are obtained. The solver is a decision procedure that is implemented as a simple algorithm [8].

![Figure 1. The integrated structure of an intelligent agent.](image)

To solve the problem of determining the space-time state of a man-made object, the authors developed a prototype multi-agent system. The system consists of a subordinator agent, an integrator agent, executing agents, and communication agents. The general scheme of interaction between agents is shown in Fig. 2 [9].

![Figure 2. Interactions between intelligent agents.](image)
In the course of work on the design of a prototype multi-agent system for monitoring the state of man-made objects, the following structural blocks were identified:

- The block of data collection, which provides for the collection, storage, transportation of data, information about the studied man-made object;
- Analytical units, providing analysis of incoming data;
- The block of user interaction, providing the user with all the necessary information about the object [5-7].

An important part of the multi-agent state-of-the-art object monitoring system is the analytics unit, implemented as a set of intelligent agents, analyzing incoming state data using various algorithms and data processing methods. When analyzing data, such algorithms as an “event tree”, an algorithm for choosing optimal solutions, algorithms for working with graphs, etc. are appropriate to apply. Figure 3 shows a generalized scheme of a multi-agent approach to solving the problem of determining the space-time state of an object.

![Figure 3](image)

Figure 3. A generalized scheme of a multi-agent approach to solving the problem of determining the STS of an object.

First, the system requests all the necessary information about the object under study from the data acquisition unit. After that, the selection of algorithms is performed to determine the STS of the object. Further, the system is able to make a management decision.

One of the actual data mining algorithms is the “decision trees” algorithm. “Decision trees” is a way of representing rules in a hierarchical, sequential structure, where each object has a single node that provides a solution. Decisive trees reproduce logical schemes that allow one to get a final decision on the classification of an object using answers to a hierarchically organized system of questions. Moreover, the question asked at the subsequent hierarchical level depends on the answer received at the previous level. We consider this algorithm on the example of a multi-agent decision-making system about the decomposition of an object in order to determine and predict the STS of the structural parts of the object. (Fig. 4) [3].

We need to note that almost any man-made object is subject to deformation. Deformation is formed as a result of uneven exposure of external factors, which leads to the structuring of the object into parts (blocks). Each structural part under the influence of external factors may have a different direction of movement in space and a different speed. In this case, the system’s tasks are to detect the boundaries between the blocks and determine the STS of each of them.

The graph presented in the form of a “decision tree” corresponds to Fig. 4. The tree includes a root node, which contains the following question: “Is the object under study as a whole in a state of relative equilibrium or not?” The ultimate goal of a multi-agent system is not only to determine the STS of an object, but also to choose the most optimal solution, selecting the strategy of developments that would provide the object with a state of “relative equilibrium”.

The object is in the state of “relative equilibrium” when the deviation of the state S from the original S0 does not exceed the permissible value E. It is expressed by the following inequality:

\[ |S - S_0| \leq E. \] (1)
Figure 4. The object decomposition algorithm for determining and predicting the STS of the structural parts of the object.

The system makes a request to the database stored on the server, after which the data processing procedure is performed using algorithms that detect the violation of inequality (1). The top of the first level “implies” that there are answers to the question that are contained in it. Answers to the question are marked as outgoing ribs. Depending on the selected answer, transition along the corresponding edge to the top of the next level is possible. If the answer that the structural decomposition of the object under study was required was obtained (provided that the inequality (1) is violated), then according to the scheme, the block is divided into additional subblocks in order to study the object.

In turn, each sub-block becomes a top at the appropriate level, so the analysis is carried out as to whether the subblock under study in more detail is in a state of “relative equilibrium.” If there is a response that there are no deviations from the norm in the subblock, a system requests additional information from the database, asks to update the data for further verification. The division into structural sub-blocks is limited by the number of sensors initially installed on the object. The more sensors there are on the object, the more accurately it becomes possible to identify the problem area, thereby increasing the time for troubleshooting. This algorithm allows one to identify the structural parts of the object and determine their STS, which contributes to the operational prevention of an emergency [8].

The advantage of using a “decision tree” algorithm is that a sufficiently clear classification model is formed, which gives high prediction accuracy [10]. When developing a multi-agent system, we took into account the fact that the user needs information about the state of the object at any stage of the system. Communication agents solve this problem; they are responsible for collecting, processing, storing, transferring data to other agents and provide user and system interaction. Thus, the user has the opportunity to obtain information on the parameters of the state of a man-made object that are specifically interested in his parameters.

4. Conclusion
In conclusion, we can say that the development of multi-agent systems is a promising direction that solves the existing problems of objectivity, timeliness, and accuracy of determining the state of man-made objects. High automation and intelligent decision making will significantly reduce the risk of man-made emergency situations.
References

[1] Gavrilova T A, and Khoroshevsky V F 2000 Knowledge base of intelligent systems (St. Petersburg, Russia: Piter)

[2] Rygalov A Yu, and Kubarkov Yu P 2012 Application of multi-agent systems in the electric power industry Proceedings of the Kola Scientific Center of the Russian Academy of Sciences 1(4) pp 102-105

[3] Bugakova T Yu, and Sharapov A A 2016 Application of a multi-agent approach for determining the space-time state of man-made systems In XII International Forum “Interexpo GEO-Siberia-2016” (pp. 189-194) (Novosibirsk, Russia: SSUGiT)

[4] Karpik A P. 2004 Methodological and technological bases of geoinformation support of territories (Novosibirsk, Russia: SSGA)

[5] Evgenev G B 2000 Multi-agent systems of computer engineering activity Information Technology 4 pp 2-7

[6] National Open University INTUIT n d Management based on multi-agent systems Available at: http://www.intuit.ru/studies/courses/4115/1230/lecture/24081 (Accessed 02 04 2019)

[7] Russell S, and Norvig P 2007 Artificial Intelligence: contemporary approach (Moscow, Russia: Williams)

[8] Bugakova T Yu 2011 On the issue of risk assessment of geotechnical systems based on geodetic data In Proceedings of the VII International Scientific Congress “GEO-Siberia-2011” (pp 151-157) (Novosibirsk, Russia: SSGA)

[9] Bugakova T Yu 2015 Modeling changes in the space time state of engineering structures and natural objects according to geodetic data Vestnik SSUGiT 1(29) pp 34-42

[10] Bugakova T Yu, Shlyakhova M M, and Knol I A 2016 Structural decomposition of an object using mathematical modeling and subsequent visualization based on WebGL In Proceedings of the XII International Forum “Interexpo GEO-Siberia-2016” (pp 142 –147) (Novosibirsk, Russia: SSUGiT)