ARCHITECTURAL HERITAGE PRESERVATION IN DIGITAL CITY

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ABSTRACT

Architectural heritage research and preservation requires development of diverse tools and a system organizing in a structured way the creation, storage and distribution of comprehensive information about historical buildings. Development of digital technologies and 3D scanning of buildings of cultural heritage combined with 3D virtual reconstruction allows creation of important tool for understanding and reconstructing the past. Photogrammetric methods for creating and processing of spatial (3D) images of historical and architectural monuments are finding a growing application. Such approach is becoming a cheaper alternative of expensive laser scanning. The article analyses the opportunities for the use of different ICT tools including inexpensive digital imaging options for preservation and exhibiting of large and diverse Bulgarian cultural heritage.

Keywords: *Architectural Heritage, Photogrammetry, 3D Image, Virtual Reconstruction, Digital restoration*

Introduction

A 3D scan is the 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 (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 USD 8,427 million in 2017 and is projected to reach USD 53,345 million by 2025 (researchandmarkets.com).

1. Digital documentation of historical objects – advantages and disadvantages of photogrammetry approach

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.

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 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 with 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* 3*D Digitization", Practical Guide,* 2014).

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: map, drawing or 3D model of a physical object or locality *("Applications of* 3*D Digitization", Practical Guide,* 2014).

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 preselected 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 ensures 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, 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 to subsequently generate different visual and spatial visualizations of 3D space. In this respect, two generic options for generating models can be distinguished:

1.1. Fast 3D models

There are software products in which the model is generated on the basis of 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 simple shape, but with many details and decorations on the facade panels – mouldings, pilasters, complicated door and window openings, etc. are relatively quickly created. These are the capabilities of Autodesk Inc.’s product – Autodesk Image Modeler 2009.

1.2. 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 softwares such as ArchiCAD by GraphiSoft, ALLPLAN by Nemetschek AG, Architectural Desktop, and REVIT Architecture by Autodesk Inc., Triforma by Bently Systems Inc. or to work with some of the numerous three-dimensional computer modelling products. In order to obtain a quality photorealistic end result, the model is usually transferred and edited in one of the visualization programs – Cinema 4D by MAXON Computer GmbH, Germany, Artlantis by Abvent, France, and 3D Studio Max by Autodesk Inc. and others. (Fig. 1)

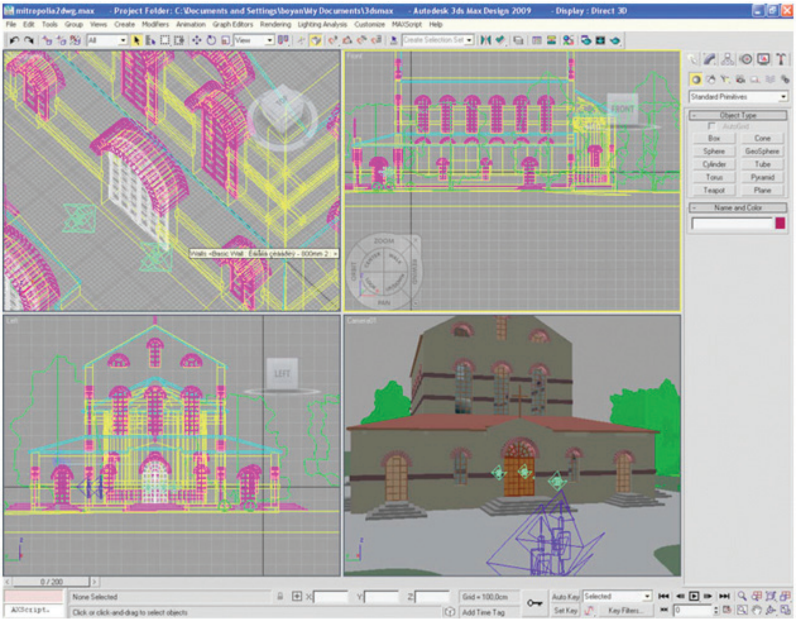

Figure 1. Model Processing in 3D Studio Max
Illustration: B. Georgiev

1.3. 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 chambers with known elements of the inner orientation could be used in the past. Now a variety of digital capture systems are being developed and their price is constantly falling. The main advantage of these cameras is the ability to create digital images to be processed directly in the digital environment.

1.4. 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) is a widespread and relatively inexpensive tool for architectural and archaeological imagery. It works under Windows and allows measuring and transforming photos into 3D models.

