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Digitalization of Bulgarian Cultural Heritage

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Abstract. *The research of historical heritage is related to creation, storage and distribution of visual information about them. With the development of digital technologies, the three-dimensional scanning and visual regeneration of buildings of cultural heritage combined with 3D virtual reconstruction is becoming increasingly important tool for understanding and reconstructing the past. Instead of expensive laser scanning, cheaper photogrammetric methods for creating and processing of spatial (3D) images of historical and architectural monuments are finding a growing application. The article analyses the opportunities for use of different ICT tools, including inexpensive digital imaging options for preservation and exhibiting of large and diverse Bulgarian cultural heritage.*

Keywords: Historical Heritage, 3D Image, Digital Scan, Photogrammetry, ICT Tools, Virtual Reconstruction

JEL Codes: R1, R2

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1. Introduction

The research and promotion of the monuments of historical heritage is related to the creation, storage and distribution of visual information about them. In the past, from the antiquity to the last century, the possibilities of creating visual information were limited to two-dimensional images created on different materials and (more recently) video and images films.

With the development of digital technologies, the three-dimensional scanning and visual regeneration of buildings of the cultural heritage combined with 3D virtual reconstruction is becoming increasingly popular method - a major tool for understanding and reconstructing the past. A 3D scan is a digital representation of the object. During the 3D scanning process, the shape of an object is captured using a 3D scanning application. The sensors of the individual device (laser scanner, digital camera, tablet or a mobile phone) collect data related to the shape, the depth and the colour of the item that is 3D scanned and as a result, the final 3D file is formed. After the 3D scan is converted into a 3D file, the result can be edited with a 3D modelling application and eventually can be 3D printed.

The worldwide 3D scanning technology market is expected to increase more than twice over a five-year period, with key applications of these technologies being involved in preservation of cultural heritage. These data are reported in the latest report by the online company “Research and Markets”. The global 3D scanning market was valued at USD8427 million in 2017, and is projected to reach USD53345 million by 2025 (researchandmarkets.com).

As a part of South East Europe Bulgaria has an ancient history and culture. Being a crossroad of civilizations and religions throughout the centuries, the region has been acting as a natural link between the East and the West. This accounts for the wealth and diversity of its cultural heritage. The region boasts

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remarkable cultural treasures with unique identity, many of them listed as world heritage monuments. Its cultural integrity is unique, pointing back to common historical roots, intrinsic links and mutual influences. The cultural and historical heritage that has survived highlights distinct cultural corridors, dating back hundreds and thousands of years. These are the axes of age-old cultural and economic links in the region that have been preserved until this day. They include both the tangible and intangible cultural and historical heritage of the countries and peoples living in this part of Europe. Today, they are among the strongest bonds between nations as well as being the living memory of the local civilizations. The current status of the cultural heritage in Bulgaria and in the region is worrying because of its fragmentation within the closed national and local systems, rather than being seen in the existing trans-national cultural corridors. In most cases, this unique cultural heritage linked together in clearly visible cultural corridors is ambiguously known in Europe, in the world and even in the region itself. There has been a deficit of effective regional cooperation for a coordinated protection and use of the existing cultural resource.

Therefore, in the second half of last century concerted actions have been started in the region under the auspice of International Council on Monuments and Sites (ICOMOS) and with the support of various stakeholders. Bulgarian national committee of ICOMOS (icomos-bg.org) was founded in 1964 right after the establishment of ICOMOS. The aim of the Bulgarian National Committee of ICOMOS, in accordance with the Charter of the ICOMOS, was to assist in the investigation, preservation and enhancement of the values of the cultural heritage: monuments of culture, historical areas, towns, ensembles and sites, as well as in the use and promotion of the heritage. ICOMOS Bulgarian National Committee (BNC) should carry out a wide range of activities:

- Implements international programs and projects aimed at providing financial resources for cultural heritage conservation, management, and promotion; manages the funds allocated for the implementation of specific projects;
- Cooperates with central and local authorities, NGOs and the private business, exchanges experience and coordinates joint actions for heritage conservation and management.

Applying of ICT can be seen also as a key driver for starting of large-scale activities in preservation of Bulgarian immovable cultural heritage.

