INTEGRATING ADVANCED TECHNOLOGIES AND METHODS FOR FAST AND RELIABLE 3D MODELING

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ABSTRACT

The paper discusses methods to combine methodologies for handling data generated from multiple sources: maps, terrestrial laser and additional measurements, in combination with digital images with the purpose of generating the 3D visualization of buildings. Three dimensional architectural models are more and more important for a large number of applications and for this reasons specialists have looked for faster and more precise ways to generate them. 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. At the present time, the research is going towards an automated reconstruction and production of fast results.

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.

KEYWORDS: *Terrestrial, Building model¸ Close Range, Visualization¸ Civil Engineering¸ Photogrammetry, Cultural Heritage*

INTRODUCTION

Generally 3D models can be subdivided into three independent classes: the wireframe model, the surface model and the solid model. This division is based on the different computer internal representation schemes and is therefore also used for the application areas of these models. Wireframe models are defined by the vertices and the edges connecting these vertices. They fix the outlines of an object and allow a view through from any point of view. This is an advantage for simple objects, but reduces the readability of more complex objects. This representation is therefore often used for simple objects. Surface models represent the object as an ordered set of surfaces in three-dimensional space. Surface models are mainly used for the generation of models, whose surfaces consist of analytical not easily describable faces having different curvatures in different directions. This is often the case for models of automobiles, ships or airplanes. Volumetric models represent three-dimensional objects by volumes. In this case, the data structure allows the use of Boolean operations as well as the calculation of volume, centre of gravity and surface area (Mäntylä, 1988). Surface modeling is the most demanding but also the most calculation intensive way of modeling. Solid models always represent the hierarchy of the object, in which the primitives and operation are defined. Each of the classes mentioned above has its specific advantages and disadvantages. Depending on the task the advantages and disadvantages are more or less important. Therefore it is not possible to make a general statement, which of the classes is the best representation of a real-world object.

Beside the 'pure' representations of object models often hybrid models are utilized. Hereby the term „hybrid model" is not clearly defined and is used for various types of models, which use different representations within one system. In principle the term can be used for all non-homogeneous models. It is often used for systems that can handle wireframe and surface models at the same time.

Others use the term „hybrid model" for using volume and surface models under the same graphical user interface. New technologies and techniques for data acquisition, data processing, structuring and representation and archiving, retrieval and analysis are leading to novel systems, processing methods and results. The improvement of methods for surveying historical monuments and sites is an important contribution to the recording and perceptual monitoring of cultural heritage, to the preservation and restoration of any valuable architectural or other cultural monument, object or site, as a support to architectural, archaeological and other art-historical research. Digital image date may be acquired directly by digital sensor, such as a CCD array camera, for architectural photogrammetric work. Alternatively, it may be acquired originally from a photograph and then scanned. The digitization of photographic images offers a means to combine the advantages of film-based image acquisition (large image format, geometric and radiometric quality, established camera technique) with the advantages of digital image processing (archiving, semi-automatic and automatic measurement techniques, combination of raster and vector data).

The quality of digital images directly influences the final result: the use of low-resolution digital cameras or low-priced scanners may be sufficient for digital 3D visual models but not for a metric documentation. The systems may be used by photogrammetrists as well as by architects or other specialists in historic monument conservation, and run on simple PC-systems that suffice for special tasks in architectural photogrammetry. Photogrammetric multi-image systems are designed to handle two or more overlapping photographs taken from different angles of an object. In the past, these systems were used with analogue images enlarged and placed on digitizing tablets. Presently, the software usually processes image data from digital and analogue imaging sources (semi-metric or non-metric cameras). The data of the computer internal representation, which is sorted according to a specific order („data structure"), forms the basis for software applications. The data basis is not directly accessed, but via available model algorithms, which allow the performance of complex functions by transforming them into simple basic functions according to a defined algorithm. The representation of a real-world object in a computer-oriented model is a synthesis of data structure and algorithms. Due to the progress in computer hard and software there is a rapid development in the facilities of visualization in architectural photogrammetry. Simple facade plans are no longer suitable for the demands and applications of many users. 3D-real-time applications such as animations, interactive fly-overs and walk-arounds, which had needed the performance of high-end workstations a few years ago, are now also available on personal computers.

Regarding these models of a monument's 3D data as a basic storage concept, a large number of resulting products can be derived from it. As an example arbitrary perspective views and orthoimages in scale should be referenced here. 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 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 modeling 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.

HARDWARE

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.

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.

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.

SOFTWARE

AutoCAD 2007

Made by Autodesk, this is a software application widely used for 3D modeling. The same CAD principles of 3D architectural modeling 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.

PhotoModeler

PhotoModeler is a software application developed by Eos Systems Inc. (Canada), used for photographic 3D modeling. 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 a good coverage.

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.

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.

3D MODELLING

Modeling Data from Total Station

The study was made using the 3D model of the „Faculty of Electrical Engineering, Mathematics and Computer Sciences" 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.

Figures 1, 2, 3, 4 and 5 illustrate the resulting model in different representations and from different views.

