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Mobile 3D Mapping Using Geodetic Drones and GPS Navigation

Abstract. The paper examines current trends in the development of geodetic mapping, with a particular focus on comparing traditional methods with innovative approaches. It is noted that classical techniques, such as the use of theodolites, levels, and GPS receivers – are still widely employed in engineering geodesy, although they present several limitations, including high labor intensity, the need for qualified personnel, and significant time consumption. At the same time, there is growing interest in automated solutions, particularly the use of unmanned aerial vehicles (UAVs), which enable rapid and accurate spatial data acquisition with minimal resource expenditure. The article emphasizes the importance of evaluating the effectiveness of different mapping methods in terms of accuracy, execution speed, and cost-efficiency, which is especially relevant in the context of the rapid development of the engineering and construction sectors.

Keywords: geodesy, mapping, unmanned aerial vehicles, theodolite, level, GNSS

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Research objective

The purpose of this study is to conduct a comprehensive analysis and comparison of the efficiency, speed of execution and economic feasibility of two geodetic mapping methods. The first method is based on the use of unmanned aerial vehicles (UAVs) equipped with geodetic sensors, which makes it possible to automate the process of collecting spatial data. The second method involves the use of traditional means, in particular GPS receivers and theodolite, which is a generally accepted approach in the field of topographic and geodetic work. In the course of the study, key parameters are considered, such as the accuracy of the data obtained, the time spent on measurements and further processing, as well as the total material and labor resources required for the implementation of each of these methods. The results

obtained will allow to draw reasonable conclusions about the feasibility of introducing modern technologies in the field of geodetic mapping.

Problem statement

The study aims to conduct a comparative study evaluating the effectiveness of two geodetic mapping methods, particularly analyzing the time and economic resources associated with using unmanned aerial vehicles (UAVs) with geodetic sensors and traditional methods such as GPS receivers and theodolites. Evaluate the accuracy of the data obtained, the time spent on taking measurements and processing them, as well as the material and labor resources required to implement each method.

Main material

A fundamental stage in construction planning, natural resource assessment, landscape modeling, etc. is geodetic surveying of the terrain. Traditional methods, such as tacheometric imaging, require significant labor and time costs. Laser scanning (LIDAR) in combination with unmanned aerial vehicles (drones) is a promising technology that allows to effectively solve the problem of high-precision terrain surveying.

An organized set of hardware, software, personnel, and geographic data designed for the efficient input, storage, retrieval, processing, analysis, and visualization of all types of geographically organized information is a geographic information system (GIS). In other words, GIS is a system that allows for professional spatial visualization of population mobility in individual settlements, districts, regions, and the country as a whole [1].

Vertical take-off and landing UAVs with three-dimensional stabilization of the position can be the best choice for solving various industrial tasks: aerial photography, industrial inspection with UAVs, mapping, construction monitoring, agricultural land diagnostics, creation of three-dimensional models of large-scale objects [3].

The principle of the remote sensing method, which uses laser pulses to determine distances to objects LIDAR (Light Detection and Ranging), is quite simple and understandable, it is similar to the principle of operation of a reflectorless electronic total station and consists in measuring the time it takes for a laser beam to travel from the emitter to the reflecting surface and back to the receiver. By dividing this time by the speed of propagation of the laser beam, the distance to the object is determined [6].

In traditional methods of geodetic mapping, the use of the Global Positioning System (GPS) plays an

important role, allowing to determine the exact position and speed of movement of an object on the Earth's surface. The GPS receiver installed on the object works on the principle of trilateration, calculating coordinates (latitude, longitude and altitude) using signals from several satellites [9].

This method is the basis for obtaining data in traditional approaches to topographic and geodetic work. However, despite its accuracy, it has certain limitations, in particular in terms of the time spent on measuring and processing data, which, compared to new technologies such as unmanned aerial vehicles (UAVs), can be less efficient.

One of the traditional tools in geodetic and surveying work is a theodolite - a device used to measure horizontal and vertical angles on the ground. Theodolite is essential in a variety of geodetic, surveying, astronomical, and other types of work where measurement accuracy is crucial [4]. It is worth noting that the cost of a theodolite directly depends on its accuracy and functionality. However, as the study shows, this method requires significant time and labor costs for measuring and processing data, which limits its effectiveness compared to more modern technologies, such as unmanned aerial vehicles (UAVs), which are capable of performing similar tasks with fewer resources.

To study the time and economic costs associated with the survey of the object, it is necessary to choose a real object for mapping and determine its area. This will allow to estimate not only the time spent on measurements, but also the costs associated with the use of various geodesy methods. The territory of the National University "Yuri Kondratyuk Poltava Polytechnic" was chosen. The area is determined using the index map of the land cadastre, which is equal to 94960,89 m² (Fig. 1).