2. Use of ICT for 3D Imaging of Bulgarian Historical Heritage

The development of modern multimedia digital technologies and the global Internet network creates new opportunities for constructing visual images of objects also for Bulgarian cultural heritage. According to Kandulkova (2009), these technologies enable conditions for a new type of restoration activities - "Virtual Restoration" ("Information Technologies in the Study and Preservation of Architectural and Archaeological Monuments of Culture", Heritage: ESPRIT, under the general editing of Prof. Dr. Todor Krustev, Varna: LiterNet, 2009). Unlike conventional restoration, the virtual one allows for the construction and depiction of several versions for a single artefact, creation of hypothetical images of the objects surveyed, without jeopardizing their authenticity. Through the construction of three-dimensional models, the spatial characteristics of the monument are examined in different moments of its existence.

The creation of graphic reconstructions is an old approach that is used for studying of the monuments. It was applied well before the emergence of digital electronic technologies. The introduction of digital technology makes this approach significantly more effective. Digital three-dimensional models allow free choice for many different views, sections or projections of the object, which greatly expands the possibilities for variable and in-depth analysis (Figure 7). In addition to the study, documentation and analysis of architectural and archaeological valuables, digital technologies create new opportunities for their presentation and promotion.

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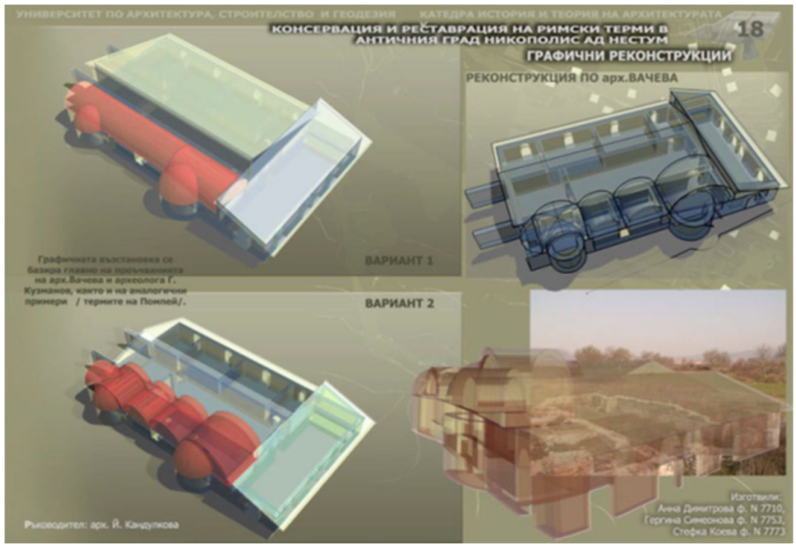

Fig. 1 Antique thermae in the late antique city of Nicopolis ad Nestum - optional graphic reconstructions; Course project on Restoration of architectural monuments of A. Dimitrova, G. Simeonova and St. Koeva, Under supervision of Assoc. Prof. J. Kandulkova, UACEG, 2007

The advantages digital technologies occur in several directions:

a. Improvement of image quality
b. Enhancement of the perception of objects by creating a three-dimensional digital image
c. Interactivity - possibility to create own "routes" of 3D image survey - the observer is an active participant and selects the ways of viewing
d. Opportunities for effective 'virtual restoration'.

3. Using photogrammetry for digital documentation of historical objects

One of the basic requirements for the restoration and reconstruction of buildings - architectural and historical monuments - is the restoration of the building with all its elements in their original shape (before the reconstruction). This requires a precise fixing of the dimensions and the spatial position of the building as well as all the facade elements - cornices, reliefs, friezes, pilasters, ornaments and others. Solving this problem by applying classical geodesic methods is too complicated and labour intensive, and in cases where the architectural layout of the building is richer - even impossible. For this reason, photogrammetric methods for creating spatial (3D) models for archiving historical and architectural monuments are finding a growing application.

Photogrammetry (from Greek: photo - light, gram - drawing, metreo - measurement) is a technology based on standard photography and projective geometry and was originally used to digitize large objects such as buildings, oil platforms and warehouses and is traditionally considered part of the geodesy belonging to the distance research direction. The principle on which photogrammetry is based is to capture a series of photo images of objects, and for subsequent processing, manual or automatic reference points for each photo are applied. Points can be added automatically or manually to create 3D measurements of the desired items from the given object. Photogrammetry is often used along with other 3D scanning technologies to provide complete surface measurements of parts of an object and to register small tolerances on large areas. Typical results are map, drawing or 3D model of a physical object or locality ("Applications of 3D Digitization", Practical Guide, Sofia, 2014).