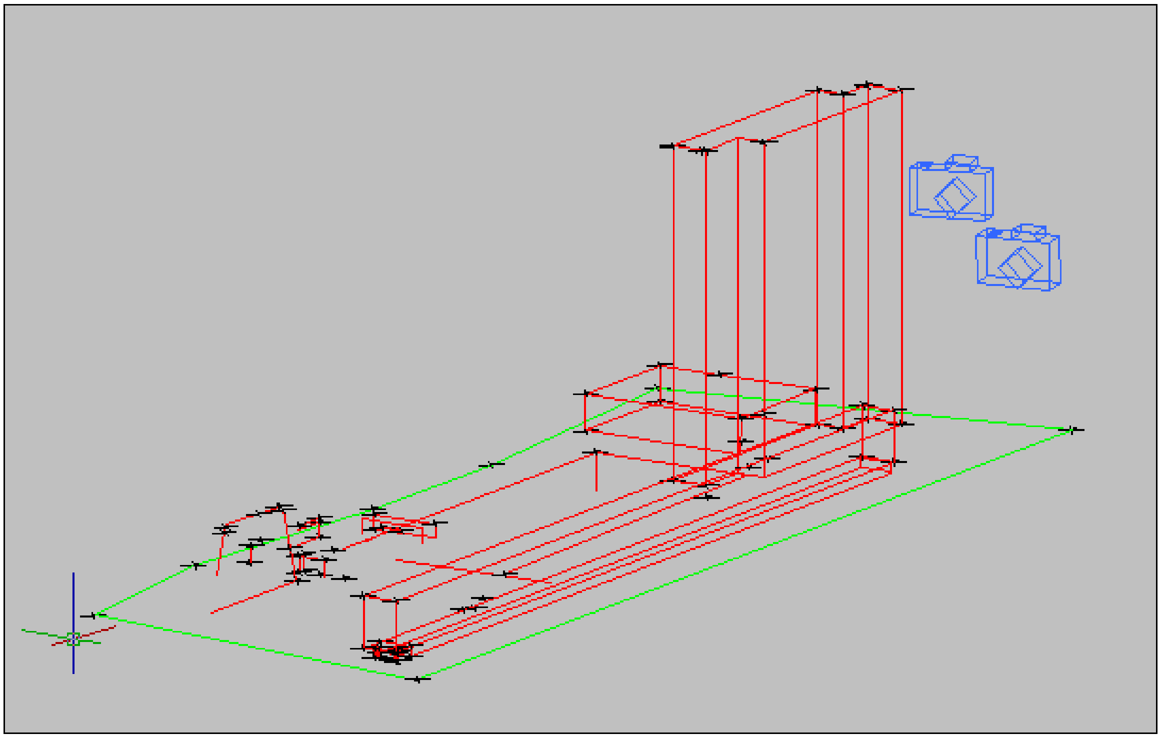

Figure 1. Surveyed points.

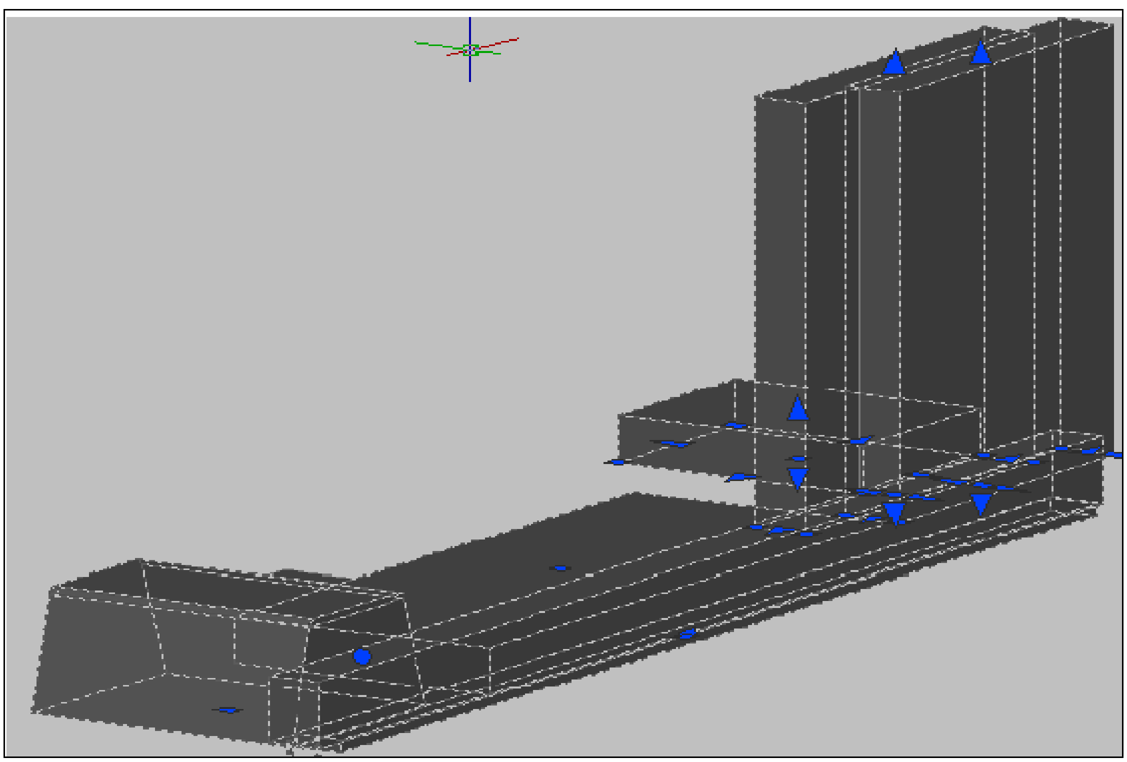

Figure 2. Surfaces and solids in AutoCAD.

