

Visualization of real objects using solid modelling

Crîngaş Marius Daniel, Călin Alexandru

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Abstract

3D modelling is the process of reconstructing the shape and dimensions of an object for further use and processing. The main technologies used in measuring include total stations, GNSS, imaging sensors, laser scanners or LiDAR systems. By using close-range photogrammetry and the Photomodeler software we will present the steps for obtaining a 3D model of the Lutheran Church in Bucharest and will discuss the advantages and disadvantages of this method.

Keywords

Photogrammetry, Calibration, 3D Modelling, Photomodeler, Architecture.

1. Introduction

In the last two decades, digital close-range photogrammetry has found many ways for extracting geometric data from objects, combining technologies such as CAD, digital image processing as well as graphic and 3D modelling software. Dimension of the objects varies from small biological cells up to large buildings and archeological sites.

Applications of close-range photogrammetry can be found in areas such as archeology, architecture, medical field, crime scene investigations, industry, etc. The methods and techniques used in aerial photogrammetry, which are well developed and understood, have been adapted to close-range photogrammetry.

Images offer a large amount of information about real-world objects and using them in the modelling of virtual realities result in the increase of overall quality of 3D models.

The advantage of using this method is that the field operations are limited only to image acquisition (and in the case of an absolute positioning a topographic survey can be executed for obtaining control points). The main processing can be done afterwards, because the geometry of the object is stored in the photos. In this case, if a building is damaged or destroyed and photos of it are available, photogrammetry could provide enough data for the reconstruction.

This paper presents the steps of obtaining the 3D model for the Lutheran Church in Bucharest [Fig. 1]. The construction began in 1851, being a basilica-type hall, and the interior is in the shape of a rectangle with balconies around it.

Obtaining the textured 3D model means the complete process which starts with data acquisition, continues with geometry extraction and finally the resulting virtual model viewed using a computer.

The main aspects which should be considered in the first phase are determining the camera positions around the object, the need of coded targets and camera calibration.



Fig. 1 Lutheran Church in Bucharest

A successful software for close-range photogrammetry is Photomodeler Scanner, developed by EOS Systems Inc. from Canada. It's a Windows based system and allows the measuring and transformation of images into 3D models. It also includes a feature for camera calibration.

2. Camera calibration

A non-metric camera is the one whose inner orientation is unknown or partially known and is characterized by the lack of reference indices.

To perform this step, the program generated a 2D coded grid which was positioned on a plane surface and photographed with a camera mounted on a tripod [Fig. 2].

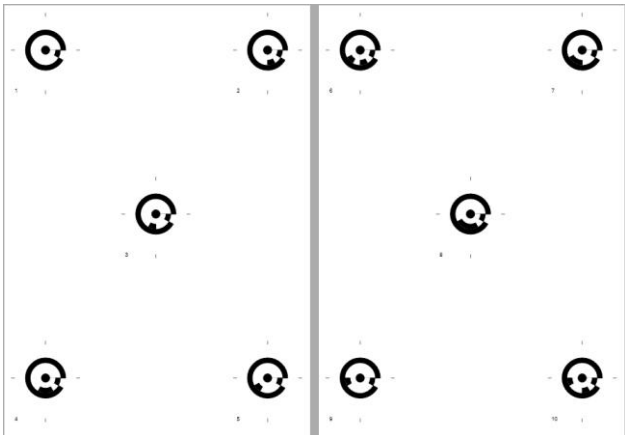


Fig. 2 Coded target calibration multisheet

Three calibrations were executed, one for each focal length used. The camera was positioned on each side and have been acquired images in the following sequence: four images oriented Landscape, four images oriented Portrait (camera turned to right) and four images oriented Portrait (camera turned to left) [Fig. 3]. Twelve images were acquired in total, the main purpose was so that the grid would cover as much of the surface of the sensor. For better

results, it is recommended to photograph the calibration grid in the same environment where the images of the object are acquired, thus compensating the effects of temperature and humidity on the camera.

