COMPARATIVE STUDY ON DIGITAL IMAGE PROCESSING FOR 3D MODELING

**Laurențiu BUDĂU[1], Simon PESCARI[1], Remus CHENDEȘ[1],
Clara-Beatrice VÎLCEANU[2], Sorin HERBAN[2]**

[1]Politehnica University Timisoara, Civil Engineer Faculty, Department of Civil Engineering and
Building Services Engineering, 2 Traian Lalescu Street, Timisoara, Romania
[2]Politehnica University Timisoara, Civil Engineer Faculty, Department of Overland
Communication Ways, Foundations and Cadastral Survey, 1 Ioan Curea Street, Timisoara, Romania

Corresponding author email: laurentiu.budau@student.upt.ro

Abstract

The needs of today's society for urban planning require realistic 3D representations of objects or cities for various purposes. The topicality of the study is given by the fact that digital recording of cultural heritage objects represents one of today's society preoccupation for purposes such as maintenance, reproduction multimedia tools for education and dissemination, to artefact condition monitoring. Analysis in a virtual world, using 3D models, for historic buildings or ancient fortresses is much more efficient than a classical 2D analysis. Thus, the aim of this study was to make a comparison between processing digital images to obtain a 3D model of an object using, in the first case, a specialized, widely used software, and, in the other cases, different open-source specialized software. The object studied was the statue of General Ion Dragalina located in Dragalina Park in Caransebeș municipality, western Romania. To process the digital images, four specialized programs were used: Agisoft Metashape, 3DF Zephyr Free, Regard 3D and Meshroom together with Meshlab. Finally, the advantages and disadvantages of each of the programs studied are highlighted by comparison.

Key words: cultural heritage; 3D representations; historic buildings; 3D models; digital recording.

INTRODUCTION

In order to carry out the documentation for the preservation of cultural heritage (Abdelhamid, 2019; Agosto & Bornaz, 2017; Balsa-Barreiro & Fritsch, 2018), a multidisciplinary approach is required, which aims to understand the heritage object itself and to collect all the information that characterizes it. Documentation for Cultural Heritage Preservation is much more than the generic term used to define the acquisition of all the information needed to understand an object for documentation in order to restore, conserve and manage it or to disseminate the results and transform them into a usable form in the future. One of the priorities of the European Parliament's Commission on 2010 - A European Information Society for growth and employment states: "In launching the Partnership for Growth and Jobs as a new start for the Lisbon Strategy, the 2005 Spring European Council recommended knowledge and innovation as drivers of sustainable growth and stated that it is essential to build a fully inclusive information society, based on the widespread use of Information and Communication Technologies (ICT), for all areas of the economy: public services, SMEs and individuals doing business. ICT can be a powerful tool for strengthening Europe's cultural diversity and can make our cultural heritage (De Luca, 2013; Di Giulio et al., 2016; Messaoudi et al., 2018) and cultural creations available to as many citizens as possible" (https://ec.europa.eu/programmes/horizon2020/en/area/ict-research-innovation).

In this context, the needs of today's society for urban planning require realistic 3D representations of objects or cities for various purposes. Analysis in a virtual world, using 3D models, for historic buildings or ancient fortresses is much more efficient than a classical 2D analysis (Micoli et al., 2013; Soto-Martin et al., 2020; Owda et al., 2018).

This is why automated procedures based on scientific protocols are needed in an ICT-based world. 3D design software applications are a modern and much more efficient solution for the realisation (Arbace et al., 2013), management

and execution of large-scale projects where a clear vision is needed to optimise expenditure and resource allocation (Figure 1).

To carry out the study, a mobile phone was used and 26 digital images were taken, keeping the same distance from the object, with the main condition being that the image of the object must be whole in each of the 26 positions.

The timeliness of the study is due to the fact that digital recording of cultural heritage objects is one of the concerns of today's society, (Maravelakis et al, 2013; Dore & Murphy, 2012) for purposes such as maintenance (e.g., computer-aided repair), reproduction (e.g., rapid prototyping), multimedia tools for education and dissemination (e.g., virtual museums), monitoring the condition of artefacts (e.g., computer-aided inspection) and many others.

