IMAGE-BASED 3D RECONSTRUCTION OF BUILDINGS FOR AUTOMATED CONSTRUCTION PROGRESS MONITORING

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Abstract: Three dimensional models are the next step from 2D models, which come with a third-dimensional addition bringing more information about the spatial objects they represent. These models can be obtained by methods such as laser scanning or image-based reconstruction, each with its own advantages and disadvantages.

Image-based 3D reconstruction has been applied in many fields, such as civil engineering, where topics such as earthquake prevention and disaster reduction, construction monitoring, and smart city construction have been studied.

In this paper, we propose to create the 3D model of the historical building Izvoranu - Geblescu based on the images taken with the drone and supplemented with the images obtained with the mobile phone, despite its height and the vegetation, respectively the trees around it. The study also explores the applicability of two 3D modeling software products in the present situation as well as the shortcomings of each of them.

Keywords: 3D modeling, civil engineering, spatial objects, control points

1. Introduction

Three-dimensional modeling of an object can be seen as the complete process starting from data acquisition and ending with an interactive 3D virtual model on a computer.

Along with the development of digitalization in many fields, 3D modeling has emerged as a problem of great interest in scientific research. For decades this technology has been used in many civil engineering applications, in the assessment of earthquake damaged structures, construction monitoring and the development of GIS systems technology.

Reconstruction and three-dimensional modeling of buildings from images is a very active research field in recent decades. Digital building models have a wide range of applicability, such as urban planning, population density analysis, disaster management, solar potential assessment.

Although fully automatic reconstruction of a building has long been researched, no such automatic system has yet been created. The 3D reconstruction of buildings without any manual intervention continues to be a scientific challenge, given the fact that they are complex objects with many architectural details, shape variations and various aspects. In addition, the buildings are located in urban scenes that contains various objects, that can prevent direct observation of the building.

The importance of 3D building reconstruction is due to its potential for using 3D models of cities in urban planning, damage assessment, monument conservation, architecture and digital tourism.

2.   Presentation of the Study Area, Materials and Equipment

2.1.   Presentation of the Study Area

The building chosen for the case study is located in Brabova Village, Dolj County and represents a fortified building, named Izvoranu – Geblescu (Fig. 1). It is located 30 km from the city of Craiova and is part of a project that aims to learn about a significant part of the history of Oltenia. Thus, from the year 2019 for the building Izvoranu Geblescu, the rehabilitation works began, these being completed in the year 2021.

(a)   (b)

Fig. 1. (a) Location of historical building Izvoranu Geblescu and (b) the building in 2022

2.2.   Materials and Methods

The images were taken using the DJI Phantom 4 RTK drone (Fig. 2) by following some basic rules: photographing the building all around, including the building in most part of an image, ensuring that there are no moving objects in the background while shooting, due to the size of the building, lateral movement from one end to the other so that the images overlap, i.e. the building appears in several images, for a good 3D reconstruction result, ensuring a constant light between images.

Fig. 2. The photogrammetric equipment – DJI Phantom 4 RTK drone

Due to the vegetation and the tall trees near the building, photographing with the help of the drone was quite a difficult task. To complete the images needed to create the 3D model, images were also taken with the iPhone 13 Pro Max mobile phone. 166 drone images and 154 mobile phone photos were taken.

2.3.   Data processing

Two software products were used for image processing, namely Autodesk ReCap Photo and Agisoft Photoscan.

Because Autodesk ReCap Photo software was used with an educational license it had a cloud processing limitation of 100 images per project. This, for the total processing of a relatively large building such as historical building Izvoranu Geblescu is impossible. Thus, each facade was processed individually. The reintegration of the building model by gluing the models of the 4 facades resulting from the processing was done with „Cloud Compare" which is an open source tool.

During the processing with the Agisoft Photoscan software, only the pictures taken with the drone were used, which allows the use of a larger number of images to obtain the 3D model of the building.

3.   Results and discussion

3.1.   Processing with Autodesk ReCap Photo

Because drone imagery contains GPS metadata such as latitude, longitude, and elevation, ReCap Photo uses this information to scale and geospatially locate the 3D model.

First, facades were processed by choosing the Aerial type reconstruction, processing that uses the images taken with the drone using the appropriate coordinate system for the location where they were made.

