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MODERN TECHNOLOGIES IN THE STUDY, PRESERVATION AND MANAGEMENT OF CULTURAL HERITAGE

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Abstract: *The new technologies, which will be briefly described below, provide opportunities for documenting cultural and historical structures as a whole and individual details with absolute accuracy and credibility, completely eliminating the subjective factor, speed, representativeness, usability in design.*

Key words: *cultural heritage, treasure-hunting, cultural policy, exploitation*

INTRODUCTION

The issue of conservation and preservation of cultural and historical heritage(CHH) is very important, topical and is largely part of our national security. Discussions on the problems related to the preservation of cultural heritage in Bulgaria have been held for years. This unequivocally speaks of the huge gap in the information and legal space regarding the cultural values of Bulgaria.

There are a number of examples of illegal export of cultural property that prove the real dangers to the preservation of our cultural heritage. They are a signal of the lack of an adequate legal framework and that the current system for the protection of cultural heritage is almost ineffective. This is the main reason for the accumulated problems during the years of transition in this area. On the other hand, the intensity and scale of criminal actions against cultural and historical heritage have led to an increase in the need to update the measures for its conservation and its protection.

For much of society, the term "cultural and historical heritage" is associated with obligations, prohibitions and many responsibilities. The existing practices for preservation and management of cultural heritage are not adequate to the modern conditions in Bulgaria. The purpose of the regulatory system is to protect the cultural values of the country and to guarantee the rights of the individual related to them. They are the right to cultural identity, the right to equality, the right to contact with cultural and historical values, the right to knowledge about history and culture, the right to information about cultural and historical heritage, the right to a quality living environment. All of the above human rights must be sufficiently balanced and in line with the cultural and historical heritage of the Republic of Bulgaria, which we are obliged to preserve for the generations after us, because it is a major factor for preserving the identity of the nation. Bulgarian cultural heritage is also part of World and European culture.

It is known that the preservation of cultural monuments is a topic related to the preservation of the national identity of Bulgarians. Bulgaria, as a member of the European Union, is also part of the global cultural market and has an invaluable contribution to European and World culture. This status gives us the advantage of promoting our history and culture over the World, but it also carries many risks. Therefore, cultural tourism is just as useful for the promotion of cultural heritage, as it is a matter of profit, which is justified by the economic development of the regions and often violates urban rules to the detriment of the preservation of cultural monuments

THEORETICAL STAGING

1. Geographic Information Systems.

Geographic Information Systems (GIS) are modern digital technologies for collection, processing, mapping and analysis of spatial geographic information [1]. GIS consists of the following main components, which include: the physical system through which GIS is implemented – hardware, software and computer network, the geographic database, the people who use and maintain it and the presence of geographical processes and phenomena.

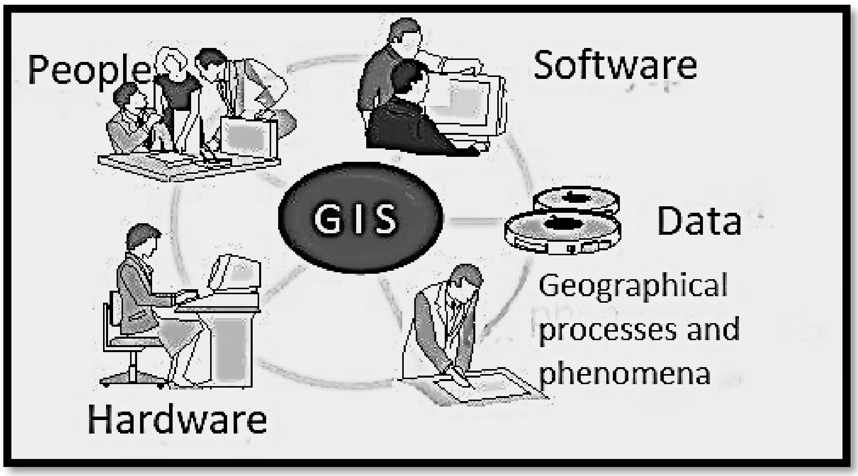

Fig.1. Main components of GIS

GIS is a set of interconnected known technologies. They allow the integration of data and methods that support traditional ways of geographical analysis, but at the same time use new forms of analysis and modeling, impossible without a computer. Prior to the advent of GIS, a fully-fledged analysis of geographic information was very rarely achieved in order to effectively make optimal decisions. Currently, GIS is an industry involving hundreds of thousands of people from all over the world.

A modern GIS is structured on a modular principle, where the user interface provides the user with the ability to access different parts of the software: data management, spatial modeling and data analysis, as well as map print management [9].

An important step (despite its obviousness) for building a GIS for the management of cultural heritage (resp. tourist sites) is the collection of cartographic (vector and raster) data. Choosing the right scale of the basic map and the optimal accuracy of all data is fundamental.

For each type of data (for example, roads, buildings, relief), a separate thematic layer is created. Each spatial characteristic can be associated with additional information (for example, the opening hours of a museum, photos, films). All data are stored in the database and can be managed by the user.