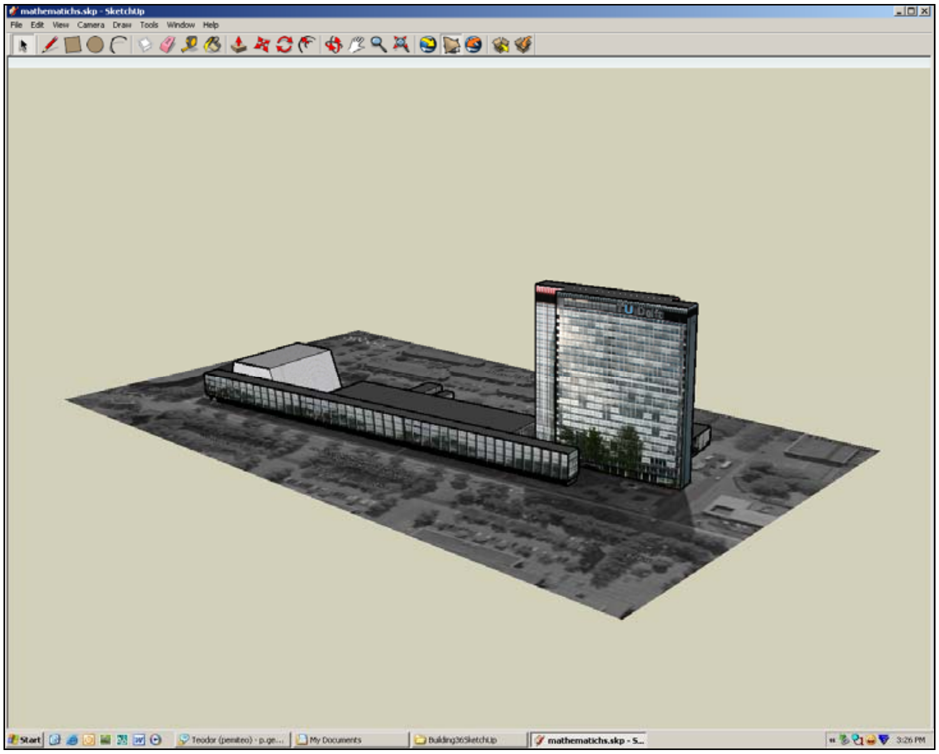

Figure 3. The 3D model of Mathematics Faculty from TU Delft in Google SketchUp.

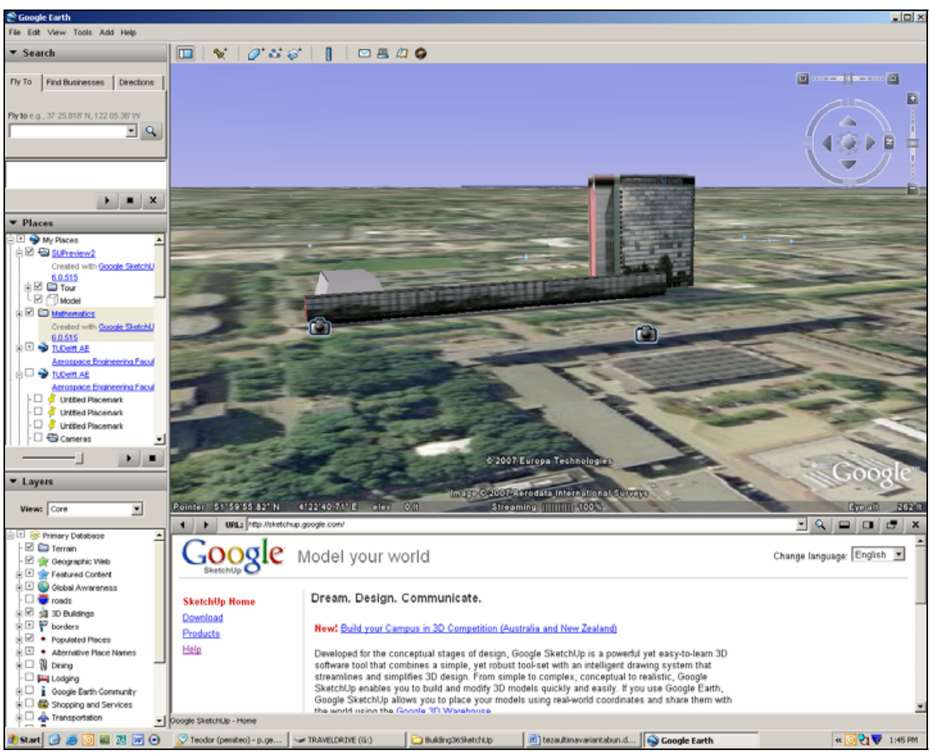

Figure 4. 3D model import from Google SketchUp to Google Earth – frontal view.

