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# Modern Technologies Applied to Archaeological Research in Voronezh Region

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# Modern Technologies Applied to Archaeological Research in Voronezh Region

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**Abstract.** Archaeological research peculiarity is that in the process of studying the monuments are completely destroyed. Further you can use only the reporting documentation, compiled in the process of excavation. Traditionally used in archeology methods (schemes, drawings, photoes), do not give a complete picture of the monument under study. Modern technologies, such as photogrammetry, laser scanning, satellite technologies, etc., allow obtaining information about historical monuments, architecture; archaeologists in the future can recreate a visual representation of them. Archaeological research include not only excavation, but also exploration during which the discovery of new monuments occurs. Modern remote sensing technologies, as well as laser scanning technologies and others allow to realize this task more effectively.

## 1. Introduction

Pursuant to definition, archaeological monument is a collection of ancient constructions, deposits and artifacts entirely connected with the history of their origin. Different categories of monuments are largely represented by the sites of ancient people, settlements, hillforts, various types of burials and funerary structures, sanctuaries, hoards, mines, irrigation systems, petroglyphs, etc. [1].

The value and reliability of accessories used for exploring archaeological sites relies on the means and methods of field anchoring and integrity of accompanying scientific documentation [2].

Scientific documentation, which contains information about archeological sites, serves as a major source for the further research. This inflicts specific requirements for the selection of basic means and methods of archaeological survey. The criterion for choosing any particular method (or even the complex of methods) is determined by the technical capabilities of the tools applied and particular tasks of the forthcoming study [3].

Currently, archaeological research increasingly tends to be accompanied by geodetic activities based on variety of modern technologies. Field geodetic operation presumes collecting data required for a detailed coordination of archaeological research. Nowadays, digital model of the archaeological

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site territory is successfully reproduced by the electronic tacheometry (TS), aerial and satellite imagery, as well as laser scanning systems. Excavations are linked to the world coordinate system, which defines the position of findings and to the artifacts. [4].

Methods and technologies applied in recent years make it possible not just accurately carry out all the necessary measurements for mapping and anchoring the site and discovered artifacts themselves, but also to model the pre-existent landscape of the site, restore its original appearance, etc.

One of the constituent elements of archaeological research is the visualization of the information received, including graphic information, which provides the most complete picture of the archaeological site, its location, the shape and size of the objects and artifacts; it also helps to understand the interrelation of all the objects discovered. Competent combination of archeology and computer technology makes it possible to obtain precious and, sometimes, exclusive results. Development and adaptation of all the known techniques for three-dimensional modeling of archaeological objects represent an important, relevant and relatively new direction.

Respectively, the main purpose of the study is to obtain and further deploy geodetic data for modeling of the outlook of archeological sites based on the territory of Voronezh region. Implementation of this goal presumed construction of a digital model of the archeological site.

In the framework of our study we applied methodological basis and comprehensive approach to existing methods of field archaeological research, which presume modern geodetic measurements as well as a systematic approach to the study of archaeological heritage sites.

Single barrow territory was chosen as the object of the study, which is the site in the form of a polygon, located 740 m southeast of the following address in Voronezh region: Voronezh, Sukhomlinov Str., 11b [5]. The site monument was discovered on July 25, 2016 by M. Ermolaev in the course of archaeological research conducted on the territory of Voronezh region.

Geodetic work in the framework of archaeological research can be carried out using various modern technologies. The choice of means and methods of measurement depends on financial capabilities of the enterprises involved in archaeological work, the complexity of the site and availability of qualified staff. In archaeological research the following modern geodetic measurement technologies are deployed:

- Electronic Total Station (TS), which converts the process of surveying and anchoring the location of the findings to largely automatic operation;
- Global Positioning System (GPS);
- Unmanned aerial photography (FPA) and digital photogrammetric image processing used for creating topographical plans and maps, and three-dimensional terrain models.

Automatic survey and data acquisition is highly efficient. The main advantage of the TS is that all the records are stored in the memory of the device. There is no need for additional field documentation, especially in case of using TS with ‘photo’ function. TS is extensively used for defining the breakdown of the archaeological excavation, for anchoring of findings and discovered objects (burials, housing pits, household pits, etc.).