It is one of image processing applications that allow multiple snapshots of an object that reflect different aspects of it (different camera position, etc.) to assemble a spatial model. This is the example of Professor Peter Waldhhausl of the Technical University in Vienna, shown in Figure 2. The basics of the capture, some of the source pictures and the model view, are seen. Photo Modeller software allows you to perform various operations on a created model (zoom-in, zoom-out, change design centre, etc.).

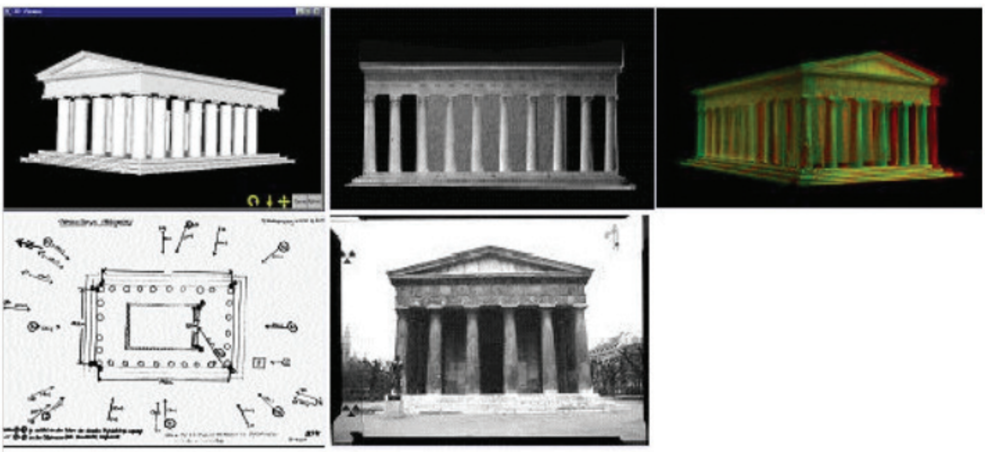

Figure 2. Example of Professor Peter Waldhhausl of the Technical University of Vienna

1.5. Using CAD systems in models of monuments of culture and architecture

The use of a CAD system to directly obtain a vectorial 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. Figure 3. shows the example in AutoCADMap, while Figure 4. shows the same object in Microstation.

Figure 3. 3D model of an architectural object created in AutoCADMap.
Source: B. Georgiev

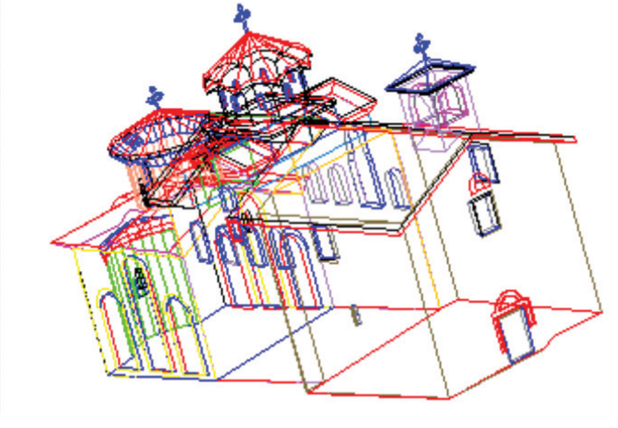

Figure 4. 3D model of an architectural object created in Microstation.
Source: B. Georgiev

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 model of the architectural object. It is possible to create special 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.

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

A modern smartphone can be used as 3D scanner. Some smartphones come integrated with a 3D scanning application. For other scanning apps can be downloaded from the internet store. 3D scanning apps are increasingly supplied by online stores. 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 or the person that is to be scanned should be placed somewhere where you can walk around it/her/him. 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 print it in 3D.

3D scanning applications for smartphones are all based on photogrammetric method. – 3D scanning technology that creates 3D models out of 2D photos. It works by taking overlapping pictures of the object you are 3D scanning from different angles. Then, the software generates your 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.

Scann3D

Used for Android smartphones, the key success for this software is its user-friendly interface. Even if you are a beginner, it is very easy to use it, as you get instant reconstruction with the 3D model. It works by taking 20 to 30 overlapping photos around the object that is 3D scanned, and then the rendering is performed on the device automatically. The result of the 3D scan is ready in a couple of minutes according to the number of the input pictures. Later on, you can create a 3D model that can be shared on your Sketchfab account, without any post-processing

Qlone

Qlone is a 3D scanning mobile app developed with 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 poses 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.

