INTEGRATING PHOTOGRAMMETRIC TECHNOLOGIES
AND GEODETIC METHODS FOR 3D MODELING

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ABSTRACT:

The main aspects of digital photogrammetry and its applications in the architectural field are illustrated in this paper. Here are also described the advantages of using modern surveying equipment in architectural photogrammetry. Practical aspects are exemplified using the 3D model of two buildings from TU Delft University: "Aula" and "Faculty of Aerospace Engineering". In addition, the aspects of collecting data using a total station, a terrestrial laser scanner and a digital non-metric photo camera are analyzed, as well as the adjustment of this information using AutoCAD, Leica Cyclone, Google SketchUp and Google Earth. A great number of users require an increasingly precise 3D buildings model. Applications can be found in the field of Geographic Information Systems (GIS), for urbanism and city planning, for flooding simulations, for microclimate investigations, for tourism offices, for 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 for the 3D urban modelling. At the present time, the research is going towards an automated reconstruction and production of fast results.

1. INTRODUCTION

1.1 General considerations

Frequently, the 3D models are used for visualization in order to generate "reality-like" scenes and animations. Speaking from the IT industry point of view, we can observe that due to the fast developments in both the software and hardware fields, at the present time, practical visualizations are possible even for composite objects and for large areas covering a vast number of 3D datasets. The main process typically results in a combination of real world data and computer generated data with the purpose of adding value and information to a 3D model in such a way that it becomes usable for various types of analyses and interrogations.

The information used in this type of projects may have numerous sources: 3D laser scanning, total stations, digital Photogrammetry, laser altimetry, maps - all of them in combination with data generated from other various disciplines – related to the project's purpose. From the point of view of 3D data gathering techniques, the latest technology developments are showing noticeably improvements, in both resolution and accuracy for all the techniques: aerial and close range Photogrammetry, airborne or terrestrial-based laser scanning, mobile mapping and GPS surveying.

There are a variety of approaches with diverse resolutions, accuracies, methods, completion times, stages and costs. I will take a look in this paper at one 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.

The development of architectural and archaeological photogrammetry has been very much a part of the whole development of close range photogrammetry since the 1960s. From the many areas of application of close range photogrammetry, this field has become one of the best established and most well known. At the same time, it has perhaps not been so glamorous or as original as some other areas of application. Nevertheless, the field is much changed from the early years of development. In the close range applications as in the whole photogrammetric methodology, the introduction of computers has very much changed the ways in which the technique works and is applied. 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. 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.

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

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.

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 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.

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 Google SketchUp

SketchUp is a 3D software application used to create everything from 3D massing models to fully rendered and highly detailed models. SketchUp is used predominately on the front-end of the design process where designs are in a fluid and tentative state.

3.3 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.

3.4 Leica Cyclone

The inherent completeness of 3D point clouds represents one of their major advantages over other sources of geometric information. Cyclone's unique Object Database Client/Server software architecture provides the highest performance environment for laser scanning projects. Cyclone software makes it easy for users to manage data efficiently in databases. Everyone can work concurrently on the point databases, thereby reducing the need to copy and/or transmit large point cloud project files.