3D scanning by photogrammetric methods is a modern, fast and accurate method for transforming the physical parameters of an object into an electronic format - a 3D digital model. Once the scanned data

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is already in the computer, all dimensions of the physical object, such as length, width, height, volume, object size, site location, surface area, etc., can be used. The development of modern digital imaging tools and, in particular, the modern possibilities for their processing and correction, create prerequisites for the application of digital photogrammetric technologies based on images obtained by ordinary digital cameras. Therefore, the financial benefits of using simple digital cameras for architectural scanning of buildings and cultural monuments are obvious. The greater is the advantage of photogrammetric methods for three-dimensional capture of architectural objects compared to laser scanning technology. This is mainly due to the huge difference in costs needed to implement the two alternative technologies. "... laser scanning takes too long and is still a very expensive technology compared to photogrammetric methods ..." ("Applications of 3D Digitization", Practical Guide, Sofia, 2014).

Many of the tasks in architectural photogrammetry are related to large amounts of information that need to be processed for a short time using modern and efficient technologies. Generally speaking, their essence is as follows: By inputting the information from the scanned images, stereoscopic observation is carried out by vectoring (three-dimensional digitization), the position of each point being determined on the display screen by the matching of similar points for each of the two images on which it is depicted. Graphics objects that are a product of such systems are typically designed for a pre-selected CAD system or for a suitable system for automated creation of plans and maps. The photogrammetric information is characterized by:

- greater completeness;
- diversity;
- structural definition.

The archiving of the monuments of architecture is usually done by photogrammetric surveying and using a precisely defined geodesic network. The digital photogrammetric cameras used provide high quality and credibility to the images. The variety of developed correlation imaging techniques and techniques allows for high quality outputs, and modern digital photogrammetry methods enable the input data to be instantiated relatively quickly and with high precision. With the use of modern digital cameras, the captured images are straightforward in digital form and avoid the technological process of scanning needed in analogue cameras. The accuracy of the geodesic support network can be achieved by precise measurements and using modern geodesic instruments. The digital three-dimensional model of the architectural object creates a significant increase in its efficiency. Besides the reliable transmission of the data on the site, an interconnection and an opportunity for their assessment are achieved, taking into account their specific features. The digital model allows not only the reliable storage of the data for an architectural object, but also the possibility to use it for the selection and assessment of new solutions related to its future development and preservation. (Pl. Maldjanski, "Development of Methods for Photographing and Processing of Data in Architectural Photogrammetry", Sofia, 2012)

By generating a three-dimensional model, a virtual description of the geometry and material construction of the surfaces of different objects is practically created. From it, it is possible subsequently generate different visual and spatial visualizations of 3D space. In this respect, two generic options for generating models can be distinguished:

3.1. Creation of "fast" 3D models

There are software products in which the model is generated based on several images from the object from different viewpoints. With their help, the program manually generates a generalized 3D pattern of the building or space. In the next phase, the specialized software takes the necessary snapshots of the photos and "dresses" the model. In this way, three-dimensional models of buildings with relatively

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simple shape, but with many details and decorations on the facade panels - mouldings, pilasters, complicated door and window openings, etc. are relatively quickly created.

3.2. Creation of detailed 3D models

This is the "classical" technology to build a complete three-dimensional model of the building or space. Besides being very labour-intensive, the process of building the model requires a considerable amount of data on the site - large and dimensioned plans, sections, views. The model can be created in various architectural design software such as ArchiCAD, ALLPLAN, Architectural Desktop, and REVIT Architecture etc. In order to obtain quality photorealistic end result, the model is further transferred and edited in one of the visualization programs - Cinema 4D, Artlantis, 3D Studio Max and others. (Fig. 2)