Figure 1. Objectives of using 3D models in the field of cultural heritage conservation

MATERIALS AND METHODS

Specialised 3D reconstruction software from photographs comes in many forms. Certainly, there are commercial solutions that are ideal for industrial and engineering applications. But there is also a good suite of software available online for free download. Users then only need a camera or smartphone to take photos and, if using a 3D printer afterwards, can even print the resulting models. (Guarnieri et al., 2006; Murphy et al., 2013)

The table below (Table 1) lists the best photogrammetric software, selected and sorted alphabetically. Firstly, free photogrammetric software tools are centralized. Secondly, professional software used to create 3D models

is also listed. (Pepe et al., 2021; Jiménez Fernández-Palacios et al., 2015)

Table 1. Specialised photogrammetric software for digital image processing

Software name	Photogrammetry type	Operating system running	Price
COLMAP	Aerial, Short distance	Windows, macOS, Linux	Free
Meshroom	Aerial, Short distance	Windows, Linux	Free
MicMac	Aerial, Short distance	Windows, macOS, Linux	Free
Multi - View Environment	Aerial, Short distance	Windows, macOS	Free
OpenMVG	Aerial, Short distance	Linux, Windows, MacOS	Free
Regard3D	Aerial, Short distance	Windows, macOS, Linux	Free
VisualSFM	Aerial, Short distance	Windows, macOS, Linux	Free
3DF Zephyr	Aerial, Short distance	Windows	From $300/month
Autodesk ReCap	Aerial, Short distance	Windows	$340/year
Agisoft Metashape	Aerial, Short distance	Windows, macOS, Linux	Starting at $179
Bentley ContextCapture	Aerial, Short distance	Windows	On request
Correlator3D	Aerial	Windows	From $295/month
DroneDeploy	Aerial	Windows, macOS, Android, iOS	From $99/month
Elcovision 10	Aerial, Short distance	Windows	On request
iWitnessPro	Aerial, Short distance	Windows	On request
IMAGINE Photogrammetry	Aerial	Windows	On request
Photomodeler	Aerial, Short distance	Windows	From $59/month
Pix4Dmapper	Aerial	Windows, macOS, Android, iOS	From $160/month
RealityCapture	Aerial, Short distance	Windows	$10 for 3500 PPI credits or $3,750 for unlimited access
SOCET GXP	Aerial	Windows	On request
Trimble Inpho	Aerial, Short distance	Windows	On request
WebODM	Aerial	Windows, macOS	$57

Short-range photogrammetry

Short-range photogrammetry is a special case where the distance from the camera to the object does not exceed 100m. Short-range terrestrial photogrammetry is based on photographs taken with a digital camera, (Kadobayashi et al., 2004) taken manually by the operator or with the digital camera mounted on a tripod. These photos are then used to create 3D models of objects such as monuments, statues and cultural heritage buildings, traffic accident scenes or

even on film sets. It also emphasises the application of effective multidisciplinary teamwork techniques on various hierarchical levels.

Advantages of using 3D models using short-range photogrammetry (Fiorillo et al., 2013; Kuroczyński et al., 2016):

- a measurement method is without direct contact with the object under study;
- results are accurate and reliable;
- data collection is realized in a short time and at low cost;
- images are retrieved and stored and can be consulted and re-measured at any time in the future;
- in the 3D plane all measured elements have dimensions and the relative differences are real;
- cost assessment as accurate as possible (in case of rehabilitation or construction of new targets);
- planning construction phases more accurately;
- control the project in a much more rigorous manner;
- helps preserve the national historical and architectural heritage and beyond (Miles et al., 2015, Pietroni and Ferdani, 2021).

Agisoft Metashape specialized digital image processing software
(https://www.agisoft.com/)
The Metashape Agisoft PhotoScan Pro software is a 3D modeling solution based on digital images and allows the creation of photogrammetric products of type:

- orthophoto plan;
- a digital reflectance surface model;
- a digital terrain model;
- tie points (correspondences) between images;
- information on camera calibration and orientation parameters.

