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COMPARATIVE STUDY OF 3D MODELING BY SHORT-RANGE PHOTOGRAMMETRY

Clara-Beatrice Vîlceanu[1], Simon Pescari[1], Sorin Herban[1], Laurențiu Budău[1]

Abstract: Preserving cultural and natural heritage is a priority for developed communities around the world. Photogrammetry is the key element that underpins the collection of information about specific heritage features through highly accurate scanning of features. 3D modeling of cultural heritage objects is also a visual method of presenting architectural design projects. By scanning and 3D modeling of certain objectives, it is possible to reconstruct the element in question with the same geometrical characteristics as the original element, using a 3D printer. The aim of this paper is to make a comparison between two specialised 3D modeling programs. In the conclusions sections, an analysis, in terms of efficiency, of the two specialized software is realized.
Keywords: 3D modeling, photogrammetry, cultural heritage, conservation.

1. INTRODUCTION

The concern for the field of 3D modeling of cultural heritage sites is highly topical, including internationally. A wide range of papers based on this topic can be found in the literature [1-3]. The need to preserve cultural heritage objects arises from the degradation state in which some objects can be found. Cultural heritage objectives consisting in buildings are mostly very old, which leads to degradation of the geometrical configuration, with various parts of the buildings being affected over time. The need to restore them to their original form is made possible by the 3D modeling technique. 3D modeling is used as a visual method of presenting architectural design projects. 3D technology shows how resource and capacity issues can be overcome with regard to limited raw materials. 3D technologies have many practical applications in cultural heritage, from online engagement to academic research, preservation and conservation and other innovations to follow [4, 5]. Photogrammetry is the science and technology behind 3D modeling, representing the first phase of the whole process by obtaining information about physical objects. The information is generated through a recording process, measuring and interpreting photographic images and models of electromagnetic radiation images and other phenomena [6]. An eloquent example of scanning a cultural heritage object is the Notre-Dames cathedral in Paris - one of the main attractions of this city, having existed since the mid-14th century. In April 2019, a fire broke out on the cathedral's roof, causing the top of the cathedral to collapse and the upper part to be consumed. In the case of Notre-Dame Cathedral, there will be huge benefits from the work of the late Vassar art department professor Andrew Tallon, who pioneered the use of laser scanning technology and advanced imaging techniques. Tallon digitally scanned Notre Dame from 2015 until his passing in November 2018 using 360-degree spherical cameras carried by drones. Ultimately generating over a billion data points, Tallon's work at Notre-Dame leaves us with a detailed picture of the cathedral before the fire (Figure 1).

Figure 1. Cloud of dots resulting from the Notre Dame Cathedral explosion

Cultural heritage organisations are joining forces and adopting new technologies to preserve and share information about our fragile shared heritage. The first step for saving our fragile heritage sites is represented by digitising their valuable collections and making data available to conservation experts, museums, libraries and archives.

2. 3D MODELING OF CULTURAL HERITAGE OBJECTIVES

The Dacian fortresses in the Orastie Mountains are among the best known ancient monuments in Romania. They have been invested by the public imagination with a multitude of meanings, and today they are places of memory with a strong identity value. The historical and archaeological importance of these sites is considerable because they represent the monumental expression of the civilization of the Dacian Kingdom from the 1st century BC to the 1st century AD, an original signature in the landscape of temperate Europe at the end of the Iron Age.

The large number of more or less scientifically accurate publications, media and virtual interventions

[1] Politehnica University Timişoara, Civil Engineering Faculty, Traian Lalescu Street, 2A, Timişoara 300223 România, e-mail addresses: beatrice.vilceanu@upt.ro, simon.pescari@upt.ro, sorin.herban@upt.ro, laurentiu.budau@student.upt.ro

is eloquent to this respect. The results of this project are made available to ordinary users interested in scientifically validated information. The project responds to European Commission Recommendation 2006/585/EC which encourages digitisation and increased accessibility of cultural heritage and its digital preservation.

The project is also part of the CARARE (Connecting Archaeology and Architecture in European) initiative developed specifically to bring 3D models of archaeological artefacts and monuments, historic and heritage buildings to the European platform.

The project was implemented by the Technical University of Cluj-Napoca in partnership with the National Museum of History of Transylvania, Cluj-Napoca, "Babeș-Bolyai" University Cluj-Napoca and the Museum of Dacian and Roman Civilisation Deva. By achieving the main objective (digitization of 500 representative Dacian artefacts) important aspects of the Dacian civilization in the Orastie Mountains are available online to the general public.

