Application of theory of multi-agent systems for operational geodetic monitoring of technogenic objects

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Abstract. The analysis of modern methods of geodetic monitoring of technogenic objects (TO) in geodesy is carried out in the paper. The information on the use of robotic devices in geodetic monitoring of technogenic objects is given. The application of the theory of multi-agent systems for the operational geodetic monitoring of technogenic objects is proposed. The concept of geodetic robot “georobot” is formulated as an intelligent robotic device capable of increasing the speed of obtaining data on the spatial-temporal state of technogenic objects in extreme conditions without human intervention, increasing the reliability of geodetic monitoring and reducing the risk of emergencies. To determine the flight path of the georobot, the categories of technogenic objects are analyzed and their mathematical formalization is carried out to a set of characteristic volumetric geometric figures. A comparative table has been drawn up containing information on the categories of technogenic objects, the geometric image of the object and the path of flying around.

1. Introduction
At present, for controlling deformations and preventing emergencies at TO various systems of geodetic monitoring of engineering structures (SGMES) with varying degrees of automation are used. The SGMES capabilities include continuous collection, transmission and processing of information in automatic and manual mode, setting individual criteria for individual subsystems, separate zones, individual sensors, monitoring and determining of deviations from standard values, creating statistical and analytical calculations, predicting the occurrence of emergencies, automated interaction of basic systems and subsystems, operational interaction with duty dispatch services [1].

The regulatory system [2] has been created for the installation and implementation of SGMES, and active work is taken place to introduce SGMES for technogenic objects. However, no matter how fault-tolerant the forecasting system for an industrial accident is, there is always a risk of its occurrence due to unaccounted human, technical or other factors. This may entail a partial or complete failure of the system used or the impossibility of the direct presence of a person at the TO to control destructive processes. For solving the problems of geodetic monitoring of TO in conditions unsuitable for humans, it is necessary to develop a new technique related to robotic and intelligent systems, which require a certain, higher level of self-organization of a group of mobile autonomous robots. This technique and information processing algorithms makes it possible to develop the theory of multi-agent systems [3].
2. Materials and methods

Data collection in the SGMES is carried out using a variety of geodetic equipment: inclinometers, strain gauges, gauges, pressure sensors, laser scanners, robotic total stations, unmanned aerial vehicles. However, in any case, such systems require the direct presence and/or participation of a person in the monitoring process, which reduces the reliability of these systems and increases the risk of an industrial accident [4].

Some robotic total stations, for example, the Leica MS60 1'' total station, are equipped with the functionality of a laser scanner. As an element of intelligence, one can note the integrated indicator, which will give information in which direction you need to tilt the rail in order to return it to the target. A piezo drive that runs on a 1GHz Dual-core ARM processor automatically points the total station to a prism. ATRplus technology enables the Leica MS60 1'' total station to track the reflector even in the event of interference and a highly reflected signal. Remote control is carried out using a field controller connected via Bluetooth. By mounting the controller on a pole with a reflector, you can shoot objects without an assistant. In most cases, when implementing algorithms for the group interaction of devices in geodetic monitoring systems, a centralized communication scheme is used in which group members need to interact with some common device for communication. In such scheme, when the main node of the device fails, the devices cease to be a system, and the obvious problem is that due to an increase in the number of nodes, the load on the central node will increase [5].

There is another type of the group interaction called decentralized. A network built by this type assumes the complete absence of a common device necessary for communication in a group.

In a decentralized network, each node can send messages to nodes that are in its own visibility range at the current time. For ensuring the effective fulfillment of the common task by a decentralized system, multi-agent technologies are used, where the main active elements are agents that can have the same or different significance and functionality in the system. The basic concept along with the agent of a multi-agent system is “cost”, which determines the sequence of actions in a conflict situation. A new generation of light and small UAVs allows you to develop the airborne robotic systems of a wide range of applications. ANCHORS (UAV-Assisted Ad Hoc Networks for Crisis Management and Hostile Environment Sensing) is a project on the use of UAV peer-to-peer network technology for emergency control and remote scanning of an infected area. The main objective of the ANCHORS project is the organization of an autonomous network consisting of various unmanned systems that can be used as an independent communication infrastructure for emergency services in case of emergency. Sensors that are rigidly fixed to a TO in the existing geodetic monitoring systems lose their functionality as a result of the breakdown of communication channels with nodal devices for processing primary data. A device that can move from place to place, coordinate a given space, determine the shape, size, spatial orientation of objects and any systems was developed and named by the authors of the paper as geodetic robot “Georobot”. There is a task of developing algorithms for the automatic generation of a flight task “Georobot”, in other words, a path task. A group of georobots moving in space along certain trajectories in the immediate vicinity of a TO and capable of exchanging measurement data will allow geodetic monitoring even after serious deformations at TO.

3. Research Results

For determining the flight path of the georobot, the categories of technogenic objects were analyzed and approximated to a set of characteristic volumetric geometric figures [6, 7].

For example, the categories “nuclear and/or radiation-hazardous facilities (nuclear power plants, research reactors, fuel cycle enterprises, storage facilities for temporary and long-term storage of nuclear fuel and radioactive waste)” correspond to the geometric figure “Single-cavity hyperboloid” (Figure 1).
Figure 1. Geometric approximation of the cooling tower of a nuclear power plant to a single-cavity hyperboloid

A set of circles at different heights, which is visualized in Figure 2 can be the path of flying around of this volumetric figure.

Figure 2. Variants of motion paths for a group of 3 georobots

For increasing the efficiency of geodetic monitoring, additional paths should be added to study the object (Figure 3).

Figure 3. Variants of motion paths for a group of 5 georobots
The paper presents an approximation for two categories of TO in the form of a comparative table 1 containing information on the categories of TO, the geometric image of the object and the path of flying around.

| Categories of TO                                                                 | Approximation       | Path of flying around         |
|----------------------------------------------------------------------------------|---------------------|-------------------------------|
| nuclear and / or radiation -hazardous facilities (nuclear power plants, research reactors, fuel cycle enterprises, storage facilities for temporary and long-term storage of nuclear fuel and radioactive waste) | One-sheeted hyperboloid (on the plane) | Circle; hyperbola; straight; |
| objects on which hazardous substances are obtained, used, processed, formed, stored, transported, and destroyed in quantities exceeding the maximum established by the legislation of the Russian Federation | Straight circular cylinder (on the plane) | Circle; broken line |

4. Conclusion
The analysis of modern methods of geodetic monitoring of TO is carried out, information is given on the use of robotic devices for geodetic monitoring of TO, the application of the theory of multi-agent systems for the operational geodetic monitoring of TO is proposed. The concept of geodetic robot “georobot” is formulated as an intelligent robotic device that can increase the speed of obtaining data on the spatial-temporal state of TO under extreme conditions without human intervention, increase the reliability of geodetic monitoring and reduce the risk of emergencies.

A comparative table containing information on the categories of TO, the geometric image of the object and the path of flying around has been drawn up. At the present stage of the development of systems and methods for geodetic monitoring of TO, there is no way to increase the fault tolerance of software and hardware with a centralized type of functioning and with a rigid type of sensor fixing. The geodetic monitoring technique of TO using robotics based on the theory of multi-agent systems will allow realizing operational, deployable geodetic monitoring in emergencies of catastrophic proportion.

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