ReCap allows the assignment of ground control points so that the resulting 3D model is aligned to the measured coordinates. A minimum of three control points is required to process, and for each control point it is mandatory to correlate with a minimum of 4 images that contain it.

When processing is complete the result can be accessed from My Cloud Projects. Five files are obtained after processing: .fbx, .fbx.zip, .jpg, .rcm and .report.zip. The software also generates a Project Report. The obtained model (Fig. 3) can be cleaned by using the editing tools.

Fig. 3. Result of processing of two facades

For the processing of the other two facades (Fig. 4), the software product did not allow the realization of their 3D model, the reason being the abundant vegetation near the building in front of them, which did not allow the creation of a sufficient number of pictures with the help of the drone for this type of processing.

However, in order to create these two facades and for a better quality of the obtained 3D model, the images taken with the drone were supplemented with images taken with the mobile phone. Thus, 100 images were processed for each facade.
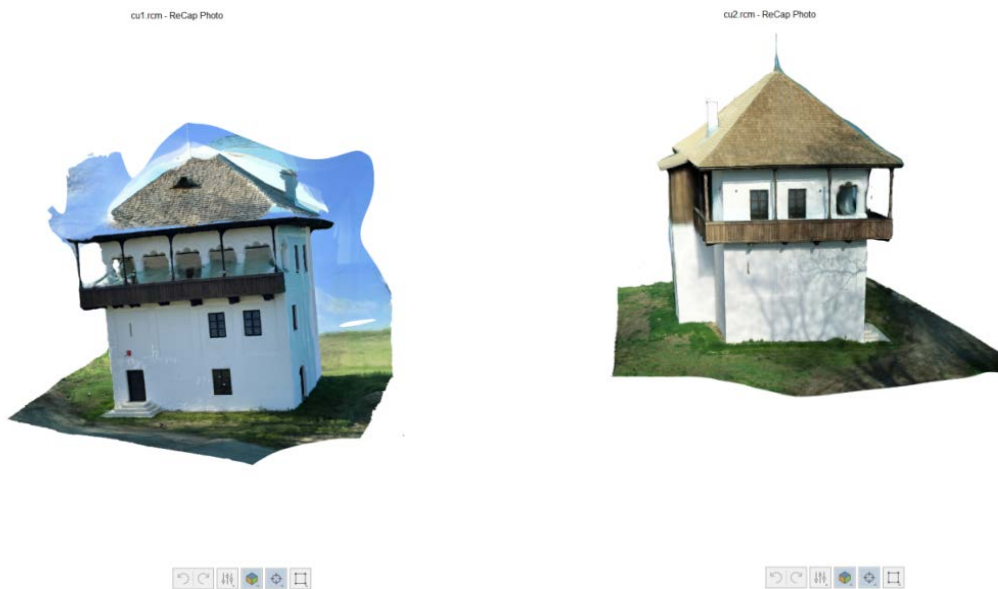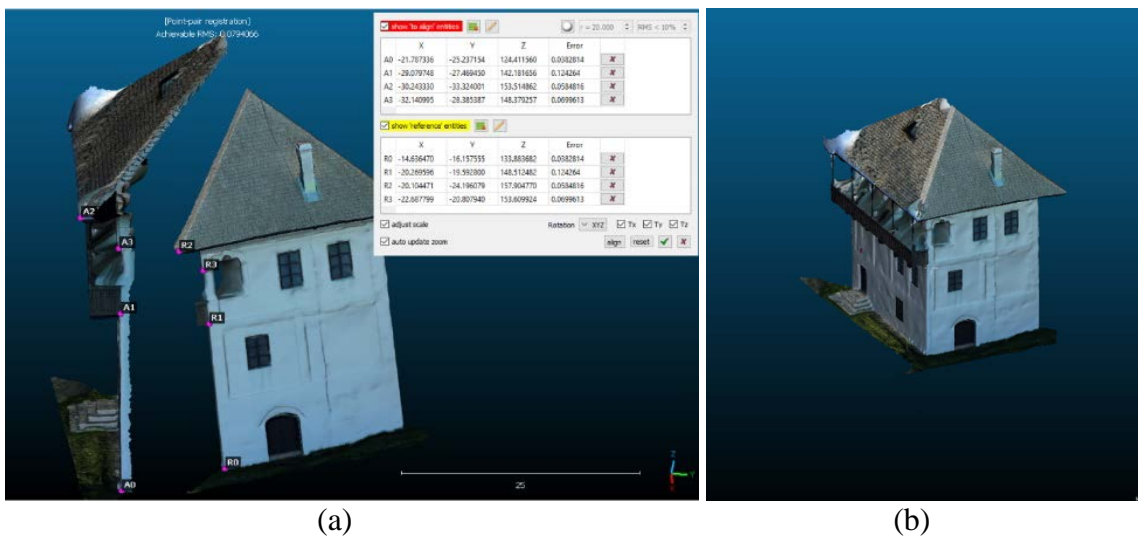