The results of the project make the historical/archaeological heritage of the Dacian sites in the Orastie Mountains (monuments on the UNESCO List since 1999) available to the general public and to specialists from all over the world. The contextualisation of the digitised monuments and artefacts with specialist information (historical and archaeological) meets the need of the general public to know the cultural heritage of antiquity, especially the Dacian heritage, and generates a positive attitude towards cultural heritage.

The online database hosted on the project website contains 500 Dacian artefacts with archaeological and historical information to contextualise and enhance them. This combination allows the general public to understand their role and functionality in antiquity. The project database offers the possibility to download the 3D model of the scanned artefacts in PDF format, the format agreed by European.

In February 2016 European Commission announced the integration of the Sketchfab.com viewer which offers stereo viewing capabilities of 3D models. The project's database is among the few in Europe at the moment that offers the possibility to view the entire collection of digitised objects with this viewer. This has been made possible by using a complex algorithm for processing 3D scanning data, which has reduced the MB size of the 3D models and preserved their quality.

The interface of the database is built in such a way as to provide smart device users with a pleasant browsing experience. They can interact with the 3D model directly on their phone or tablet without the need for special software directly from the web browser.

The implementation of the project allowed the project promoter and partners to develop their digitization capabilities by purchasing two laser scanners for artefacts and a terrestrial scanning solution composed of: Terrestrial Laser Scanner for short distances (180m), Terrestrial Laser Scanner for long distances (1800m) and total station. With this technology, the project implementation team was able to digitise artefacts and monuments at high resolution.

A novel element for the museum area in Romania is the creation of 3D reconstructions of the Dacian monuments in the form of 3D puzzles with the help of 3D printing equipment purchased within the project. These will be used in the museum pedagogy activities that will take place in the two spaces set up within the project.

Through the implementation of the project, the general public has easy access to a significant number of monuments and artefacts belonging to the Dacian civilisation and to the related scientific information (online and in the two exhibitions in Cluj-Napoca and Deva). The 3D models are of very good quality and visitors can interact with them both online and in the two exhibitions in a way that is not possible with real exhibits/monuments.

The general public is very interested in learning about the cultural heritage of Dacian antiquity. The way to access the virtual version (3D models) of representative monuments and artefacts, accompanied by scientific information presented in an appropriate way, is convenient and attractive. Both the general public and the specialised public (scientists, students, researchers, pupils, teachers) benefit freely from the cultural products of the project, from quality scientific information. These cultural products can also be used as research and teaching resources. The following figures show examples of 3D modeling of cultural heritage objectives (Figure 2, Figure 3).

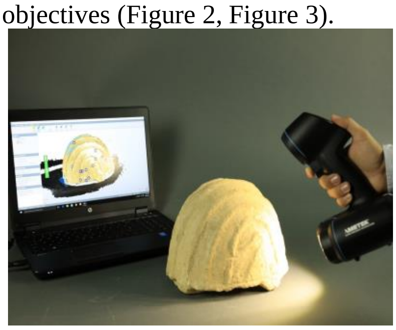

Figure 2. Stages in the process of making 3D models for heritage objects

Figure 3. 3D Modeling

3. PHOTOGRAMMETRY

Photogrammetry has roots going back centuries. Its history can be traced back to the time of Leonardo Da Vinci, the great Italian scientist, engineer, inventor and artist. He dealt with geometry, optics, mechanics and geophysics. In 1492, he graphically demonstrated the principles of optical and aerodynamic projection, inventing mechanisms for polishing and grinding lenses.

Photogrammetry is a set of applications of remote sensing imagery that uses metric elements of imagery (dimensions, distances, areas) to extract the precise, quantitative information needed to represent planimetric and altimetric features on plans and maps.

Photogrammetry is a part of geomatics that lies at the boundary between remote sensing, mapping, surveying and GIS applications. Photogrammetry uses aerial and terrestrial images of objects to reconstruct their geometry and to represent them as accurately as possible on maps and charts.

Photogrammetry is known under two aspects: terrestrial photogrammetry (the set of applications using images obtained with a phototheodolite from a station point located at ground level) and aerial photogrammetry (this involves the exploitation of images using photogrammetric techniques obtained from station points located at certain altitudes above the ground).