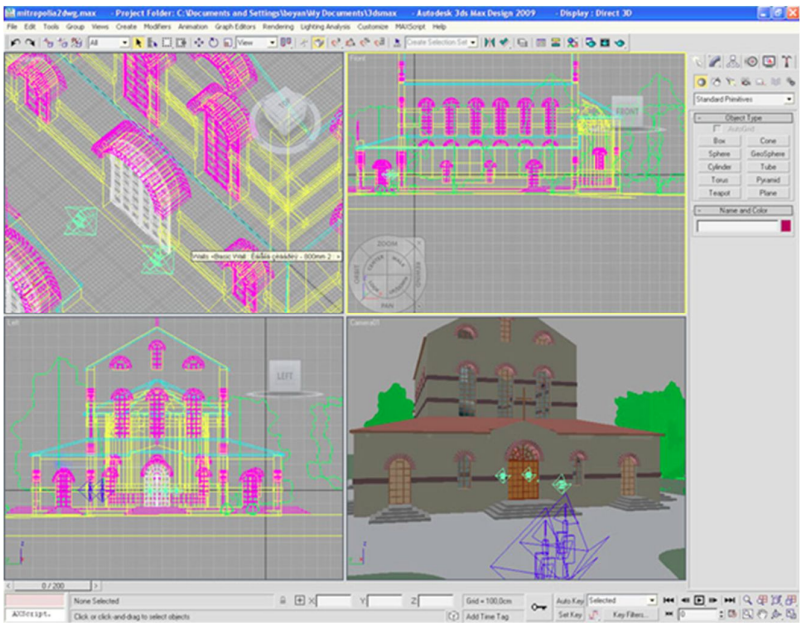

Fig. 2 Model Processing in 3D Studio Max, Source: Assoc. Prof. Dr. B. Georgiev

3.3. Photo cameras used in architectural photogrammetry

In modern architectural photogrammetry, digital images are most often used. They can be obtained directly via a digital sensor such as a CCD (Charge-Coupled Device) camera. They can also be captured with a traditional camera and subsequently scanned. For architectural purposes, the choice of cameras has long been limited to expensive and specialized metric cameras. Due to the limitations of the photogrammetric process, only metric cameras with elements of inner orientation were used in the past. Now varieties of digital capture systems are being developed and their price is constantly decreasing. The main advantage of these cameras is the ability to create digital images to be processed directly in the digital environment.

3.4. Image processing software

In order to process the images of the scanned object taken by digital cameras different image processing software is used.

Photomodeler (www.photomodeler.com) ia a widespread and relatively inexpensive tool for architectural and archaeological imagery. It works under Windows and allows measuring and transforming

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photos into 3D models, being one of image processing software that allows multiple snapshots of an object that reflect different aspects of it (different camera position etc.) to assemble a spatial model. This is an example of Professor Peter Waldhhausl of the Technical University in Vienna (Fig. 3). The basics of the capture, some of the source pictures and the model view, are seen. Photo Modeler software allows you to perform various operations on a created model (zoom-in, zoom-out, change design centre etc.). The use of CAD software to obtain directly a vector 3D model to which individual textures can be attached is the most common way to create digital models of architectural objects. Almost all 3D CAD modelling software allow this, but the most effective ones are 3D Studio-Max, Microstation and AutoCADMap. Fig.4 shows an example in AutoCADMap, while Fig. 5 shows the same object in Microstation.

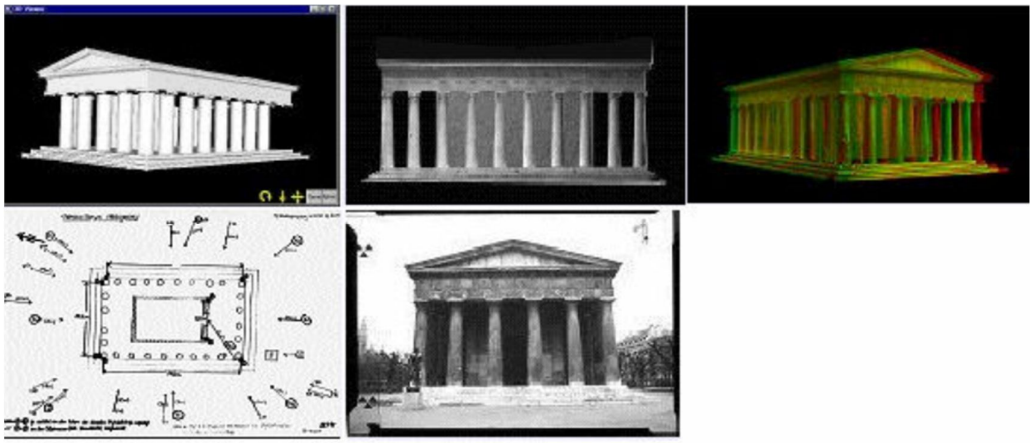

Fig. 3 Example provided by Professor Peter Waldhhausl of the Technical University of Vienna

