Building 3D GIS Model of a University Campus for Planning Purposes: Methodology and Implementation Aspects

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Abstract:

The objective of this work is to elaborate on the demand and usefulness of three-dimensional modeling, and also, explore the capabilities of current technologies via a pilot project. Through this, one can discuss the corresponding required production workflow for building three-dimensional GIS Model of a complex site of interest using Digital Photogrammetry techniques and GIS modeling. In our case, two University campuses are modeled using two different cameras: the first uses the RC30 aerial camera format and the other uses new up-to-data digital camera technology (Kodac 4X4K that deliver very sharp colored images). Assessment of the results and discussions of the over all project precision and reliability, and orthophoto products are the focus and our objectives of this study.
The study will present the methodology and the implementation techniques used to build first the three dimensional model, and also, construction of the GIS data-model with required relational database to offer the possibility of flexible and interactive visual GIS analysis of the ever changing situations in the University site. Furthermore, the work shed lights on possible GIS spatial analysis techniques in three-dimensional, which will provide a very useful and effective interactive tool. Decision support system for planning purpose in a 3D visual environment for emergency, evacuation and security matters will be illustrated based on suggested scenarios. The mechanism of using suitable software that are of importance for the success of this work will be explored. Finally, visualization results of the projects with suitable example of possible analysis for several applications will be presented and discussed.

Introduction

Demands for three-dimensional GIS modeling are increasing rapidly with the new evolving and supporting technologies for various applications. It is charting the new trend/direction for our Geo-Spatial community. Three-dimensional modeling is the true Simulation of Reality, especially if it is accurate. On the other hand, using this model in GIS environment offers a flexible interactive system for providing the best visual interpretation, planning and decision making process. The built model becomes one of the most efficient technologies for spatial data management and analysis.
In the past twenty years, three-dimensional modeling is the focus of many researches. Nowadays with the new development of technology, fast processors, and digital devices tools, and software is becoming more feasible and requires much less time and effort using proper procedures.
Three-Dimensional Modeling Using Digital Photogrammetry techniques to build 3-D model is one of the most suitable and efficient technologies for producing fast accurate geographic data sources. It optimize time and cost for producing 3D spatial data by indirect measurement technique rather than field surveying. Also, one get the highest precision of 3D spatial data

for large area which consider one of the most reliable method for obtaining 3D data which cant be obtained from GIS.

The Digital Photogrammetry techniques is, in fact, used to build the 3-D GIS base for the studies for two University Campuses, The Balqa Applied University (in Salt city), and the Yarmouk University (in Irbid City). Furthermore, a 3-D GIS database model is build for Yarmouk University, in addition of creating the relationship-classes between spatial data to allow for 3-D spatial analysis. All attribute data can be obtained, retrieved, and updated through Access database that contains huge information about the university and its departments, which can be used for many scenarios to support planning and execution decisions. In the following section, discussions and elaborations of the following are illustrated: planning process, requirements and work follow of the digital photogrammetry technique, comparisons of the two constructed 3D model of the tow campuses, and the 3D GIS model and conducted spatial analysis.

Project Planning:

To conduct successful GIS project to build 3D GIS model, Figure 1, illustrates the planning: steps taken into consideration in implementing this project. As shown in the first step, the project objectives are:

- Build 3D model of The University Campuses
- Build a relational spatial data base that correspond to the 3D model
- Offer flexible and interactive visual presentation of the ever changing situations.
- Offer an interactive decision support system for data management of all departments and units in the University.

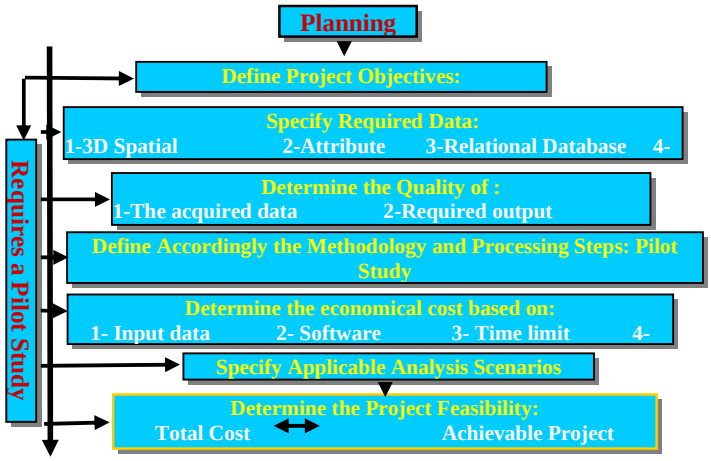

Figure 1: Planning and Implementation Steps

Three-Dimensional Modeling

With the new advancement in digital Photogrammetry and software automation techniques, 3D modeling is becoming more feasible and much less time-consuming process, especially with the use of digital cameras. However, the technique requires the availability of Digital Photogrammetric software (such as SOCET SET or Z/I) and experienced human resources in this field.