Besides spatial data, an important part of GIS is their analytical capabilities related to spatial analysis functions. Spatial analysis tools define the trends of the data, as well as the relationships between them, stored in the spatial database, using attributes (spatial and non-spatial) to answer the user's question.

Much of the information related to cultural and historical heritage sites is available to users via the World Wide Web. One of the advantages of GIS (and WebGIS) is the centralization of all interesting data from different sources, in a single environment and visualization of cartographic data. Maps are the most natural way to present data and the easiest way to present tourist information.

Tourism-related cultural heritage maps and information are an excellent contribution to raising visitor awareness.

2. Global navigation satellite systems.

With the astonishingly rapid advances in information technology, GNSS (Global Navigation Satellite System) can be assumed to be the most common and only method of collecting cartographic information in the near future. Of the global location systems, the most popular system is GPS. The system can quickly and accurately determine the spatial position (latitude, longitude and altitude or spatial Cartesian coordinates) of points on or above the Earth's surface. The accuracy that is achieved is centimeter for geodetic applications, if two receivers are used simultaneously.

Fig.2. GPS receiver

In recent years, the method – real-time measurement RTK (Real Time Kinematic) is increasingly used in the field of geodesy and cartography. The essence of the kinematic method of measurement also consists in the use of two receivers (reference and mobile) that have a connection for transmitting and receiving data with each other. The realtime method is highly dependent on the way of transmitting data from the base station. The connection is made by radio-modem or GSM-modem, the data transmitted from the reference to the mobile receiver are most often ambiguous and differential corrections in the coordinates.

Practically, this method is optimal only when using two-frequency apparatus and is subject to the following requirement. The two receivers must be at a distance of not more than 10 km from each other, the reference being located at a point of known coordinates called the reference station. It can then be considered with sufficient confidence that the atmospheric disturbances for the two receivers are approximately the same (especially with a small difference in altitudes). Thus, on the basis of the coordinates known and determined during observation, the reference receiver calculates differential corrections to the coordinates and transmits them to the movable.

In the classic variant – with one base station, the RTK application is possible within a radius of up to 10 km around it. If a virtual base station (VBS) is created, this range can be expanded 3-4 times. In the latter case, it is necessary to operate a reference network of at least 3-4 stations at a distance of 50-70 km between them, and it is best to create such a network with a national scope.

The accuracy of determining the position of a point by this method is of the order of 2-3 cm in position and 5-10 cm in height.

Real-time operation has the following advantages:

- The results of the measurements and their processing are obtained on site, which almost excludes the possibility of allowing for poor quality results;

• A large part of the time is saved for the post-processing of the results if the points are not part of a geodetic network.

In RTK mode, it is possible to massively coordinate shooting and other detailed points, capture linear and area objects, update spatial and attribute data, trace points, straight lines and curves, and perform many other routine geodetic tasks.

One of the main advantages of measurements in RTK mode is the ability to accumulate a large amount of data in a relatively short period of time, which allows the direct determination of the coordinates of the points in the planning and altitude positions without additional processing and to solve applied geodetic problems of different nature.

Depending on the specifics of the problems solved, with the help of GPS a number of types of measurements can be carried out, and their mathematical processing can be carried out in a variety of ways. As is known from the theory of geodesy, the measurements of geodetic networks are necessarily subject to an equalization process to determine the coordinates. This means that the processing of the results of RTK measurements is mandatory.

In geodetic surveying, tracing of objects and other types of geodetic activities, the accuracy requirements as well as the technical indicators of the respective equipment must be taken into account. In these activities, two-frequency equipment (receiver) should be used, in which the volume of information collected is significantly large, which creates more opportunities to obtain better results in processing, to control measurements and to determine and eliminate atmospheric interference.

Where it is necessary to use more receivers, it is mandatory that the apparatus be of the same type (production of the same company) in order to be able to process the data together without using the RINEX format.

When making a measurement, it is necessary that the receiver is able to receive signals from all visible (above the horizon) satellites. To fulfill this requirement, single-system receivers (working on one of the two navigation systems – GPS, GLONASS) must have not less than 12 channels, and two-system receivers - not less than 20. It is recommended to use two-system receivers due to the fact that they collect a larger amount of observations, which are usually with better accuracy, and the geometric configuration of the satellite constellation is significantly improved.

The antennas of the receivers used for precise measurements need to have a filter to eliminate multidensity and interference of signals. The internal memory of the controller must be able to store the data from continuous observations with a small recording interval. The power supply of the receivers must be capable of operating continuously for a long time. This is extremely important for stations that are used as reference (stationary). When operating in RTK mode, the receivers must be equipped with the appropriate radio modems for data transmission.

When purchasing a new GNSS system, it is necessary to check all technical parameters against prospectus data. In case the receivers are not new, they must be calibrated and tested before starting work.

