TECHNOLOGY FOR DOCUMENTING AND PRESERVING CULTURAL AND HISTORICAL SITES IN THE SHUMEN REGION

Sabin Ivanov¹, Krasimir Videv², Penka Kastreva²

Assist. Dr. Sabin Ivanov
Shumen University "Neofit Rilsky", Faculty of Mathematics and Natural Sciences, Department of Geodesy
Bulgaria, Shumen, 9700, 115, Universitetska St,
sabin.ivanov36@gmail.com

Krasimir Videv, PhD student
South-West University "Neofit Rilsky", Faculty of Mathematics and Natural Sciences, Department of Ecology and Geography
Bulgaria, Blagoevgrad 2700,66 Ivan Michailov st.
videvv@abv.bg

Assoc. Dr. Penka Kastreva
South-West University "Neofit Rilsky", Faculty of Mathematics and Natural Sciences, Department of Ecology and Geography
Bulgaria, Blagoevgrad 2700,66 Ivan Michailov st.
penkakastreva@gmail.com

Abstract
The preservation, conservation and promotion of the cultural values of our country are responsibility of all. In this process, the geodesists and cartographers are responsible for mapping the sites of cultural heritage.

In this report are presented the field activities for mapping, description and attractive visualization of the rich cultural and historical heritage left by our ancestors on the lands of Pliska, Veliki Preslav, Madara and other remarkable places of the Shumen region.

The aim of the study is to develop theoretical and methodological bases for cartographic documentation, which later can serve to create specialized maps for the management of cultural heritage. The described technology for documenting and preserving cultural and historical sites is based on the use of the modern technology for air-photographing of the areas occupied with archaeological monuments by unmanned aerial vehicles (UAVs), commonly known by the name drone. As a result of the surveyed objects the relevance of some of the principles of the cartographic documentation is illustrated. A database of cultural and historical heritage sites in the Shumen region has been created in the form of various digital documents - orthophotomaps, 3D models, photographic pictures, texts from historical sources for description of cultural objects, etc.

Key words: cultural heritage, Shumen, 3D models

INTRODUCTION
The theme of cultural heritage and its conservation has always been part of the public and professional debate on the development of the regions and their future. The researches on the cultural heritage, its place and importance for the development of the regions are becoming more and more topical not only in Bulgaria but also in Europe and globally. The preservation and the "inclusion" of the heritage in the process of inevitable changes in the modern living environment are achieved with an acceptable balance between conservation, reconstruction and integration.
The existing practice of preserving and managing cultural heritage has always been linked to the planning of areas where there are cultural monuments. Most often, the territorial feature is a separate settlement, complexes or separate buildings. For easy management of such territories, it is established practice to observe the cultural heritage and respectively to have it restored and preserved by the municipalities. In today's complex economic and political environment, the imposition of such a model is of a financial nature but also is one of the ways for economical development of the regions.

The review of the publications dedicated to the cultural heritage in Bulgaria mainly deals with the normative basis, the history, the contemporary state of the models for preservation of the cultural heritage. On the subject of cultural heritage there are still insufficient current studies in Bulgaria for systematizing and collecting of digital information on the cultural monuments. However, it is noteworthy the activation of the scientific circles in the field of history, archeology, architecture, culture and others to describe, classify and offer a methodology for their preservation. In practice, however, there has been no elaboration of a mapping project for cultural heritage sites and their introduction into the GIS environment for Bulgaria (with few exceptions, such as the map of cultural monuments in the central part of Sofia). Even areas with a concentration of cultural and historical heritage such as the palace complexes in Madara, Pliska and Veliki Preslav in the cadastral maps are "white spots".