The purpose of photogrammetry is to make rigorous metric determinations, in plane and space, of any object, such as: the surface of the Earth and other celestial bodies, a meteorological or morphological phenomenon, a building or building element subject to deformation, a plant, a cloud, etc., using their records.

The advent of photogrammetry was driven early on by the need to obtain rapid and accurate topographic plans and maps over large geographical areas. Thus, in almost a century of evolution, contemporary general photogrammetry has many branches of application, each equally important in its field of use. In the field of terrestrial mapping, the vast majority of plans and maps are produced by photogrammetry (90% worldwide and 95% in our country). It is also worth mentioning the use of photogrammetry in the outer space and on other celestial bodies. A conventional application of photogrammetry is the production of topographic contour maps based on measurements and information obtained from aerial and space photographs with optical analogue instruments and/or analytical computers. Similarly, the principles of topographic precision measurement 4 are applied in close-range photogrammetry for the representation of objects whose study in other ways is difficult for the recording of measurable deformations in engineering models, for the medical study of life forms, etc. Another important application of photogrammetry, of great topicality and especially of great future, is the use of laser scanning, in which images are obtained with a sensor other than (or alongside) the conventional photogrammetric camera, in which an image is recorded as an electronic sweep in the visible or using radiation outside the visible range on film, microwave, radar, thermal infrared or ultraviolet. Short-range photogrammetry is a special case where the distance from the camera to the object does not exceed 100m (Figure 4).

Figure 4. Photogrammetric techniques

Towards the end of the 20th century, the concept of imaging in a fully digital format began to take hold, providing an opportunity to extend the analytical approach by introducing digital image processing techniques. The extension of photogrammetry to digital models marks the beginning of a new era, the digital age. Electronic computing techniques have allowed analogue photogrammetric devices to be replaced by analytical apparatus and methods. As computing and data storage capacity has increased, the use of capture and processing systems has become easier and easier in wider application areas, as can be seen in (Figure 5).

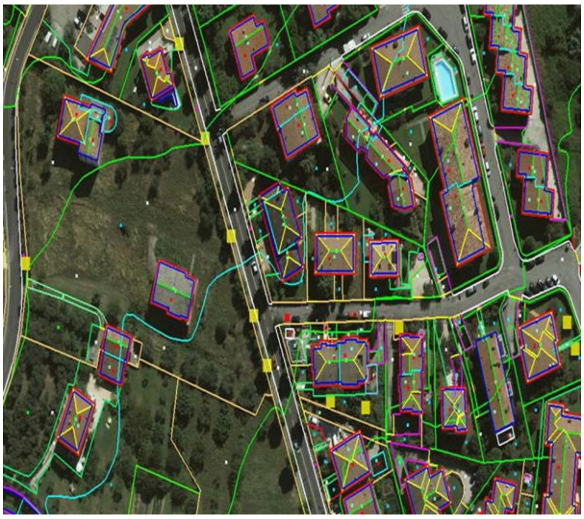

Figure 5. Orthophoto plan

Electronic scanning of images in digital form has become commonplace in photogrammetric operations, allowing the widespread use of automation techniques in image exploitation. In the same way that electronic computing techniques have proved their usefulness in analytical photogrammetry, digital techniques, allowing the efficient processing and storage of massive amounts of data, have made digital image processing possible. Digital photogrammetry (1990s to present) - aerial and satellite photogrammetry with digital exploitation of the doublet and frame block, semi-automatic and automatic orientation, GIS and digital mapping applications (Figure 6).

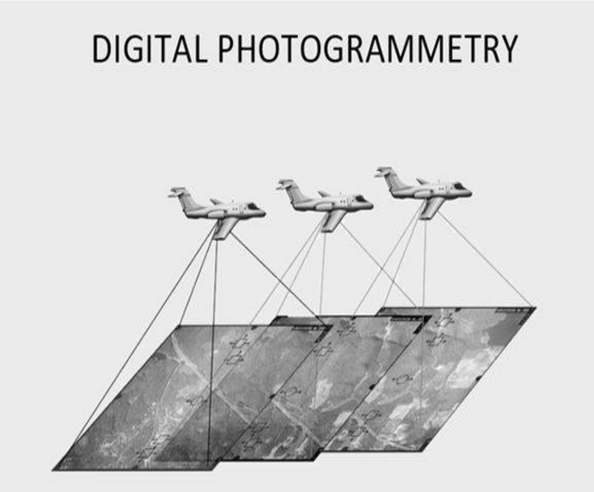

Figure 6. The principle of digital photogrammetry

Digital photogrammetry is based on hardware (computers) and software (specialised computer applications) solutions in the acquisition and processing of digital images to collect information and data and to obtain cartographic products such as: digital plan, digital terrain model, digital surface model, orthoimage etc. The rapid development of computing technology has led to the emergence of digital photogrammetric stations.

