Analysis and Comparison of Technologies of Survey of Buildings and Structures for the Purpose of Obtaining a 3D Model

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Abstract. In the framework of the preservation of historical and cultural heritage, it is important to provide for the possibility of preserving and recreating a virtual historical model of the city, first of all - architectural structures. To obtain reliable spatial data about the location and configuration of the building, tacheometric survey, laser scanning and photogrammetric methods are usually used. In this paper, an experiment was conducted to obtain a three-dimensional model of the building using all the above methods. As a result, the following conclusions were made: all technologies allow us to obtain a 3D model of the property; in time field and office work, the advantages are laser scanning technology and photogrammetric methods with UA VS; in terms of efficiency, it is possible to distinguish aerial photography from UAVS, since it is relatively inexpensive compared to laser systems; in accuracy, tacheometric survey will have an advantage, since measurements are made at a specific point, and its coordinates are calculated, but this advantage can only be for buildings that are simple in geometry, for complex architectural forms and complex technical structures, the use of an electronic tachymeter is impractical

1. Introduction
Modern construction is based on the existing layout of the city. The main highways of the city are geographically unchanged, in contrast to the changing architectural appearance. Quite often, old buildings that do not have the status of a cultural heritage monument are subject to demolition due to the improvement, expansion, redevelopment of streets, etc. In the framework of the preservation of historical and cultural heritage, in the construction of new buildings, it is important not only to take into account the historical architectural style, but also to provide for the possibility of preserving and recreating the historical landscape of the city.
In particular, one of the buildings to be demolished is the building of the city polyclinic Number 10 (formerly Chizhovskaya Zemskaya Hospital) at Voronezh, str. 20 letia oktyabrya, house 82.

The building is located in the upper (northern) part of the street, indented from the building line. The street is facing the south-west facade. There are no separate bibliographic publications concerning the history of the building of the Chizhovsky Zemsky Hospital. Some information is contained in the collection “Historical and cultural heritage of Voronezh. The materials of the Code of monuments of history and culture of the Russian Federation ”[1], as well as in the monograph of P.A. Popova “Voronezh. The history of the city in the street names ”, where this building is referred to as the building of the Chizhovsky Zemsky Hospital. [2]

It is known that the Chizhovskaya Zemstvo hospital, consisting of two blocks - medical and ambulatory, was built in 1907. In 1908, the maternity unit was added. Archival photographs of the building of the early twentieth century was not found. The author of the building project is also not known.

Today the maternity hospital is closed, but the functional use of the building remains the same - for medical purposes (Medical and Diagnostic Center of Polyclinic Number 10). Thus, the initial functional use of the building for medical purposes did not change from the very beginning of its discovery - from 1907 to the present.

At present, the original architectural appearance of the building can be judged by the southern facade, the first floor of which is marked by three light uniaxial risalits. Windows with an accentuated bow lintel, keystone, ears and a window sill, complete with an apron, are located on the left side of the facade. The first floor is completed by a ledge encircling the building.

![Figure 1. Str. 20 letia oktyabrya, 82 (modern view).](image)

2. **Relevance**

In connection with the approved plan for the demolition of this building and the construction of another at this place, the question arose of preserving the appearance of the old building for history and with the possibility of recreating it in a virtual model. In order to reliably recreate the building model in the future, it is necessary to carry out accurate measurements using technologies that allow it.
Analysis of foreign and domestic experience in obtaining high-precision 3D models of various types of real estate [3, 4, 5, 6, 7, 8, 9] led to the conclusion that to solve the problem of reliably obtaining spatial data on the location and configuration of the property, the most common received the following methods:

- tacheometric survey (electronic total station should measure without a prism reflector, i.e., receive signals from any reflecting surface, work in the so-called non-reflective mode, then – tacheometric survey);
- laser scanning (ground, air, mobile). Laser scanning systems are quite complex and expensive technology, but in obtaining three-dimensional models, especially complex architectural or technical structures, it is more efficient. Among the existing types of laser scanning for obtaining 3D models of buildings and structures, the most effective option is ground-based laser scanning [3, 4, 5];
- photogrammetric methods (ground photogrammetry, survey by unmanned aerial vehicles (UAVS) from low altitudes). Undoubtedly, technologies based on photogrammetric methods have taken a new level with the advent of UAVS and HD cameras. Modern UAVS consist of three main elements: an unmanned aerial vehicle, ground control and data transmission channels. In addition, the aircraft consists of a glider, a power plant, a flight controller, an accurate navigation system and a detection system. Thanks to highly detailed images from digital cameras for aerial photography, it is possible to reduce the cost of work, reduce the time of their execution and automate the process of obtaining data.

UAVS — This is not only aircraft, but also photogrammetric software and special software for data visualization and analysis. Such a set of tools allows you to perform work faster and safer, save money and make quick and effective decisions.

3. Formulation of the problem
The use of these methods is used to solve various problems, most often for the renovation of facades, decorative refining, insulation, various repairs, this is especially true when it comes to complex configuration and a large area of the property.

In this study, an experiment was conducted to obtain a three-dimensional model of the building using an electronic total station, mobile laser scanner and UAVS.