**BRIEF OVERVIEW OF THE MODERN TECHNOLOGIES IN STUDYING, PRESERVING AND MANAGING OF THE CULTURAL HERITAGE**

The subject of this paper was also to analyze the use of modern technologies for documentation of the territory occupied by cultural and historical objects and to create a basis for preparing a project for their management. Below we will briefly recall their essence and application:

- **Geographic Information Systems (GIS)** are a modern digital technology for collecting, processing, mapping and analyzing spatial geographic information (Andreev A., Markov M., 2009).
- The **Global Navigation Satellite System (GNSS)** in the near future will be the most common method for collecting cartographic information. The system can quickly and accurately determine the spatial position (latitude, longitude and altitude or spatial Cartesian coordinates) of points on or above the ground. The accuracy that is achieved is centimeters for geodetic applications.
- **Remote sensing** is a group of methods designed to collect information about the Earth's surface from a distance, as well as atmospheric and ocean data. The data acquisition process is based on the use of satellites equipped with air sensors to detect and classify objects on Earth. The cartographic applications derived from remote sensing include the following: planimetric (coordinate) information; digital elevation models (DEM's); thematic and topographic mapping.
- **Air photogrammetry** is the first remote method. The photogrammetric methods are used to make airplane aerial photographs on the territory, after their processing the orthophoto images are obtained. They become orthophoto maps by adding of mapping symbols. Photogrammetric photos are the main source of data for creating a DEM. Over the last decades the unmanned aircrafts (UAVs) have been successfully developed and used. They are more known as "drones". They have numerous applications, both military and civilian function. As we will see later, the drone is an invaluable assistant for 2D and 3D mapping of cultural monuments.
- **Laser scanning** is used to capture 3D data. It can be used to scan features on both, the terrain surface as well as volumetric objects and buildings (Maldžhanski Pl., 2012). In practice, terrestrial and aerial laser scanning is used.
- The **2D and 3D computer modeling** is the result of the processing of the technologies described up to here - photogrammetric, satellite, laser scanning, very often in combination with GNSS to determine the exact location of the objects and the invaluable GIS help with storage and visualization capabilities. 2D images and maps provide a lot of information about historical events and monuments and the surrounding area. The 3D models of areas with concentration of cultural and historical objects allow users to navigate space easier. They combine the DEM and the monuments of culture located on the Earth's surface. This provides the best possible visual image for them and the environment.
- **Web mapping.** Interactive maps provide users with the ability to preview, enlarge, or move the map. These maps have two advantages over traditional paper maps - access to the most up-to-date information and specialized tools to extract information.

From what has been described up to now, it is understood that each of these technologies is important in order to reach the end result - documenting the cultural and historical heritage through a database and presenting it to the public. A general benchmark regarding the accuracy and volume of captured cultural and historical heritage areas can be found...
among all technologies that provide images in digital form. For example, the methods for remote sensing and photogrammetry can serve archaeologists for capturing the visible parts of archaeological excavations and ruins, as well as for the discovery of cultural monuments known only to historians from written sources. Appropriate examples for the application of these technologies are the activities carried out for the detection of the lost castles of Denmark.

The technology for terrestrial scanning is very successfully used in architecture, photogrammetry and archeology for the creation of digital 3D models of buildings and other cultural monuments undergoing reconstruction. The ground scanning can complement the aerial laser scanning to create a three-dimensional environmental model. (Kamburov, 2010).

The described three-dimensional imaging and modeling technologies provide capabilities for documenting the cultural and historical objects in general and in individual details with high accuracy and reliability, speed for reaching the end results, representativeness, and usability in design. The application of the technologies, despite the undeniable quality of end products, is still costly for mass use, especially for our country.

TECHNOLOGY FOR DOCUMENTATION AND PRESERVATION OF THE CULTURAL AND HISTORICAL SITES IN SHUMEN REGION

The cultural heritage of the Shumen region covers a great historical period - from the monuments of the ancient ages to the unique sites of the XX century. 141 sites are declared as national, historical and cultural. Most of them are part of palace complexes, which are marked in the cadastral map only with their outline. There are fortress walls, earth and stone fortifications, churches and monasteries, shrines, stones, fortresses, etc.