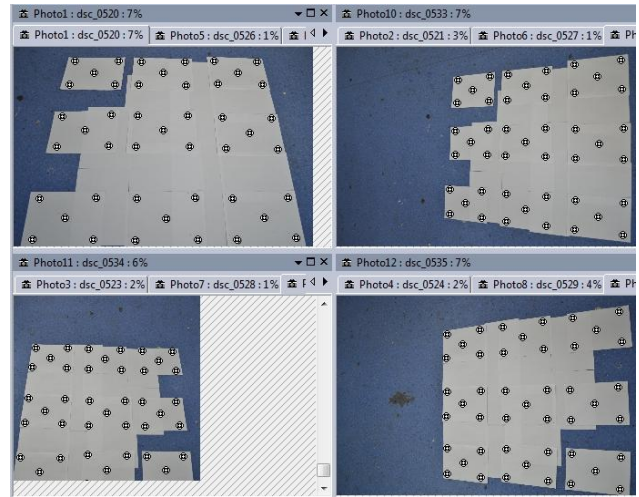


Fig. 3 Automated recognized targets

After the automated calibration we obtain the camera parameters for the focal length used. These parameters are focal distance, coordinates of the principal point, radial distortion coefficients (K1, K2, K3) and the coefficient for the lens optical axis eccentricity [Fig. 4].

Name NIKON D3100 [18.00]		Used by Photos 1,2,3,4,5,6,7,8,9,10,11,12	
Calibration Type Calibrator (multisheet)		Image Size W: 4608 H: 3072	
Focal Length 19.3052		Fiducials Type: No Fiducials Fiducials: mm	
Format Size W: 24.0150 H: 16.0000		EXIF Fields Make: NIKON CORPORATION Model: NIKON D3100	
Principal Point X: 12.0223 Y: 8.0444		Focal Length 18.0000	
Lens Distortion K1: 2.296e-004 P1: 4.444e-005 K2: 2.781e-008 P2: 1.067e-005 K3: 0.000e+000		Format Size W: 24.0000 H: 16.0000	
Calibration Quality Values Overall Residual RMS: 0.2126 Maximum Residual: 0.7485 Photo Coverage (%): 89			

Fig. 4 The results for the 18mm calibration

The best calibration was achieved for the 35 mm focal length, resulting a 0.12 pixels overall residual RMS, with a

photo coverage of 86%.

3. Data acquisition

The data required for achieving this model split in two categories: photogrammetric data (required for measuring the points of the model) and survey data (for scaling the model).

In most cases using a single pair of photos isn't enough for reconstructing a complex building. Therefore, a large number of overlapping photos will be used for the desired object.

There were selected 55 images from the camera [Fig. 5]. These were acquired only from eye-level (at around 1.8 meters above ground), in this case many superior parts of the building couldn't be photographed resulting in "hidden" parts of object.

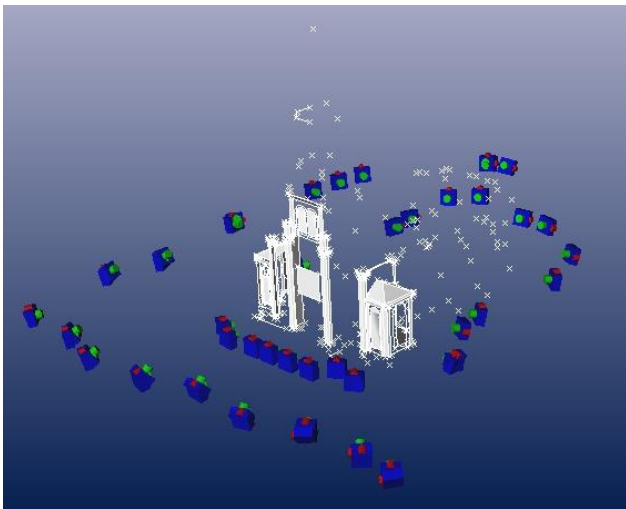


Fig. 5 Camera positions

The nearby building made the work difficult in achieving the best angles of the photos and some of them don't cover the entire object. The shape of the object and the presence of some natural obstacles gave the need of using several focal lengths in acquiring the photos. These focal lengths are:

- with the lens at 18 mm focal length for the whole building including parts of the tower [Fig. 6]
- the 24 mm focal length in order to photograph the main facade of the
- the 35 mm focal length to photograph the details on the tower.

The format used for the photos is JPG, with the resolution of 4608x3072 pixels. The greater the resolution, the better we could mark details as control points precision. The acquisition was made using the same configuration of the camera, in "Manual" mode.

For scaling the object, lengths were measured on the object. There were measured the width of three windows with the values: 142 cm, 142 cm, and 214 cm [Fig. 7].



Fig. 6 Photos taken using 18 mm focal length

Because of the size of the building, we couldn't use coded targets, because there needed to be positioned on the entire surface of the building. In that case, correspondent points on the photos will be selected manually.