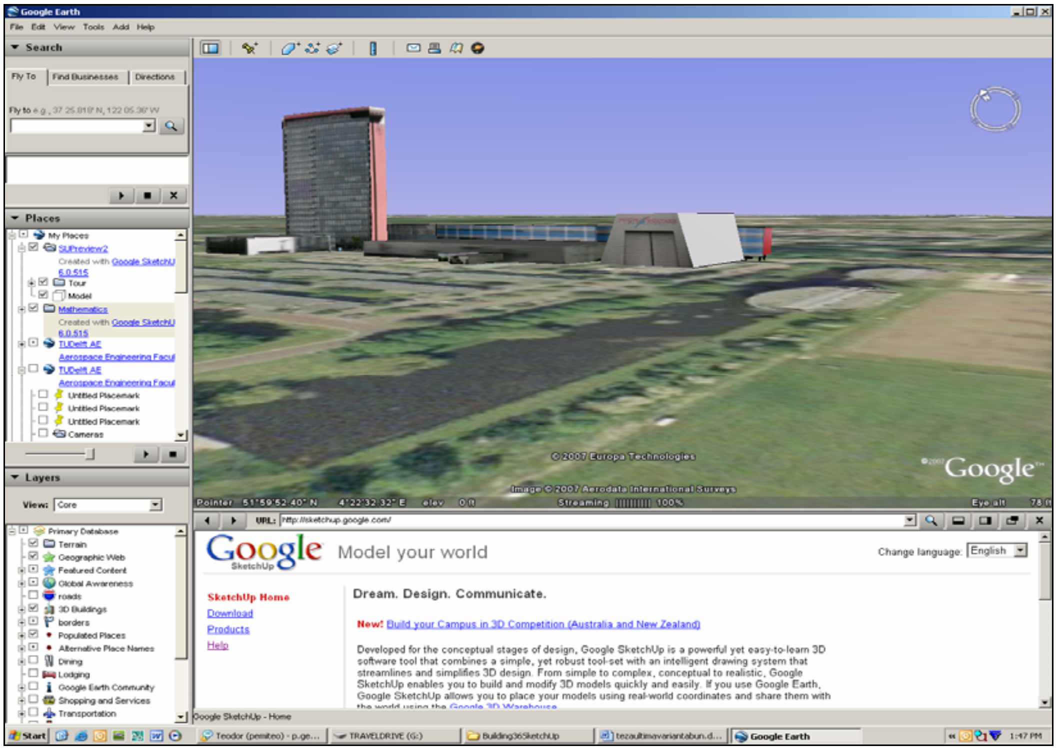

Figure 5. The imported 3D model from Google SketchUp to Google Earth – lateral view.

Modeling Data from Terrestrial Laser Scanner

The registration of building was made in Cyclone and the surfaces were generated using the same application. For registration of the building we imported pairs of scans – two by two – (for ex. Scans 001 and 002), choosing 6 common points for each pair of "cloud points". If the model met the precision requirements (~2mm), we than added the next cloud points (Scan 003), based on the common points between 002 and 003 scans. After we obtained the registration for all scans, the building's model was generated using lines and surfaces with help of the functions offered by Cyclone. At the end of this stage, the 3D model from Cyclone was imported in PhotoModeler, version 6. Here we already had the model based on the lines, points and surfaces so we had to add only the texture using the images taken with a non-metric digital camera, model Canon EOS 350D. We had to calibrate the camera in advance with the focal length of 18 mm. Because the building has 20 façade we took 70 images from 3 different stations with a large coverage and with the objective's aperture of over 40 degrees. There was only one exception – a façade with the length of approximately 25 m for which it was necessary to acquire more than 3 pictures. We made the geo-reference for control points and obtained orientation of images. The texture was added using the command "*surface-option-path mode*".

Figure 6. The Physics faculty.

Figures 7 – 15 illustrate the resulting model in different representations and from different views.