Photogrammetric stations are a complex of software and hardware, which must ensure automatic geometric and radiometric processing of digital photograms at all stages of the photogrammetric process. They process digital or scanned images and produce both raster and vector products. In order to ensure a single input format of the basic data into the processing system, digitizing or scanning must be ensured with high-performance devices that ensure optimal format, accuracy and throughput (Figure 7).

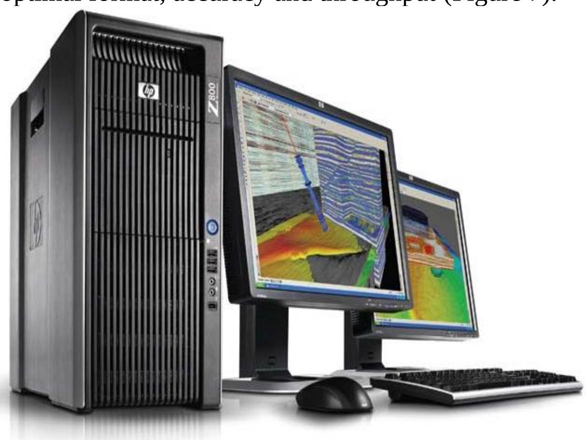

Figure 7. Digital photogrammetric station

Digital photogrammetric stations have the following advantages over analogue and analytical technologies:

-high throughput and accuracy;

- lower cost of stereoscopic observation equipment;

- image analysis as well as multispectral classification can be carried out if the photogram acquisition was done with digital cameras in multispectral mode;

- the main steps of the stereophotogrammetric operating process: interior orientation, exterior orientation, measurement of image coordinates of aero triangulation points, calculation and compensation of aero triangulation, etc. are performed automatically or semi-automatically;

- automatic production of orthophoto plans, orthophoto maps, 3D perspective representations, etc;

- automatic generation of the digital elevation model of the terrain;

- display of data in plan projection, three-dimensional perspective, 3D animation.

4. COMPARATIVE STUDY OF 3D MODELING

In this study, we will compare the processing of digital images in order to obtain a 3D model of an object using, in the first case, a specialised software that has to be paid for and, in the second case, an open-source software available online for free download.

4.1. 3D modeling of the heritage object using the specialized software Agisoft PhotoScan

The Metashape Agisoft PhotoScan Pro software is a 3D digital image-based modeling solution and allows the creation of photogrammetric products such as: orthophotoplan; digital reflectance surface model; digital terrain model; image connection points (correspondences); data on camera calibration parameters or orientation parameters.

For the processing of digital images, the specialized software Metashape Agisoft PhotoScan was used. This program is an advanced image-based 3D modeling solution used to create professional and quality 3D content. The field campaign involves taking digital images, establishing reference points, possibly materialising them where possible. Figure 8 shows the studied statue and Figure 9 shows the model obtained by displaying the position of the cameras after performing all the necessary operations.

Figure 8. The studied Statue

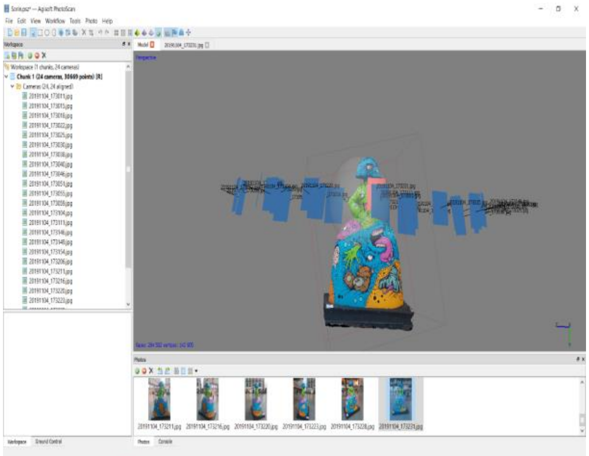

Figure 9. 3D model obtained with camera position display

4.2. 3D modeling of the heritage object using the specialised 3DF Zephyr software