Figure 1 – Territory of the National University "Yuri Kondratyuk Poltava Polytechnic"

The main advantages of mapping with UAVs are the speed of work, but despite everything, there are other significant advantages. The method of laser scanning from drones allows to obtain data with high accuracy (up to 2-5 cm), even in difficult conditions. LIDAR effectively penetrates vegetation, allowing for the creation of accurate digital models of the earth's surface. Drones ensure safety and efficiency of filming in hard-to-reach areas (mountainous areas, wetlands),

which greatly facilitates the work, but there are also disadvantages in this method - the high price of devices, which in some cases can make it impossible to carry out work, the great dependence of the UAV on weather conditions [7].

For better comparison and understanding of the survey, it is possible to use two types of geodetic quadcopters for example, namely Leica BLK2FLY and DJI Matrice 300 RTK.

Table 1 - Main characteristics of the UAVs

Name	Leica BLK2FLY	DJI Matrice 300 RTK
Flight time	15 min	50 min
Flight altitude	1800 m	7000 m
Sight	360°	300°
Wavelength of vision	830 m	450 m
Measurement speed	420000 dots/sec	240000 dots/sec
Measurement accuracy vertical/horizontal	20 mm to 50 m/20 mm to 50 m	50 mm to 50 m/10 mm to 50 m
Price	2 669 265 UAH	721 079 UAH

Comparing the parameters of two geodetic UAVs, the following conclusions can be drawn: The DJI Matrice 300 RTK has a significantly longer flight time, exceeding the Leica BLK2FLY on 233%. The flight altitude is also significantly higher – 289% more, making it more suitable for surveying large areas. However, the field of view of the DJI Matrice 300 RTK is 16.7% smaller than that of the Leica BLK2FLY, and the visual wavelength is 45.8% shorter, which may affect scanning accuracy under certain conditions. DJI Matrice 300 RTK significantly outperforms the Leica BLK2FLY in measurement speed, which is 471% faster. This allows you to process large areas faster. In

terms of measurement accuracy, the DJI Matrice 300 RTK performs 150% worse in the vertical direction, but in the horizontal direction, the accuracy, on the contrary, is 80% higher. One of the most significant factors is the price: the DJI Matrice 300 RTK is 73% cheaper, making it a more cost-effective option. So, the DJI Matrice 300 RTK surpasses the Leica BLK2FLY in measurement speed, flight altitude, and cost, but is inferior in wavelength, field of view, and vertical measurement accuracy. Based on the result of the comparison, it can be concluded that in most parameters, the DJI Matrice 300 RTK leaves far behind its opponent, so its choice is a more expedient option.

Table 2 - Comparative Analysis of the Accuracy of Geodetic Measurements Using the Trimble R8 S and Leica GS08 GNSS Receivers

Name	Trimble R8 S	Leica GS08
Measurement accuracy in plan: static shooting	3 mm + 0,5 mm/km	3 mm + 0.5 mm/km
Accuracy of height measurements: static shooting	5 mm + 0,5 mm/km	6 mm + 0.5 mm/km
Accuracy of measurements in plan: kinematic shooting	8 mm + 1 mm/km	10 mm + 1 mm/km
Accuracy of height measurements: kinematic shooting	15 mm + 1 mm/km	20 mm + 1 mm/km
Accuracy of measurements in plan: diff. Shooting	8 mm + 1 mm/km	10 mm + 1 mm/km
Accuracy of measurements by height: diff. shooting	15 mm + 1 mm/km	20 mm + 1 mm/km
Price	360 000 UAH	155 000 UAH

Performing a task using GPS and a theodolite can provide quick results, sometimes even in real time. The ability to determine coordinates in daylight and dark, the ability to operate in difficult meteorological conditions – this method of shooting has a large number of advantages, but among them, compared to UAVs, one can single out the low price of equipment and less dependence on weather conditions. This method also has significant drawbacks - a deterioration in the quality of results when working in a zone of high

interference, next to intense sources of electromagnetic radiation, as well as in conditions of significant limited visibility of the celestial hemisphere, in comparison with geodetic drones, much more time is spent.

For better comparison and understanding of the shooting, for example, it is possible to use two types of GNSS receivers, namely Leica GS08 and Trimble R8S. When choosing a GNSS receiver, it is important to consider not only the price, but also the accuracy of measurements. Consider the percentage difference

between the two popular models: The Trimble R8S demonstrates higher accuracy in kinematic and differential shooting, second only to the Leica GS08 in cost. In particular, in high-altitude accuracy during kinematic shooting, the Trimble R8S is 33% more accurate, and in planned accuracy during differential shooting - by 25%. This makes it an ideal choice for applications where maximum precision is required. However, the Leica GS08 has a significant cost advantage - it is 132% cheaper than the Trimble R8S. This makes it an attractive option for those who are willing to sacrifice some precision for cost savings. Thus, the choice between these receivers depends on priorities: if accuracy comes first, the Trimble R8S is the undisputed leader. If budget is the key factor, the Leica GS08 offers acceptable accuracy at a much lower price, or rather a price difference of 132%.

