Hardware and software complex for geomonitoring of the upper shell of buildings or engineering structures

I A Knol¹, T Yu Bugakova¹, P Yu Bugakov¹

¹Siberian State University of Geosystems and Technologies, 10, st. Plakhotny, Novosibirsk, 630108, Russia

E-mail: Bugakova-tu@yandex.ru

Abstract. At this stage, the most suitable method for geomonitoring of the upper shell of engineering buildings and structures is the use of unmanned aerial vehicles (quadcopters) with scanning laser systems fixed on board. For the efficiency of obtaining data on the state of the upper shell of an engineering structure, several quadcopters can be used simultaneously. However, the main disadvantage of this method is the lack of functionality that allows combining several devices into groups for the organization of continuous geomonitoring. The authors proposed a hardware and software complex for geomonitoring of the upper shell of buildings or engineering structure, the basis of which is the principle of functioning of both decentralized systems and a multi-agent approach. The development proposed by the authors makes it possible to exclude the direct performer presence of the geomonitoring process in an emergency situation and gives a chance to receive information in real time about changes in the state of the upper shell object.

1. Introduction
Modern technologies in construction, unfortunately, do not provide complete safety for the operation of buildings and engineering structures. In order to prevent and predict the emergency state of buildings and engineering structures, geomonitoring of the spatial state is carried out, including both traditional methods of geodetic measurements and the use of automated monitoring systems for engineering structures, the capabilities of which include: continuous collection, transmission and processing of information in automatic and manual modes and the development of control decisions.

However, in emergency condition situations, the functioning of automated systems can be disrupted, and for geomonitoring of the state by traditional methods using geodetic instruments, it is not always possible for a specialist to have a direct access to structural elements of buildings and engineering structures for the purpose of identifying the capability of their further safe functioning. To the greatest extent, this circumstance applies to the upper shell, i.e. the roof of a building or engineering structure [1, 2, 3].

2. Materials and methods
At this stage, the most suitable method for geomonitoring of the upper shell of engineering buildings and structures is the use of unmanned aerial vehicles (quadcopters) with scanning laser systems fixed on board.

For the efficiency of obtaining data on the state of the upper shell of an engineering structure,
several quadcopters can be used simultaneously. However, the main disadvantage of this method is the lack of functionality that allows combining several devices into groups for the organization of continuous geomonitoring, since in case of a battery discharge of one of the quadcopters, the data acquisition process is interrupted. An emergency situation is characterized, as a rule, by fast processing, therefore, data acquisition and analysis should be a continuous process. The efficiency of the process of obtaining and geomonitoring data will significantly increase when several quadcopters work together, interconnected by functional links. This requires the development of a fundamentally new technology based on the interaction of several quadcopters equipped with additional specialized measuring equipment and functioning on the basis of intelligent algorithms, which will enable to adjust flight trajectories for the smooth operation of the entire geomonitoring system and ensure the continuity of data acquisition and processing [4, 5, 6].

3. Results and Discussion
The development of algorithms for generating motion trajectories of quadcopters, resolving conflict situations when crossing flight trajectories, ensuring the continuity of data acquisition seems possible when using the theory of multi-agent systems, which is based on the idea of group interaction of intelligent agents (quadcopters).

In most cases, when implementing algorithms for group interaction of agents, a centralized communication scheme is used (Figure 1), in which members of a group of quadcopters need to interact with some common device. When the master node fails, the agents cease to be a group, and the obvious problem is that the increase in the number of nodes increases the load on the central node.

There is another type of group interaction of agents, which is called decentralized one (Figure 2). A system built on this type assumes the complete absence of a common device necessary for communication in a group.

![Figure 1. Example of a centralized network](image1.png)

![Figure 2. Example of a decentralized network](image2.png)

The main idea of organizing group interaction of quadcopters for geomonitoring of the upper shell of buildings and engineering structures is the use of a decentralized network. In a decentralized network, each quadcopter can interact with other quadcopters of the system that are in sight. To ensure the effective implementation of the general task by the decentralized system, the principle of multi-agent is used, which implies the organization of the functioning of agents (quadcopters) according to the principle of "dispute resolution" for more effective achievement of the goal. The “cost” plays an important role in such system and it determines the order of actions of an agent in a conflict situation [7, 8, 9].

A characteristic feature of multi-agent systems is the ability of system elements to collectively interact in order to solve a common problem. The method of collective interaction consists in the fact that each agent independently controls the process of its functioning, that is, determines its actions, and also "coordinates" these actions with other agents of the group for the most effective solution of
the target problem.

Based on the principle of functioning of a decentralized system, the authors have developed a hardware and software complex (Figure 3) to perform geomonitoring of the upper shell of buildings or engineering structures in emergency situations.

