Combining modern techniques for urban 3D modelling

First impressions of an architectural modelling project

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Abstract - **This paper will give an insight into modern ways of buildings modelling considering the case of TU Delft's campus with the use of classic photogrammetry tools and terrestrial laser scanning data. In addition we will use airborne LIDAR (Light-Imaging Detection and Ranging) for generating of extrusion models.**

The used methods aim to obtain models which can be used in Geographical Information Systems supporting different level of details. The detail factor may vary from pure city models, which are only blocks containing no façade information, to more complex 3D models with façade information as a texture and/or geometry. In our paper we will make some comparisons using a building model and discuss upon its information type and the achieved accuracy. Further more we will show an application example for the extrusion models.

Keywords: Terrestrial laser, 3D, Modelling, Laser altimetry, Visualization, Digital, Photogrammetry

I. Introduction

Nowadays a great number of users require an increasingly precise 3D model of buildings. Applications can be found in the field of Geographic Information Systems (GIS), for urban and city planning, flooding simulations, microclimate investigations, tourism offices, disaster management, police and military activities, in telecommunications for signal propagation analyses, for landscaping, etc. This significant demand for 3D city models is leading to efforts greater than before, in developing 3D building reconstruction methods intended to minimize the costs and to expand the efficiency of the 3D urban modelling. At the present time, the research is going towards an automated reconstruction and production of fast results.

More often than not, the 3D models are used for visualization in order to generate realistic scenes and animations. From the computing point of view, we can observe that due to the rapid developments in both the software and hardware areas, practical visualizations are feasible, at the moment, even for complex objects and areas covering large 3D datasets.

The main process usually consists of a combination of real world and computer generated data with the purpose of adding value and information for various types of analyses and interrogations.

As a difference between architectural models and city models, we can consider the use of airborne laser altimetry (LIDAR) as a practical data source for reconstruction [1]. An extruded city model can be generated from a combination of maps and LIDAR data sets [4].

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 processes image data based on digital and analogue imaging sources such us pictures from semi-metric or non-metric cameras.

In the 3D modelling field, terrestrial laser scanning is becoming more and more important. Laser scanners can produce around 125.000 points/second and all those points are 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.

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.

II. Hardware

A. Canon EOS 350D

The specifications of the Canon EOS 350D camera are given with a sensor resolution of 8.0 Megapixels that matches an image size of 3456 x 2304 pixels, a three times optical zoom with a focal length between 18-55 mm named in the technical description of the manufacturer.

B. *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 785nm. The maximum scanning speed is 120.000 3D measurements per second. In our project we used measurements with lower angular resolutions of 1/5 or 1/4 of the maximum resolution.

III. SOFTWARE

A. *PhotoModeler*

PhotoModeler is a software application developed by Eos Systems Inc. (Canada), used for 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 of building. Further more, in order to achieve precise results we have to calibrate camera.

B. *FARO Scene*

FARO Scene – made by FARO Technologies, Inc. – is a tool, which is 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, 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.

IV. 3D MODELLING

A. *Modelling from maps and LIDAR data sets*

For generating basic extrusion models we used maps that represent the footprint of the buildings as closed polygons. The LIDAR data and the cartographical map data were already georeferenced in the Dutch reference coordinate system called RD-coordinate system. With the help of proprietary software we extracted the LIDAR points inside the polygons and extruded them by the median height of all the points inside the polygon. The result of this extrusion can be seen in Fig.1 - the picture shows a view on the extrusion model within the Google-Earth viewer.

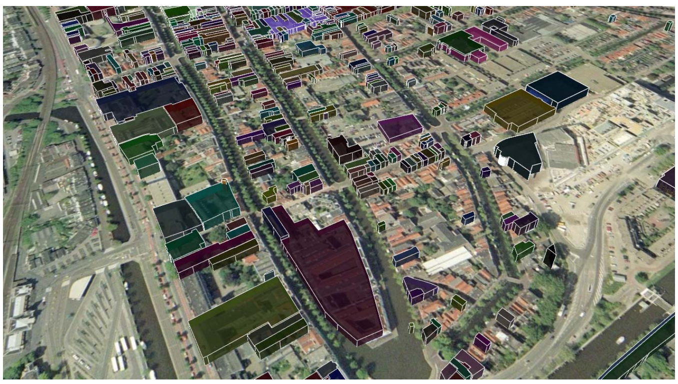

Figure 1. Extrusion Model of the City Centre of Delft.

B. *Modelling from Photographs*

Our study was made using a 3D model of the „Cultural Centre" at TU Delft, using version 5 of the PhotoModeler application. The above mentioned Canon EOS 350D 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 and by choosing appropriate viewing angles at the building, only 12 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 used common points 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 2, 3 and 4 illustrate the resulting model in different representations and from different views.