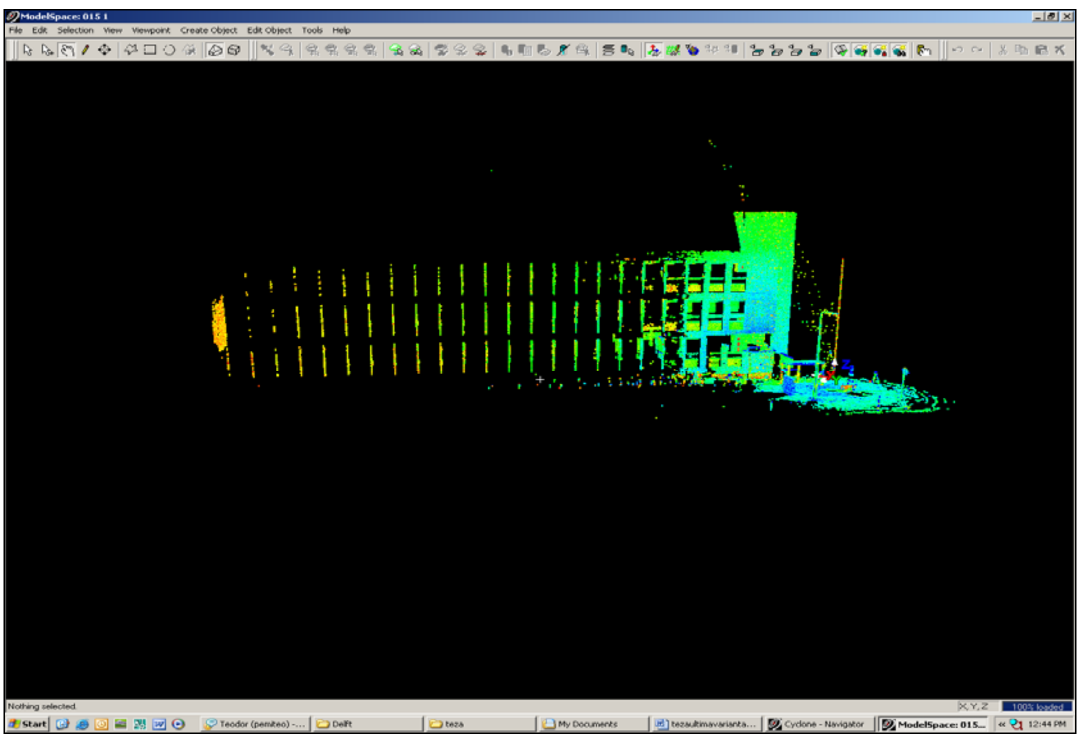

Figure 7. Cloud points in Cyclone.

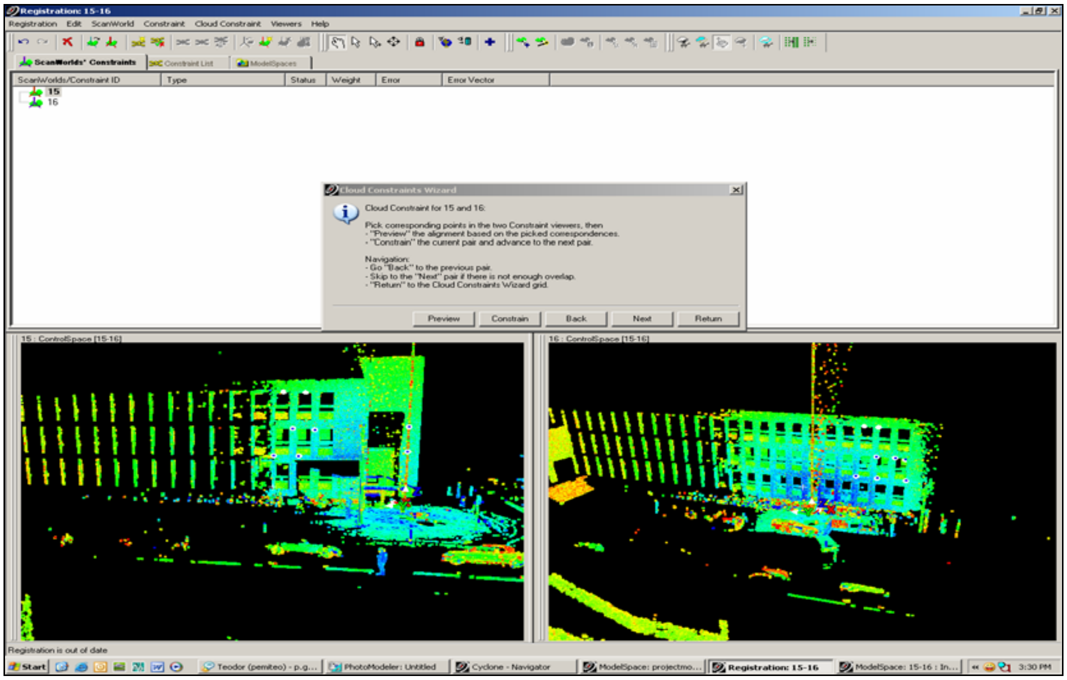

Figure 8. The registration of two scans in Cyclone.