4. 3D MODELLING

4.1 Modelling data from Total Station

The study was made using the 3D model of the „Faculty of Aerospace Engineering" building from Technical University of Delft's campus (Netherlands). 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 totals 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 ±5mm precision and the 3D model was realized 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. This 3D model was imported in Google SketchUp were we able to define the texture and with help at this software knowledge I exported the 3D model in Google Earth. Figures 1-7 illustrate the resulting model in different representations and from different views.
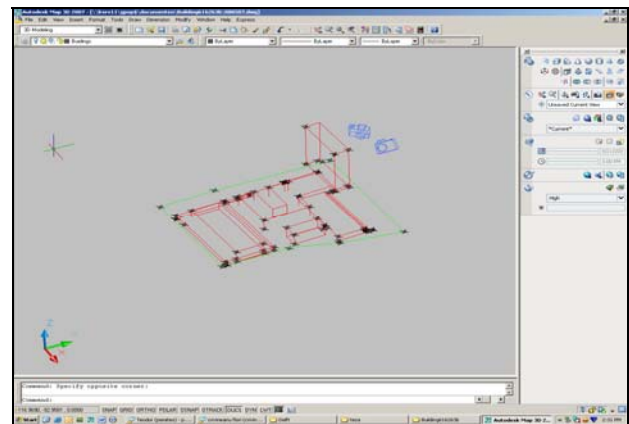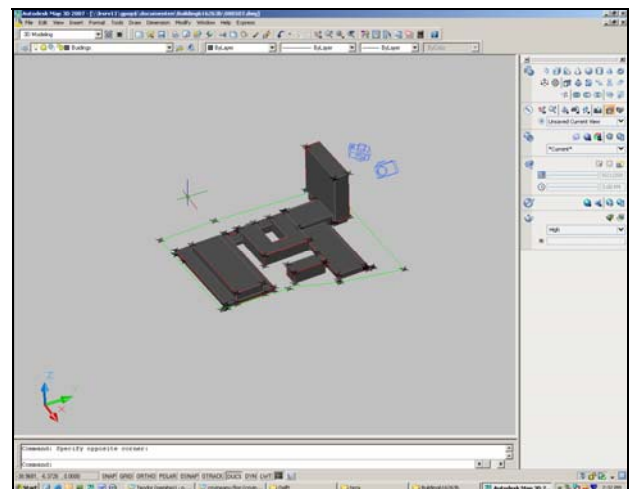

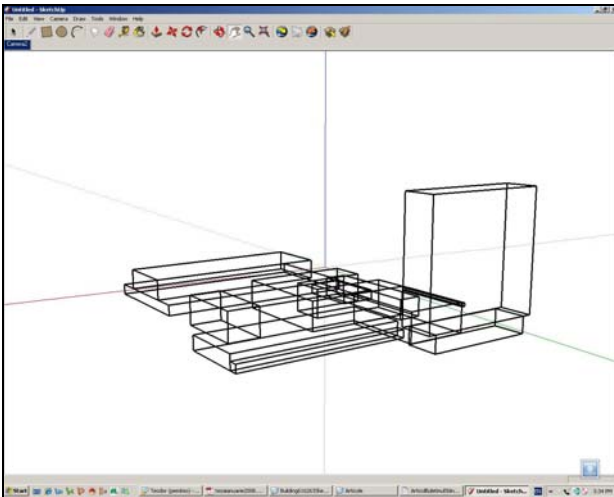Figure 1. Measured points

Figure 2. Surfaces and solids

Figure 3. 3D model of building – from lines and points in Google SketchUp
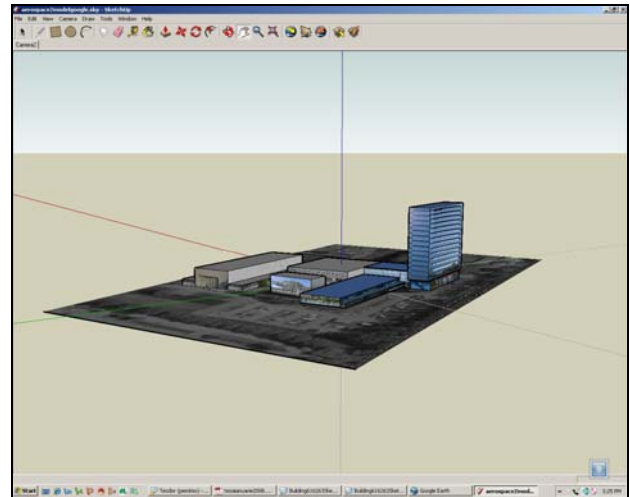

