

3D CITY RECONSTRUCTION BY DIFFERENT TECHNOLOGIES TO MANAGE AND REORGANIZE THE CURRENT SITUATION

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ABSTRACT:

Three-dimensional (3D) city models present and animate all urban features such as buildings, highways, parking areas bridges on computer platform. 3D city reconstruction helps to set a base for reorganizing current city structures and it is an important requirement to help future decision-making process. A 3D model shows what is going to change and happen at the end of a new design. It explains the result of recommended changes visually. To reach a beneficial decision, it convinces decision maker by providing sufficient argument. Simulating real world and reconstructing planned projects trains the related user to evaluate possible results. 3D models make perceiving real world easy. There are many application areas such as urban planning, archeology, virtual tourism, simulation, restoration.. etc. for 3D reconstruction. In this study different methods and data acquisition techniques were examined for 3D city modeling. Various pilot works were done with using of the Photogrammetry and the GIS. For example, in Photogrammetric application, 3D model building started with the acquisition of the sufficient image data and was completed by constructing graphical data. In GIS application, graphic and non-graphic data related to a local urban area were collected to integrate and update information about created 3D model and GIS infrastructure was built depending on data base design. Each technique was tested in view of their usability, ease, effectiveness, and the optimum way in building 3D city was determined, depending on used data and requirements in the case study.

1. INTRODUCTION

Three-dimensional city models are usually comprised of a description of the terrain, streets, buildings and vegetation in build-up areas. Interest in 3 Dimensional (3D) building models has raised significantly in the past years. Originally, simulations for propagation of electromagnetic waves were thought of being one of the major application areas. These are used by network operators for the planning of antenna locations. Although there might be an additional need in the near future due to the other areas evolving, for example 3D car navigation systems, virtual tourism information systems and visualization for city and building planning or architectural contests (Brenner et al., 2001).

Many cities in the second and third world experience currently strong urbanization and are expanding fast. Due to the improvement of transportation infrastructures, rural migration as well as high natural birth rates, expanding economies and the effects of globalization in general, these cities increase quickly in size and get a regional extend. Meanwhile, planning remains mostly local and focused on the main urban area of a region, while urbanization prevalently occurs outside of it. Development is often so rapid that traditional maps are even not any more accurate enough to serve as a planning basis. And also these development dynamics are so strong, that the traditional maps as a basis for planning are often out of date or are in certain cases just not available. However, to monitor, control and guide these development trends, up-to date maps are needed as a basis for urban and regional planning (Zhang et al., 2002).

The Visually Realistic Model (VRM) of a city is a digital 3D representation of existing objects within a town that contains all

the information necessary to view and recognize each object from all sides (Varshosaz, 2003).

Building models an important part thereof, even though it has to be noted that for many applications, additional information is necessary. For example, a faithful representation for virtual reality applications can only be obtained when the texture of the ground, roofs and facades is present and important details like trees, walkways and fences are present (Brenner et al., 2001). Such three dimensional realistic representation provides designers, planners, the public, and the others with imagery closely coupled with the human experience and, hence, is of great interest (Varshosaz, 2003). With an effective use of generated 3D city model, it is possible to quickly provide height data and engineer preventative measures for the civil protection in the affected region.

The biggest advantage of the 3D model is its mobility (Sauerbier and Lambers, 2003) and its convince effect on users for future decision making processes. It can be shown everywhere and allows people who cannot or do not want to travel to get to know the region all the same. Also by creating a virtual flight through the 3D model can substitute a real flight over the region that many people cannot afford. By this way it is hoped that the model will help to make the local population aware of the richness of their cultural heritage and of the need to preserve it.

Thus, the 3D model is a valuable tool also for archaeological researches. In the first plan investigate the topography, the visibility, and the accessibility of the historical sites are basic ideas, but there are many more interesting aspects. Static views of the 3D model can furthermore serve as illustrations in publications. All these investigations have in common that a

highly accurate 3D model is needed to ensure reliable results (Sauerbier and Lambers, 2003).