3DF Zephyr specialized digital image processing software (https://www.3dflow.net/ 3df-zephyr-photogrammetry-software/)
3DF Zephyr is a commercial 3D photogrammetry and modelling software. (Koeva, 2016) 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. It enables 3D reconstruction from both photos and videos by automatically extracting frames and selecting the most suitable ones for computation.

Regard 3D specialized digital image processing software
(https://www.regard3d.org/)
Regard3D is a free and open-source photogrammetry software that uses the Structure from Motion (SfM) method to convert photographs of an object taken from different angles into a 3D model. It offers an extensive set of tools for editing the point cloud, either with coloured spikes or a texture, before generating a 3D mesh. But it might take some time for users to get familiar with using all the settings and parameters that can be adjusted in Regard3D before getting the kind of results they want. However, even if users are new to using photogrammetry software, the Regard3D website provides all the guides and tutorials needed to get started quickly.

Meshroom and Meshlabs specialised digital image processing software
(https://alicevision.org,
https://www.meshlab.net)
Meshroom is an open-source photogrammetry software based on the AliceVision framework. With it, users can generate a 3D model using large images of an object taken from different angles. The software calculates the distance between surface points and creates a mesh.
MeshLab is an open-source solution for processing and editing 3D meshes. It provides a set of tools for editing, cleaning, inspecting, rendering, texturing and converting meshes. It provides functions for processing raw data produced by 3D digitizing tools/devices and for preparing models for 3D printing.

RESULTS AND DISCUSSIONS

The aim of this study was to make a comparison between processing digital images to obtain a 3D model of an object using, in the first case, a specialized, widely used software, available at low cost, and, in the other cases, different open-source specialized software, available online for free download.
Thus, the object under study is represented by the statue of General Ion Dragalina located in Dragalina Park in Caransebeş, western

Romania, which was photographed using a mobile phone, namely the iPhone 12 Pro.

The characteristics of the camera sensor of the phone with which the digital images were taken are shown in (Table 2).

Table 2. Camera sensor features

Main camera	12megapixels
Video Features	4K@24/30/60fps, 1080p@30/60/120/240fps, Dolby Vision HDR, stereo sound recording
Photo Features	Dual Pixel, PDAF, OIS, wide camera, ultra-wide camera, telephoto camera, 2x optical zoom, 3D LIDAR TOF sensor
Telephoto camera	12megapixels
Ultra-wide camera	12megapixels
Front Camera	12megapixels

For the study, a mobile phone was used, and 26 photographs were taken. Each of these photos was taken keeping the same distance from the object, considering, as a main condition, that the image is whole in each of the 26 positions.

To process the 26 digital images that were processed in the field, the four specialised programs described in the previous chapter were used: Agisoft Metashape, 3DF Zephyr, Regard 3D and Meshroom together with MeshLab.

The statue of General Ioan Dragalina (Figure 2) was unveiled on 3 June 1943, depicting the general in a reconnaissance with map and binoculars in hand. It is the work of the Romanian sculptor Mihail Onofrei (http://cnipt-caransebes.ro/zona-turistica/obiective-turistice-din-caransebes/statui/statuia-generalului-ioan-dragalina/)

Figure 2. The object under study: the statue of General Ion Dragalina, Dragalina Park, Caransebeș

Digital image processing and 3D modeling using Agisoft Metashape software

The data processing and modeling using the specialised software consists of the following workflow (Herban et al., 2014):

1) Importing photos via the suggestive command "Add photos" or they can be brought in via the drag&drop method".

2) Selecting the area of interest, in the sense that the program allows the processing of complete images, with the disadvantage that the point cloud obtained will be very dense and will also contain elements that are not important. Also, the processing time will be very long, so it is preferable to crop the images (eliminating the vegetation) using the "Intelligent scissors" tool. Pick points on the outline of the object, in this case points on the outline of the statue and use the "Invert selection" and "Add selection" commands to remove unnecessary parts of the images. Selecting the outline of the object is done by placing a series of points (vertex), and when closing the created polyline, the MASK image for each photo is obtained and saved. This must be repeated for each individual digital image.