For the spatial situation of the individual sites were used data from the approved cadastral maps, digital models of the map of restored ownership in a scale of 1: 5000 and the capture of some of the objects with GPS equipment. The following geodetic and photogrammetric activities were carried out:

- Creating of a geodetic network necessary for georeferencing of the objects

For each area of study, existing points of geodetic networks (triangular and working) were used and new (control) points were created. The new ones are measured with a GPS receiver TRIMBLE R4. Their coordinates are calculated in accordance with the existing regulations. This process is described in detail by (Ivanov, S., 2017).

- Photogrammetric surveying of valuable archaeological sites

The selected archaeological sites were surveyed with UAVs (drones), model: PHANTOM 3 Professional. The process involves two main parts - planning and making the flight. The survey is conducted in fully automatic mode.

- Photographing of individual objects

The photographic capture of individual objects is used to get an idea of the current state of the objects. A rich photographic material is collected for them. Most often such objects are houses - museums, religious buildings located in settlements, heavily forested shafts, trenches, stone-earth barriers and others.

- Processing of geodetic measurements

GPS measurements of the control points required for georeferencing and controlling of the photogrammetric model to the actual coordinates of the territory are performed. Coordinate registers of points from geodetic networks that are close to the surveyed areas are used.

The root mean square error (RMSE) of the coordinates obtained with the TRIMBLE R4 GPS receiver for real time kinematic positioning (RTK) is:

- horizontal accuracy- 8 mm + 1 ppm and
- vertical accuracy- 15 mm + 1 ppm.

High accuracy of the coordinate definitions of the cultural heritage sites is required when they fall into a settlement and are property within the meaning of the Cadastre and Property Register Act. In (Kastreva, P., Drenovski, Iv., Ivanov, S., 2015) are given detailed descriptions of different possibilities and requirements for accuracy in the creation of a future specialized map of the cultural heritage sites when they are or are not land properties within the meaning of the Cadastre and Property Register Act
Photogrammetric processing

The process involves processing the captured image to obtain a raster image in which all distortions and errors caused by lens distortions, camera rotation and tilt in exposure times, differences in the scale of individual photos, relief effects, and so on are removed. This raster (orthorectified) image is a digital map in an orthogonal projection. Therefore, it is possible to make direct and accurate measurements in the scale of the image. Any quantitative (metric) and quality (semantic) information can be derived from the created orthophoto plan.

In our case, the photogrammetric processing of the digital aerial photos was done with AgisoftPhotoScan Professional (Agisoft, 2016a). Upon its completion, it is possible to generate: Digital Elevation Model (DEM); OrthoMosaic; spatial TIN (Triangulated Irregular Network) model; a dense cloud of dots (Dense Clouds); hierarchical block model (Tiled Model); contours; Textures; exporting cameras with their parameters and positions (Cameras); Markers export - these are the Ground Control Points (GCP) with their geographic and plane coordinates and Shapes export;

CREATION OF 3D DIGITAL MODELS OF THE OBJECTS OF CULTURAL AND HISTORICAL SITES IN SHUMEN REGION

The technology described briefly was applied for the creation of 2D and 3D models of part of the cultural and historical sites in the Shumen region. For this purpose, objects of different shape and size were selected:

- Bas-relief form - Madara Rider;
- Fortresses - Shumen fortress and Madarska fortress;

Creating a 3D model of Shumen Fortress

For the transformation of the model into the actual coordinate system, 9 control points defined with their GPS coordinates and evenly distributed over the whole area of the object (Fig. 1).

![Figure 1. Location of the control points](image)

The surveying of the territory was done at a height of 30 meters. The number of received aero-photos is 114. After the photogrammetric images are processed, their position coincides with the position of the cameras during the exposures. As a result, a sparse cloud of link points is generated, then a dense cloud of points (Fig. 2). All points of the dense cloud are joined in non-overlapping and connected triangles, resulting in a three-dimensional polygon model (Fig. 3).