Directly obtained coordinates from RTK measurements can be used for small-scale and thematic mapping, where the accuracy is sufficient without post-processing of the results. This is the case of using RTK measurements to coordinate a network of control points for geodetic attachment of photogrammetric images of archaeological and architectural monuments of culture.

High-precision capture of detailed points of areas with a concentration of CHH can also be done using GPS technology for real-time operation. The detailed GPS image serves to create databases structured in a GIS environment.

3. Remote sensing methods.

The remote sensing methods (RSM) dates back to Napoleon's time, when the French used balloons to reconnaissance the enemy's position before battle. Today, RSM are differentiated as an independent scientific direction based on the collection of information about the Earth's surface at a distance from it, as well as data on the atmosphere and oceans. The data acquisition process involves scanning and recording information about the energy reflected or emitted by objects for post-processing, analysis and practical use. As a rule, remote sensing methods use satellites equipped with airborne sensors to detect and classify objects on Earth.

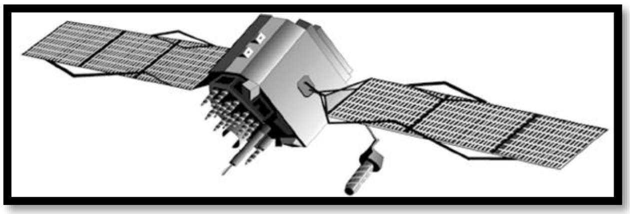

Fig.3. Satellite

One of the features of RSM is the influence of the environment (the atmosphere through which the signal from the satellite passes). For example, in the presence of cloudiness, objects are obscured, become invisible in the optical range. But even in the absence of cloudiness, the atmosphere weakens the radiation from objects.

RSMs are divided into active and passive. When using active methods, the satellite sends to Earth a signal from its own power source (laser, radar transmitter), its reflection is registered. Passive methods detect reflection from the surface of objects due to solar energy or thermal radiation on Earth.

When remote sensors record electromagnetic radiation (Electromagnetic Radiation – EMR) from the source (the investigated object), they actually create a high-speed communication link between the sensor and the object. The information that can be obtained in the electromagnetic reflection from objects, both inside and outside the visible spectrum, provides invaluable knowledge about them.

When the information is combined with active technologies for remote monitoring, such as the systems for: global positioning (Global Positioning System – GPS); light detection and measurement (Light Detection and Ranging – LIDAR), and radio detection and measurement (Radio Detection and Ranging – RADAR), then the absolute position (x, y) and height (h) of the object can be determined with high precision and accuracy. Much of the high-resolution imagery and location data, once only available to the defense community, is now available in the open market for a host of public and private, consumer and professional applications.

The following lines give a brief overview of Earth observation from the point of view of evolution for data collection, processing and dissemination.

Since its inception in the 1960s, remote sensing of Earth by satellites has been a major U.S. government operation primarily with military and meteorological goals and tasks related to the end of the Cold War [10]. The significant costs associated with the design and construction of satellites and rocket launchers are the main reasons why remote sensing has been and continues to be programs implemented at the government level. Although most of the technology was developed for military purposes, there have been and continue to be civilian applications, such as remote detection of "biophysical" variables. Vegetation, water, soils and rocks, atmosphere and urban structure are examples of some biophysical variables measurable from space.

The United States' oldest civil satellite for remote sensing is the first optical satellite LAND – satellite (Landsat 1,) which was launched in the early 1970s, and the last, Landsat 7, was launched just a millennium ago in 1999. Landsat 7 (Enhanced Thematic Mapper) is a sensor whose spectral sensitivity range and large swath (strip between two sections) makes it particularly suitable for biophysical and environmental applications. Therefore, Landsat images continue to be the most preferred source data for many scientific applications, such as wetland analysis, vegetation health determination, etc.

The former Soviet Union also has a long history of satellite observation dating back to the mid-1960s, and thirty years later, Russia was the first country to provide high-resolution images intended for businesses with an open international market.

The remote sensing programme of France's National Centre for Spatial Learning (France's Centre National d'Etudes Spatiales – FCNES) also dates back to the early 1970s, when France launched its first satellite Satellite Pour l'Observation de la Terre or SPOT-1. It should be noted that in 1986 SPOT used a high resolution sensor (High Resolution Visible – HRV) and a charge-coupled device (CCD). The program successfully represents the government and private sector.

The initial experience in remote sensing of Japan has been of a very similar approach as the US Landsat programme. This country's system is designed primarily to meet the need for research and civil applications. Japan launched its first Marine Observation Satellite (MOS) in 1987 and has since used its Advance Land Observing Satellites (ALOS) and Information Gathering Satellites (IGS) satellites for multiple purposes.

India launched its first satellite Remote Sensing Satellite (IRS) in 1988 and Canada launched RADARSAT-1 in 1995.

All of the above countries (USA, Russia, France, Japan, India and Canada) represent the first remote programs that have established themselves as fully developed programs.

Despite efforts of commercialisation that began in the early 1980s, ongoing and planned satellite programmes continue to be funded directly or indirectly by individual governments or government-consortia [10]. For example, the European Space Agency (ESA) and the Disaster Management Constellation (DMC) programme.

