

## 3D BUILDINGS MODELLING BASED ON A COMBINATION OF TECHNIQUES AND METHODOLOGIES

Georgeta Pop (Manea), Alexander Bucksch, Ben Gorte

Delft Technical University, Department of Earth Observation and Space Systems, Delft, the Netherlands -  
(g.pop, a.bucksch, b.g.h.gorte) @tudelft.nl

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### ABSTRACT:

Three dimensional architectural models are more and more important for a large number of applications. Specialists look for faster and more precise ways to generate them. This paper discusses methods to combine methodologies for handling data acquired from multiple sources: maps, terrestrial laser and additional measurements, together with digital images for the purpose of generating the 3D visualization of selected buildings.

The information used in this kind of projects may have numerous inputs: 3D laser scanning, total stations, digital photogrammetry, laser altimetry, maps - all of them in combination with data generated from other various disciplines and related to the project's purpose. All 3D data gathering techniques show significant improvements in resolution and accuracy. In this context, aerial and close range photogrammetry, airborne or terrestrial-based laser scanning, mobile mapping and GPS surveying are also on the same trend. A variety of approaches with different resolutions, accuracies, methods, completion times, stages and costs exist. In this paper, an approach towards 3D modelling of buildings and information collection using combined data from digital photogrammetry, mobile mapping, laser scanning, conventional surveying and cartography-based reconstruction, is considered.

## 1. INTRODUCTION

### 1.1 General Instructions

In the past, photogrammetric multi-image systems were used together with enlarged analogue images placed on digitizing tablets. Two or more overlapping photographs taken from different angles were usually handled with those kinds of systems. Currently, software applications may process image data based on digital and analogue imaging sources such as pictures from semi-metric or non-metric cameras (Kasser, M. and Egels, Y., 2002).

The 3D reconstruction of buildings has been an active research topic in Computer Vision as well as in Digital Photogrammetry in recent years. 3D building models are increasingly necessary for urban planning, tourism, etc. (Suveg, I., Vosselman, G., 2000).

In the 3D modelling field, terrestrial laser scanning is becoming more and more important. Laser scanners can produce around 125.000 points/second all located in a 3D space. The terrestrial Laser Scanner instrument used for the building considered in our paper was a FARO LS880, which belongs to the family of phase based laser scanners. To acquire the distance between the optical centre of the scanner and the object-surface, e.g. a façade, this type of scanners measures the phase difference between the emitted laser beam and the returned laser reflection. Thus, the 3D-points obtained from a laser scanner do not correspond to a building feature. On the other hand, in the photogrammetric approach the 3D points are known features like corners, edges, etc. We should keep this in mind during the following comparison.

## 2. HARDWARE

### 2.1 GPT 7003i-Topcon total station

The versatile GPT 7003i total station from Topcon's GPT-7000 series gives us up to 250 m reflectorless range measurements and up to 3000 m with a prism. Dual optical EDM design it maintains focused beam accuracy and allows us to measure only the target we select even at long distances. Captured site photos are incorporated into the measurement data to superimpose design points or stakeout points.

### 2.2 Canon EOS 350D

We used for our project a Canon EOS 350D photo camera with the following specifications named in the technical description of the manufacturer: a sensor resolution of 8.0 Megapixels that matches an image size of 3456 x 2304 pixels and a three times optical zoom with a focal length between 18-55 mm.

### 2.3 FARO LS880

The FARO LS880 laser scanner has a maximum vertical field of view of 320° with an angular resolution of 0.009°. In the horizontal direction the field of view is 360° with a resolution of 0.00076°. The scanner operates in the near infrared spectrum at a wavelength of 785 nm. The maximum scanning speed is 120000 points (3D measurements) per second. In our project we used angular resolutions of 1/5 or 1/4 from the maximum resolution.

### 3. SOFTWARE

#### 3.1 AutoCAD 2007

Made by Autodesk, this is a software application widely used for 3D modelling. The same CAD principles of 3D architectural modelling apply to any object from toasters to the "Taj Mahal" building. For example, the 3D model in AutoCAD can be generated using surfaces and solids. Creating 3D objects is a lot easier than before, because the process is more interactive and there's more visual feedback as you work. You just drag across to create the base and drag up (or down) to create the height. Or you can enter exact measurements. Other solid commands use the same interactive process and you can use complex solids like the pyramid and the helix.