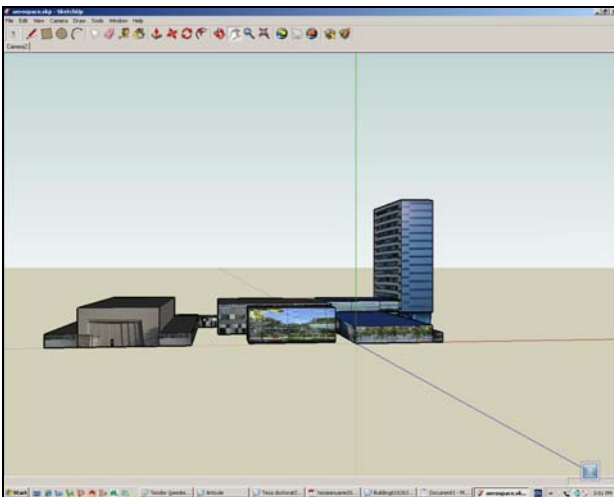Figure 6. The 3D model of Aerospace Faculty from TU Delft in Google SketchUp

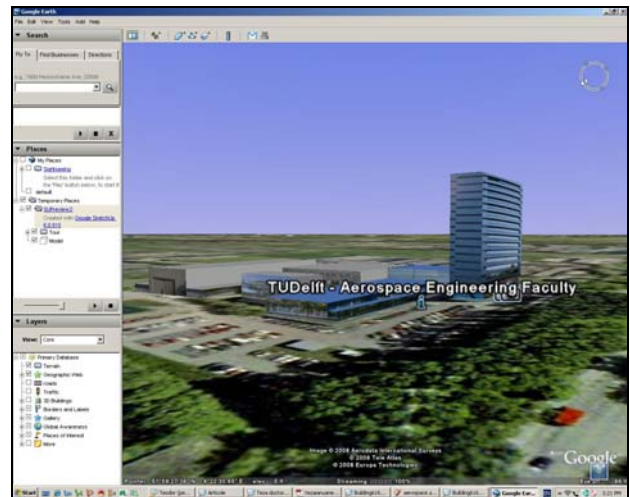Figure 4. 3D model of building - with texture in Google SketchUp – lateral view

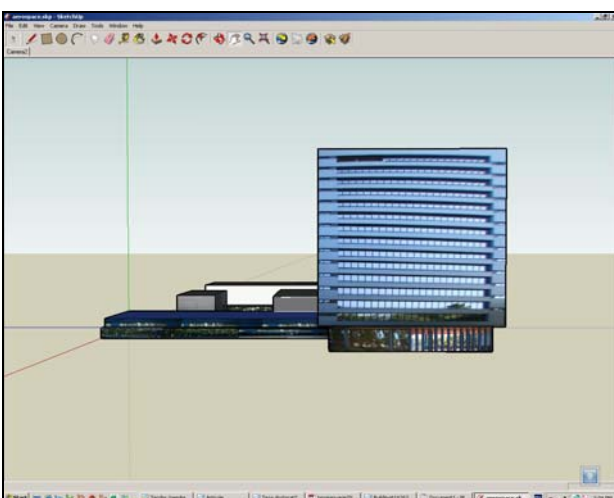Figure 7. 3D model import from Google SketchUp to Google Earth – lateral view

4.2 Scanning principles

The FARO scanner uses a visible „eye safe" laser to scan at high speed. A grid of points is produced based on a user-defined spacing over the chosen area, thus creating a 3D „Point Cloud" of the site, up to 360° and at distances of maximum 76 m from the scanner. In this respect, the scanner is like a camera which records the detail that can be seen at each location. As in photogrammetry, control points are required to link the various scans together in order to create a continuous model. This is done by placing targets within the scanning area and either surveying their locations or scanning the same control points from other locations.

The scanner is attached to a laptop that runs the FARO Record software, allowing the data to be viewed and manipulated on site. The data captured by the scanner forms a dense cloud of 3D points classified by colour or hue based on the intensity of the returned signal. This helps to give the cloud depth and texture, in order to enhance the interpretation of the details from the cloud.