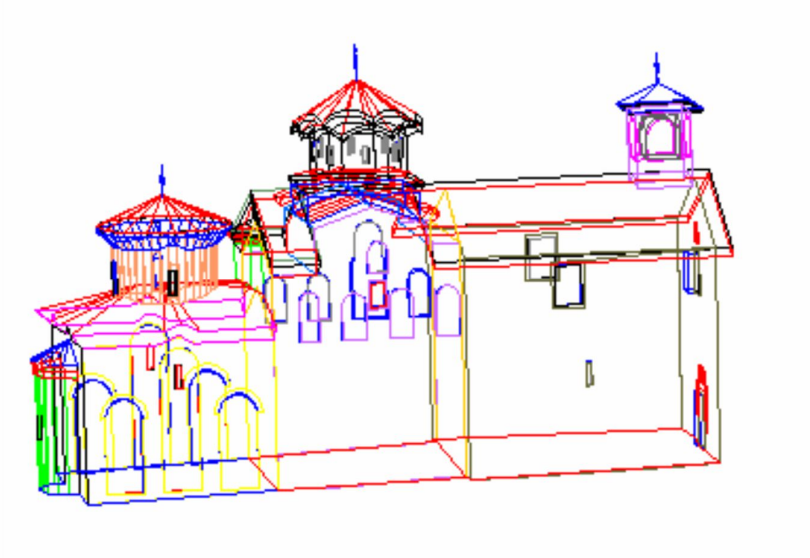

Fig. 4: 3D model of an architectural object created in AutoCADMap. Source: Assoc. prof. B. Georgiev

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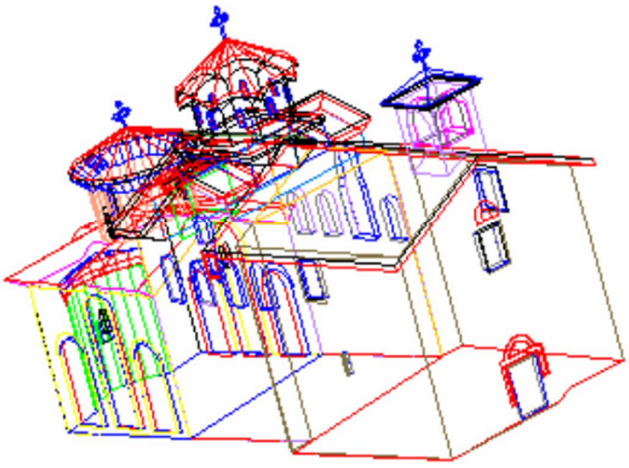

Fig. 5: 3D model of an architectural object created in Microstation.
Source: Assoc. prof B. Georgiev

The 3D Max software allows simultaneous creation of the digital model together with multimedia applications (*.avi files) that complement the multifunctional application of the digital image of the architectural object. It is possible to create video clips for different architectural features of an object, which besides for cognitive purpose can also be used as useful information for revealing the interrelations between objects.

4. Use of mobile phones to receive 3D digital object images

A modern smart phone can be used as 3D scanner. Some smart phones come integrated with a 3D scanning application. For other scanning apps can be downloaded from the internet store. Online stores increasingly supply 3D scanning apps. It is becoming quite easy to 3D scan an object or a person using a smart phone. More or less, the procedure of the 3D scanning for all phone-scanning applications is similar. First, the object that is to be scanned should be placed somewhere where you can walk around it. Then, the scanning procedure is started as indicated by the app, and the sensors of the camera of your mobile phone collect all the needed data. Once the 3D scanning is finished, and the data is collected, the app turns automatically them into your digital 3D model. After that, you can save the result and 3D print it.

4.1. D scanning applications for smartphones

The 3D scanning apps listed below are all based on photogrammetric method – 3D scanning technology – that creates 3D models out of 2D digital photos. It works by taking overlapping pictures of the object from different angles. Then, the software generates 3D model by combining all these images together.

Trnio

One of the best 3D scanning applications for mobile phones is **Trnio.** This 3D scanning app is available only for iPhones and it offers two scanning modes: the object mode and the scene mode. For the object mode, the user walks around an object and the app captures while the user moves in a circular pattern around the object. The scene mode is used for free formed scanning, meaning it can be used it for 3D scanning outdoors scenes or large items.

Scan 3D

It is used for Android smart phones; the key advantage of this application is its user-friendly interface. Even for a beginner, it is very easy to use it, as it allows instant reconstruction with the 3D model. It works by taking 20 to 30 overlapping photos around the scanned object and then the rendering is performed on the device automatically. The result of the digital scan is ready in a couple of minutes according to the

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sufficient number of the input pictures. Later on, a 3D model is created and can be shared on a Sketchfab account, without any post-processing

Qlone

Qlone is a 3D scanning mobile application that features near real-time 3D scanning and generates results locally, not through a cloud platform. In order for Qlone to be used, users need to print a black and white mat (similar to QR code). They then need to place the object they wish to 3D scan on top of the printed map. Users can print several maps depending on the object's size. The key feature of Qlone is its merging capabilities. The 3D scanning app is able to merge two different positions of the same 3D scanned item for a better overall result. Users can also share their 3D captures with friends on social media platforms such as Facebook, WhatsApp, and other apps. Qlone is a free application, but the exports of the generated 3D scans – that are available in common formats such as .OBJ, .STL, .PLY and .X3D are paid. Fig. 6 shows a small object, 3D scanned by use of Qlone application.