3DF Zephyr is a commercial photogrammetric and 3D modeling software. Developed and marketed by Italian software house 3DFLOW, 3DF Zephyr was first released in January 2014 and continuously updated since then. It is a complete photogrammetry software package that includes many post-processing tools for measurements, 3D modeling and content creation, users can solve any 3D reconstruction and scanning challenge, no matter which camera sensor, drone or laser scanning device they will use. It enables 3D reconstruction from both photos and videos by automatically extracting frames and selecting the most suitable ones for computation. Figure 10 shows the dense point cloud and Figure 11 shows the mesh. Figure 12 shows the 3D model obtained after performing the necessary processing operations in the program.

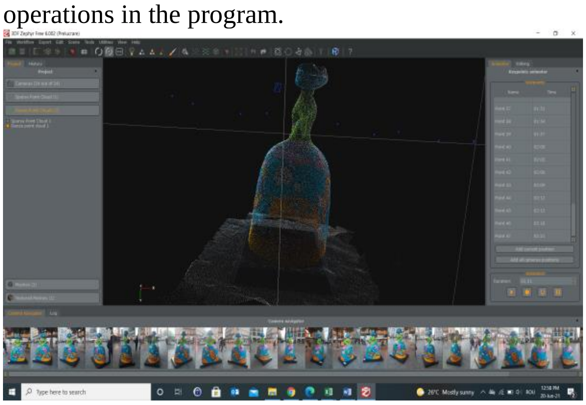

Figure 10. Dense point cloud

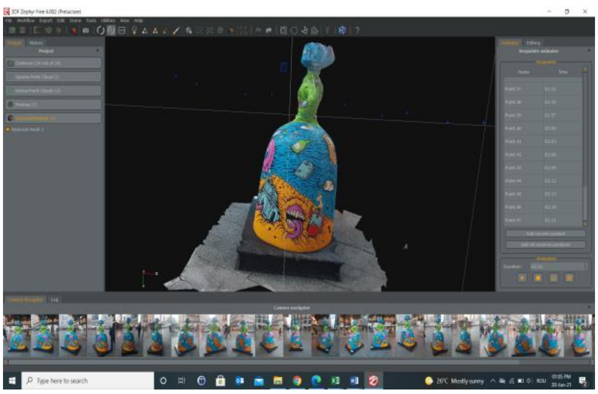

Figure 11. Mesh with texture

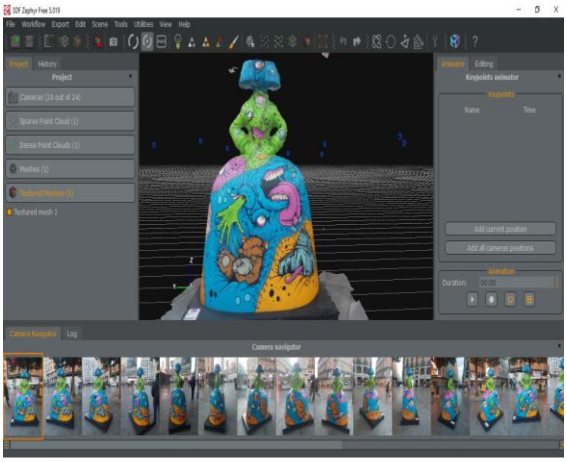

Figure 12. 3D model obtained

5. CONCLUSIONS

To benefit from Agisoft PhotoScan a fee is required. It comes in 2 variants: the Agisoft Metashape Professional Edition and the Agisoft Metashape Standard Edition. The first variant, the professional one costs $3499 and the standard variant costs $179.

3DF Zephyr is a free modeling software. The program is fully automated, the user contributes only by pressing commands, processing of digital images is faster than with the specialized Agisoft program - the generation of the dense point cloud took 5 minutes. Comparing the two models, the Agisoft PhotoScan model is much more accurate. With this software the modeling is complete, whereas with 3DF Zephyr, the statue is not complete. The upper part of its head has not been modelled.

Another conclusion is that the software to be paid for offers better accuracy. Both specialized programs have the possibility to add the position of the cameras from which the digital images were taken.

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