Another aspect which was taken in consideration was the lighting of the object and avoiding shadows. For this reason the data acquisition in the field was held on a cloudy day.

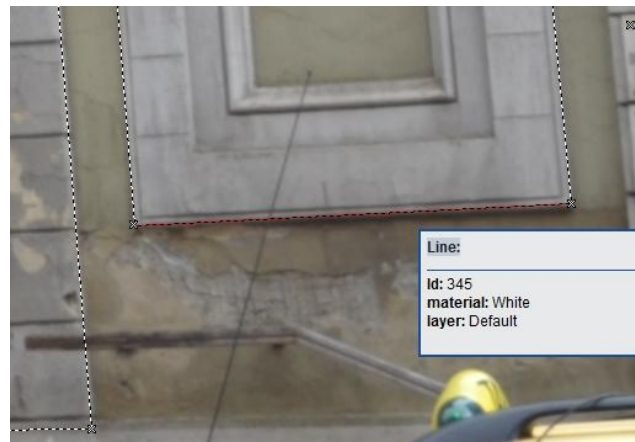


Fig. 7 Length measured on the building

4. Constructing the 3D model

All the inserted images were programmed to identify and use the parameter set for their respective focal length. For bringing the photos to an optimal form, the "Idealize Project" feature is used. In this step, the camera distortions are eliminated, the pixels are made square and the principal point is brought to the center of the image [Fig. 8]. The smaller the focal length, the greater the distortions.

The reference points were selected manually and represent corners of the building and details easy to identify and mark. Between two adjacent photos the correspondent points will be marked. After this process the program goes into orienting the photos.



Fig. 8 Idealized image

To determine the outer orientation three control points on the object are needed.

The adjustment of the project is iterative, and the software does this using the "Process" command. If the control points haven't been marked correctly, processing will fail [Fig. 9].

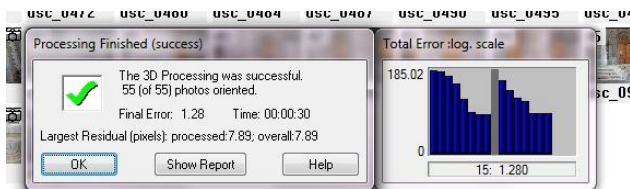


Fig. 9 The result of the processing

The processing report show us information about the outer orientation parameters for each photo in the project. Also, the residuals of the control points are offered [Fig. 10].

For obtaining the final model, we have considered dividing the project into two sub-projects. Because we used a 35 mm focal length for the modelling of the tower, these photos were taken with a good coverage for the lower part of the building.

Using the connection points from both sets, we managed to integrate and orient the images of the tower in the rest of the project.

After orienting all photos, the next step is the solid modelling of the object through marking details and drawing lines, which result in polygons used for creating textured surfaces [Fig. 11,12].

Using the "External Geometry" feature we attach the length measured on the real object with the line in the model. This step brings the model to its natural scale. For a better constraining the model three such lengths were measured and associated to their respective lines [Fig. 13].

In the "3D Viewer" the result of the modelling can be viewed. Photomodeler has the following viewing options:

- points and lines [Fig. 14],
- wireframe,
- shaded [Fig. 15],
- fast textures,
- Quality textures.

