Methods of geomonitoring of technogenic objects to determine fast-flowing deformation processes using robotics

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Abstract. A method of geomonitoring of technogenic objects to determine fast-flowing deformation processes using robotics based on the theory of multi-agent systems is proposed. The methodology is based on the conceptual geomonitoring scheme of an anthropogenic object by a group of "georobots" and a hardware and software complex represented by intelligent "georobots" that are functionally interacting with each other. The method developed by the authors makes it possible to exclude the direct presence of a person from the process of collecting data on the spatio-temporal state of an anthropogenic object. This method helps to promptly provide information on the state of an anthropogenic object in dangerous fast-flowing processes, which contributes to the timely determination of a practical managerial function to eliminate the accident.

1. Introduction

At present, various automated monitoring systems are used for controlling deformations and prevent emergencies at technogenic objects. These objects which allow transmitting data on the spatio-temporal state of a technogenic object with any degree of sampling in any weather conditions, regardless of the time of day, with varying degrees of automation. The automated monitoring systems capabilities include continuous collection, transmission and processing of information in automatic and manual mode, monitoring and determining deviations of deformation parameters of technogenic objects from standard values, the use of statistical and analytical data processing algorithms, predicting emergencies, operational interaction with duty dispatch services [1, 2, 3]. Data collection in automated monitoring systems is carried out using a variety of equipment: inclinometers, strain gauges, gauges, pressure sensors, laser scanners, total robotic stations, crewless aerial vehicles. However, these systems require the direct presence and/or participation of a person in the monitoring process [4, 5, 6]. In an emergency, the presence of a person sometimes becomes impossible, due to the influence of external threatening factors, such as environmental pollution, fast-moving destructive processes. In this regard, it is necessary to develop new methods and technologies based on robotic and intelligent systems.

2. Materials and methods

No matter how fault-tolerant the automated monitoring system is, there is always a risk of an emergency due to unaccounted human, technical or other factors. This fact may result in a partial or
complete failure of the system used. And in fast-flowing processes, a failure in the system means a loss of control over the situation. Besides, if the accident has already happened as a fact, the direct presence of a person at the facility for manual monitoring of destructive processes is not always possible (for example, an accident at A-plant). Because of a failure or malfunction of the automated monitoring systems, when a manual monitoring mode is not possible, the question arises of the use of mobile robots that allow remote control and measurement work to obtain information about changes in the maintenance and repair environment in dangerous conditions for human life and health [7, 8]. For solving the problems of geomonitoring of technogenic objects in conditions unsuitable for humans, the authors proposed a method based on the use of robotic and multi-agent systems, which suggest a higher level of self-organization of a group of mobile autonomous robots [9].

3. Research Results
The authors developed a prototype of a mobile robot called a “geo-robot”, the hardware base of which is the DJI F450 quadrocopter and the NAZA MV2 flight controller. An ultrasonic rangefinder HC-SR04 is built into the design of the “georobot” (Fig. 1).

![Figure 1. "Georobot" equipped with an ultrasonic range finder](image)

The task of geomonitoring spatio-temporal state of technogenic objects is solved by a group of "georobots," each of which is equipped with a range finder, gyroscopic, temperature sensor, has its onboard server, software and mathematical algorithms that determine the flight path. The spatial coordinates of the technogenic objects are calculated according to the data of the ultrasonic range finder. "Georobots" are interconnected by intelligent algorithms that allow solving trajectory problems of each of them, i.e. each "georobot" is an agent in a multi-agent system. For example, if one of them runs out of charge, it transfers its functions to the other agent. Because each "georobot" is equipped with its onboard server, which transfers data to a central Web server, the information loss does not occur.

In general, the conceptual scheme of geomonitoring of technogenic objects by the group of "georobots" is presented in Figure 2.
Stage 1. Systematization of existing information of technogenic objects and its transfer to a central Web-server.

Stage 2. Determination of the starting point for the first “georobot” in a safe for humans proximity to the industrial object using high-precision geodetic equipment (robotic tachymeter).

Stage 3. Determination of the flight trajectory of “georobots.” Correction of trajectories depending on the form of technogenic objects. Determination of the spatial coordinates of the technogenic objects by “georobot.”

Stage 4. Recalculation of flight trajectories of the entire group of “georobots” in case of a change their number.

Stage 5. Processing the data received from the “georobots” on a central Web server using software that implements a mathematical algorithm for combining the results of measurements of “georobots” into a single digital model.

Stage 6. Construction of a digital model of the “hazardous” zone of an industrial object and its 3D visualization using software tools on a central Web-server.

Stage 7. Determination of changes in the spatio-temporal state of the “dangerous” zone and prediction of the dynamics of hazardous processes.

**Figure 2.** Conceptual geomonitoring scheme of technogenic objects by the group of “georobots”

Figure 3 schematically shows an example of a “georobot” flight mission.

![Figure 3](image)

**Figure 3.** An example of a “georobot” flight mission

As a result of the “georobot” flight in the altitude hold mode, an onboard server generates a table of values of the distance to the surface of the technogenic objects coming from the ultrasonic sensor (measurement accuracy according to the specification is ± 3 mm., the real measurement accuracy is increased to ± 1 mm. due to the use of the software algorithm, developed by the authors). Based on the analysis of the data received by the “georobot,” a digital technogenic objects model is built on the common Web server using software tools. Then the flight and analysis are repeated, the number of additional "georobots" is determined. "Georobots" can adjust their flight mission based on intelligent...
algorithms that functionally link them together. For example, if two "georobots" intend to occupy the same location, based on the developed algorithm, robots decide: which of them should take this place first. "Georobot" is capable of taking values of the following parameters: height, latitude and longitude in the WGS-84 or PZ-90 coordinate system, range to neighbouring georobots (based on a radio signal and an optical laser system), tilt angles from a gyroscopic sensor, and ambient temperature for amendments, an indicator of own speed, data from ultrasonic sensors.

4. Conclusion

The methods proposed by the authors for the geomonitoring of the spatio-temporal state of technogenic objects using mobile robotics based on the theory of multi-agent systems should, first of all, be considered as the primary control used in difficult shooting conditions, followed by the use of traditional geodetic methods with higher measurement accuracy.

The performed studies in the field of geomonitoring of technogenic objects using mobile robotics make it possible to exclude the direct presence of a person from the spatio-temporal state of technogenic objects data collection process. They can quickly provide information on the maintenance of spatio-temporal state of technogenic objects in dangerous fast-flowing processes, which allows timely determining the effective management function to eliminate the accident.

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