The effective operation of GIS can hardly be imagined without satellite methods for research of territories, i.e. remote methods. Therefore, a skill is needed to extract useful information from the satellite image. The objectives of the DM, as it became clear, can be objects visible in the photo with the following characteristics [2]:

- Objects can be represented by points, lines or polygons, as they are structured in GIS;
- Objects must be different from each other. This means that the image should be contrasting.

As is known, remote sensing images can also be represented by a computer as arrays of pixels, with each pixel corresponding to a number representing the brightness level of that pixel in the image. In this case, the data is in digital (digital) format.

When remote sensing data are available in digital format, digital processing and analysis can be performed using a computer. Digital processing and analysis can also be performed by fully automatically identifying objects and retrieving information about them without manual intervention by a person. Rarely, however, is a complete replacement of man possible when interpreting information.

Mapping applications derived from remote sensing include the following:

- Planimetric information;
- Digital Relief Models (DEM's);
- Thematic and topographic mapping.

Planimetry consists in identifying and determining the location of geographical objects of land cover (e.g. forest, lake, etc.), other natural units (e.g., catchment areas) anthropogenic features (e.g., urban infrastructure, transport networks) in the x, y plane. Planimetric information is usually required for wholesale large-scale applications – urban planning, facility management, military intelligence, and general landscape information.

Digital Elevation Models or DEM provide information on elevations and allow the generation of horizontals and other terrain patterns (of slope gradients, shadow relief, surface water runoff model, etc.), thus providing another source of information for terrain analysis. Image-integrated relief data is also used to create perspective views useful for tourism, route planning, delineation of major transport routes, etc.

The generation of DEM from data obtained from remote sensing measurements can be cost-effective. Various sensors and methods are used to generate such models for cartographic applications. There are two main methods used to model altitude data: 1). Stereophotogrammetric method using aerial photographs (photogrammetry), or 2) Radar interferometry for radar-derived data (radarrometry).

The preservation and recreation of important historical and architectural monuments has become a serious challenge for specialists who use but also constantly expand the techniques and capabilities of photogrammetry and laser scanning to achieve this goal. And it is related to the virtual presentation of buildings, churches, museums and even entire cities, but also acquires irreplaceable value in photographing and documenting them. Recently, there has been a dynamic increase in the practical use of creating accurate virtual three-dimensional models applicable in various fields – in navigation systems, urban planning, architecture, disaster simulation, and even in the field of video games and animation. Naturally, the above applied practices are only part of the long list of possible applications of three-dimensional modeling.

4. Aerial photogrammetry.

Aerial photogrammetry was the first remote sensing method to emerge. In photogrammetric methods, aerial airplane photographs are taken of the territory, after the processing of which orthophotoimages are obtained (Fig.4.). With the addition of cartographic signs, they become the basis for making orthophoto maps [10].

Fig.4. Part of an orthophoto image

To study large areas, it is more appropriate to use other methods, most of which are based on satellites thousands of kilometers away from the Earth's surface, such as SPOT or radar images.

Photogrammetric photographs are the main data source to produce a digital elevation model (DEM) needed to obtain the horizontals for the national topographic maps. Stereophotogrammetry involves the extraction of heights information when overlapping stereo images, usually aerial photographs. Additional satellite sources such as SPOT are also used for other DEM applications.

In recent decades, unmanned aerial vehicles (UAVs) have successfully developed and used, or as more are known "drones". UAVs have numerous applications, both for military purposes and in the civilian sphere.

Specialized flying platforms for professional aerial photography have a built-in GNSS receiver, professional cameras or camcorders, trajectory planning and control software, and 3D processing software. Systems of this class have a high load capacity, with the possibility of long flight and capture images in high resolution. These images can be transformed into orthomosaics and 3D models with absolute accuracy.

The fields of application of digital photogrammetry are constantly expanding. Photogrammetric studies of historical monuments can be grouped into two categories:

• Research on historical monuments for the restoration and improvements of cultural sites (terrestrial photogrammetry);

• Research for detailed documentation of cultural heritage (aerial photogrammetry).

Accurate research is used to document the technical history of construction, to analyze structural lines, to document the current state and the need for restoration and conservation. For example, in some countries, precise photogrammetric studies have been made of ancient bridges and viaducts of artistic value [6].

5. Laser scanning.

The laser scanner is designed to capture three-dimensional or 3D data. It can be used to scan features of both the terrain surface and voluminous objects and buildings [6]. In practice, two types of laser scanning are used – terrestrial and airborne (Fig.5.).

Laser scanning is applied in various fields of science and practice – geodesy, photogrammetry and remote sensing methods, geography, geology, geomorphology, archaeology. For this purpose, modern laser instruments, called lidars (LiDAR – Light Detection and Ranging), have been developed that collect spatial data about the surrounding environment. In a short time, a laser scanner can capture a large amount of information, making it more efficient than conventional scanners.

