Monitoring infrastructure facilities of territories in agricultural sector

D Gura¹², Yu Dubenko¹, I Markovskiy¹, S Pshidatok²

¹Kuban State Technological University, 2, Moskovskaya str., 350042, Krasnodar, Russia
²Kuban State Agrarian University named after I.T. Trubilin, 13, Kalinina str., 350004, Krasnodar, Russia

E-mail: vera.murgul@mail.ru

Abstract. The paper is devoted to topical issues of monitoring infrastructure facilities. The aim of the study is to compare the already established traditional method of ground-based laser scanning and its aerial analogue based on the use of compact drones in collecting data on road structures. The question was raised about the possible ways to modernize the existing monitoring procedure for the timely detection and prevention of dangerous emergencies at engineering structures. The most effective technologies for obtaining comprehensive information on the technical condition of such structures are analyzed. It was determined that the most rational method from the point of view of information content, mobility and examination time is the method of using airborne laser scanners in conjunction with unmanned small-sized aircraft. The procedure of the entire cycle of obtaining information, including its subsequent processing, is described. The analysis of stationary and other applied methods of monitoring infrastructure facilities is made, their advantages and disadvantages are described. A question was raised about the prospect of creating software that uses artificial neural networks as a means of automating the processes of subsequent processing of primary scan data and analysis of the obtained object model. Conclusions are made about the appropriateness and prospects of using similar tools and methods for the needs of monitoring engineering infrastructure facilities, as well as the need for further development of software that will automatically analyze the accumulated data on the same infrastructure object.

1. Introduction

Monitoring as a means of controlling the state of objects and the changes to which they are subject is of great importance in many branches of science and technology. One of the main tasks of monitoring is the prevention of emergency situations at engineering structures and infrastructure facilities, i.e. ensuring their safety. It should be noted that its implementation directly depends on the quality of the work carried out, which is determined by the reliability and accuracy of the applied technical means. In this paper, we study the possibility of using airborne laser scanning technology based on the use of drones as a possible replacement for traditional methods of obtaining data on the technical condition of infrastructure facilities, and also discusses the prospect of creating software using artificial neural networks that will automate the processing of scan data and analysis of the resulting model of a specific infrastructure object. In the aggregate, all this will increase the quality of information about the state of objects and will allow timely identification and prevention of dangerous processes and
situations, while reducing the level of influence of the human factor. Combining laser scanning and neural network technologies into a single tool for monitoring the state of infrastructure will open up the possibility of combining the accuracy of the data and the speed of decisions made to eliminate threats to their security through neural network algorithms and artificial intelligence methods when processing data in specialized software [1]. Ultimately, one can get a single system for solving the problem of monitoring the state of infrastructure facilities and ensuring their safety. As a result of the symbiosis of achievements in the modern fields of surveying and programming, it is expected that the client will save time and budget, which will have high commercial demand among organizations interested in introduction of innovative technologies into their production.

2. Methods

The materials of airborne laser scanning (ALS) and ground-based laser scanning (GLS) conducted in the Krasnodar Territory in the spring of 2019 are used in the paper.

Justifying the choice of a tool for collecting information about infrastructure objects, it is necessary to highlight the advisability of using laser scanning for such work, since it is the fastest means of obtaining high-precision measurements and one of the best tools for conducting various types of monitoring in general [2]. In this case, the choice of a specific scanning system depends on the type of object about which it is necessary to collect relevant information. According to the results of the experiment, it was found that in most cases, the most optimal solutions would be airborne laser scanners mounted on radio-controlled unmanned aerial vehicles (UAVs), namely quadcopters. The drone shown in Figure 1 was used in this study.