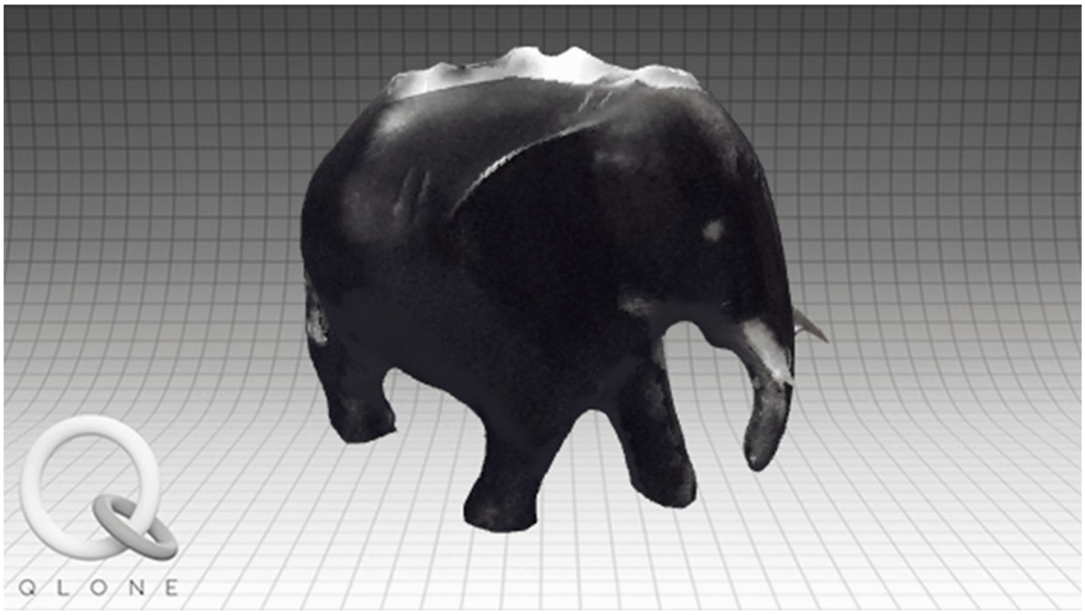

Fig. 6 A small object, 3D scanned by use of Qlone app, Source: Prof. Dr. Arch. G. Georgiev

5. Use of photogrammetry approach in Bulgaria

5.1. Work of Pl. Maldjanski

Regarding the theoretical development and the experimental application of the methods for capturing and processing data in architectural photogrammetry in Bulgaria, the leading contribution of Prof. Plamen Maldzhanski should be noted. His monograph "Development of methods for data capture and processing in architectural photogrammetry" (Maldjanski, 2003) is the most serious study in this field in Bulgaria. The monograph deals with photogrammetric methods for archiving cultural monuments and architecture, developing photographic techniques, coding of photogrammetric information and spatial data, technologies for creating and using digital models, ways of interpreting and publishing data, used equipment, methodology of technological processes, preparation of digital models of surfaces, buildings and voluminous bodies, architectural surveying, facade plans, aerial laser scanning, reconstruction and

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reconstruction upgrading objects according to their photos and prepared models as well as techniques for 3D photorealistic modelling.

Prof. Plamen Maldzhanski has a number of other publications on the topic of photographic surveying of architectural monuments. In one of them - his applied research study "Creating Digital Facade Plans"(Yearbook of the University of Architecture, Civil Engineering and Geodesy - Sofia, 2002-2003) he investigates the application of the method in capturing of architectural facades.

The article highlights that: "... facade shooting is a common task of photogrammetry practice. Facade plans represent an end-product for many activities related to the archiving of architectural sites and cultural monuments. Until recently, the technology used to produce facade plans was analogous. As a final product, an orthophoto map of the facade is used to document the cultural monument and contains complete metric information for individual details. The recent development of digital photogrammetry and the creation of digital imaging systems have enabled new effective digital technologies to create frontage plans where the final product is already digital and façade documentation is more complete and more effective in terms of resource saving and technological time" (Maldjanski, 2003).

Especially important is the conclusion that although the use of laser scanners leads to high accuracy and efficiency of technological processes, the high cost of laser scanners and digital stereo cameras is a prerequisite for searching for cheaper technological schemes to find a reasonable compromise in terms of quality and price when choosing an effective technology for facade plans.