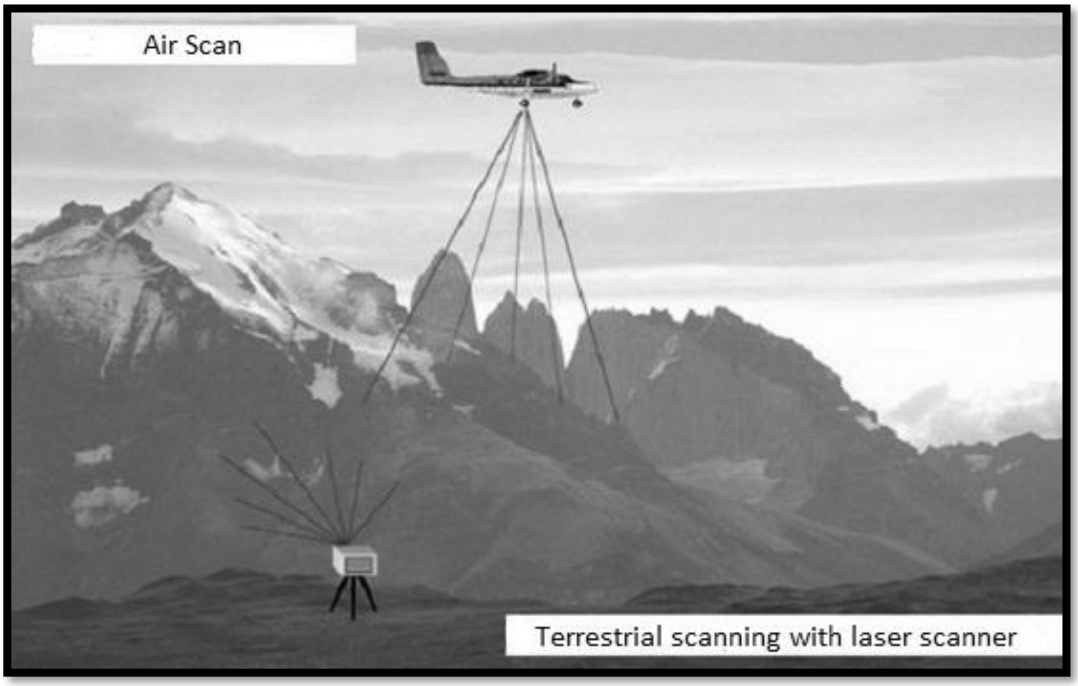

Fig.5. Earth and air laser scanner

The accuracy of the digital models resulting from the application of laser scanning technology is limited only by the instrumental accuracy of the particular equipment [7]. For the efficiency of the technology, the choice of certain parameters is important, for example, distance to the site, number of stations, interval between scans, resolution, etc.

In connection with the topic of the dissertation, we will focus on the extremely successful use of LiDAR technology for ground scanning in architecture, photogrammetry and archaeology to create digital 3D models of buildings and other cultural monuments subject to reconstruction. In this technology, the laser scanner creates the so-called. a cloud of points, each of which contains geometric information about the object, on the basis of which its shape is determined by extrapolation. Ground scanning can complement aerial laser scanning, creating a three-dimensional model of the urban environment [3].

The resulting 3D model is subsequently the basis for obtaining all the necessary documents for the site in an appropriate form and scale and depending on the required accuracy and detail. When preparing the specialized documentation for the site, the created 3D model can be used for:

- Retrieval of data for the needs of restoration and conservation of the site;
- Obtaining cuts, facade plans, architectural distribution;
- Supplementation with cadastral data, data from previous different types of surveys; future projects;
- Extraction of silhouette plans;
- Assessment of urban planning norms and parameters, etc.

When restoring the authentic appearance of cultural and historical heritage sites, it is often necessary to use data on them from previous periods (photogrammetric models, photo photos, architectural plans). They can easily be complemented in the model if selected common situation points of the 3D model of the site are used [7]. Thus, it is easy to assess the impact of newly designed construction and its combination with old architectural spaces.

6. Comparison of methods.

From what has been described so far, it is understood that each of these technologies is important to get to the end result – documenting CHH through a created database and its presentation to the public. Here we shall rather make a comparison of the methods which provide data on CHH for their introduction into GIS. Therefore, we will make a comparison only of them. In principle, all of these technologies have their rightful place in exploring our digital world.

A common basis for comparison on the accuracy and volume of captured areas with CHH can be searched among all technologies that provide images in digital form:

- Remote Sensing Methods and Photogrammetry.

These technologies serve not only surveyors, but also archaeologists, both for photographing the visible parts of archaeological excavations and ruins, as well as for the discovery of cultural monuments that are known only to historians from written sources. Suitable examples of the application of these technologies are the activities carried out to find the lost castles of Denmark. A team of surveyors and archaeologists discovered and again depicted on the map of the country these amazing monuments of culture. Specialists have mapped the terrain from thousands of photos taken and built 3D models. Today, scientists, combining remote sensing methods with archaeology, can do research from the smallest thing to the largest – by changing scale. After hard work, four castles have already been identified and opened.