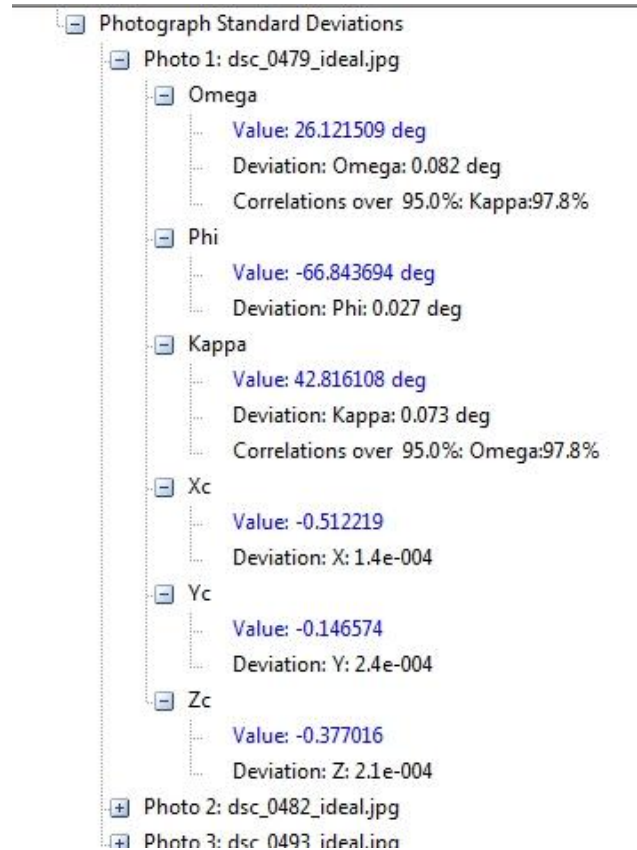


Fig. 10 Outer orientation parameters for photo 1



Fig. 11 Extracting geometry features from the photos

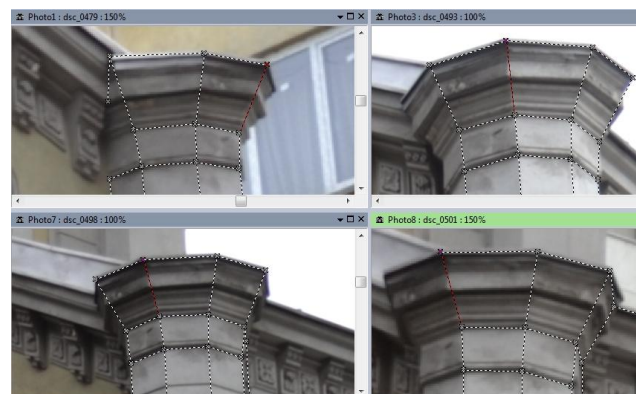


Fig. 12 Extracting geometry features - detail

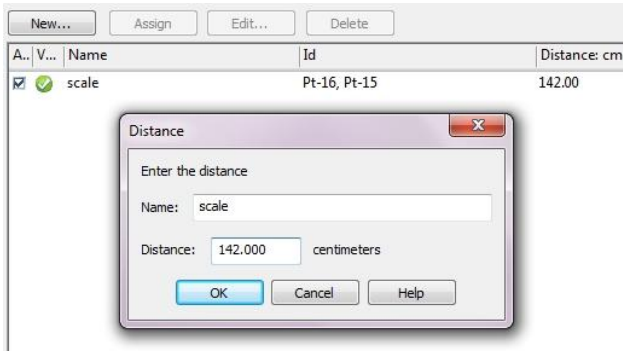


Fig. 13 Scaling the object



Fig. 14. Viewing the model with points and lines

The results of the solid modelling are:

- 2D orthophotos
- 3D model with lines and textured surfaces [Fig. 17]
- point coordinates list

Exporting the data can be done in the following formats: AutoCad 3D, 2D (.dxf) [Fig. 18], 3Dstudio (.3ds), VMRL (.wrl), Rhino (.3dm), Maya Script (.ma). This allows for transferring the model into a 3D software, where it could be used for various purposes, such as shaping virtual realities for web pages or even an urban GIS. There are numerous

programs which work with 3D models, and most of them recognize the formats exported by Photomodeler.

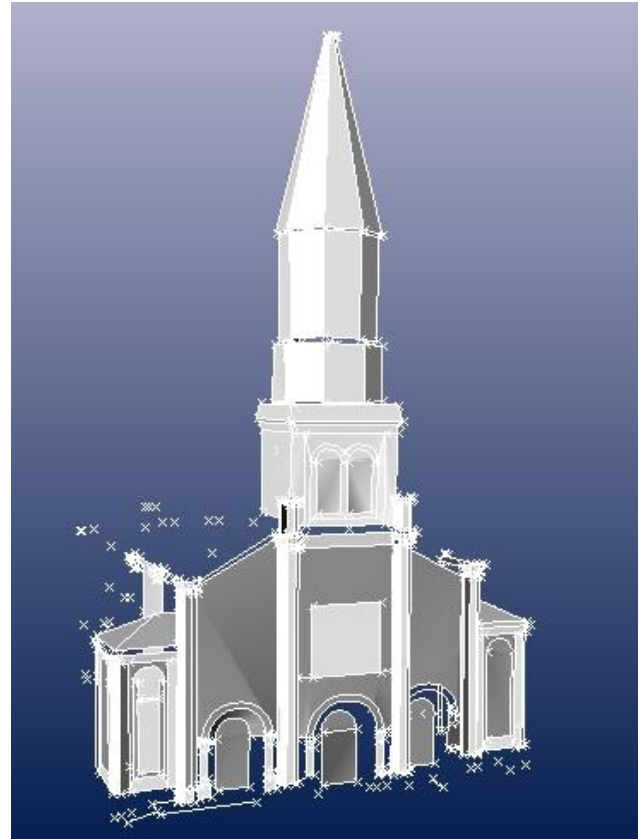


Fig. 15. Viewing the model with shaded surfaces

For each surface an original texture can be associated, choosing in the Properties Panel the photos which is used for extraction [Fig. 16].