It is well acknowledge that photogrammetric modeling based on collinearity equations eliminates these errors most efficiently, and creates the most reliable orthoimages from the raw imagery. It is unique in terms of considering the image-forming geometry, utilizing information between overlapping images, and explicitly dealing with the third dimension: elevation. In addition photogrammetry can also provide other geographic information such as a DEM, topographic features, and line maps reliably and efficiently. In essence, photogrammetry produces accurate and precise geographic information from a wide range of

photographs and images. Any measurement taken on a photogrammetrically processed photograph or image reflects a measurement taken on the ground. Rather than constantly go to the field to measure distances, areas, angles, and point positions on the Earth's surface, photogrammetric tools allow for the accurate collection of information from imagery. Photogrammetric approaches for collecting geographic information (3D coordinates of object-points), Topographical and thematically maps, Rectified photographs (orthophoto), save time and money, and maintain the highest accuracies. In addition, with the fast moving development of LIDAR in combination with photogrammetry techniques, the production is much faster, efficient and accurate. However, special camera is required and in many cases it is not available. Figure 2, illustrate the workflow procedure followed to build the 3D features and DTM models, in addition to the extract 2D GIS layers projected on the ortho-photo of the area.

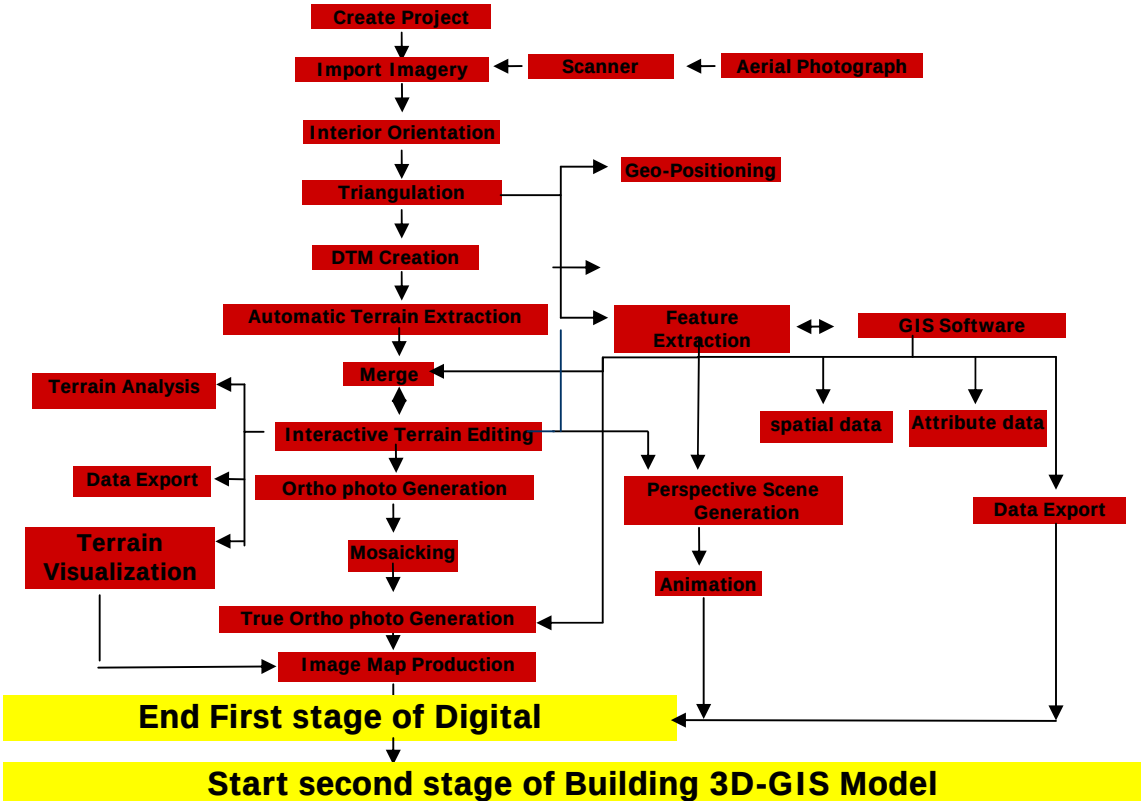

Figure 2: Digital Photogrammetry Workflow to build 3D models

SOCET SET digital photogrammetry in addition to Microtstaion software packages were used to create these products. It is very important to note that creation of an accurate DTM is a key and pre-requisite for accurate feature extraction and 3D modeling. Figure 3 is the 3D features model built for Al-