- Laser scanning method and photogrammetry capabilities.

The comparison between the photogrammetric method and the laser scanning method is based on the number of stereopairs needed to cover the area of the facades of individual objects (buildings) and the area of the 3D-point model directly obtained as a result of the scan. With the help of both methods, high accuracy is achieved. They differ in the stationery processing of results.

Both methods have real results for their applicability. The laser scanning method was used to assess the erosion processes of the Madara Horseman rock relief, which show that the accuracy of the technology meets the requirements for archaeological research and analysis [7].

The advantages, disadvantages, the technical and software equipment used for three-dimensional modeling using the above technologies, incl. and by using available architectural drawings of individual cultural monuments (for example, buildings, churches, etc.) are described in detail by [5].

The described technologies for three-dimensional visualization and modeling are of great importance. The application of technology, despite the indisputable quality of the final products, is still expensive for mass use, especially for our country.

7. Photogrammetric processing.

The process involves processing the captured images to obtain a raster image in which all distortions and errors caused by the lens distortions, the rotation and tilt of the camera at the moments of exposure, the differences in the scale of the individual photos, the influence of the relief and others are eliminated. This raster image is called orthorectified. It features the pixels from the original photos, but have been rearranged, so that each of them corresponds to a place "seen" right from above. In practice, an orthorectified image is a digital map in orthogonal projection. Therefore, direct and accurate measurements can be made on it at the scale of the image. Any quantitative (metric) and qualitative (semantic) information can be extracted from the created orthophoto plan.

The steps described below for performing the photogrammetric processing of the digital aerial photographs were carried out with a specialized software system AgisoftPhotoScan Professional (Agisoft, 2016a). They are the following:

7.1. Loading the photos – determine the aerial photos that will participate in the processing. Each of the selected photos is displayed with its status, which can be:

- NC (Not Calibrated) – no internal orientation data was found for the photo. In this case, it is necessary to calibrate the camera and manually enter the parameters for focal length, distortions, etc. The geographic coordinates of the camera at the time of exposure are added to the information for each photo;
- NA (Not Aligned) – the external orientation parameters have not yet been defined for the corresponding photo.

7.2. Alignment of photogrammetric images – two types of points are used for this purpose:

- Tie Points – these are clearly distinguishable points in the area of double and triple overlap between the photos. They serve to connect photos to each other, as well as to unify their scales when they differ [8];
- GCP (Ground Control Points) – these are marked points with known coordinates, determined by direct geodetic measurements or photogrammetric methods [8]. They serve to attach the spatial model to a particular coordinate system and its georeferencing.

Once the photogrammetric images have aligned, the elements of external orientation are fully defined for each photograph individually. Thus, the position of the photos coincides with the position of the cameras during the exhibitions [8]. As a result, a sparse cloud (SPARSE CLOUD) is generated from connecting points selected in the overlap zones.

7.3.Generation of dense cloud (DENSE CLOUD) from points.

Based on the camera positions defined above, the software calculates a depth map with spatial information about the points, with the help of which the diluted cloud of points is drastically compressed. From several thousand points, their number increases to several tens of millions. This builds a detailed spatial model of the photographed area or object. It is important to know that a significant share of the calculations at this stage fall on the graphics video accelerator. To increase productivity in calculations, the use of powerful graphics boards is necessary.

If the texture of some elements is poorly expressed or the images are not focused, it is possible that for certain places the software will be wrong and some of the points may be incorrectly positioned in space. In these cases, different methods are provided for filtering the points from the dense cloud. The greatest degree of screening is achieved by selecting the AGGRESSIVE variant from the software used.

7.4. Construction of a three-dimensional polygon model – TIN (Triangulated Irregular Network) or Mesh.

It is a vector reconstruction of objects and relief through a network of connected and non-overlapping triangles, the vertices of which are the points of the dense cloud. Its density depends on the nature of the relief and the shapes of the objects, and also on the amount of details falling into a unit of space. The grid is made up of triangles, as only the triangle closest to the surfaces. The reason is that its tips are at a minimum distance from the surface it touches.

Before starting the stage for the construction of the polygon model, the following parameters for surface reconstruction must be adjusted:

• Type of surface to be modelled (Surfacetype). Two options are possible:

– Random type (Arbitrary) – recommended for reconstruction of buildings, monuments and sites of random shape;

– Height field – suitable for modeling of flat surfaces, bas-reliefs, etc.

• Source data – determine the source to be used in constructing the TIN model. Possible sources are:

– sparse point cloud (SPARSE CLOUD);

– dense cloud of points (DENSE CLOUD).

It is advisable to use the dense cloud of points.

• Number of polygons (Polygoncount) – the maximum number of triangles involved in the TIN-model is specified. In case the dense cloud of points is chosen with the Source data parameter, then millions of triangles with vertices of these points will be generated. The model thus obtained will be very heavy to open and use, even for computers with great computing power. Therefore, it is good to reduce the number of participating polygons. The reduction process is called the Decimate Mesh and is conclusive in the construction of the spatial model.