3) Once the Mask images have been created, their alignment follows, i.e., the program must identify the common points in each of the positions and determine how to translate them. The result of this step is a point cloud. The joining/triangulation of the photos is done using the "Align photos" command to obtain the point cloud, choosing the high precision option.

4) Build the geometry of the point cloud using the "Build geometry" command.

5) Build Mesh.

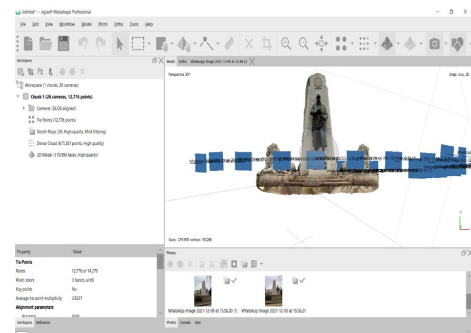The 3D model obtained can be seen in the image below (Figure 3).

Figure 3. 3D model obtained with camera position display

Digital image processing and 3D modeling using the specialized software 3DFZephyr

Although there are notable limitations between the Free and retail versions of this software, it still gives us an overview of how to work with it. The first step is to open a new project and set its parameters. The next step is to import the digital images by using "Workflow" and "New Project" commands. The users should make sure that the following are ticked: "Compute 3D Model after project creation", "Compute Texture after Surface extraction" and "Check online for precomputed camera calibration". Once the options needed have been set, the photos can be imported by using the "Copy-Paste" command. To start modelling the digital images, the "Run" button should be used. To continue modelling, the user needs to call the commands "Point Cloud", "Dense Point Cloud" and "Meshes"(Figure 4).
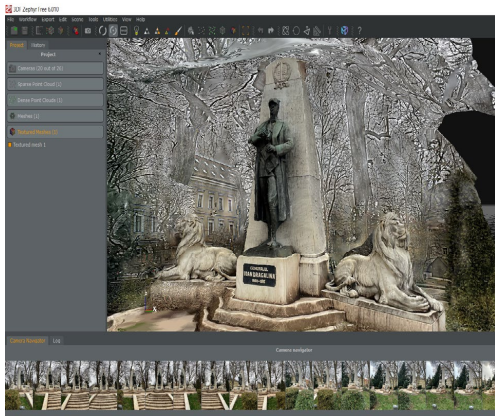

Figure 4. 3D model obtained with camera position display

In the following table (Table 3), advantages and disadvantages of the above mentioned 2 software are presented.

Table 3. Advantages and disadvantages of Agisoft Metashape and 3DFZephyr specialized software

Specialized software	PROs	CONs
Agisoft Metashape	o Better control (manual) of selecting the subject from the background image; o Good quality of the obtained images;	o The manual selection process is very time-consuming; o The way of interacting with the program, as well as the steps required to complete the project, are not intuitive and do not guide the user to
3DF Zephyr (Free)	o For different monuments known worldwide, there is a database where mask selections are already made.	achieve the proposed goal.
	o The initial interaction with the program is friendly; o Almost the whole process is automatic, once the desired settings are established; o It benefits from online databases for the type of camera used/its parameters can also be set manually.	o The quality of the final model is weaker (in the Free version); o Markers cannot be added for scaling (in the Free version)

Digital image processing and 3D modeling using the specialised software Regard3D

Processing of digital images using the specialised Regard 3D software is carried out automatically after they have been inserted (Figure 5).
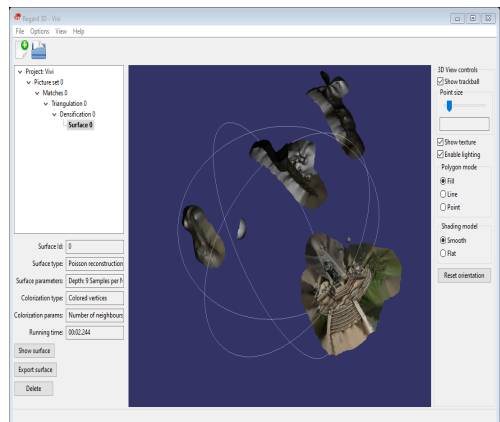