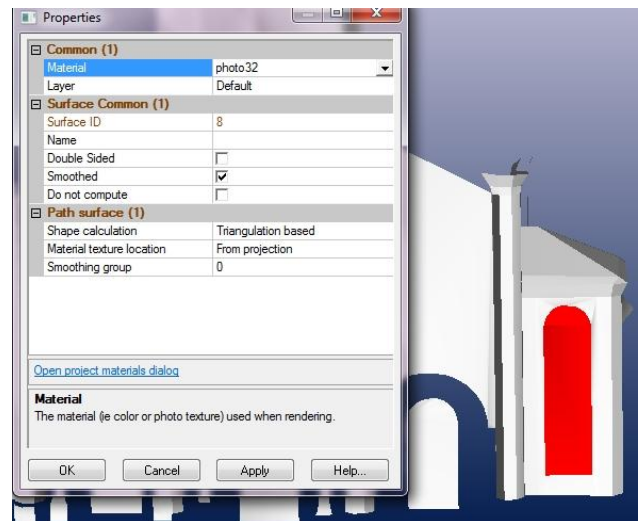


Fig. 16 Adding real textures to each surface

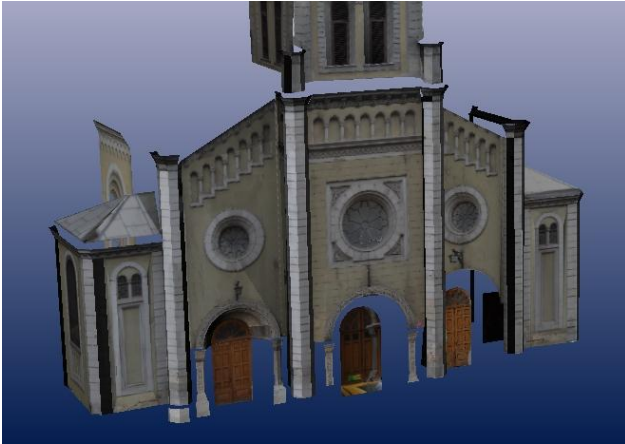


Fig. 17 The main facade with real textures

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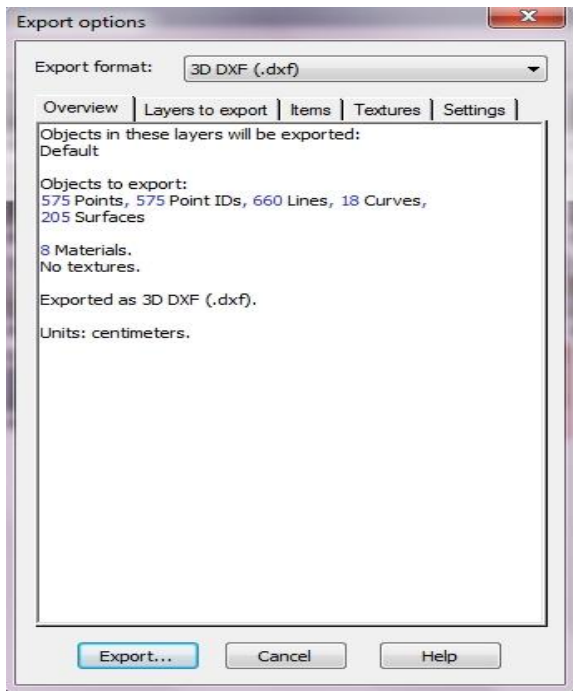


Fig. 18 Exporting geometry in .DXF format

5. Conclusions

Despite other technologies, such as terrestrial laser-scanning, close-range photogrammetry offers a fast and cheap alternative. The main advantage is the short time of data acquisition. In the field, we should consider that acquiring the photos should not be affected by the presence of large objects nearby which could reduce the field of view.

For a quality digital model, we recommend using many geometric constraints and there should cover all the surface of the object.