• Creation of the textures covering the spatial pattern. Select the mode for superimposing textures, or how textures will be stored in the texture atlas. The right choice will lead to optimal storage of texture data and improve the quality of visualization of the final product. The following modes are possible:

– generic mapping mode – in this case, the software does not make any assumptions about the type of scene being processed and strives to create continuous texture coverage as much as possible;

– adaptive orthophoto mapping mode – the texture coating is subdivided into planar part and vertical regions. The planar part is textured using orthoprojection, and the vertical areas are textured separately for more accurate recreation of the texture in them. The mode is suitable for obtaining good quality textures on vertical surfaces, such as building walls, statues, etc., as well as compact texture sizes in flat areas;

– orthophoto mapping mode – the entire surface of the spatial 3D model is textured by orthoprojection. This mode allows to obtain the most compact storage of texture data in the atlas compared to all other modes, but at the expense of a strong decrease in the quality of textures in vertical areas.

• Construction of a hierarchical block model (Tiled model) with textures. The format allows to visualize 3D-models of a large number of high-resolution objects according to the scale of display. The model is built on the basis of the dense cloud of points, and the textures for the hierarchical blocks are created from the source photographs.

It is necessary to set the following parameters:

– pixel size (m]) – the dimension can be set manually (in meters) by the user, but the software makes its own judgment and value proposition, referring to the effective resolution of the photos used;

– block size – set in number of pixels. For smaller blocks, faster visualization is expected.

• Generation of Digital Elevation Model (DEM). The model represents the surface as a regular grid of altitude values. Physically, it is a two-dimensional raster image presented in GrayScale mode (16 bits or 32 bits), in which the height of each pixel is set with its "color" – grayscale. A value of 0% (black) corresponds to sea level (0 m) and a value of 100% (white) corresponds to the highest point on the planet (8848 m). The Digital Elevation Model (DEM) is also called the elevation map. Its creation is possible only for models that are geodetically tethered (georeferenced). Therefore, the first necessary setting is the indication of the coordinate system in which the model is. For the very construction of the DEM, the sparse cloud (SPARSE CLOUD), the dense cloud (DENSE CLOUD) or the polygon model (Mesh) can be used as a source. The most accurate results are obtained when the altitude model is generated based on DENSE CLOUD POINTS.

• Creation of an orthophotoplane (Orthomosaic). It is created on the basis of the data from the source photos and the reconstructed model. It is a raster image with high resolution and detail. In it, the points of the source images are rearranged so that they represent the captured surface in a planar projection. In the orthophotoplane are eliminated all the errors with which the initial photos were loaded at the very time of shooting [8].

To make the orthorectification, it is necessary to choose values of the following parameters:

• Surface – indicates on the basis of which surface the orthomosaic will be built. There are two possibilities:

– DEM – it is effective in processing planned aerial photographs;

– mesh – suitable for reconstruction of facades of buildings and other complex objects that may not be attached to a specific coordinate system.

• Blending Mode – it is determined by what sign to select the pixels in the places where the photos are joined;

• Mosaic – in this mixing mode, the data from different photos are divided into several categories, which are mixed independently. The components with the highest frequency are mixed exactly along the joining line. With increasing distance from the boundary line the number of components being mixed decreases;

• Average – for each individual image, the values of the respective pixels are taken and averaged;

• Disable – the color value of each pixel is taken from that picture for which the reconstructed surface at the corresponding point is parallel or almost parallel to the plane of the photo;

• Enable Color Correction – applied only in cases where the source images have luminous variations within extremely wide limits. In these cases, it is necessary to unify the brightness characteristics of the participating photos. Processing takes a considerable amount of time and therefore applies only exceptionally.

Some of the typical outputs that can be generated after completion of photogrammetric processing are:

• Export the digital elevation model – DEM (Digital Elevation Model);

• Export the orthomosaic;

• Export the spatial model – TIN (Triangulated Irregular Network). Before writing the output, one can limit the number of triangles (Decimate Mesh);

• Export the dense cloud of points (Dense Clouds);

• Export the hierarchical block model (Tiled Model);

• Export textures (Textures);

• Export the cameras (Cameras) with their parameters and positions;

• Export of markers – these are the GCP (Ground Control Points) points known on the photos with their geographical and image coordinates;

• Exporting shapes (Shapes);

- Export the horizontal (Contours) which are generated with a step specified by the user.

The results broadcast as files can be used in various programming systems to solve a wide range of tasks such as:

- linear and area measurements directly on the orthomosaic;
- making cuts and cross-sections to analyze the shapes of objects and relief;
- mapping and creation of various digital products;
- classification and segmentation of objects in a captured area by various features;
- production of thematic maps, cartographic materials and applications;
- creation of an advertising and tourist product.