The article offers such technology, consisting of:

1. Taking photos by analogue photogrammetric camera and a digital camera on the individual facades of the building.
2. Obtain a geometric pattern for each facade by using the captured data with the analogue camera.
3. Digital image transformation for individual zones of the images obtained with the digital camera.
4. Application of geometric adjustments of the individual sections and creation of a common mosaic for the façade.
5. Obtaining a digital orthophoto in a geodesic coordinate system.

Experiments were made by capturing the facades of a monument of culture and architecture and applying the proposed technology (Figure 7.). The experiments included shooting the facades of the building with the architectural detail, Plovdiv, 163 Shesti Septemvri Street with SMK 0808/56, with a 40 cm base and a CANON 7.2 Mpix digital camera. Subsequent data processing was performed with ERDAS IMAGINE software.

"Architectural Photographing of Building Facades by use of Digital Photometric Methods" - another article by Plamen Maldzhanski describes the results of an architectural archiving experiment at the Military Marine Club building in Varna. The main objective of the experiment is to formulate the following: investigate the possibility of creating an ortho photo image on the facades of a building decorated with a significant number of architectural elements and frames with the aid of the ERDAS software system based on the use of terrestrial digital photographs taken with a non-photometric camera (photo theodolite). In order to achieve this goal, the following private tasks are solved:

1. Choosing the appropriate method for photographing the building;
2. Experimenting of the appropriate technology and stages of processing of the terrestrial photos obtained.

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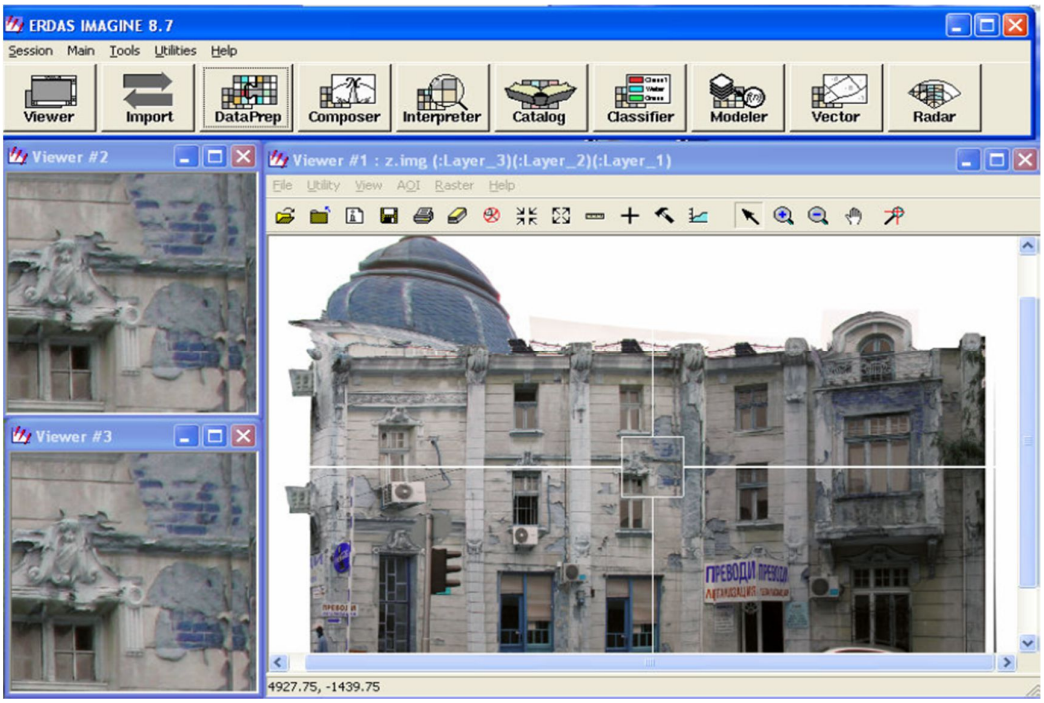

Fig. 7 Capturing of the facades of the building, Plovdiv, 163 Shesti Septemvri Str., Source: Pl. Maldjanski

Another research paper by prof. Pl. Maldjanski, focused on use of photogrammetry approach in research and preservation of architectural heritage, is outlining the advantages of digital photogrammetry versus analogue photogrammetric technologies (Maldzhanski, 2012). In this paper a comparative analysis between analogue and digital technologies in photogrammetry is made. Meanwhile, we highlighted the advantages of digital technologies in terms of the following: greater possibilities for managing and use of various types of data, corrections to the geometric model and introduction of systematic errors locally, process automation, expanded analysis of results of technological process, automatic formation of terrain data, detection of identical areas, etc.