4. Experimental part
The tachymeter TRIMBLE 3300DR was used for tacheometric surveying, which allows surveying in non-reflective mode and has an accuracy of measuring angles - 5", distances - 3 mm + 2 mm / km (without reflector) [13]. Tacheometric survey refers to the methods of classical geodesy. To obtain an accurate three-dimensional model of the building, the technology of a tacheometric survey should involve the creation of a survey study around the building. The points of the survey justification should be located in places convenient for surveying the facades of the property, it is desirable to place them in the middle of the facade and avoid sharp corners, because in this case, the laser range finder may not work correctly and subsequently the measurement results will be inaccurate. With the help of an electronic tachymeter around the building 9 points of the filming justification of temporary fixation were laid. From each survey point, measurements were taken on all the visible elements of the facade, regardless of whether they belonged to a single or different planes of the facade, to control the elements of the facade were removed with overlap.

In the process of facade imaging with the aid of a total station, the measurement results were entered into outlines, which indicated and designated the removed elements of the building, and other necessary information. It took 2 days to carry out a tacheometric survey, with the inception of survey justification points. As a result of the survey, 710 points were obtained.

The main software tool for processing a total station survey is the AutoCAD program. After importing to AutoCAD, an arbitrarily oriented “point cloud” is formed, which forms the faces of the facades, openings and walls. As a result of the vectorization of all points captured in the process of survey, a full-fledged three-dimensional model of the building is obtained, with applied openings and other necessary elements. The result of processing the "point cloud" is shown in figure 2.
Figure 2. 3D model of the building, resulting from the processing of the tacheometric survey.

The resulting three-dimensional model of the building after processing in AutoCAD is quite visual and detailed, and is also an effective tool for further design and other necessary work.

To conduct research using laser technology, we had a mobile laser scanner (MLS) Topcon IP-S3 at our disposal. The IP-S3 system includes the following devices: a spherical camera, a laser scanner, an inertial control unit and indicators, a distance sensor, a GNSS receiver. The MLS IPS3 structure is represented by a single laser scanner, which is located at an angle of 45° and an angular resolution of 360° horizontally and 40° vertical [14], which allows you to collect all the information around the vehicle during its movement. To improve the accuracy of the coordinates of the route and point cloud in MLS, GNSS differential technology is used, which requires careful pre-planning of routes and deployment of base stations, as well as transmission of corrections from the base station to the GNSS receiver in MLS in real time. In our case, to obtain corrections in real time, a permanent active reference base station was used at a distance of 7 km from the object. To collect data, in order to obtain a 3D model of the building under research, a detour around it was made at a distance of 5 m, the congestion area did not allow for a detour at a greater distance. In the process of moving the vehicle and surveying, Topcon Mobile Master Field program manages the IP-S3 MLS system. As a result of surveying with MLS, the three-dimensional coordinates of a dense cloud of points were obtained.

For further processing, the data were uploaded to the MAGNET Collage program, which allows processing and combining information from various devices and laser scanning systems: ground-based, mobile and airborne [15, 16]. Also in this program you can measure, create three-dimensional models of buildings and structures, as well as project the faces of the facades on the coordinate plane. As a result of data processing, a three-dimensional model of the object of study, obtained in figure 3, was obtained.
UAVS are of two types: aircraft and helicopter; to solve the problem of obtaining a three-dimensional model of an individual building, it is necessary to withstand the following conditions: low survey height; manual control; the possibility of flying around the building, in order to obtain detailed survey. Such conditions can be fulfilled by a helicopter-type UAVS only, for this study a DJI Phantom 3 quadcopter was used.

As a result of field aerial survey work, the planning and altitude training was carried out. Natural (clear contours) and imaging points prepared for the tacheometric survey were used as identification marks. Aerial photography was carried out according to the specified parameters in two control modes - automatic and manual. Automatic control mode was used for flights along a given route over the object of study, manual was used for detailed shooting of facades. The result of aerial photography is aerial photographs with the image of the object in JPEG format and text files with navigation parameters of photographing centers. As a result of the survey, about 300 aerial photographs were obtained, and it took 20 minutes to take aerial photographs.

Processing of aerial photography was carried out in the program Agisoft PhotoScan, which in the process of work converts the data set into a cloud of points and builds a 3D model of the building. As a result of photogrammetric works, a three-dimensional image of the hospital was obtained, which can be seen in figure 4.
5. The results of experimental studies
The result of the study is to obtain three-dimensional models of the property, made as a result of the use of three technologies: electronic total station, mobile laser scanner and UAVS.

6. Findings
Comparing the technologies used to obtain a 3D building model, the following can be noted:
- All technologies allow you to get a 3D model of the property;
- On the time of field and office works, the advantages are laser scanning technology and photogrammetric methods with UAVS;
- by efficiency, it is possible to distinguish aerial photography from UAVS, since it allows you to collect data for 3D modeling for the entire building (side facades and to the upper part), which cannot be achieved by alternative methods, also UAVS is a relatively inexpensive technology compared to MLS;
- in accuracy, tacheometric survey will have an advantage, since measurements are made at a specific point, and its coordinates are calculated, but this advantage can only be for buildings that are simple in geometry, for complex architectural forms and complex technical structures, the use of an electronic total station is impractical;
- for a complete and reliable obtaining of a 3D model of a structure, the complex use of data collection technologies for three-dimensional modeling is possible, since they complement each other.

7. Figures
Each figure should have a brief caption describing it and, if necessary, a key to interpret the various lines and symbols on the figure.
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