Figure 3: Three dimensional Model for Yarmouk University

Yarmouk University site, and, Figure 4, illustrates the 3D building model built for Al-Balqa Applied University site, and

Digital Camera Vs Aerial Camera

Recently, Al-Balqa Applied University acquired a new digital camera that can be used for various projects either aerial or terrestrial. It is the Kodac ProBack a 4Kx4K camera resolution sensor (see Figure 5) with a size of approximately 40X40 mm, with a very precise Biogon lens. It is equivalent to small camera format. Table 1b shows the specs of the camera compared to the RC30 camera used to build the 3D model for the Yarmouk University. Table 1a shows the flight planning and project implementation specs.

The photos used from aerial camera RC30 wre scanned to 20 microns pixel size. The nice thing about the digital camera is no need for scanning nor fiducial transformation. Off course both requires the interior orientation calibrated parameters.

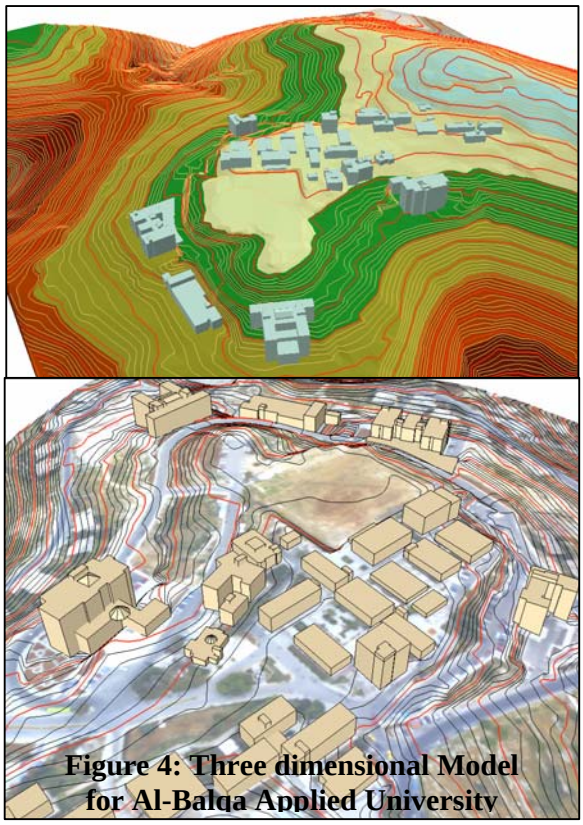

Figure 4: Three dimensional Model for Al-Balqa Applied University

Table 1a: Flight Planning

Flight Planning	AL-Yarmouk	BAU
FLYING HEIGHT	2200 m	1935 m
PHOTO SCALE	1:10000	1:25000
PHOTO COVERAGE	1 Km^2	1 Km^2
OVER LAP	60+%	85+%
AVERAGE TERRAIN	740 m (MSL)	960 m (MSL)
STRIPS	1	1
PHOTO PER STRIP	3	4
TOTAL PHOTOS	3	4

Table 1b: Cameras Specifications

Image Specs.	RC30 metric camera	Kodak digital camera
FOCAL LENGTH	153.279 mm	38.274 mm
DIMENSION	23x23 cm	4x4 cm
PIXELS	12000x12000	4080x4080
STORAGE SIZE	410 MB	45 MB
BANDS	3 RGB	3 RGB
FIDUCIALS?	YES	NO
PIXEL SIZE	20 µm	9.1 µm
GSD	20 cm	23 cm
ENHANCEMENT	EQUALIZED	EQUALIZED

Figure 5: The Used Cameras

The flight planning with the Kodak camera was via a Helicopter. The operator was acquiring the images directly according to special theme. Hand held GPS was utilized

in addition to the Helicopter navigation system to organize the acquisition process. Although the flying height and the photo scale is larger than for the digital Kodak camera, the sharpness we achieved from the photos allowed to get very accurate resolution measurements for building our 3D model. However, sine because of the flying conditions, we chose a very high overlapping percentage to manage the adjustment of the photos with good accuracy and stable results. Detailed comparison aspects are provided in the Al-Durgham and Nour 2005 and Al-Awamleh 2005, and also, more aspects related to the digital Kodak camera is provided in Kolbl 2005.