#### 3.2 PhotoModeler

PhotoModeler is a software application developed by Eos Systems Inc. (Canada), used for photographic 3D modelling. In order to create the 3D model of a building with the help of PhotoModeler, we need multiple photos that have a good resolution and with a good coverage.

#### 3.3 Semi-automatic registration procedure

This procedure is developed by the Department of Earth Observation and Space Systems from TU Delft and is used for registering the point cloud data. The method is based on a least square adjustment in the Cartesian 3D space of features. These features were extracted from the intensity images obtained with the laser scanner (Kang Z., 2007).

#### 3.4 FARO Scene

Made by FARO Technologies, Inc. – this is a modern tool, mainly used for controlling the scanner and registering the point cloud data. The registration process can be done either with natural targets (like corners) or with the help of spherical targets. Further more, it is also possible to set the scanning parameters like horizontal and vertical angle resolution. During scanning we have the possibility to get a real-time overview of the scanned environment and therefore we can easily manage the quality of our measurements (Pop G., Bucksch, A., 2007).

## 4. 3D MODELLING

#### 4.1 Modelling data from Total Station

The study was made using the 3D model of the „Faculty of Electrical Engineering, Mathematics and Computer Sciences” building from TU Delft’s campus. The measurements were taken with a GPT 7003i-Topcon total station and processed with the Topcon Link software. Pictures of the surveyed points and site were made directly using the total station but also with a digital non-metric camera Canon EOS 350D. Laser technology instead of infrared measurements was used for acquiring the points with a  $\pm 5\text{mm}$  precision. The 3D model was realised with AutoCAD 2007 software.

More than 400 points have been measured and calculated for the 3D model. These points were exported from Topcon Link as .dxf files and then imported into AutoCAD. The 3D model was generated based on surfaces and solids from measured points using AutoCAD 2007.

Figures 1, 2 and 3 illustrate the resulting model in different representations and from different views.