When storing information on the coordinates of each survey point (picket) into the memory of the device, it is possible to enter the picket codes that can be further duplicated. Ability to use different types of picket coding and decorating the outlines allows developing the fastest and most convenient TS survey, adapted to the specifics of different types of operation and simplify desk processing.

Further, in the process of cameral work, the TS survey data is exported to special programs for processing geodetic information (Surfer, AutoCAD, Maplnfo, Credo, etc.). The choice of the program depends on the goals and tasks set by the researcher, technical requirements, compatibility of formats, and price parameters. [6].

Applying of GPS in archaeological research.

Previously, for various reasons, the satellite methods in archeology were applied only in very specific cases. One of these reasons was the high cost and limited possibilities for financing archaeological research combined with the lack of knowledge of this technology. In modern practice, archaeological research often deploys satellite equipment to create geodetic justification, whereas the detailed survey is carried out by the TS. However, there is a methodology for surveying the sites using only the GPS equipment.

The main purpose of GPS measurement is to deploy three segments of the system:

- Space segment, consisting of a complex of satellites, which belong to the scope of different projects (GLONASS, GPS, GALILEO, etc.);
- Ground control segment, formed by the ground stations, which perform the tracking, controlling and satellite controlling functions;
- User segment, whose tasks are to get the results of the entire system.

The operation of the whole system includes transmitting of the information about satellites location and time of signal output at certain frequencies as well as converting of this data by a satellite geodetic receiver with the issuance of just three coordinates of points. The main task of GPS is to consider these factors and to introduce appropriate corrections in the measurements.

In order to obtain the exact coordinates, it is necessary to use two receivers, one of which is attached to the point with known coordinates (basic point), and the second one is attached to the points whose coordinates need yet to be determined (rover point). When using satellite equipment, there are many modes of operation. The 'real-time mode' is the most effective for topographic surveying, where the base receiver transmits corrections to the rover point on-line. This option allows obtaining the coordinates of the points directly in the field with the required accuracy, and if necessary, they could be checked and promptly adjusted.

Unmanned aerial photography (FPA) shooting applied to archaeological surveys

Today, the way of shooting from FPA is quite popular due to its cost efficiency. FPA have different characteristics by weight, design, working methods, etc.

Aerial photography (FPA) basically does not differ from the surveys of previously used aircrafts, but it has certain features. The FPA flight is usually performed at a speed of 70-110 km / h (20-30 m / s) at an altitude of 300 to 1500 m. Cameras or video cameras with a matrix size of 10-20 MP are mostly used for shooting. The focal length of such cameras is usually 50 mm, which corresponds to the pixel size on the ground (GSD) from 7 to 35 cm. GSD determines the degree of detail of the aerial photo. In other words, it is the distance between the projections of the centers of two neighboring pixels on the earth's surface. The value of GSD depends on the focal length of the lens, the linear dimension of the CCD matrix element and the survey height. The pixel size on the ground (GSD) is determined by the formula of the initial source [7].

With the aerial survey parameters mentioned above, the results correspond to the accuracy of orthophotomaps with the scales ranging from 1: 500 to 1: 2000 depending on the survey height. That meets the requirements for archaeological research materials.

Due to design peculiarities the FPA flight is not stable. It is very dependent on meteorological conditions, being affected by wind gusts, turbulence and other disturbing factors. As aerial photography performed from the standard planes is planned with 60% overlap along the route and 20-30% between routes, FPA shooting should be designed with 80%, overlap along the routes and - 40% between the routes in order to exclude breaks in the phototriangulation block if possible [8].

It is also necessary to withstand certain requirements for cameras installed on the FPA for photogrammetric processing. The main issue is to calibrate them [9].

Unfortunately, nowadays the outlook of most of the barrows has changed significantly due to the extensive economic activity and under the influence of natural processes. Creating of a three-dimensional digital model of a barrow is one of the possibilities to preserve and present the information about the past.