Figure 5. 3D surface obtained

Digital image processing and 3D modelling using specialised MeshRoom and MeshLab software

A disadvantage of this specialized program is that users cannot select and delete information that is extra. Thus, the created model was exported to be further processed with another specialized program, namely MeshLab (Figures 6 and 7).
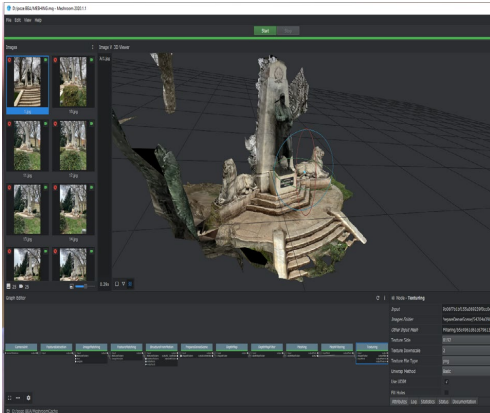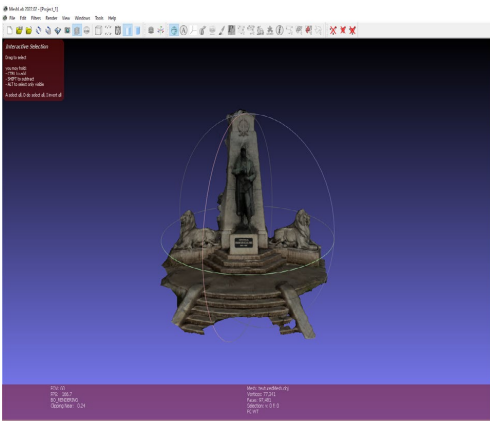
Figure 6. Result in Meshroom

Figure 7. Result in MeshLab

CONCLUSIONS

In carrying out this study, we started from the premise that the implementation of new technologies for various industrial and socially important tasks is a way of promoting low-cost research and documentation methods. For the field of cultural heritage conservation, 3D models have many practical applications, from the implications of their online availability to academic research, conservation and other innovations to come.

Although, it can be said that the result is sensibly the same, the processing manner in the chosen specialized programs is different, mainly due to the working algorithm of each individual software. The more laborious the model creation methodology, the more faithful the representation of the models is to reality. It also

comprises more steps or stages that require appropriate tools and equipment.

Agisoft Metashape is available in 2 versions: Agisoft Metashape Professional Edition and Agisoft Metashape Standard Edition. The first version, the Professional Edition costs $3499 and the Standard Edition costs $179.

In the case of 3DF Zephyr, the Free version was used. The program is fully automated, the user only contributes by pressing commands, processing digital images faster than with Agisoft.

Comparing the two models, the one realized with Agisoft Metashape software is much more accurate, the modelling is complete, whereas with 3DF Zephyr, the statue is not complete and the upper part of its head has not been modelled. Paid software may provide better accuracy.

As for the specialised programs Regard 3D and Meshroom, they have a user-friendly interface, do not require advanced knowledge of 3D modelling, the controls are intuitive, but have the disadvantage that the auxiliary surfaces cannot be deleted, requiring export for further processing in another program, in this case MeshLab. It also does not require higher performance requirements of the technical specifications of the computer on which the processing is performed.

For the processing of the 26 digital images in order to obtain the 3D model of the statue of General Ion Dragalina, a Dell laptop with an 8th generation Intel® Core™ i5-8250U processor has been used. The first 3 programs ran on this PC, but for the processing using the specialised MeshRoom program a much more powerful computer was needed. Thus, the processing was done on a gaming laptop, the Asus Rog Strix G with a 9th generation Intel Core i7 processor.

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