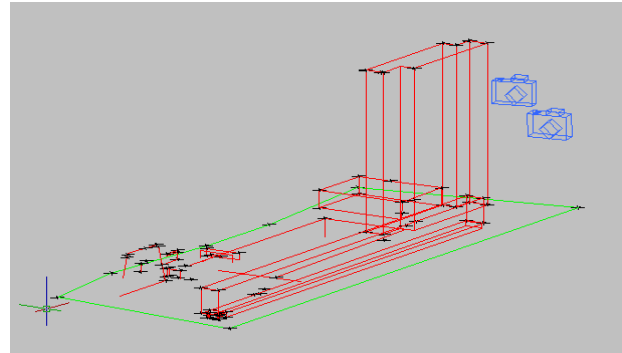


Figure 1. Measured points

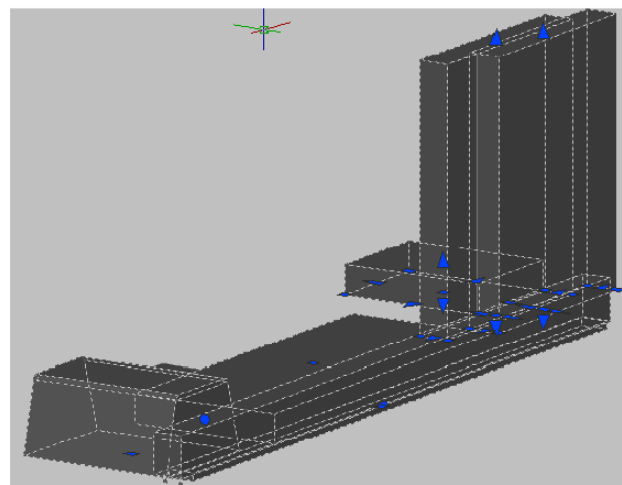


Figure 2. Surfaces and solids

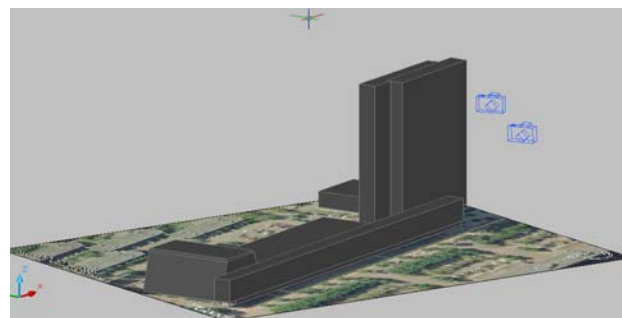


Figure 3. Rendering of the 3D model

#### 4.2 Modelling from Photographs

The 3D modelling using the version 5 of the PhotoModeler application was based on pictures of the same building (mentioned in the previous paragraph). A Canon EOS 350D photo-camera was used during the picture acquisition phase and the images were imported into PhotoModeler. The calibration of the camera was done with a focal distance of 18mm. By choosing appropriate viewing angles at the building, only 8 pictures were necessary. For the two-by-two adjustment of the pictures we used at least 6 common points for each pair of images.

The number of the common points taken into account is a very important aspect: the higher this number is, the better the accuracy of our model is. Based on the referenced pictures we marked the points and the lines that compose the 3D model of the building and we added the photo texture with the help of surface option – path mode.

Figures 4 and 5 exemplify the resulting model in different representations and from different views.



Figure 4. 3D model of the building - with texture



Figure 5. 3D model of the building - view from left side

### 4.3 Point Cloud modelling

We measured the „Aula Congress Centre” building in the TU Delft site with a FARO LS880 laser scanner. The building was surveyed from 20 scans that resulted in a global data set of about 14,000,000 points processed with the FARO Scene software and with the semi-automatic registration method.



Figure 6. Aula Congress Centre - TU Delft

For the registration process we tried two different applications:

- the semi-automatic registration method
- the FARO Scene software.

In the first case we need 3 corresponding points to register every combination of two scans. All the scans were globally registered with a residual error (RMS) of 10 mm.

Figures 7 and 8 show the resulting model for a section of the building and for whole the building.

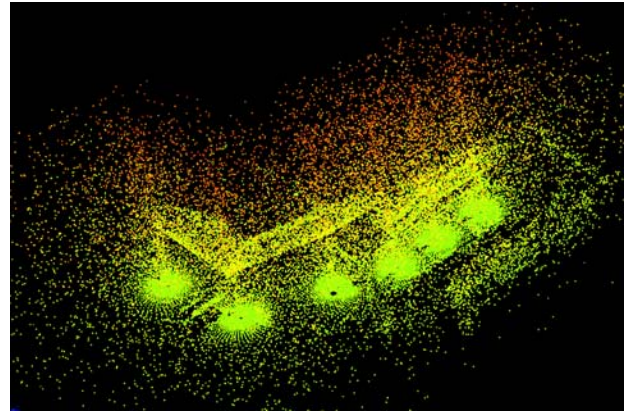


Figure 7. Cloud points from 6 scans after registration

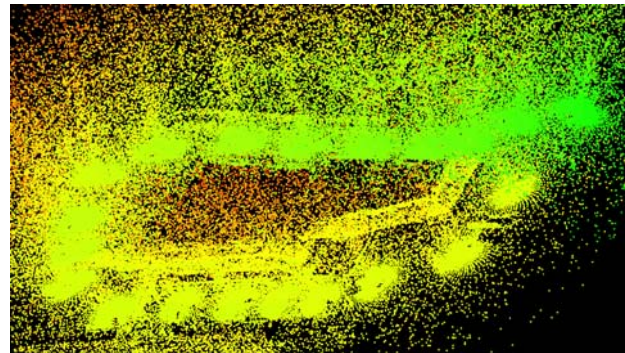


Figure 8. Cloud points for the whole building after registration

In the second case we used for the registration process the FARO Scene software and we achieved the results listed in the table 1.

With the use of spherical targets we achieved a less time consuming registration procedure, by fitting spheres into the points cloud. The points of the fitted spheres are the input values for the ICP-Algorithm (Besl, P.J. and McKay, N.D. 1992).