Figure 5. A small object, 3D scanned by use of Qlone app
Illustration: G. Georgiev

3. Use of photogrammetry approach in the field of historical objects in Bulgaria

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 Maldjanski should be noted. His monograph *"Development of methods for data capture and processing in architectural photogrammetry",* 2012 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 reconstruction upgrading objects according to their photos and prepared models as well as techniques for 3D photorealistic modelling.

Prof. Plamen Maldjanski 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,* 2002–2003*)* 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 are 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 an end product, an orthophotomap of the façade 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 effective in terms of resource saving and technological time. ".

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 façade 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 an 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 (see fig.6.). 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.

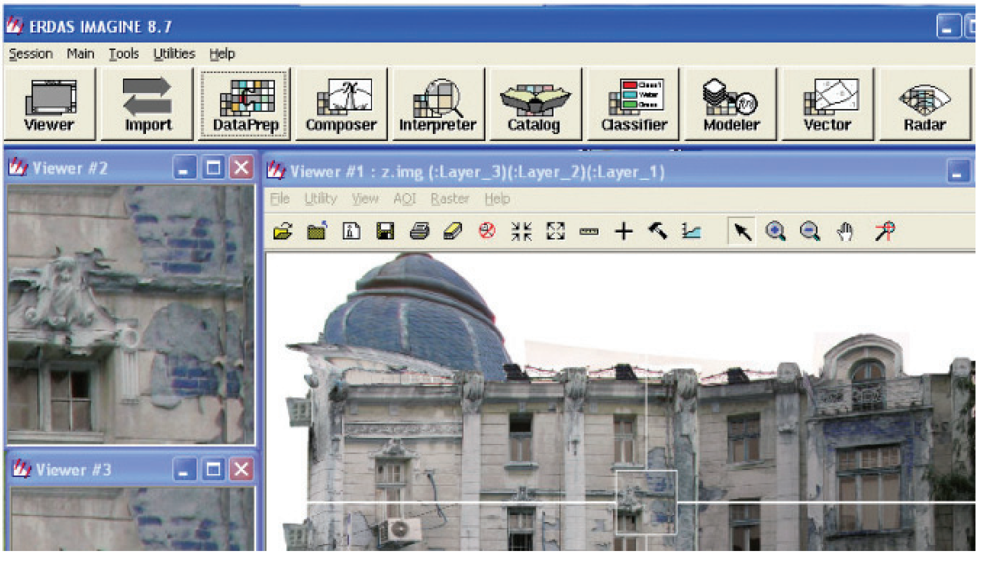

Figure 6. Capturing of the facades of the building,
Plovdiv, 163 Shesti Septemvri Str., Pl. Maldjanski

"Architectural Photographing of Building Facades by use of Digital Photometric Methods" – another article by Plamen Maldjanski 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 (phototheodolite).

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.

Another research paper by prof. PhD Pl. Maldjanski, focused on used of photogrammetry approach in research and preservation of architectural heritage is: “Advantages of digital photogrammetry versus analogue photogrammetric technologies”. In the paper a comparative analysis between analogue and digital technologies in photogrammetry is made. Highlighting the advantages of digital technologies in terms of: 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.

With the means from targeted project financing in the Multimedia Laboratory at UACEG a study was conducted and a technique for three-dimensional modelling of objects was delivered through software processing of two-dimensional digital photographic images. Regarding the use of photogrammetric methods for obtaining a three-dimensional image of architectural objects, both the technique and software purchased, as well as demo versions of software products, have been experimented within this project:

A. REALVIZ software from France, which enables the generation of photorealistic 3D models based on two-dimensional photographic images of the object. The product called ImageModeler® reached version 4.0 (Figure 7).