When comparing Trimble R8S and DJI Matrice 300 RTK for georecognition, it is worth considering their key features: DJI Matrice 300 RTK has a long flight time (50 minutes) and an average stabilized flight altitude (2000 m), which allow to cover large areas. High measurement speed (240,000 dots/sec) and measurement accuracy. However, it has a limited field of view (300°) and a shorter viewing wavelength (450 m). Significantly cheaper than the Leica BLK2FLY, making it an economically attractive option.

Trimble R8S - high accuracy in static and kinematic measurements (3-8 mm in plan, 5-15 mm in height). It is more suitable for detailed local geodesy, in particular differential surveying. More expensive than the Leica GS08, but 25-33% more accurate in different modes. Less depends on weather conditions and obstacles, unlike UAVs.

Based on the above facts, we can draw the following conclusions, if georecognition requires large-scale coverage of areas with a high data collection rate, DJI Matrice 300 RTK will be a better choice, but if maximum measurement accuracy is required for

local areas (e.g. detailed topography, terrain mapping), Trimble R8S will be more appropriate.

But taking into account our task, we can say with confidence that DJI Matrice 300 RTK will be many times more efficient, since the studied area of the territory is quite large.

Now you can imagine how the study will take place. Before starting work, the operator sets up the mission in the software, setting the flight path and shooting altitude. The optimal height for such a task is 50-100 meters, which provides detailed coverage of the area. Due to the high speed of measurements (240,000 dots/sec), the drone is able to completely cover the studied area in 1-2 flights. The time of one flight is 50 minutes, which allow to quickly get the necessary data. Using the RTK module, the drone provides maximum accuracy of the coordinates of each point of the terrain. During shooting, the laser sensor creates a detailed 3D terrain model, which allows you to identify surface features, assess altitude differences, and prepare an accurate topographic map. The obtained data is transmitted to a computer, where it is processed in specialized geodetic programs. Thanks to DJI Matrice 300 RTK, geodetic surveying of an area of 94,960 m² is performed many times faster than traditional methods, which saves time and resources.

Conclusion

So, after the study, we can make the following assumption: each of the above methods of geodetic survey is relevant and in demand in its field. However, each of them has its own advantages and disadvantages. At the same time, when trying to reach a specific conclusion, the use of unmanned aerial vehicles (drones) for filming will look more effective. This is confirmed by the results given in the tables, which show a significant reduction in time costs, a decrease in economic costs and an increase in accuracy, which allows you to achieve maximum efficiency compared to traditional method.

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Мобільне тривимірне картографування за допомогою геодезичних дронів та GPS

Анотація. Сучасний розвиток геодезичного картографування характеризується широким спектром методів, кожен з яких має свої особливості, переваги та обмеження. Традиційні підходи, такі як використання геодезичних приладів — теодолітів, нівелірів та GPS-приймачів, досі застосовуються в інженерній геодезії. Проте цей метод має значні обмеження: високу трудомісткість, необхідність залучення кваліфікованих спеціалістів та значні часові витрати на проведення вимірювань і обробку даних. Останнім часом спостерігається тенденція до автоматизації геодезичних процесів, що дозволяє підвищити точність, швидкість та економічну ефективність виконання картографічних робіт. Одним із перспективних напрямів є використання безпілотних літальних апаратів (БПЛА), оснащених сучасними сенсорами та камерами високої роздільної здатності. Інноваційні технології БПЛА забезпечують оперативний збір просторових даних з мінімальними затратами людських ресурсів, відкриваючи нові можливості для створення детальних картографічних матеріалів. Незважаючи на появу інноваційних рішень, значна кількість компаній у сфері геодезії досі використовує традиційні інструменти для виконання топографічних знімачів та дослідження рельєфу місцевості. Такий підхід залишається трудомістким, вимагає значних часових витрат і залучення кваліфікованих спеціалістів, що може бути критичним у умовах швидкого розвитку будівельної та інженерної галузей. Тому виникає актуальне питання: чи є альтернативні методи картографування, які б забезпечували вищу ефективність, скорочення витрат часу та ресурсів без втрати якості отриманих даних. З огляду на це, важливим є порівняння традиційних і сучасних методів картографування з метою оцінки їх ефективності, швидкості виконання та економічної доцільності.

Ключові слова: геодезія, картографування, безпілотні літальні апарати, теодоліт, нівелір, GNSS

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