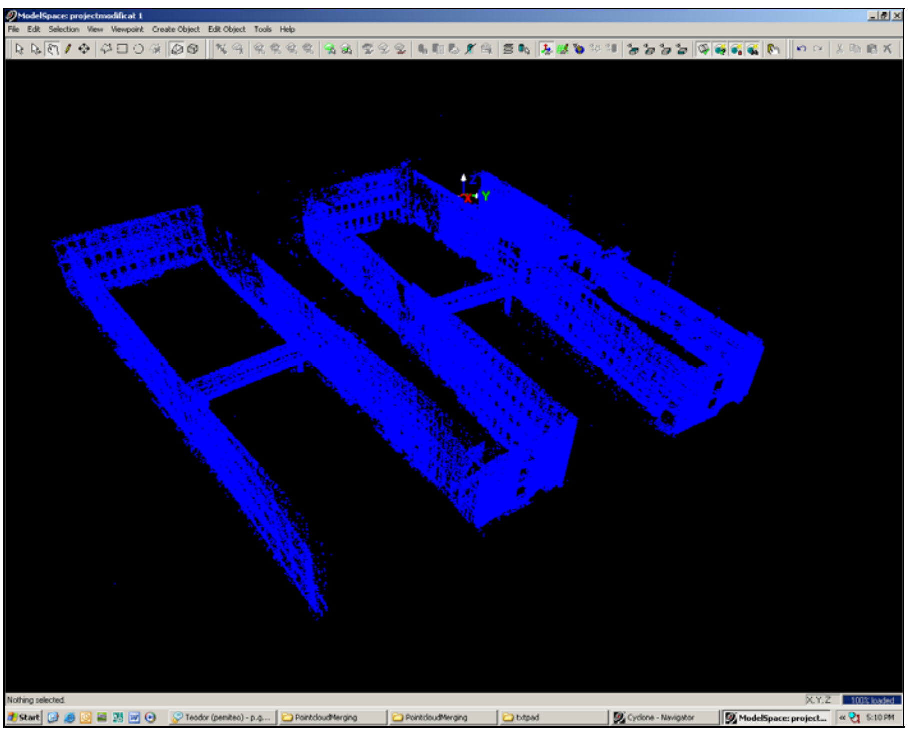

Figure 9. The registration of building in Cyclone.

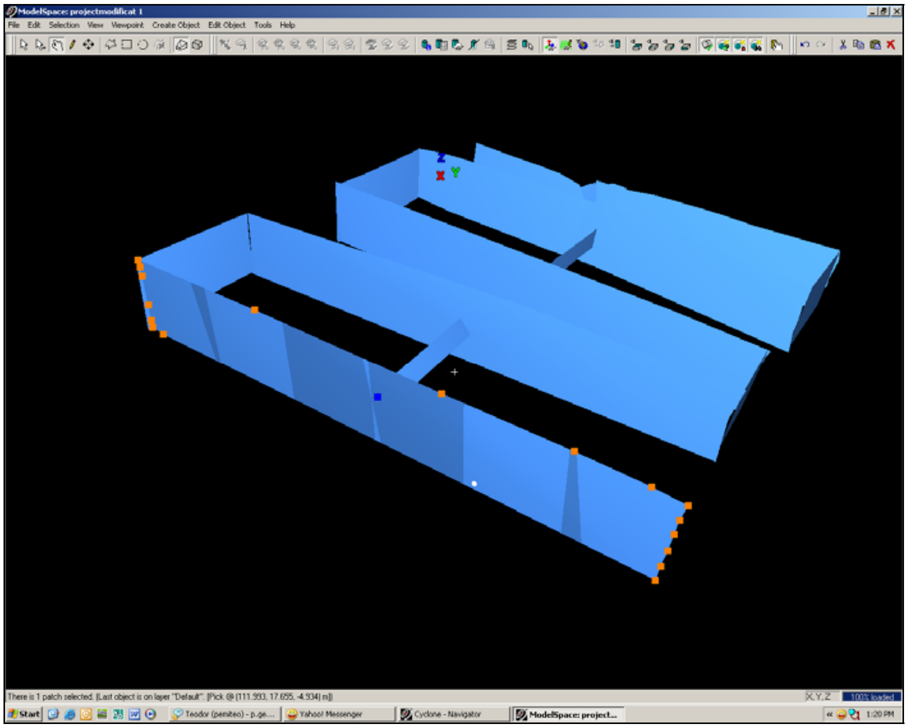

Figure 10. The surface obtained in Cyclone.

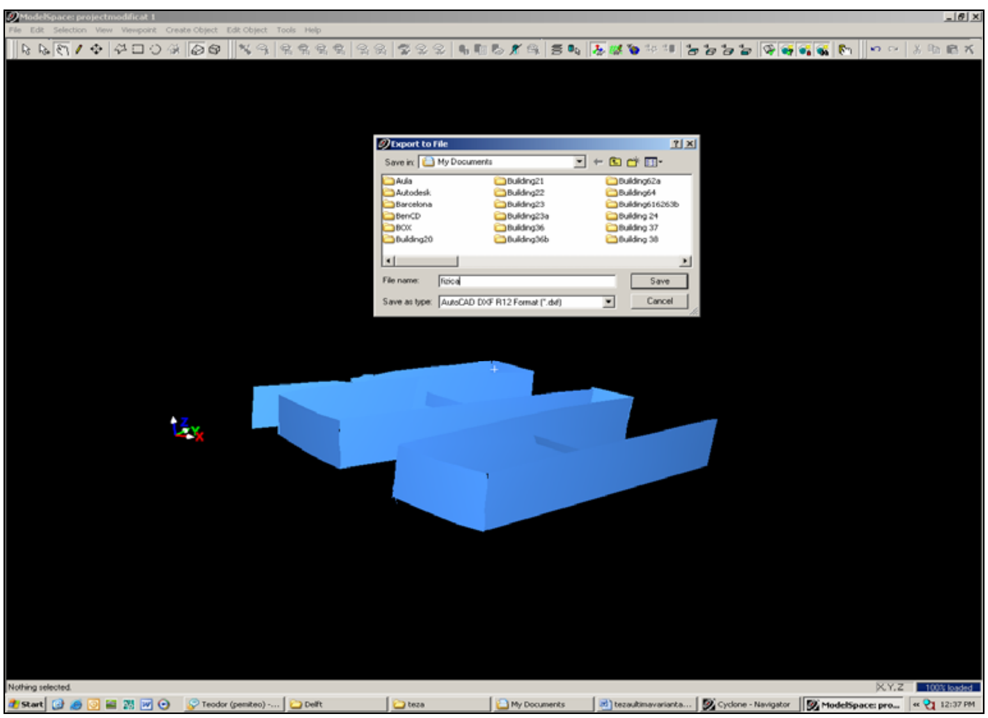

Figure 11. The export of building from Cyclone in dxf. Format.