Figure 9. Registration using spherical targets in FARO Scene

Figure 10 shows the 2 points, 1 plane and 2 spheres we used and table 1 summarizes the accuracy we have achieved with Faro Scene.

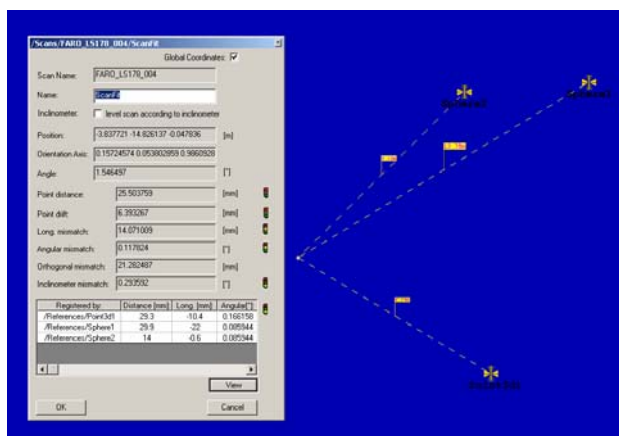


Figure 10. Registration with 2 spherical targets and one corner point

Registration accuracy	Spherical Targets
Point Drift (mm)	6.39
Angular mismatch (°)	0.117
Orthogonal mismatch (mm)	21.29
Long mismatch (mm)	14.07

Table 1. The registration accuracy in FARO Scene

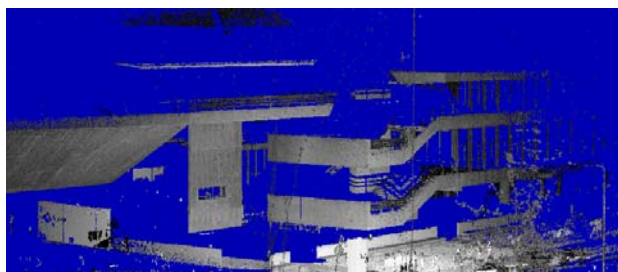


Figure 11. Cloud points for two scans after registration in FARO Scene

## 5. CONCLUSION AND FUTURE WORK

### 5.1 Total Station

#### 5.1.1 Advantages:

- Easy to use topographic equipments and techniques.
- Standard modelling software, like AutoCAD or 3ds Max®, can be used to generate the model from the surveyed points.

#### 5.1.2 Disadvantages:

- Surveying with topographic equipments and techniques it is time consuming especially during the measurements phase.

### 5.2 Photogrammetry

#### 5.2.1 Advantages:

- Easy to use because we can be flexible in choosing the type of source images and cameras: metric or non-metric
- Several software packages are available to choose from. Some examples: Photomatrix, Apollo Photo3D, DigiCad 3D, etc.

#### 5.2.2 Disadvantages:

- We have to do a precise camera calibration because this is a very important process that influences the quality of 3D model.
- Image resolution is related to the type of the camera used to acquire the pictures - usually the capabilities of even the most advanced cameras are not sufficient for some projects.
- Hard to use in the case of tall buildings.

### 5.3 Laser scanning

#### 5.3.1 Advantages:

- Fast acquisition of a huge amount of 3D data in a short period of time (125,000 points/second), making the laser scanning probably the most efficient method for data acquisition.
- Good metric accuracy - depending of what instrument we use, it can be millimetre precision. (Bucksch, A., Lindenbergh, R. and van Ree, J., 2007)

#### 5.3.2 Disadvantages:

- Not so developed 3D modelling capabilities – for example modelling edges in software applications like FARO Scene is not an easy job.
- The huge amount of measurements makes data handling difficult, requesting some special hardware and software requirements.

Loss of data because of occlusions is the most common problem for total station, photogrammetry or laser scanning. And filling these holes is mostly done by manual work.

Considering this we may conclude that total station, the image approach and the laser scanning are not competitive but rather complementary methods. The selection of the measurement method (reconstruction system) depends on many factors: budget, application, object shape, processing time. A second problem is the varying measurement accuracy due to different remission properties of the scanned surfaces. Different researching programmes are currently addressing this issue (Bucksch, A., Lindenbergh, R. and van Ree, J., 2007).

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