1.1. Generation Systems of 3D City Models

The needs for 3D city models are growing and expanding rapidly in a variety of fields. In a steady shift from traditional 2D-GIS toward 3D-GIS, a great amount of accurate 3D city models have become necessary to be produced in a short period of time and provided widely on the market (Takase et al., 2003). Traditional modeling method of 3D city models had required enormous amount of time for manual works. Ordinary modeling method of 3D city used to be:

1. Scan map and get digital image,
2. Trace digital image of map with 3D CAD software resulting in 2D data of buildings outlines,
3. Manually make 3D modeling of buildings with 3D CAD by extruding 2D outlines to building height, and/or modeling manually detailed 3D geometry referring to drawings and photographs also with 3D CAD.

Especially, manual modeling with 3D CAD software was most time-consuming and required operators' expertise. Therefore the old method was not applicable for production of great area of city model in a short period of time. The system development of automatic generation of 3D city model aimed great saving of production time. The new method has realized surprising reduction of time in production of 3D city model through automatic generation programs. Moreover, efficiency in texture mapping as well as quality and accuracy of 3D city model has been greatly improved. In the 3D City Model automatic generation systems the material data includes laser profiler data, aerial image, and 2D digital map. With the material data, detailed and accurate 3D city model is automatically generated (Takase et al., 2003). Automatic reconstruction from aerial images, has shown promising results, however one has to note that often special image material has been used which is not available in general, for example large scale, multiple overlap or color images, or additional height models. Even then, the reliable extraction of buildings in densely build-up areas has not been demonstrated yet. Semi automatic approaches have been reported both for image -and Digital Surface Model (DSMs)-based systems. They can be divided into approaches which model buildings from a fixed set of volumetric primitives which are combined and approaches which build the topology of the surface directly (Brenner et al., 2001).

1.2. Data Source of 3D City Models

Various methods of data capture are available for generation of 3D city models (Wolf, 1999);

- *Photogrammetric method:* The Photogrammetric method is proven and provides exact and definite interpretation results.
- *Laser scanning method from airplanes:* The laser scanner method provides a large quantity of unstructured elements it cannot be used optimally for achieving the interpretation processing.

If we can extend these two titles in detail, we can category as aerial imagery, terrestrial imagery, satellite imagery and

laserscanner data. These are used as raw data whereas depending on requirements, different approaches are applied.

1.2.1. Aerial Imagery

Photogrammetric methods are well suited for the economic acquisition of 3D city models, making it possible to recover the structure as well as the dimensions. On the other hand, classical photogrammetric measurement is mostly point based, which does not exploit the inherent structure of buildings and thus cannot be optimal economically (Brenner et al., 2001). At that moment, aerial images are the most common used raw data. For capturing the 3D point cloud, the stereo pairs of the images are needed. The scale of the images depends on the accuracy that is required for the 3D model and is normally about 1:5000 with a forward and a side overlaps of 30 and 60 percent respectively. If the images are used for True-Orthophoto, the side overlap is suggested to be 60 percent. Using this data, many building details can be measured from the aerial images and the measurement error is maximal 0,2 meter in height (Ulm, 2003).

1.2.2. Terrestrial Imagery

Almost all current systems apply airborne data for the collection of 3D city models. Of course data capture is also feasible based on terrestrial images. Commercially available software tools allow for 3D measurement at high accuracies, nevertheless close range techniques for architectural photogrammetry currently are too time consuming for an area covering data collection. Airborne data is more or less equivalent to terrestrial images if geometric data capture is aspired, but the integration of terrestrial imagery is mandatory for applications like texture mapping (Brenner et al., 2001).

1.2.3. Satellite imagery

In case of large areas, recently high resolution satellite imagery is used, like the 1-meter panchromatic from Ikonos. The data capturing process is the same as with aerial images, but the accuracy is less, measurement error can be up to 1 meter in height. DTM and Orthophoto can be derived automatically (Ulm, 2003).

1.2.4. Laser Scanner Data

For the generation of 3D city models from laserscanner data, a density of laser scanner points of more than 2 points/sqm are required. Big areas are already surveyed with laser scanner, which is seen as an advantage for the application of this data. The procedure for the calculation of 3D building models from laser scanner data uses a tangential plane as a first approximation that suits the laser scanner points. From this geometric model, edge lines are derived whereas edge lines of building structures are generated (e.g. eaves lines, ridge lines etc.). The accuracy is expected to be 0.3-0.5 meters in height (Ulm, 2003).