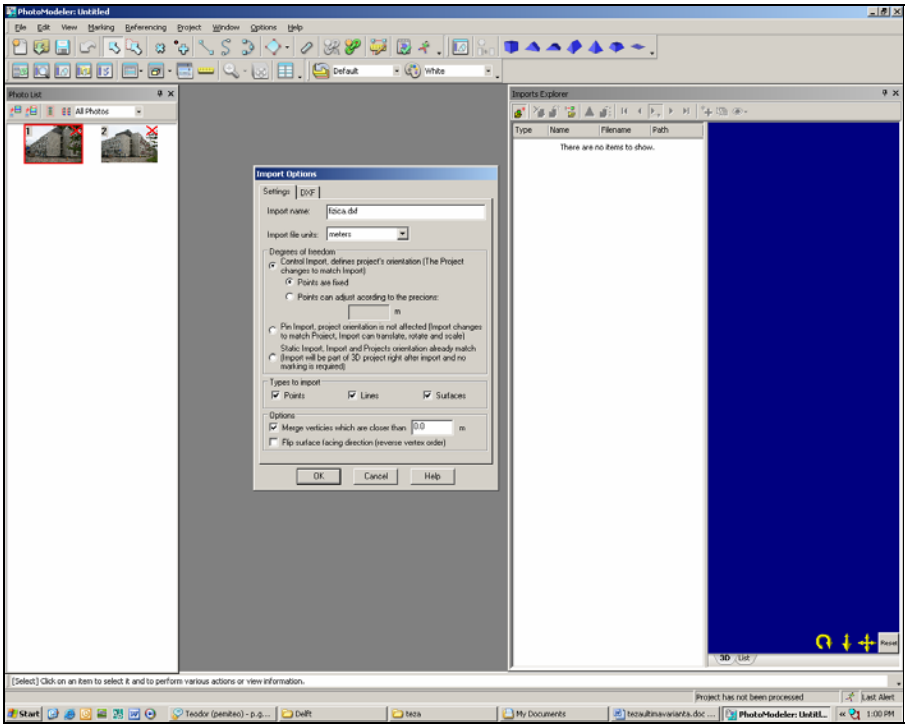

Figure 12. The import of model from Cyclone in PhotoModeler.

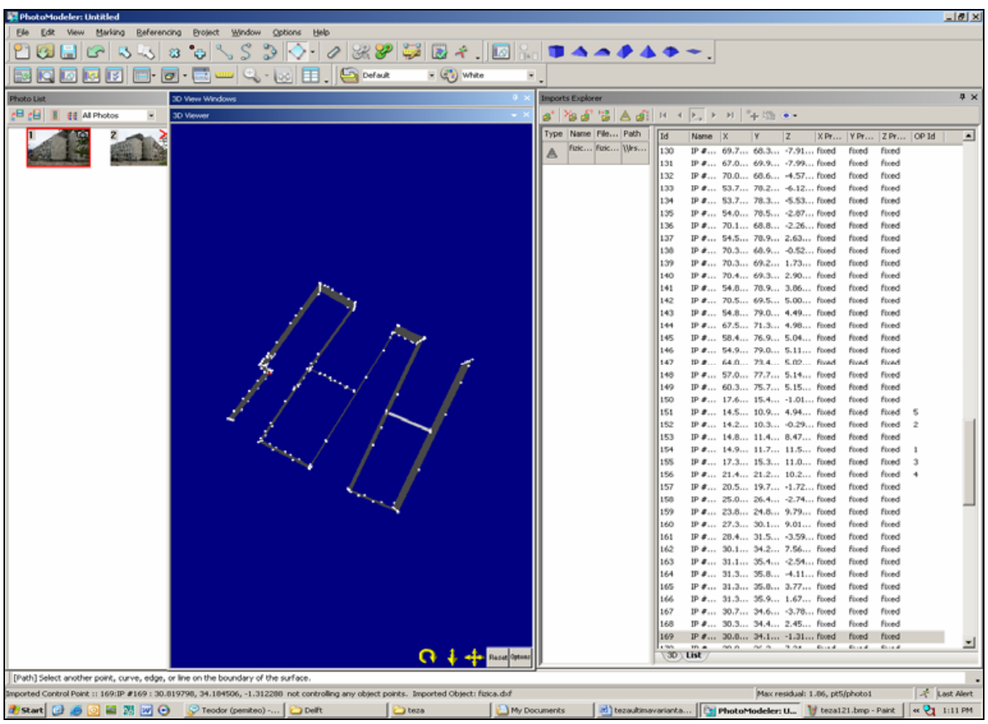

Figure 13. The 3D model imported in PhotoModeler and the list of coordinates points.