5.2. Project "Heritage: ESPRIT"

The project "Cultural Heritage: Education – Science – Preservation – Integrated in Tourism" (liternet.bg/ebook/kulturno_nasledstvo/content.htm) has won a competition of the Ministry of Science and Culture (2006) and was implemented in 2007-2008 by the Bulgarian National Committee of ICOMOS with several Bulgarian partners: University of Architecture, Civil Engineering and Geodesy, National Academy of Art and Association for Cultural Tourism. It was targeted at creation of exchange, interaction and communication network between different sectors, associated to cultural heritage: science, education, preservation and cultural tourism, by use of the information technologies capacity. The project ambition was to create the missing communication between these sectors. Aiming this, in the frames of the project, an open scientific, educational and expert network was created.

An educational course "New Technologies in the cultural heritage and cultural tourism" was organized under the project. It was directed to students and young specialists in the field of preservation of the immovable architectural and artistic heritage. The course programme consisted of:

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- presenting modern digital technologies promoting cultural heritage, supported by use of new equipment of the Multimedia Laboratory for documentation and presentation of the immovable cultural values, created under the project.
- pilot use of the new technologies for preservation of the cultural monuments

Prominent Bulgarian experts – assoc. prof. Boyan Georgiev, PhD, assoc. prof. Stefan Tupanov, Ivan Delchev and Deliana Kostadinova – presented the lectures. The practical part of the education took part at two sites in the course of restoration – the Rila Monastery and the church St. George in Dolni Lozen village. The participants had documented the sites with the help of the new equipment. The educational program has ended with the processing of the data from the site using special software in the Multimedia Laboratory for Cultural Heritage.

5.3. Multimedia Laboratory for Cultural and Historical Heritage (MMLKH)

In March 2005, a Multimedia Laboratory for Cultural and Historical Heritage (MMLKH https://www.uacg.bg/?p=156&dp=110&l=2) was established at the Faculty of Architecture of Sofia University of Architecture, Civil Engineering and Geogesy. It was created as a technological platform for the research and educational network in the first stage of the project "New Technologies in Training, Preservation and Promotion of Cultural Heritage" with the support of the British Council for the Cultural and Natural Heritage of Southeastern Europe and the British Council, Bulgaria. A research was elaborated and a series of pilot informational products (digitalized monuments of culture, 3D models, a pilot territory for cultural tourism - Rhodopi Cultural Area) were developed.

This was and still is one of the first attempts in Bulgaria to provide a more extensive and resource-assured use of the capabilities of modern digital technologies in exploring material objects of historical heritage, including the creation of three-dimensional models. Through the creation of the Multimedia Laboratory, the Faculty of Architecture of the University of Architecture and Geodesy (UACEG) creates a foundation for modern infrastructure and the training of students in architecture in the field of cultural and historical heritage. Under the project, a training events and a workroom were set up for the preparation of training sessions, storage and management of the laboratory's resources. (Boyan Georgiev "Possible technological solutions for realization of information infrastructure for research, training, preservation, promotion in the field of different cultural and historical heritage", Heritage: ESPRIT, under the general editing of prof. Arch. Todor Krastev, Varna: LiterNet, 2009).

6. Conclusion

ICT tools are relatively well used for systematization, exhibition and promotion of Bulgarian cultural heritage. However, in development of modern digital technologies for constructing and processing of digital spatial images of cultural heritage objects, Bulgaria is lacking the needed scale and advancement of research activities. The application of digital technologies in investigation and preserving architectural monuments is relatively well covered by various specialized scientific publications. However, with the exception of limited in scale and scope projects, developed by Multimedia Laboratory for Cultural and Historical Heritage of UACEG, no other practically oriented activities in Bulgaria exist. The vast possibilities to apply at a large-scale inexpensive digital photogrammetry tools for preserving cultural monuments in Bulgaria are still unexplored. As evidenced in this article such possibilities are real and they need urgent implementation. Therefore, based on the above-mentioned conclusions, a pilot project developed by NBU and supported by Bulgarian National Research Fund, will explore the viable options for creation of digital archive of selected examples of Bulgarian housing architecture from XIX century by use of inexpensive digital photogrammetry approach. Once tested successfully, such approach will reveal a vast opportunity for start of larger scale activities in the area of digitalisation of Bulgarian cultural heritage buildings.

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