On the basis of the dense cloud of dots and the output photographs, a hierarchical block model with textures is constructed (Fig. 4). To achieve higher accuracy in generating the digital elevation model (Fig. 5), we used the compressed cloud of points. The spatial resolution of DEM is 2.4 cm / 2.4 cm for each pixel.
Figure 2. A dense cloud of dots on a part of a fortress wall

Figure 3. TIN model based on a dense cloud of points

Figure 4. Hierarchical (Tiled) 3D model of a part of a fortress wall
Based on the data from the original aerial photos and their processing an orthophoto plan was created (Fig.6). The spatial resolution of the ORTHO file is 2.4 cm / 2.4 cm for each pixel. Together with DEM, a 3D model of Shumen Fortress is obtained (Fig.7). In addition to making measurements, it can also be used to advertise the cultural historical objects as it gives a realistic picture of them.
Creating a 3D model of "Madara Rider"

Capturing vertical objects is fundamentally different from surveying objects in the horizontal plane. While with horizontal objects can be pre-set the flight height, area of captured region, start and end point, etc., the vertical surveying is carried out entirely by manual control of the unmanned aircraft. The number of photos taken is 66. As a result of the photogrammetric processing of the photo material, a 3D model for the rock bas-relief "Madara Rider" (Fig.8) is obtained.

![Figure 8. 3D model of Madara Rider](image)

Creating 3D Model of Madara Fortress

The air survey of the Madara Fortress took place at a height of 40 meters, which is 10 meters more than when surveying the Shumen Fortress. The change in flight height affected the spatial resolution of DEM and ORTHO files:

- Accuracy of DEM: 7.89 cm / pix.
- Accuracy of the ORTHO file: 3.9 cm / pix.

120 photos were taken. After the photographs processing an orthophoto and 3D model of the Madara fortress were obtained (Fig.9). On the orthophoto model, in spite of its poor spatial resolution compared to that of Shumen Fortress, very accurate measurements and sections can also be made. To check the claim, a cross-section of a battle tower from the fortress was made and tower width of 2,873 meters is obtained. The width of the same tower is 2,865 meters, measured with 5-meter tape-line. This example shows the high spatial accuracy of the mapped objects.

![Figure 9. 3D model of Madara Fortress](image)
CONCLUSION

The results of this study provide a unique historical perspective for the cultural monuments located in the Shumen region. The created models show that the graphic editing, remote sensing methods and GIS technology used in this study are effective tools for presenting and managing cultural and historical resources and the environment.

The study shows the contemporary ideas of the authors for cartographic documentation of the sites of cultural and historical heritage in the digital environment. The resulting 2D and 3D cartographic models that characterize the objects studied differ significantly from the traditional models used so far. The distinctive feature of the models is the way information is provided and their proven high precision. As a conclusion, the use of digital cartographic methods and technologies can be successfully applied to all cultural heritage objectives - design, restoration and conservation, studying, storing and advertising of the Bulgarian history and its monuments that have preserved the Bulgarian spirit and culture.

REFERENCES


BIOGRAPHY

Assist. Sabin Ivanov, PhD at department of Geodesy, Shumen University.

MSc - National Military University, specialty of Geodesy, Photogrammetry and Cartography in 2002.

PhD - Shumen University, in the field of Cartography in 2017.

Research interests in the field of cartography and geodesy.

Krassimir Vedev is a PhD student in cartography (including thematic geographic mapping) at the Southwest University "Neofit Rilski", Blagoevgrad.

He has Bachelor's Degree in Geography and Master's degree in Regional Development. His research interests are the cartographic symbols in GIS medium.

Penka Kastreva graduated the University of Geodesy, Photogrammetry and Cartography – Sofia in 1982 (now University of Architecture, Civil Engineering and Geodesy). Since 1984 she practices as an engineer of Geodesy. She worked for the government office of cadastre. Since 1995 she works for the South - West University in Blagoevgrad as an assistant of cartography and GIS. Becomes a Doctor of Geodesy in 2001 with dissertation “Improving of existing geodetic nets”. Since 2005 she is a Associate Professor at South - West University. Her interests are in the fields of GIS and theoretical and thematical cartography.