![Figure 1. AGM-MS3.100 mobile laser scanning system mounted on the DJI Matrice M600 UAV (drone).](image)

This choice is caused by a number of advantages of quadcopters over controlled aerial vehicles:

- Lower cost of ordering work - $100 for a quadcopter and $3,500 for a helicopter;
- High mobility - quadcopter launch time - 30 minutes;
- Small dimensions - such a device usually occupies no more than 1 m³, which allows not only lifting the device into the air directly at the facility itself, avoiding the cost of flights, but also to examine in detail tunnels and multi-level junctions from any direction;
- Ability to pre-design a flight route - using special software, an engineer can pre-plan a flight route, thereby saving time and money;
Autonomy - such small-sized aerial vehicles have several advantages over their manned analogues, for example: a simplified procedure for obtaining permission to fly, less impact of weather conditions, the absence of a large number of specialists involved in the scanning process;

Less complexity with the launch and control of equipment needed for surveys.

During a series of experiments to determine the area of the territory covered by the survey made from the drone in one day of work, it was found that on average, they are able to scan an area of 100-250 hectares depending on the installed laser scanning system. For example, for the AGM-MS3.100 system, the flight altitude is 50 m, the scanning area of an areal object per flight is 70 - 100 ha, for a linear object, scanning wide is 120 m, the length of a surveyed area per flight is 10-12 km, the scanning area per flight is 120 - 140 hectares. For a system with a range finder of 200 m - AGM-MS3.200, the flight altitude is 150 m. The scanning area of an areal object is 210 - 250 ha, linear, 320 m wide - 320 - 380 ha, the length of the section per flight is 10-12 km.

This allows collecting information about most types of infrastructure facilities, with the exception of linear ones characterized by a very long extent (roads and railways, pipelines for various purposes). In addition, such aerial vehicles are more environmentally friendly in comparison with airplanes and helicopters, which pollute the environment with fuel combustion products.

Summarizing the above advantages of quadcopters, it is possible to conclude that their use for the purpose of obtaining data on various infrastructure facilities will save money and time for the customer and performers - criteria that are the main indicators of the project’s profitability.

The choice of laser scanning as a source of obtaining data on the earth's surface is caused by the unprecedented accuracy and versatility of scanning systems compared to their analogues. In addition, on such devices as drones, it is possible to install only a specialized video camera or laser scanner - Figure 2. However, the scanning system has a great advantage when working in the night time or in low visibility conditions. This allows, if necessary, to collect information about the object of study regardless of the time of day, which increases the versatility of this method of obtaining data.

In cases where the use of airborne laser scanning is impossible or impractical, it is most rational to use ground-based and mobile laser scanning systems, the most advanced of which can produce up to 2 million measurements per second. Their application will allow obtaining information about the object in the same extensions for all types of scanning.

In the process of scanning the traffic intersection in the city of Sevastopol, simultaneously with the airborne laser scanning, a ground-based airborne laser scanning with a system shown in Figure 3 was presented.

![Figure 2. Laser scanning system for unmanned small-sized aerial vehicles - AGM-MS3.100.](image_url)
Figure 3. Leica Scanstation C10 scanner.

A comparison of the main time and resource costs is presented in table 1.

**Table 1.** Comparison of the main time and resource costs when working with different scanning systems.

| Indicator                          | Ground-based laser scanning          | Airborne laser scanning |
|-----------------------------------|--------------------------------------|-------------------------|
| Total scan time of the object, hours. | 30 hours + rest time                 | 6 hours                 |
| Number of specialists performing work, people. | 2 (Engineer and technician)          | 1 (Engineer)            |
| Cost of work, dollars/hour.       | 50                                   | 100                     |
| Total cost of work at this object, dollars. | 1500                                 | 600                     |

According to the table, we can conclude that airborne laser scanning is several times faster and most often cheaper than its ground-based analogue. In addition, when conducting it with the help of an UAV, it is possible to plan a flight route in advance. This will speed up the data collection process and minimize the possible skipping of parts of the scan object. The data of ground-based scanner is more accurate than the airborne one, but when monitoring deformations of the road infrastructure facilities, ALS is quite sufficient to obtain comprehensive information about the condition of the object being examined.