Fig. 4. Result of processing of the other two facades

Furthermore, to complete the 3D model of historical building Izvoranu Geblescu, the software product CloudCompare was used, where the facades were aligned (Fig. 5) according to the common sides.

(a)　　　　　　　　　　　　　　　　　(b)

Fig. 5. (a) Matching the facades and (b) the result

3.2. Processing with Agisoft Photoscan

Using Agisoft PhotoScan photogrammetric software after importing the taken images all the steps in the Workflow menu have been run: Align Photos, Build Dense Cloud, Build Mesh and Build Texture.

The first step is to align the photos (Fig. 6). At this step the software looks for the link and key points, i.e. the corner points on each image. After that compares the local keypoints around the connection points to match them between the images. The global optimization of all images determines: the 3D position of the connection points, the position and orientation of the camera for each image, the camera parameters such as the focal length and the distortion model.
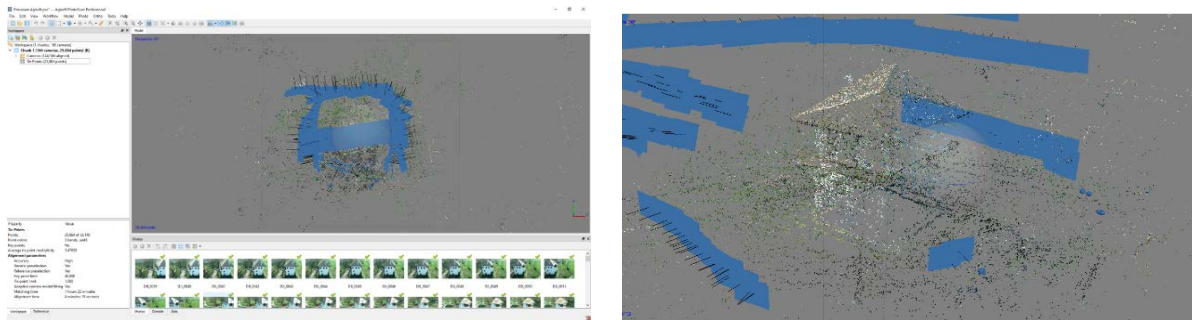

Fig. 6. Image alignment result

The next step is to calculate the dense cloud (Fig. 7). In this step PhotoScan calculates the depth information for each image and combines it into a single point cloud.
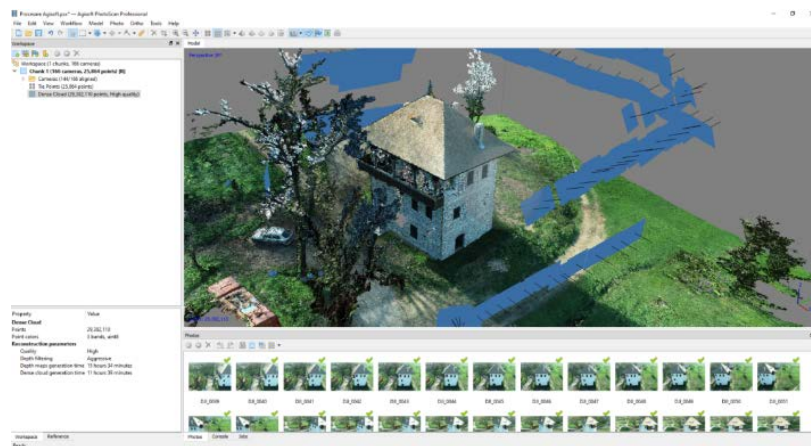