If we turn back to the definition, the barrow is a kind of funerary monument, which is characterized by the construction of an earth embankment above the burial pit. In archeology, there are numerous barrows, featuring different funeral chambers and embankment constructions [10].

The single barrow No. 1 under investigation located on Sukhomlinov Str., Voronezh, is of a round-spherical form. It has all the features of the "cultural heritage site" and is included in the list of “identified objects of the cultural heritage of the Voronezh Region, representing historical, artistic or other cultural value, as the identified object of the archaeological heritage”.

To register the archaeological heritage site we determined geographical coordinates of the embankment center N 51 ° 30'42.2 "E 39 ° 09'38.2", its diameter of 30 m and its height of 1.5 m with the help of satellite equipment [11.

In the course of archaeological research the following geodetic activities were carried out:

- with the help of satellite systems, the coordinates of the center and the turning points of the boundaries of the territory of the identified cultural heritage site are determined: Solitary barrow No.1 located Sukhomlinov Str., Voronezh, Russia;
- with the help of TS equipment, the territory of the barrow was surveyed in a conventional coordinate system;
- Aerial survey with a quadcopter was carried out. The images of the territory of the solitary barrow were obtained.

Based on the results the approximate dimensions of the barrow were obtained, for which a 3D model with 30 m diameter and 1.5 m height was created:. The outer part of the barrow is represented by truncated pyramid.

After TS surveying the terrain, the coordinates of the terrain points of the barrow were obtained. The processing and construction of the digital model of the barrow site was further carried out in the Surfer program. In addition, a photogrammetric processing of the aerial photo data of the barrow from the DJI Phantom 3 Professional quadrocopter was carried out in PHOTOMOD 5.2. photogrammetric system.

At the next stage, the construction of the three-dimensional model of the barrow area on Sukhomlinov Str. based on aerial photographs was carried out.

Three-dimensional models of the site is a modern and relevant type of spatial models of terrains or objects. The site models obtained from photogrammetric measurements and processing differ from the common three-dimensional models. It is possible to measure the coordinates and heights of the object points on photogrammetric models. Digital stereoplotters, digital photogrammetric stations and other has a standard set of systems that provide for the construction, observation and measurement of the stereomodel of the site, as well as displaying information collected.

The pattern for creating of a three-dimensional digital site model based on FPA materials does not differ from the scheme for creating a two-dimensional model, however there are some features, which entitle you to observe additional conditions that determine the specifics of working with three-dimensional information.

Above all, these requirements presume the preparation of geoinformation support, such as:

- analyzing and adding of the classifier of photogrammetric or GIS software;
- following the rules for collecting digital information on the terrain and objects located on the given terrain on a digital photogrammetric system.

For three-dimensional modeling it is necessary to make additional layers that provide the formation of a volumetric kind of structural elements of structures in the classifier of the program. For example the elements of the upper parts of buildings and structures.

Also, to obtain a digital model, it is necessary to include additional characteristics, which distinguish the altitude component of the object in the form of an absolute value.

To create three-dimensional models of archaeological sites, semantic information about the objects should include the information about material and characteristics, reflecting the appearance of the objects (the number of repeated elements, the type of soil, the type of surface, etc.), which will further provide realistic display of three-dimensional objects if the volumetric modeling is applied.

In order to make a three-dimensional model of the barrow located on Sukhomlinov Str. we used images taken by the DJI Phantom 3 Professional in September 2017.

Three-dimensional FPA model in a digital photogrammetric system was made depending on the nature and complexity of the territory out and was based on:

- the pickets in the form of a regular network for territories with a plain relief (GRID-model);

- the pickets in the form of irregular triangulation network for terrain with explicit relief (TIN model).

In the first case, based on the GRID model data, the network step size depends on the required scale of the territory representation.

The basic representation of the 3D model in the PHOTOMOD program is the TIN model, which is a piecewise linear surface model, based on interpolation. If necessary, you can convert the TIN model to a regular height matrix.

In order to obtain a three-dimensional model of the site, a set of pickets can be made both in automatic mode and manually using various graphic programs.