Automatic systems working solely on the basis of DSMs acquired by laser scanning have been reported. Since DSMs represent the geometry of the surface directly, they have advantages with regard to automated interpretation (Brenner et al., 2001).

1.3. Visualization of 3D Models

In the photogrammetric community, the first attempts in the visualization of 3D models were done at the beginning of the '90. Small objects (e.g. architectural models, cars, human faces) were displayed in wireframe format or using CAD packages, while terrain models were visualized in perspective wireframe models with draping of orthophotos or orthophotomaps. Nowadays, with the increasing of the computer memories, shade and texture are added to all the models, but in order to accurately visualize big data sets, much information contained in photogrammetric models is often reduced. The consequences are that the accuracy of the data is lost (many tools use single precision files) as well as the geo-referencing (most of the software has their own coordinate systems) and that high resolution textures are unusable (because of the control on the Level of Detail). On the other end, low accuracy in the visualization does not attract the end-users and cannot justify the high cost of producing the photogrammetric 3D model. After the creation of a triangular mesh, the results are usually visualized, according to the used package and the requirements, in the following manners:

- *Wireframe mode:* It is the easiest way of representing a 3D object. It consists of points, lines and curves and describes only the edges in a transparent drawing, without texture or shading information. This technique is mainly used in computer-aided design (CAD) packages.
- *Shaded mode:* It is based on the optical theory (Lambert's Cosine Law) which states that the brightness of any small area (polygon) of a perfectly diffuse undulating surface arises as the cosine of the angle of incident parallel light.
- *Textured mode:* It is used for photorealistic visualization of the 3D models (image-based rendering). Texture mapping in its simplest form involves a single texture (image, orthophoto) being mapped onto the surface composed of one or more polygons.

In general, creating realistic 3D models (shaded or texturized) helps to visualize the final result much better than a wireframe representation (Remondino, 2003).

2. CASE STUDY

In this study, a simple and a basic 3D city model is tried to be built using different data sources such as terrestrial and aerial photogrammetry, and different visualisation techniques. In the first part, photogrammetric data acquisition method is used in two applications, in two different places.

The first one is an Opera House in Hannover-Germany. In this application we aimed to create a 3D building using one of the terrestrial photogrammetry tool Photo Modeller Software and visualize it in 3D with GIS environments. The second application is in centre campus area of Blacksea Technical University in Trabzon, Turkey. All centre campus area is digitized from stereo images after stereo-photogrammetric evaluation in Zeiss-SSK Software. Then buildings extended to their original height in AutoCAD program. Finally, gained vector data rendered with rectified photos for photorealistic visualisation of 3D model.

In the second part, a 3D GIS application was done using the photogrammetrically gained digital vector data in the first part

of study. Firstly a terrain model is created from vector data and then a shaded 3D City model is generated over this terrain, with a simple information system in ArcView 3.2. At the end of the case studies, produced models are compared with the view of usability and effectiveness.

2.1. First Part of Case Study

2.1.1. First Application

In this contribution, Opera House in Hannover (Germany) was chosen and, eighteen photos that surround this building, which were taken by one of the Institute of Photogrammetry and GeoInformation's staff in Hannover, were used. The images were taken with Olympus E10 digital camera with 2240×1680 geometric resolution and 9 mm focal length. Photo Modeler software by EOS Systems Inc. was used for photogrammetric evaluation. The Canadian PhotoModeler Software Package is well known as a low cost 3D-measurement tool for architectural and archeological applications. It is a Windows based software that allows measurements and transforms photographs into 3D models. The image coordinates of corresponding points and control points were measured manually and the images were oriented automatically. After the facades of building was identified as a surface patches, the wireframe and photo-texture model were built up using the oriented images (Fig. 1).