Three-Dimensional GIS Modeling

Detailed Schematic diagram shown in Figure 6, illustrate the procedure followed to build the three-dimensional GIS model and the required relational database for Yarmouk University site. The following are the data sources used for this:

1. Aerial photograph for AL-Yarmouk university scale 1/10000, dated 2000. It is used to produce orthophoto and 3d model from the stereo models.
2. Topographic maps of the area that can act as control field area.
3. Blueprint maps from the Engineering department of the university. It is used as a guide for extracted feature layers
4. Attribute data from Yarmouk university administration office about all colleges and departments in the university.

Three software packages were used to build the feature classes layers geo-referenced to the Jordanian projection system as shown in Figure 7.

I. 3D geo-referenced feature classes: The software used to extract these features is the feature collection module of the SOCET SET package installed within the Microstation software as an mdl module. The extracted 3d feature were the Buildings layer and the contour line layer, see Figure 3

II. Geo-referenced Orthophoto and true Orthophoto maps of the University campus (Map scale up to 1:500). SOCET SET package was used, see Figure 7.

III. 2D feature class layers geo-referenced. Microstation software is used to create the following layers (, see Figure 6): the roads layer; the parking layer; the forest layer; the olive trees layer; the garden layer; the pavement layer; the tiles layer; and the land sport layer, see Figure 7.

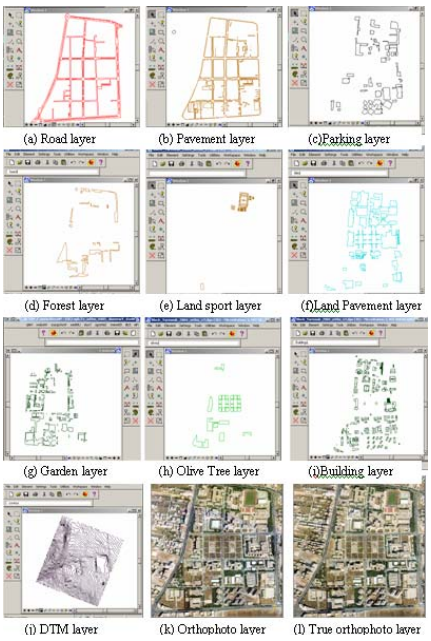

Figure 7: Extracted feature layers for Yarmouk University

Relational Database Modeling

All layers then exported to the ArcGIS environment to build the relational database and to work in three dimensional environments using the ArcScene of the ArcGIS software, as shown in Figure 8 and 9.

Three Dimensional Spatial Analyses

One scenario that is illustrated in Figure 9, is to know in case of a fire break down in the Chemical labs Supply building, what are the affected neighborhood buildings and what are

the same ones and the same floors of the affected buildings. Also, it can be illustrated with different zone colors according to danger to warning areas.
The illustrated spatial query illustrated the answer in three dimensional environments with animated virtual reality that provided all the answer needed. This made the problem easily visualized that provided very solid base to take immediate actions that is almost impossible to do without it. This in fact makes these types of queries feasible and open new era of applications.