For the processing of TS data it is convenient to use the Surfer program and it is most often used by archaeologists. The program is user friendly and accessible.

To create a 3D model we used the Surfer program. We imported the points into the program and built a 3D model of the site. This program allows constructing a three-dimensional model of the site in automatic mode based on three coordinates received in the process of shooting a barrow with TS equipment.

The results are shown in Figures 1 and 2.

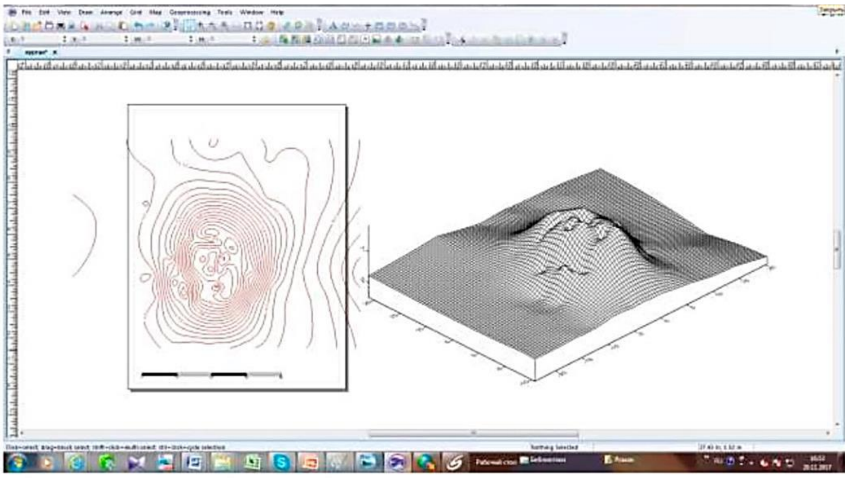

**Figure 1.** Constructing of three-dimensional barrow model.

To build a 3D model using quadcopter, you can use the AutoCAD program.

The initial data comprises: relief of the site taken from FPA photos; focal length equal to 50 mm; photographing height equal to 40 m; We determined the basis for shooting based on the photographs: b = 41.9 mm

Sequence of completing the task:

- Structural points were outlined, the selected area and points are numbered,
- The log was filled out: "Determining the marks of characteristic relief points", the leveling between the reference points was carried out, then the leveling between the reference points and the nearest structural points was carried out, and the point marks were calculated.
- After filling out the log, the data was transferred to the AutoCAD and a digital site model was created.

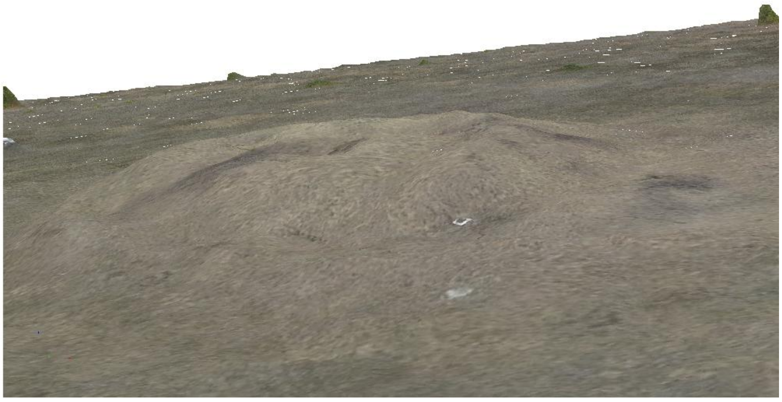

**Figure 2.** Three-dimensional model of the archeological site “Solitary barrow on Sukhomlinov Street”.

## 2. Conclusions

- Using UAVs, and quadcopters in particular, as an aerial survey platform has great perspectives for shooting small archaeological sites.
- Paper proposes technology for creating three-dimensional models of a landscape of an archeological site on the basis of TS shooting in Surfer program, and also based on the aerial photos received from DJI Phantom 3 Professional quadcopter.
- It is possible to use images obtained as a result of UAV surveys as well as TS ground survey results for 3D modeling of cultural heritage sites.

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