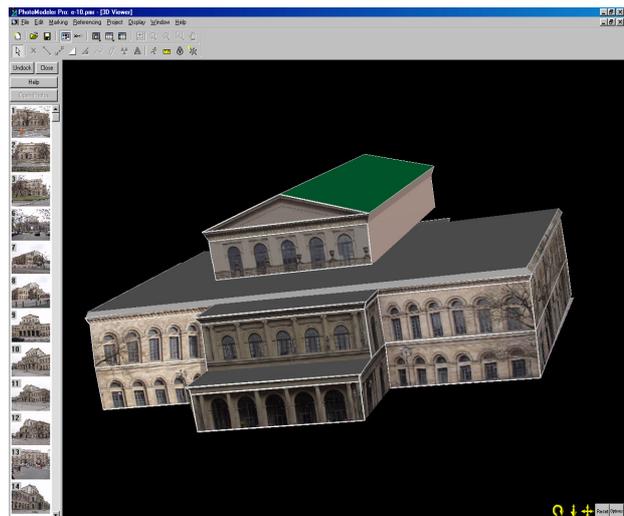


Figure 1. Photo-texture Model of Building Created by Photo Modeler

2.1.1.1. Visualization and Querying of the 3D Model in GIS

The 3D DXF file created in PhotoModeler is converted to SHP file format in ArcView. Base map with control points is imported to ArcView program. A georeferencing has to be done to make association between base map and 3D model to see them together in 3D scene. With the help of the TFW (world file for tiff image) file belongs to ArcView, base map is registered and transformed into same coordinate system with 3D model.

One of the main objectives of this application was visualizing the photo texture in GIS environment. However, only the shaded parts of the building can be seen in 3D in ArcView. For

this reason photo texture could not be used in a structure representation aim. But there is another very important point that, in this application there is no information reduction in the photogrammetric model, during visualization. Original measurements transferred to GIS tool.

It is also possible to make miscellaneous queries like building's archive number, building name, number, construction date, previous works on it and owners' name, over joined layers (Fig. 2) (Karsli et al., 2003).

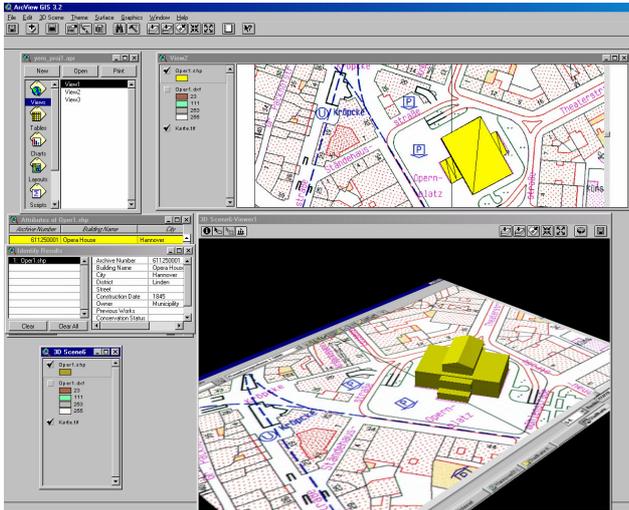


Figure 2. Visualization of 3D Model in Arcview

2.1.2. Second Application

In the stage of the study, KTU Centre Kampus area in Trabzon, north east of Turkey (Fig. 1) is used. There are many buildings in the campus area. Therefore, for the photo-texture documentation, a group of buildings including Atatürk Cultural Centre, Faik Ahmet Barutcu Library, Students' Affairs, Rector's Office, and a statue of Atatürk were selected because of their complicated facades. These buildings and KTU centre campus area are shown in Figure 3.



Figure 3. The Aerial Image of KTU Campus

Here, we used a pair of aerial infrared images that cover the campus area. They had taken over the site in 2002 at an image scale of 1/16000 with the RMK TOP 15 type of camera with a camera constant 153 mm. They were scanned with 21 µm geometric resolution using a photogrammetric scanner. Terrestrial images concerning selected buildings facades' were taken with Nikon E2/E2s digital camera with 1280×1000 geometric resolution. Nikon digital camera produces TIFF and JPEG images. A total of 20 images were acquired from terrestrial viewpoints using 24 mm focal length. These images were transferred into computer media via PCMCIA card. The images of the facades were rectified by using Elcovision 10 software by PMS Inc. (PMS, 1997).