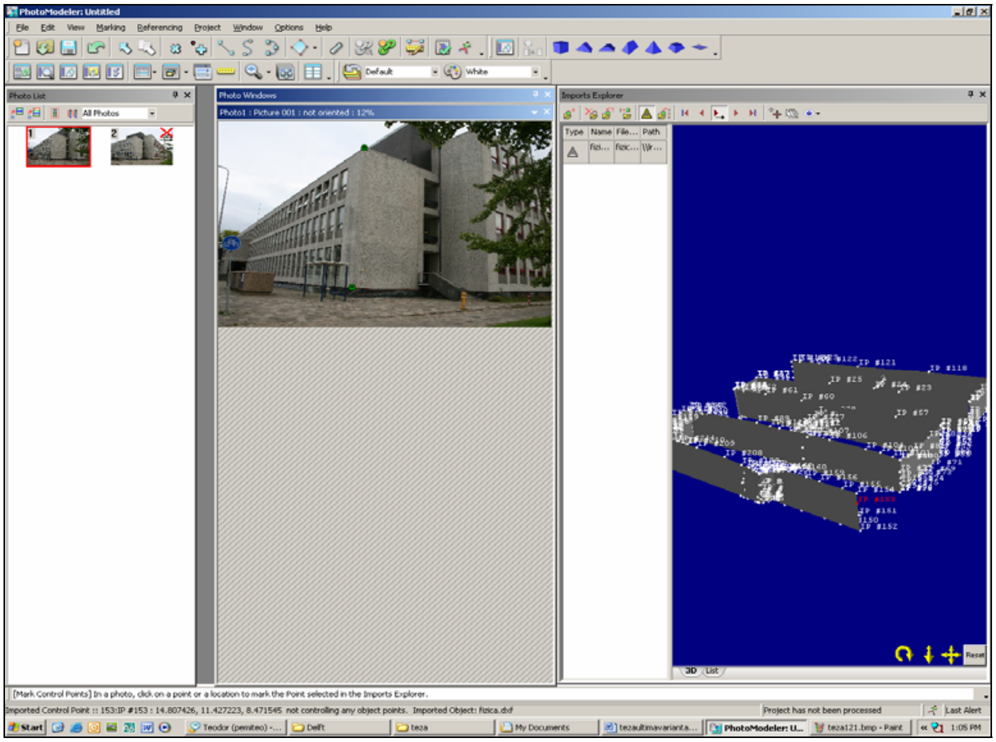

Figure 14. The orientation of images in PhotoModeler for add the texture.

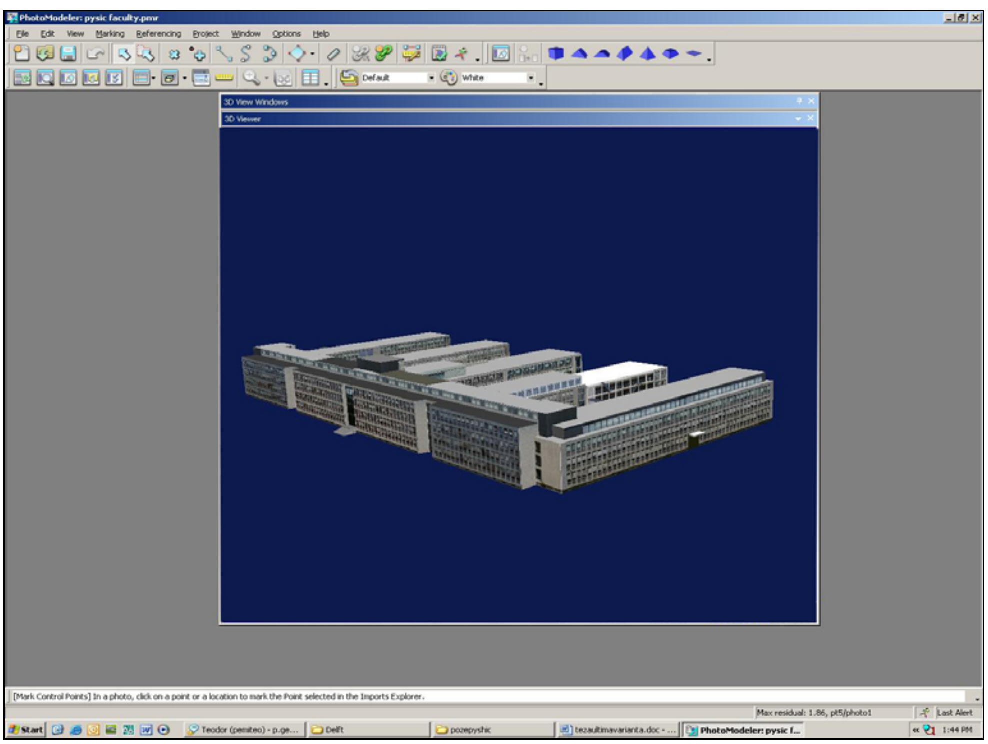

Figure 15. The 3D model of building – lateral view.

CONCLUSIONS AND FUTURE WORK

Total Station

Advantages:

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

Disadvantages:

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

Laser scanning

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 millimeters in precision.

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.

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