Figure 5. 3D model of building - with texture in Google SketchUp – frontal view

4.3 Site operations

The study was made using the 3D model of the „AULA-conference centre" building from Technical University of Delft's campus (Netherlands).

In this case, using a somewhat different approach than in the first case, I wanted to realize the registration of the building using the measurements obtained with FARO LS880 laser scanner imported into the LEICA Cyclone software.

The exterior of the building "Aula" - the conference centre - was scanned in two days using 20 scans of the building from 20 locations, with each scan taking no longer than 20 minutes. This increased the number of scans and scanning locations that would normally have been required, as it was essential to achieve a good coverage of points throughout the scanned areas.

Figure 8. Aula – the conference centre

4.4 Working with „points cloud"

Within the scanner software, the „point cloud" can be viewed from any location where snapshots can be taken as additional visual aids. This information can be used as cloud data or as a meshed surface to give a photo-realistic image over the surveyed site.
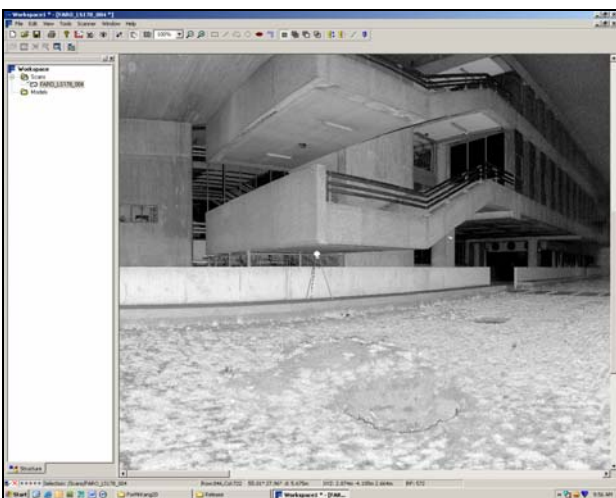

Figure 9. „Points Cloud" for building's facade

The exterior of the building was scanned using the FARO LS 800 terrestrial laser scanner and each "points cloud" was imported in the FARO Scene software. The scans were viewed in real time on the laptop computer and checked - before moving on to the next location - to ensure that the area had been fully captured.

From FARO Scene software each "points cloud" was exported like a pts file in order to allow the registration with the LEICA Cyclone software. For the registration of the building we imported pairs of scans – two by two – (for ex. Scans 001 and 002), choosing 6 common points (corners of windows or spherical targets) for each pair of "points cloud". If the model met the precision requirements (~2mm), we than added the next "points cloud" (Scan 003), based on the common points between 002 and 003 scans. Using the LEICA Cyclone software, I have applied different filters (for example: luminescence) and on the same phase I erased the points that were not necessary for building modelling.