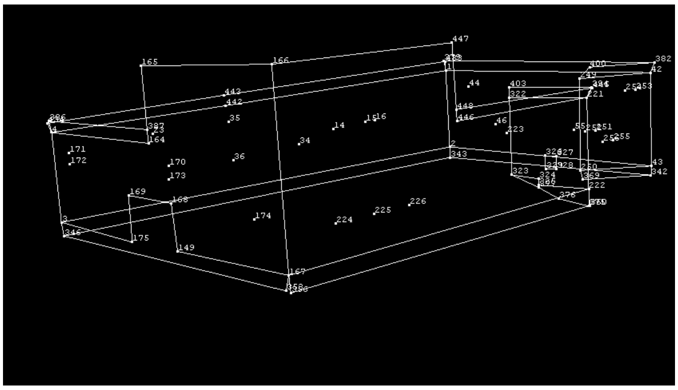

Figure 2. 3D model of building - Id points and lines

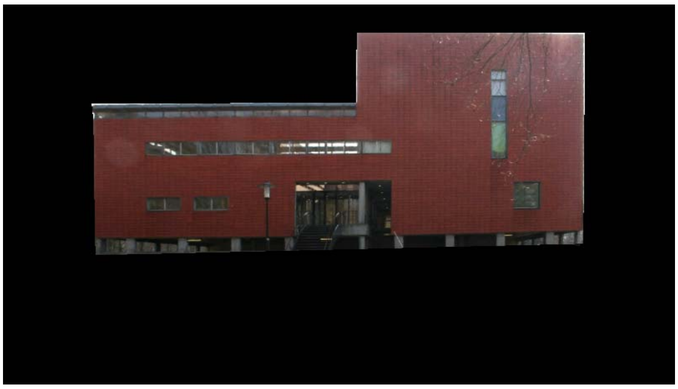

Figure 3. 3D model of building - with texture

Figure 4. 3D model of building - view from the back

C. Point Cloud modelling

This method is composed by two major procedures:

1) Registration of the point cloud with the Iterative Closest Point Algorithm (ICP) [3].

2) Creating a polygonal mesh by triangulating a selected area.

For the registration process we tried two different approaches within FARO Scene. The first approach uses natural targets like corners of windows and in a second one we used white targets of spherical form. In the first approach we needed 3 corresponding points and 1 corresponding plane to register the two exemplified scans [5]. We introduced the requirement of the 3rd point as it was not possible within FARO Scene, to achieve acceptable registering results for own purposes, with the use of minimum two points and one plan - even if this is accepted in theory.

Figure 5. Registration using natural targets

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 [3].

Fig. 6 shows 2 points, 1 plane and 2 spheres we used and Table 1 summarizes the achieved accuracy with both approaches. This comparison shows that the registration with spherical targets gives better results.

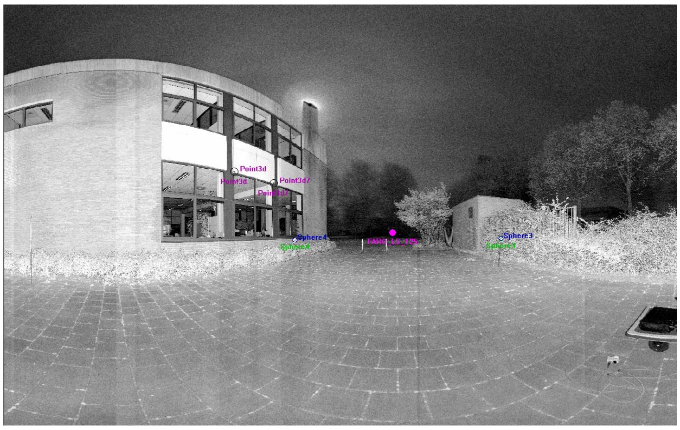

Figure 6. Registration using white spherical targets

TABLE I. COMPARISON OF THE REGISTRATION ACCURACY IN FARO SCENE

Registration accuracy	Natural Targets	Spherical Targets
Point Drift (mm)	16.48	2.15
Angular mismatch (°)	0.188	0.082
Orthogonal mismatch (mm)	28.63	9.89
Long mismatch (mm)	17.29	10.65

In the last step we created meshes which were exported to AutoCAD® 2007. In Fig. 7 such an unfiltered mesh is visible. The distortions in the mesh are the result of points measured on translucent materials – for this example in the case of windows. As an observation we noticed that this kind of points occur most often on glass.

Figure 7. Unfiltered mesh

V. Conclusion and Future Work

A. LIDAR and Maps:

Extrusion models from airborne LIDAR data sets are suitable to generate city models without detailed façade information. One of the benefits is definitely, that extrusion models are directly supported by environments like Google Earth. So they are preferably used in city models.

B. Photogrammetry:

Advantages**:**

- Easy to use because we can be flexible in choosing the type of source images and cameras: metric or non-metric
- We also have more 3D modelling software applications to choose from, programs that are usually simple to learn.

Disadvantages**:**

- We have to do a precise camera calibration as this is a very important process because the quality of 3D model will depend upon the precision of the camera calibration.
- Image resolution is related with the type of the camera used to acquire the pictures and usually the capabilities of even the most advanced cameras are not sufficient for the project requirements.
- The use of photographic equipments and techniques is it time consuming during the measurements phase.

C. Laser scanning:

Advantages:

- Fast acquisition of a huge amount of 3D data in a short period of time, making the laser scanning probably the most efficient method for data acquisition.
- Good metric accuracy (depending of what instrument we use).

Disadvantages:

- Registration without targets it is a time consuming tedious task and the use of natural targets like windows and buildings corners is not always efficient.
- 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 points makes the data handling a complex process, involving some special hardware and software requirements.

Loss of data because of occlusions is the most common problem for photogrammetry and laser scanning is. Filling these holes is mostly done by manual work.

With the help of photogrammetric methods we can achieve higher overall model accuracy, while terrestrial laser scanning delivers a higher level of detail on the façade as geometry. This proves that the laser scanner is a good tool for architectural models, coding the façade information into geometry. The façade relief as textured only surfaces will result in flat model, but this is more than often sufficient enough in order to generate a city model [1].

Based on our previous analyse we may conclude that laser scanning and the image-based approach are not competitive but rather complementary methods. The reconstruction system depends on many factors like: application, object shape, processing time, etc. In both approaches the modelling part (from 3D cloud points to surface) is still the most problematic and time consuming. Future work should still be focused on automatic solutions for this problem. The known approaches like power crust reconstruction [5] still have too many limitations and disadvantages compared to achievable results of manual assisted work.

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