2.1.2.1. Photogrammetric Evaluation

Photogrammetry is one of the generation systems of 3D City Models with the stereo-photogrammetric approach. The object is photographed with metric cameras, having a fixed focal length and fiducial marks on the calibrated frame, so that the imaging bundle of rays can be reconstructed. The images are taken in stereo pairs with approximately parallel axes. In this study, stereo photogrammetric evaluation was performed by using aerial photographs of KTU campus. In the evaluation stage, a stereo pair was constituted and CAD data of the buildings were collected from the model (Fig.4). Digital Photogrammetric Workstation Zeiss SSK was used for photogrammetric evaluation.

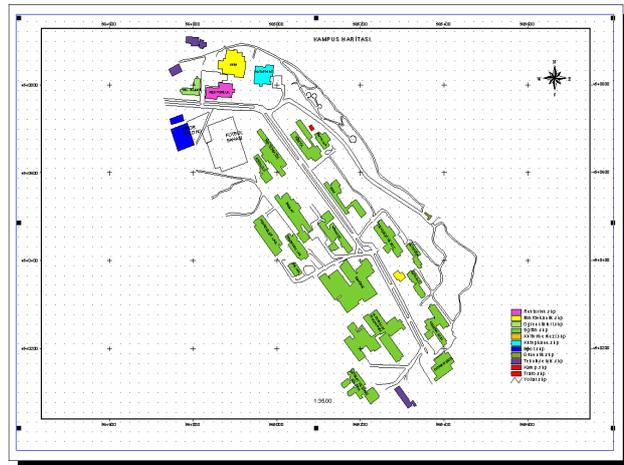


Figure 4. The CAD Model of KTU Campus in 1/3500 scale

2.1.2.2. Photo-Texture Mapping in AutoCAD System

The CAD model created in SSK software was transferred into AutoCAD system. In AutoCAD, 3D model of buildings were created, then a wireframe model was constituted (Fig.5). The facades images rectified in Elcovision 10 were superimposed into wireframe model of selected buildings. Therefore, 3D photo-texture model have been constituted. Besides, some texture such as tree can be added to photo-texture model of the campus area (Fig. 6) (Karsli et al., 2003).

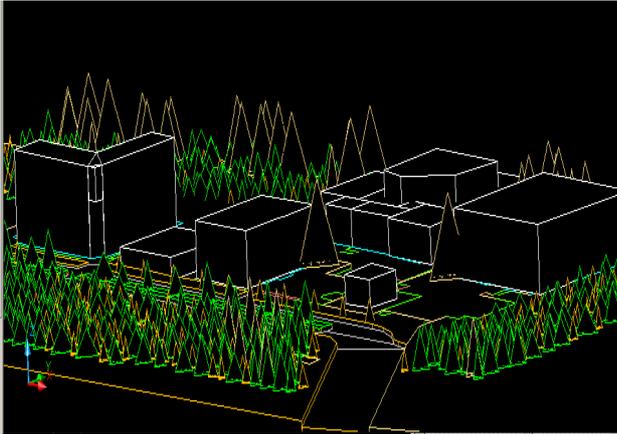


Figure 5. 3D Wireframe Model Created by AutoCAD System



Figure 6. 3D Photo-Texture Model Created by AutoCAD System

2.2. Second Part of Case Study

2.2.1. Building 3D Building Model in ArcView

The CAD model created in Zeiss SSK software was converted to shape file format and transferred into GIS software Arc Toolbox to build the topology of buildings and roads. First the building heights were defined through their flat numbers then, attributes data were added in ArcView 3.2 software. By this way, various queries can be done in building layer and 3D building model was produced for the visualization. Finally it is draped on a TIN surface created from contour lines (Fig7).

The Figure 8, in the following is also a small example view of 2D City Information System. Here user can query all the buildings and also see the attached image to the relevant building.