It is also necessary to mention other solutions in the field of collecting data on infrastructure facilities. One of the methods being tested now is the technology of “computer vision”. Its capabilities are actively being studied in many branches of science by scientists from different countries [1-8]. It allows collecting data on the technical condition of such structures in real time. However, such systems are stationary and their use is not always economically justified. They are more suitable for collecting information about unique and complex engineering structures, as well as about objects that require constant monitoring due to increased operating load. In addition to the above method, there are applied methods for assessing the state of individual elements of infrastructure facilities, based on thermal imaging and visual methods for assessing damage [9,10]. However, they have a narrow specificity of application and are suitable only for specific building elements. Their other disadvantage is the low speed of data collection, and, accordingly, the overall low productivity.
After carrying out the scanning procedure, it is necessary to solve the problem of processing the obtained material and its classification. Usually this is done manually by specialists in office analysis. However, this method of information analysis has a number of drawbacks, the main of which are: the dependence of the study time on the volume of obtained data, the influence of the human factor on the accuracy and reliability of the final results. In some cases, the influence of these circumstances can lead to emergencies at infrastructure facilities, thereby harming the economy of a single enterprise, the whole city or the whole country, and sometimes even threatening people's lives. Therefore, the task of processing and classifying the obtained information in the automatic mode is of particular interest and is being tested in various fields of research using laser scanning systems [11,12,13].

Processing of the obtained primary scan data was carried out in the Leica Cyclone 9.4 software product. The result was a transport interchange model that was cleaned of vegetation, on which, using the subsequent method of coloring the heights, it was possible to track the deformation of the asphalt concrete pavement - Figure 4.

At the moment, there are specialized software solutions that allow processing digital survey data in a semi-automatic mode. One of the most popular products is Microstation (Terrasolid). A feature of his work is the preliminary detailed adjustment of various program parameters, which depend on the nature and properties of the object scanned on the ground, as well as the necessary results that are required to be obtained from the final product (object). As a result, the program creates a three-dimensional model of the situation on the ground, after which the specialist evaluates the correctness and accuracy of the result. Figure 5 shows a screenshot of the classification stage of laser reflection points in this software in the work of the team for assessing the automatic recognition of power line points.

**Figure 4.** The final model of the object.
Figure 5. Laser reflection points of the road surface and adjacent vegetation after the classification stage in the Microstation (Terrasolid) software.

Significantly simplifying the processing of an existing point cloud, this software solution does not fully solve the existing problems in the field of office analysis of laser scanning data, which is indicated above. In general, it only speeds up the process of creating the model of the object itself, but cannot automatically find and recognize the zones of deformation and destruction of structures. In addition, there are also problems with this software regarding universality and the number of optional settings [14]. However, it is also necessary to mention that there are proprietary methods developed by research teams from different countries that allow automating the process of solving problems of determining certain structures and types of vegetation [11,12,13,15]. Most often, they are implemented as add-ons to various applications such as CAD. Such solutions have a high percentage of determining the necessary objects, accurately determine their boundaries, but also allow working with a small list of objects necessary for research. Such an approach to solving individual, specific problems causes fragmented methods of obtaining and processing information in general.

From the point of view of a comprehensive solution to the above provisions, the most correct and promising way to eliminate existing disadvantages and, as a result, modernize this monitoring system is to create a unified and more advanced software. The main tasks that must be solved in the framework of creating such products are: ensuring timely processing of laser scan data arrays, automatic classification of various types of objects, identifying phenomena and processes that adversely affect the object of analysis. In addition to the above reasons, each country that will legislatively regulate and financially stimulate the creation of such programs will thereby support the digitalization of its economy and the development of high technologies.

3. Results
During the study, an assessment was made of the use of airborne laser scanning systems in conjunction with small and compact drones for monitoring road infrastructure facilities. We can conclude that this method opens up great prospects for the rapid receipt of data in comparison with the ground-based analog. Its use in the survey of engineering structures will allow:
1. Receiving the most comprehensive data on the technical condition of the facility;
2. Conducting a survey without interrupting the regular functioning of the facility;
3. Conducting a survey remotely, without the need for a large number of specialists;
4. Monitoring the condition of facilities recognized as emergency ones in the shortest possible time and without threatening the life of people;
5. Collecting data at any time of the day;
6. Collecting and accumulating information in digital form with the possibility of subsequent comparison of object models to determine the dynamics of changes in technical condition. Thus, the method described in the paper is one of the most rational solutions among the methods of mobile monitoring of infrastructure facilities. However, the question about the development of a software base for the subsequent processing of primary data and their further analysis remains open.