Fig. 7. Dense cloud point generation result

The last steps are to generate the 3D mesh (Fig. 8) and calculate the texture (Fig. 9). The software projects and merges images onto the model to generate the texture. The size of the texture has a significant effect on the final yield. After generating the texture we get the 3D model of the building.
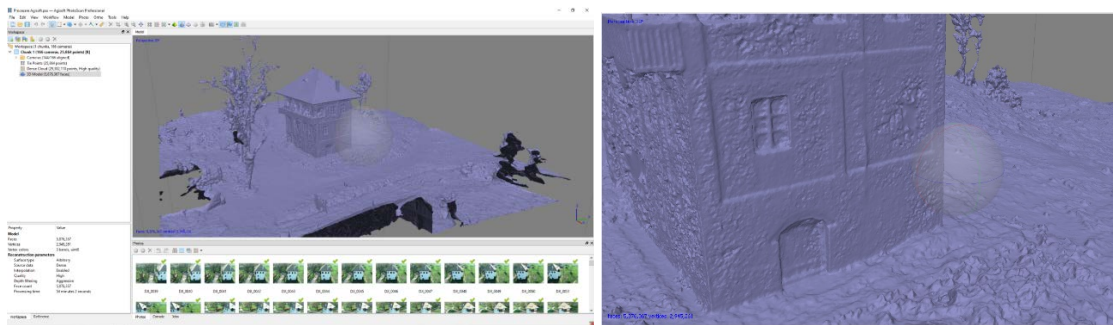
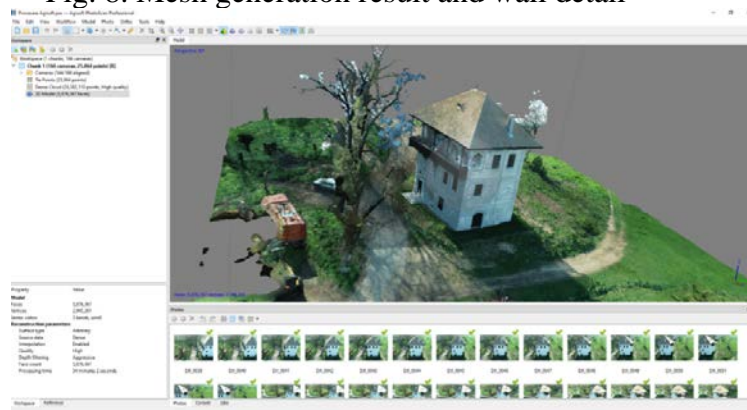Fig. 8. Mesh generation result and wall detail

Fig. 9. Texture generation result

After the structure of the digital model has been built, certain contextual adjustments can be made manually and the model can be cleaned up by removing areas of no interest. Once this stage is completed, it can be considered that the model is in the final stage (Fig. 10).

Fig. 10. Final result

4.   Conclusions

Nowadays the use of drones offers new possibilities in a wide range of applications. An example is the 3D reconstruction of buildings. Drones are able to observe the entire 3D scene and capture complete images of the object of interest from different perspectives.

The purpose of this work was to create a three-dimensional reconstruction of a fully automatic building based on images taken with a drone. For this, two 3D modeling software products were used, namely Autodesk ReCap Photo and Agisoft PhotoScan.

The workflow in each of the two products was different. ReCap Photo involved a cloud-based modeling process, compared to Agisoft PhotoScan which required desktop-based processing directly related to hardware capabilities.

The major difference between the two products is that ReCap Photo does not allow for project manipulation or quality control. Unlike it, Agisoft PhotoScan allows to modify projects to a certain extent, having a more informative and explicit workflow.

Another limitation of the ReCap Photo product was the use of a limited number of 100 images, insufficient for the reconstruction of a building. PhotoScan's image upload capacity was more generous, although there were trade-offs between the large amount of images and computer power, processing time, and RAM.

The result produced by ReCap Photo highlighted the fact that the software product is capable of generating a good quality textured 3D model, but the need to use another software product to complete the 3D model of the building is a major inconvenience, since the final product does not have spatial references. On the other hand, Agisoft PhotoScan generated the full 3D model of the building quite well textured with the major difference being the georeferenced result.

Taking into account all the limitations that have been discussed previously, in this study we analyzed the applicability of the two software products through a case study, as well as mainly through visual inspection; thus, it would not be sufficient either to assess the technical accuracy of the results or to determine which software was better.

Furthermore, despite the differences identified as a result of the comparison, it could be suggested that both software products are useful for photogrammetric projects, and the choice of one or the other largely depends on many aspects of the users, including purpose, budget, requirements, etc.

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