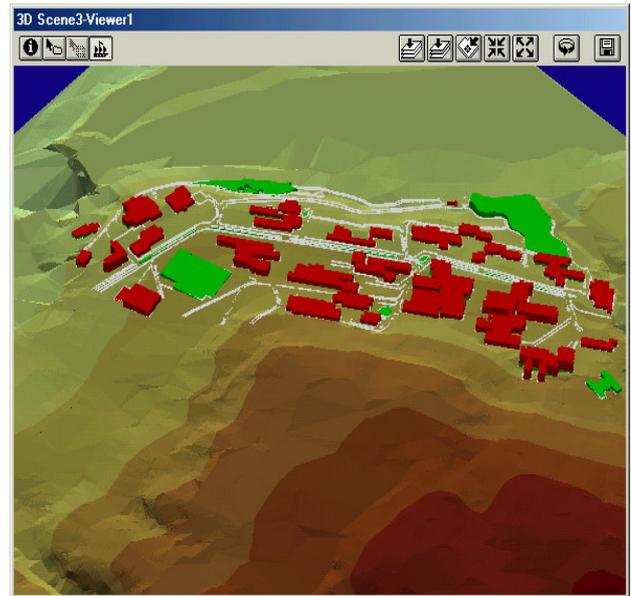


Figure 7. 3D Model of KTU Campus Created in ArcView

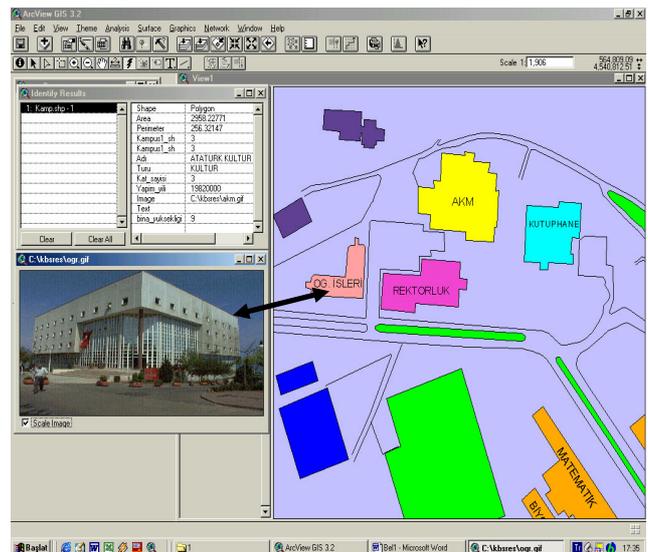


Figure 8. 2D City Information System of KTU Campus Created in ArcView

2.3. Comparisons Between Created 3D City Models

The 3D city created in the first part in first application by photogrammetric software “Photomodeler” is visualised in Arcview 3.2. The vector data of the building extracted from terrestrial images. Generated 3D building was in original position and it was referenced with the cadastre map. Also attribute data belong to the building was added to the 3D graphical data in 3D scene. The only negative point is that the texture parts of the building can not be seen in 3D in ArcView. In the second application vector data of the 3D city model is extracted at the end of aerial image evaluation with Zeiss SSK software. And the visualisation of photo textured model is realized in AutoCAD. It is also possible to inquire 3D position information. The negative point is the lack of attribute data

inquiry. In addition to this manual modelling with 3D Cad software was most time consuming and required operators' expertise.

In the second part of the study, photo texture couldn't be draped to the vector data in 3D scene in ArcView, but by preparing a large information table and linking the images, which are belong to buildings, to the vector map, a simple information system was generated.

3. CONCLUSION

In this study, introduction to 3D City model has been realized in a simple sense. From the CAD model produced by aerial photogrammetric technique, 3D photo-texture model has been introduced by using building heights and its rectified images. And then, an integration between the 3D model of object generated from photogrammetric techniques and attribute data concerning the same model of object has been provided on ArcView which is a GIS tool. With this integration, the data will be continually updated, analyzed and queried. During this integration for visualization, there is often a data reduction in photogrammetric model. This data reduction has been seen also in our applications, except the first one which is terrestrial application. In other applications data loss has been seen while extruding the polygons. Aspect of generation systems, data acquisition techniques and visualization of 3D city models, two techniques used is nicely proportioned.

As a result, photogrammetry is an appropriate method as a data acquisition method, and GIS (ArcView) and CAD System (AutoCAD) are appropriate tools as data visualisation and information storage tools for 3D City Modelling. The result of the study also confirms that building 3D Campus Model with the defined method and required data through the user needs was performed very easily and effectively.

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