4. Discussion
Modern laser scanning systems have tremendous performance potential. They are capable of performing up to 1 million measurements per second, thereby covering vast areas. This gives huge amounts of data on the points of laser reflections obtained from the results of laser scanning. However, the performance of software designed to process the received information does not allow using the full potential of this technology, inhibiting the production process. It is obvious that in the future, to continue the development, and most importantly, the growth in the use of three-dimensional laser scanning, it is necessary to improve the algorithms of the software for processing field measurements [14]. One of the possible options for such programs can be solutions based on neural networks, which allow automatically classifying three-dimensional models of objects, reconstructing spatial scenes and highlighting their overall dimensions, analyzing changes in the technical condition, both in statics and dynamics. For this, it is necessary to develop methods for multiclass segmentation of digital images of spatial data obtained as a result of air-laser scanning. This will fully automate the process of visualization of three-dimensional spatial scenes of infrastructure objects, determine their exact overall dimensions, classify these objects and their location. As a result of such a modernization of the means and methods of monitoring infrastructure, positive dynamics are planned in the economic and social life of citizens through the introduction of new digital intelligent information technologies.

Acknowledgment
The reported study was funded by Russian Foundation for Basic Research and Administration of Krasnodar Region of the Russian Federation according to the research project № 19-48-233020 Study of the possibility of using the complex of three-dimensional laser scanning for monitoring and ensuring the safety of infrastructure facilities in the city of Krasnodar and the Krasnodar Territory. Initiative comprehensive research work AAAA-A18-118121290132-9 “Theory and methods of researching laser scanning data for the management of digital infrastructure”

References
[1] Spencer Jr B, Hoskere V, Narazaki Ya 2019 Engineering 5 pp 199-222
[2] Sánchez Rodríguez A, Riveiro Rodríguez B, Soilán Rodríguez M, Arias Sánchez P 2019 Degradation Mechanisms, Health Monitoring and Service Life Design Woodhead Publishing Series in Civil and Structural Engineering pp 265-285
[3] Koch C, Georgieva K, Kasireddy V, Akinci B, Fieguth P 2015 Advanced Engineering Informatics 29 2 pp 196-210
[4] Feng D, Feng M 2018 Engineering Structures 156 pp 105-117
[5] Jahanshahi M, Masri S 2013 Smart Materials and Structures 22 3
[6] Liu Y, Cho S, Spencer Jr B, Fan J 2014 Smart Structure and Systems 14 3 pp 719-741
[7] Yeum C, Dyke S 2015 Computer-Aided Civil and Infrastructure Engineering 30 10 pp 759-770
[8] Ahuja S, Shukla M 2018 Information and communication technology for intelligent systems 2 pp 55-63
[9] Tselykh D, Privalov O 2012 Proceedings of International scientific conference (Chita: Molodoy Ychenyy Publishing House) pp 74-78
[10] Melnikova I, Dayneko K 2016 Vestnik of the Belarusian-Russian University 3 52 pp 136-145
[11] Han W, Zhao S, Feng X 2014 International Journal of Applied Earth Observation and Geoinformation 30 pp 56-64
[12] Ma H, Zhou W, Zhang L 2018 ISPRS Journal of Photogrammetry and Remote Sensing 146 pp
260-271

[13] Liu L, Lim S 2018 *Measurement* **123** pp 135-144

[14] Gura D, Kuziakina M, Dubenko Yu, Pshidatok S, Shevchenko G, Granik N, Markovskii I 2019 *Proceedings of the international symposium "Engineering and earth sciences: applied and fundamental research" dedicated to the 85th anniversary of H.I. Ibragimov*

[15] Fisher R, Sawa B, Prieto B 2018 *Remote Sensing of Environment* **218** pp 201-206