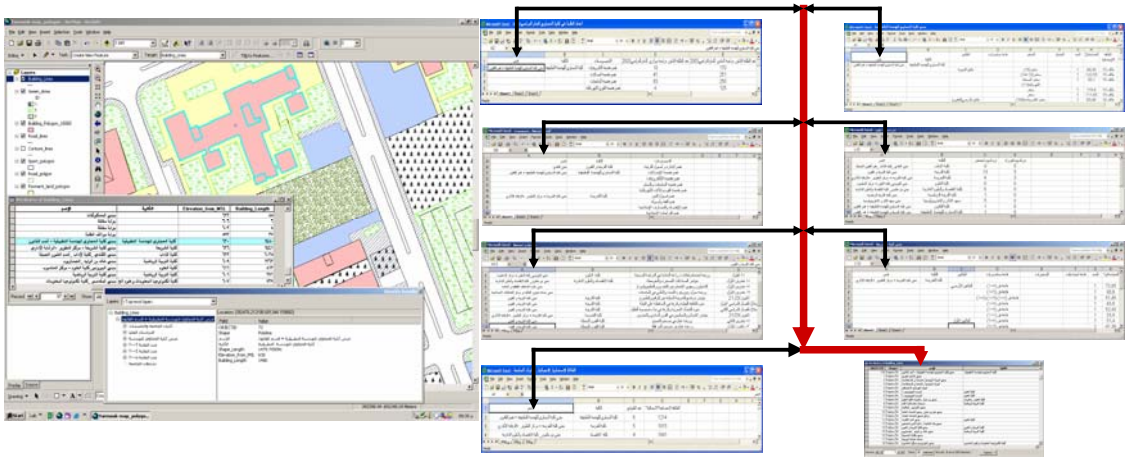

Figure 8: Relational Database scheme of 3D GIS data-models

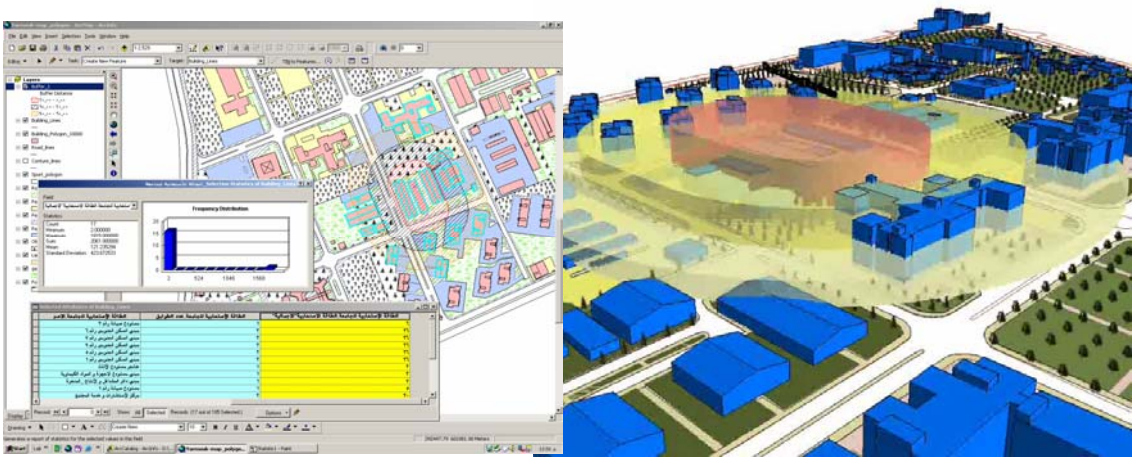

Figure 9: Three-Dimensional Spatial analysis with Virtual Reality Animation results.

Results, Conclusions and Future work

This work is the result of one year of research that shows the effective use of 3D GIS modeling. The study also shows the feasibility to do such work using small digital camera for small projects wit easy work scheme. This project corresponds to the complete production workflow of the new trend in building up three dimensional model of a complex of interest using the Digital Photogrammetry techniques. The work flow should start using the Digital Photogrammetry workstation to extract the DTM, to produce the orthophoto and true orthophoto, and finally to extract 3D features and building. The positional accuracy were measured compared to the blue-prints drawing of the building where within 10 cm.

Then two-dimensional database layers for all features were created to model the reality of the site, so that any three-dimensional analysis will include all related information that affect any decision. All these, were integrated into one environment to build the 3d GIS model of the university campus. Finally, 3D perspective scene with true animation for the area using the SOCET SET software and ArcScene software packages were created.

The concluded Photogrammetry results discussed in the thesis shows good conversion results with overall rigorous aerial triangulation adjustment of 0.112 m. The quality of the produced orthophoto with a GSD (pixel to ground ratio) of 0.15 meter matches the observation accuracy of about 0.14 m, which shows reliable results and that ware true for digital camera also.. In addition the analysis and measurements of the relief displacement and geometric differences of some building that shows reliable results between the produced orthophoto and the true orhtophotos. Finally, the precision of the extracted DTM shows to be good enough when compared with control points coordinate.

Future work and recommendation of this work can be summarized in using a different software that allow to add texture to the 3D objects to provide more realistic view to provide real virtual reality environment. This will make the product more live and easier to visualize. One suggested software is the Geographics and Decart packages that are a continuation product to the Microstation software, which were not available to the authors to try. To make full use of this work, the university administration should try to adopt the system and then many applications will for sure become totally dependent on such environment for better analysis and management.

Finally actual texture of the building to the 3D model is still to be carried out; one more important application is to define an automatic procedure for fitting available vector data such as streets to provided OrthoPhotos. More work is still to be done for the 3-D such as adding details for

- Building Texture Using Close Range Photogrammetry Techniques
- Building Floors using the CAD drawing details
- Adding Attributes to these floors

This type of applications is very useful in many other applications, which is the focus of the next research areas such

- 3D Cadastral Mapping Applications to build virtual reality city-models in 3D for roads and Buildings.
- 3D GIS Models for Tourism
- Archaeological Documentation such as for Jerash and Petra cities in Jordan.

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Figure 6: Schematics diagram of the Pilot Project Implementation Scenario to build 3D GIS data model.