The subsystem for collecting spatial data consists of a set of N quadcopters functionally interacting with each other at the multi-agent level, equipped with measuring equipment. Each quadcopter works in tandem with a robotic electronic total station, which determines the X, Y, Z coordinates of the quadcopter with an accuracy of 1 mm. At the heart of the process of functional interaction of quadcopters at the multi-agent level, a decentralized communication scheme is used, assuming that a server for collecting and processing discrete measurements is located on board of each quadcopter. A feature of the functional interaction of quadcopters at the multi-agent level is the software-intelligent interaction of agents (quadcopters), which allows optimal construction of flight trajectories and the distribution of tasks for each quadcopter, depending on the area of the building or engineering structure and the influence of external factors. The main task of the subsystem is to determine the coordinates of the set of points of the upper shell of a building or engineering structure for further construction of a three-dimensional surface and determining its deviations from the standard values.

The analytics and data processing subsystem is determined by the synthesis of the computing power of the quadcopter servers and it is a set of mathematical algorithms and subroutines for multi-parameter processing of heterogeneous data. The analytics subsystem is not expressed as a separate centralized server, but it is a parallel computing process implemented using software located on the server of each individual quadcopter. After receiving, accumulating and transmitting data, mathematical processing and data analysis is performed on the server of each quadcopter to solve trajectory problems and build a digital model of the upper shell of a building or engineering structure. The subsystem of visualization and information presentation contains a software module for visualizing a mathematical model of the upper shell of a building or an engineering structure built along the coordinates X, Y, Z and a software control module functioning through a web application, which allows displaying information about an object on a digital mobile device (tablet, laptop).
Figure 4 shows a diagram of a quadcopter equipped with measuring technological equipment.

The quadcopter body combines such elements as a microcontroller, flight controller, radio transmitter-radio receiver with a frequency of 433 MHz, a radio receiver for manual control of 2.4 GHz, a board for connecting to a GSM network, a power supply, motors, a GNSS-receiver, a video camera, a laser rangefinder and a geodetic reflector.

The quadcopter has the following hardware and software functionality:

a) determination of spatial data on the upper shell of a building or engineering structure using a laser rangefinder, a gyroscope - for measuring deviations from the vertical, a video camera - for video recording of the object's surface;

b) data record to internal memory drives;

c) transmission of this data over the 433MHz radio channel to the entire group of quadcopters, and then over the GSM network using the GPRS add-on in batch mode for the web application.

4. Conclusion

The software and hardware complex for geomonitoring of buildings or structures developed by the authors based on the principle of decentralized systems and a multi-agent approach makes it possible to exclude the direct performer presence of the geomonitoring process in an emergency situation, and gives a chance to receive information about changes in the state of the upper shell object in real time.

5. Acknowledgments

The algorithm of the hardware-software complex based on the theory of multi-agent systems was developed by the author, which is confirmed by the certificate of state registration of the computer program No. 2016661521 "MAS PVS TO".
References

[1] Karpik A P 2004 Methodological and technological foundations of geoinformation support of territories (Novosibirsk: SSGA).

[2] National standard of the Russian Federation GOST R 22.1.12-2005, Structured monitoring and control system for Engineering systems of buildings and structures. General requirements. Moscow, IPC, Publishing house of standards. 2005

[3] Russell S, Norvig P 2007 Artificial Intelligence. The modern approach (Moscow: Williams).

[4] Bugakova T Yu, Shlyakhova M M, Knol I A 2016 Structural decomposition of an object by mathematical modeling methods with subsequent visualization based on WebGL. Proceedings of the XII International scientific congr. Interexpo GEO-Siberia-2016, April 18–22, Novosibirsk (Novosibirsk: SSUGT) 142 –147

[5] Grif M G, Kochetov S A and Ganelina N D 2016 Functional-structural theory based techniques for human-machine systems optimal design. Proceedings of the 13th International Scientific Technical Conference. on Actual Problems of Electronic Instrument Engineering 1 494-97

[6] Savich A I, Bronshtein V I, Groshev M E, Gaziev E G, Il'in M M and Rechitskii V I 2013 International Journal on Hydropower and Dams 20(6) 453-458.

[7] Leibo J Z, Zambaldi V, Lanctot M, Marecki J, Graepel T 2017 Multi-agent reinforcement learning in sequential social dilemmas. Proceedings of the 16 International Conference on Autonomous Agents and Multi-Agent Systems 464–473.

[8] Stupina A A, Tynchenko S V, Kukartsev A V, Lobkov K Yu, Fedorova N V, Danilchenko Y V 2020 State of the art of consumer video surveillance standards in Russia and abroad Journal of Physics: Conference Series

[9] Andriyanov N A, Andriyanov D A 2020 The using of data augmentation in machine learning in image processing tasks in the face of data scarcity. Journal of Physics: Conference Series