Application of photogrammetric methods in architecture, construction and land management

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Abstract. One of the important tasks is the photogrammetry application study in construction with the aim, namely, to determine the engineering structures’ deformations, to study the engineering structures’ models and to solve other problems. With the use of modern technologies, it is possible to make photogrammetric surveys of buildings and structures using certain methods of performing these works. Photogrammetry plays a significant role not only in architecture, construction and land management. Photogrammetric methods make it possible to solve some applied problems directly from the images economically and fairly accurately, for example, to measure the terrain areas, determine their slopes, obtain quantitative characteristics of erosion processes, and perform vertical planning with the determination of the earthwork amount. In the article, the main goal is to consider the implementation of architectural and construction measurements for the purpose of reconstruction and restoration of buildings, as well to complete visualization of the area of interest, performed using photogrammetric methods on the basis of aerial photographs. The analysis made allows us to conclude that both classical and modern digital photogrammetry can be used in architecture, construction and land management.

Introduction
The relevance of the work is due to the fact that modern digital photogrammetry makes it possible to reveal its shape, size and spatial position in a given coordinate system, as well as its area, volume, various sections at the time of survey and changes in their values after a certain time interval from the images of the object under study.

Photogrammetry is used in a wide variety of science and technology branches [1, 2]:
– in geodesy and cartography (for creating plans and maps);
– in construction (for control measurements and structures’ deformation research);
– in architecture (for shooting historical monuments);
– in astronomy and cosmonautics (for determining the position of space objects and mapping planets);
– in military engineering (to determine the target coordinates, trajectory).

All building structures are constantly exposed to the destructive forces of nature and civilization. If to consider the architectural monuments, the necessary work should be prepared with special care and carried out taking into account a number of points [3]. For example, such work requires mandatory
inventory surveying, accurate and in accordance with the applicable standards. The same applies to the ruins, which must be preserved for humanity as an architectural heritage. At the same time, there is often a need for special scientific research, which in turn puts forward special requirements.

**Discussions and results**

Digital photogrammetry is based on the use of computer technologies for processing photographs. It should be noted that due to the high performance of the laser scanner, it is possible to quickly obtain complete information about the objects’ geometry. Such scanners use coordinate points to provide data on object reflection. This reflected object can be perceived as these three-dimensional discrete models. Thus, today scanning can be performed using digital photogrammetric survey. That is, as a result of combining laser scanning data and digital photogrammetric survey, a realistic color three-dimensional model is obtained (Figure 1).

![Figure 1](image)

**Figure 1.** An example of a colored three-dimensional model of the monument to Nicholas I.

The main methods of photogrammetric processing technology are the digital methods of image processing. By scanning, the image is divided into a number of tiny equal areas called pixels. Each such area contains sufficient information regarding color and color density. In digital photogrammetry, the accuracy of obtaining results increases with increasing scan resolution. The smaller the pixel size, the more accurate the result.

In construction, photogrammetry is used to determine the deformations of engineering structures, control the large-panel buildings’ installation accuracy, study the engineering structures models, calculate the volume of earthworks and select the optimal road route as well as to solve other problems. Engineering structures’ deformation occurs under the influence of an external force - load. If the load does not exceed the limit established for a given material, then after the load termination, the structure returns to its original shape due to the material particles’ interaction. Under heavy loads, permanent deformations appear [4, 5].

To study the engineering structures’ deformation, photogrammetric and stereophotogrammetric methods are used. The photogrammetric method gives a possibility to determine the deformations that occur in the plane, and is used to study flat objects. The essence of the method is that several images of the object under study are obtained from the same fixed point, for example, the first one before the load, the second during the load, and the third after the load. In this case, the camera is installed so that the plane of the applied frame is parallel to the plane of the object and the orientation elements of the images are preserved. The photogrammetric method makes it possible to quickly measure architectural structures and get their projections on the horizontal and vertical planes. The application of this method is especially effective for studying hard-to-reach and complex architectural structures. The stereophotogrammetric method gives an opportunity to determine the deformation that occurs in space, and is used to study spatial objects. Several stereopairs of the studied object are obtained from the same basis, for example, the first one before loading, the second during loading and the third after
unloading. To improve the accuracy of determining the deformation, special marks attached to the object under study are used.

With the market economy development in our country, the requirements for cadastral registration have changed, which is inextricably linked with the territory mapping [6, 8]. Orthophotomaps created on the basis of remote sensing data were selected as a cartographic basis. Land management includes aerial survey, topographic and geodesy, soil, geobotanical and other surveys and measurements, boundary surveying, development of proposals for the rational land use.

Digital 3D terrain modeling based on aerial photographs gives a complete territory visualization. The interactivity of 3D aerial photography is convenient for spatial analysis. For this, drones are used for aerial photography and this is justified, especially in the small areas and as a result, a full range of ready-made materials is created, including a 3D relief model. For the greatest detail, aerial point objects photography must be carried out both in nadir and with a difference from nadir, and the UAV in this case is the most optimal, in addition, cross photography is required on large areal objects, and from a financial point of view, the drone in aerial photography is the most profitable.

As the results of 3d aerial photography of the relief, the following data are possible are shown on figure 3.