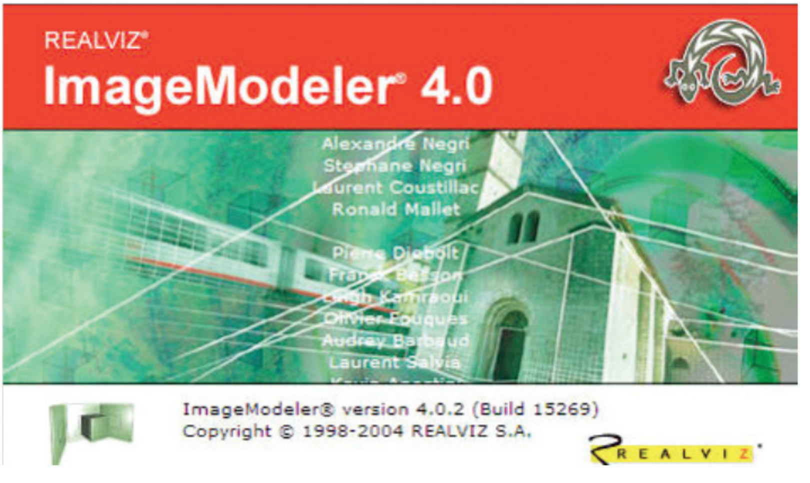

Figure 7. ImageModeler, version 4.0

In the summer of 2007, with the demo version of the product, experiments were made to create sample 3D objects. Working with the program is easy and intuitive to use, but results are of relatively low quality. In order to achieve optimal results, it is necessary to have pictures from different points of view but also from different heights, which according to the participants in the project is difficult to achieve without special means. In conclusion, it is concluded that: “The main reason for the inapplicability of this product in our conditions is the nature of the objects that are subject to modelling. If, for example, we analyse the forms of a Plovdiv house, we will find that it has a complex, geometric form, obtained as a combination of many elementary forms – parallelepipeds, cylinders, pyramid shapes, etc. The individual boards are rarely ornamented; the windows and doors have simple ornamentation and shape. This requires full construction of the basic forms, which is almost impossible to achieve with the program. It achieves good and quick results in simple common forms and great fragmentation and detail in the small details – frames and shapes of windows, cornices, flat pilasters, etc. (Figure 8).

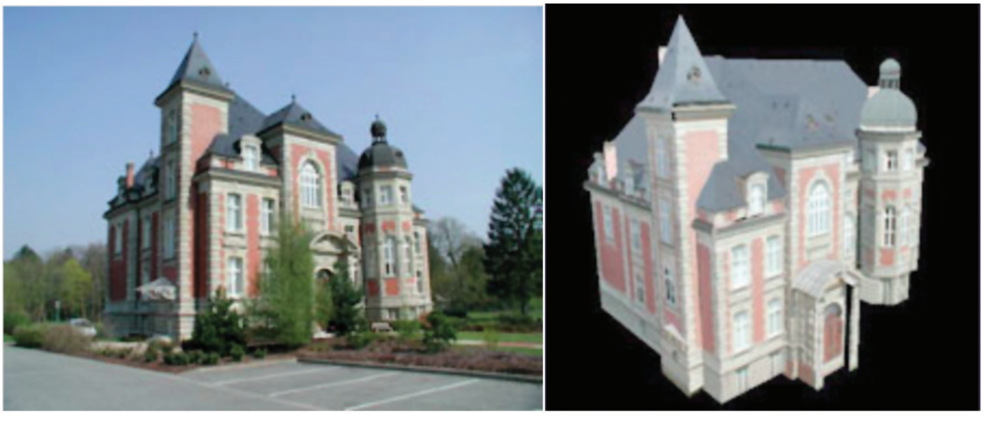

Figure 8. Three-dimensional representation of a building with Image Modeller, version 4.0 Photographs: REALVIZ

The authors of the project study conclude that “at this stage of development, the program will not be useful”. This is the reason for the refusal to purchase the license. In the first half of 2008, REALVIZ was purchased by one of the giants in the software industry – US firm Autodesk Inc. The ImageModeller product is now distributed under the name Autodesk Image

Modeller. In the review in question, Boyan Georgiev suggests that “this will surely play a positive role in his development, which should be carefully monitored in the future”.

In another article, Boyan Georgiev *(“Technologies for the Visualization of the Cultural and Historical Environment for the Purpose of its Promotion”, Heritage: ESPRIT, under the general editing of Prof. Arch.Todor Krastev,* 2009) presents technological possibilities developed within the above project for generating three-dimensional information and its visualization in order to obtain a maximum picture of the volumes and spaces for sites of cultural and historical heritage.

In general, despite the existence of a number of theoretical publications on the application of photogrammetry in studying and preserving architectural monuments in specialized scientific publications, in addition to the projects related to the Multimedia Laboratory for Cultural and Historical Heritage of UACEG, there are no other practically oriented activities in Bulgaria.

Conclusion

ICT tools have proven to be an effective means for systematization, exhibition and promotion of Bulgarian cultural heritage. The application of digital technologies in investigation and preserving architectural monuments worldwide is well covered by specialized scientific publications. However, Bulgaria lacks the needed scale and advancement of research activities in development of modern technologies for constructing and processing of digital images of architectural heritage objects. In addition, 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.

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