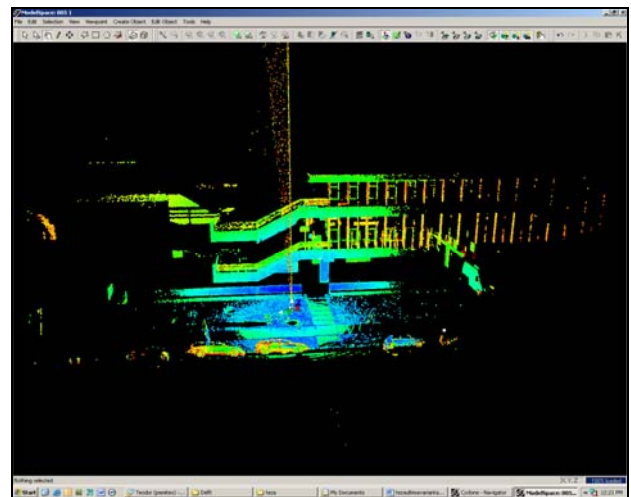The results of the case study are shown in Figures10-13:
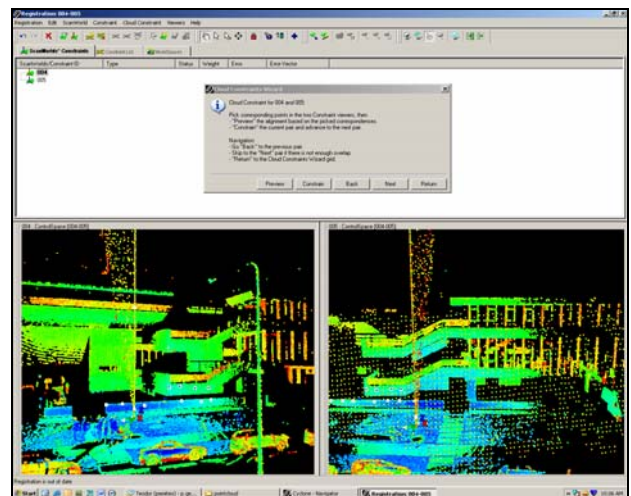

Figure 10. „Cloud points" in Cyclone

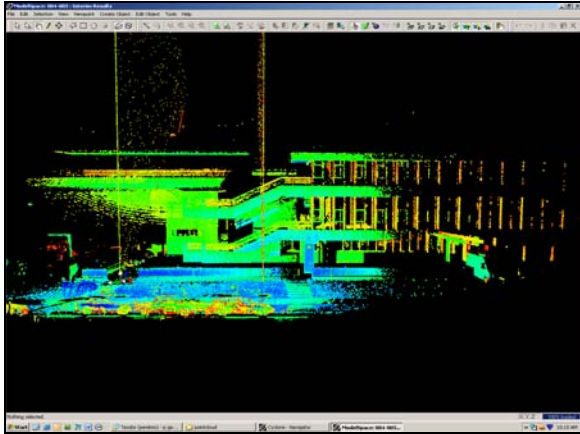Figure 11. The registration of two scans in Cyclone

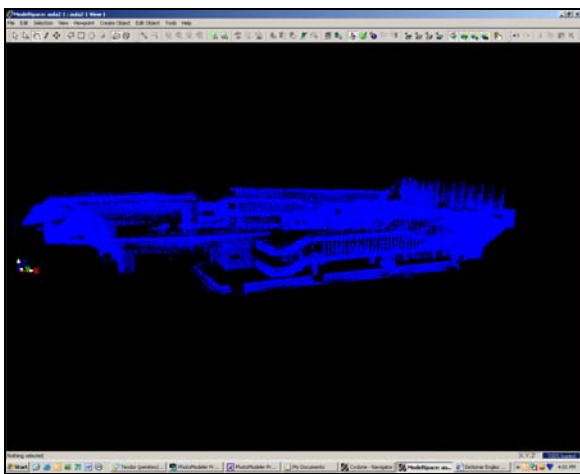Figure12. The result of registration for two scans in Cyclone

Figure13. The result of registration for whole building in Cyclone

5. CONCLUSIONS

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 Laser scanning

5.2.1 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 of a few millimetres in precision.

5.2.2 Disadvantages:

- Registration without spherical targets requires much more time and, on the same time, is not efficient enough to use only natural targets, because the control points are not always superimposing the natural details (like building corners, for e.g.).
- The software applications currently on the market are complex and sometimes not to easy to learn and manage.
- Due to the large number of data – million of points for a single scan – the overall information is hard and difficult to handle and requires dedicated hardware and software applications.

Considering this, we may conclude that total station 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 studies are currently addressing these.

The greatest advantage in using of the 3D models is the possibility to extract virtually any information we want. For example: we can determine surfaces and volumes, make sections or flatten views of the object. As it is easy to observe from my case study, the use of non-metric photos had also offered some advantages: less time in acquiring the images, high precision and wide covering of the model.

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