Digital terrain model (DTM) applications:
- forecasting taking into account the landscape characteristics; calculation of geometric characteristics for engineering surveys, routing - navigation, architectural planning; possible risks assessment, taking into account the characteristic features of the relief - flooding areas at the time of floods, landslides and avalanches, etc. environmental monitoring taking into account the steepness of the slope, wind balance, illumination; - 3D visualization for laying power lines, designing highways, pipelines (gas, oil). 3D relief model makes it possible to eliminate possible errors in design and construction at an early stage.

Architectural design includes the design of new areas, buildings, structures, the development of new architectural forms, interior architecture. This also includes the spatial arrangement of objects, the choice of design and building materials, the organization of workplaces and other tasks. And here photos, photomaps, orthophotomaps can be used. Optical editing of photographic and stereo perspectives is used very often. Photos of the future structure are obtained through drawings or models. Architectural measurement is necessary in the absence of drawings during the restoration, reconstruction and restoration of structures, as well as when studying architectural monuments, making models and dummies, during archaeological excavations. Both photogrammetric and stereophotogrammetric images are used.

**Table. 1. Measurement accuracy characteristics.**

| Measurement type | Limit errors, cm | Scale | Type of work |
|------------------|------------------|-------|--------------|
|                  | major            | subsidiary |       |
| High precision   | 0.3-0.5          | 1-1.5   | 1:20         | Drawings |
| Exact, II        | 1-2              | 3-5     | 1:50         | Drawings |
| Exact, III       | 3-5              | 10-15   | 1:100        | Drawings |
| Technical, IV    | 10-15            | 20-30   | 1:200        | Sections, general drawings |
| Technical, V     | 20-30            | 30-50   | 1:500        | Sections, schemes |

Monuments of architecture and history, preserved in photographs, are restored using stereo models of single photographs received from different stations. Not only parts of the structure visible in photographs are restored, but also the invisible ones, using such indirect signs as shadows, profiles, color nuances and architectural style features. In this area, all activities are considered in accordance with the current laws on the historical and cultural monuments’ preservation.
Figure 2. As the results of 3d aerial photography of the relief, the following data are possible: a - “relief shading” and wireframe; b - generalization of heights isolines with a possible step of up to 0.2 meters (data can be converted to available formats for engineering programs, for example, Autocad); c - DTM transformation based on aerial photographs in color layout and gradation of heights by colors; d - aerial photography and digital terrain model (DTM) with “pulling” aerial photography on digital wireframe.

Figure 3. An example of work as a result of architectural measurement.
And these activities are associated with inventory, research of the state of monuments, including the deformations’ determination, restoration of drawings during restoration, creation of an archive, promotion of national monuments, organization of exhibitions and expositions.

Of particular importance is the systematic nature of the documentation of existing monuments of architecture, not related to the needs of construction, but rather necessary for inventory. The resulting materials form the basis for repair or restoration work in case of damage. Finally, art research studies are based on such materials, if certain conclusions can be drawn from the shape and size of the monuments.

Part of the materials required to solve the above-mentioned problems, especially the images of monuments, can be quickly obtained using the ground-based photogrammetric methods with little manual labor and can be financially profitable. Compared to surveying by classical methods, photogrammetry, despite the high cost of the instruments, has numerous advantages: no need to climb the building structures; there is no need for the construction of forests; the duration of field work is reduced.

The development of modern photogrammetry and methods of photogrammetric processing of images is based on the use of new hardware and software.

New technical means include:
- GPS – to determine the elements of external orientation in flight;
- INS – to determine the corner elements of external orientation in flight;
- Latest precision aerial cameras;
- High and medium resolution space imaging equipment for multispectral survey;
- Scanner imaging systems (including laser survey);
- Digital filming cameras.

The software includes:
- GIS- systems;
- Computer graphics systems e.g. Autocad;
- Multi-area imagery analysis tools e.g. Erdas Imagine;
- Network software.

Summary

The use of photogrammetric methods has significant economic advantages, which, however, largely depend on the nature of the object and, above all, on the technical characteristics of the used survey equipment. Thus, digital systems allow performing all the processes of creating maps after carrying out the corresponding preliminary work (aerial photography and determining the control points’ coordinates). In addition, the images obtained with digital systems can be corrected based on the satellite measurements taken both in the air and on the ground.

Based on the technical capabilities of modern technology of photogrammetric survey methods, a classification of the accuracy of performing measurement work is established, which is indicated in the Table. When creating photomaps of building facades, compiled for the survey purposes, the perspective displacements of minor parts (cornices, balconies) exceeding the tolerances are allowed.

Thus, one of the main tasks of photogrammetry in architecture is the performance of architectural and construction measurements for the purpose of reconstruction and restoration of buildings, as well as for the research purposes. The scale of the dimensional drawings, plans and individual fragments, the requirements for the completeness and accuracy of their compilation are determined in the terms of reference, depending on the purpose of the architectural and construction measurements. Photogrammetric work is the main component of modern technologies for creating and updating topographic maps, making photo maps, creating and updating topographic and specialized plans, i.e. play an important role in solving the problems of land management, land cadaster and monitoring, construction and architecture.
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