8. Requirements for software and technical equipment for digital image processing.

With the advent of digital images and their establishment as a standard for quality and storage of information, a completely new direction has developed - digital stereophotogrammetry. The methods used in this direction serve to determine the shape, location in space, quantitative and qualitative characteristics of objects only on their digital images. Both classical stereophotogrammetry and digital are based on stereopairs, but in digital the storage format is digital. This radically changed the concept of the technical means of photographing, storing and processing digital information. Filming can be done with compact digital cameras carried by drones. The processing of the digital information obtained does not require specialized photo laboratories and facilities. We only need to have a suitable computer configuration that meets certain technical and software requirements.

8.1. Software requirements.

For the processing of digital images and the creation of 3D-models, specialized photogrammetric software systems are used, capable of covering all possible activities – processing, evaluations, analyzes and applications. Such systems are: Erdas and Pix4D. Due to the high cost of these products, they are mostly used by larger companies or government organizations. There are also cheaper software systems that only do photogrammetric processing. One such system is AgisoftPhotoScanProfessional. This product enables us to generate various output data in formats allowing analyzes and applications to be made in other programming environments – ArcGIS, Global Mapper, AutoCAD, etc.

8.2. Technical equipment requirements.

The requirements for the computer configuration are directly related to the software used for 3D processing of captured images.

• AgisoftPhotoScan:

– Processor (CPU) – Six-core Intel Core i7 CPU, Socket LGA 2011-v3 or 2011 (Haswell-E, Ivy Bridge-E or Sandy Bridge-E);

– Motherboard – each LGA 2011-v3 or 2011 model with 8 DDR4 or DDR3 slots and at least 1 PCI Express x16 slot;

– RAM – DDR4-2133 or DDR3-1600, 8 x 4 GB (32 GB total) or 8 x 8 GB (64 GB total);

– Video card (GPU) – Nvidia GeForce GTX 780 Ti, GeForce GTX 980 or GeForce GTX TITAN X (Agisoft, 2016 b).

• Pix4DmapperPro:

– Processor (CPU) – Intel i7 5960X (8 cores, 16 threads);

– Random access memory (RAM) – DDR4-2400 64 GB;

– Hard Disk – SSD: Crucial MX100 512 GB;

– Video card (GPU) – GTX 980, TITAN BLACK (Pix4D, 2016).

The aerial drone with which the shooting will be carried out is also part of the technical equipment. It must be autonomous as long as it is programmed to perform tasks independently, but it can also be remotely controlled. It is necessary to have the following systems:

• Lifting system – provides the necessary lift and thrust;

• Energy system – includes rechargeable batteries that must provide flight time for at least 20 minutes. It follows that the battery power must be above 5000 mAh;

• Control system – the drone must allow remote and program control. The remote control must be at least 500 m in radius;

• Navigation system – the drone must have a GPS compatible with specialized software products for flight planning and control;

• Protective system – provides numerous protective functions such as:

– automatic return to the take-off point in case of loss of coverage with the remote control or in case of low battery;

– sensors for collision protection with obstacles;

– alarms (audible and visual) in the event of various events.

• Shooting system – stand (the so-called cradle), camera and memory for data storage. An important requirement for the stand is to have gyroscopic stabilization along the three axes. The camera must meet the following requirements:

– to have as large as possible RGB – sensor (matrix), which is related to the noise and dynamics of the captured images;

– be equipped with professional optics that eliminate optical distortions;

– to use a high resolution sensor (18-20 Mp), which is relevant to spatial resolution and detail in the image;

– to support different file formats;

– to record to the EXIF of each photo the GPS-coordinates of the points where the exposures were made.

With the described methodology, problems from different areas of life and science can be solved. In geodesy it is applicable to mapping, land division and cadastre. In architecture, for the preservation in digital form of priceless architectural monuments that are crumbling or threatened with collapse. In case they ever break down, they can again be accurately restored according to the digital model.

CONCLUSION

A brief reference is made to the concepts related to cultural heritage, legislation and new technologies for mapping, preservation and monitoring of cultural heritage sites in Bulgaria. It is obvious that urgent measures are needed to bring order to the management of compact territories with a concentration of CHH. The new legal framework created so far requires the introduction of European and world practices and standards. In the author's opinion, it is necessary to raise the place and role of the state through its specialized institutions.

The subject of this paper was also to analyze the use of modern technologies for documenting territories occupied by CHH sites, which can be used to create a basis for the preparation of a project for their management.

The results of the literature review give us the opportunity to draw conclusions related to the cultural policy in our country and to make a comparison with the countries of Europe. Despite the relatively short review of what has been done in Bulgaria and around the world, it gives us the opportunity to understand that cultural heritage speaks of traditions, beliefs and achievements of a country and its population, as well as the history, art, spiritual beliefs and social values of a certain group of people. Cultural heritage tells us about the past and demonstrates the excellence of past generations. It represents our identity and helps us to appreciate the cultural diversity of humanity. And most of all, studying CHH helps us realize how important it is to protect it.

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