

Texture Mapping and Implementation Aspects for 3D GIS Applications

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Abstract:

In the past twenty years, three-dimensional modeling was the focus of many researches. Nowadays with the new development of technology, fast processors, and digital devices tools, and software, 3D modeling is becoming more feasible and requires much less time and effort using suitable procedures. The objective of this research work is to examine the current off-the-shelf software technology to build texture for 3D GIS models using several techniques for various applications. The importance of such trend in city planning is a focus of this work in order to illustrate the effective use of 3D modeling and visualization techniques in the decision-making process to communicate ideas very quickly, which help take better decisions. This work will present the gained experience in texture mapping through two pilot projects using off-the-shelf software. Texture mapping is done within the GIS environment with an add-on-module that reflects the true/actual scene. Although the results are not very accurate, but the methodology is fast with a true scene and delivers a solution for some applications such as 3D Cadastral mapping, and tourism. The implementation aspects and the methodology used will be discussed. Furthermore, accurate texture implementation procedure will also be presented and illustrated.

1. Introduction

Three-dimensional visualization with texture mapping is the true simulation of reality, especially if it is relatively accurate. On the other hand, GIS environment offers a flexible interactive system for providing the best visual interpretation, planning and decision making process, see Al-Hanblai et. al. 2007 and 2005, and Al-Hanbali and Sadoun 2006. Thus adding texture to 3D models would produce efficient use of technologies for spatial data management and analysis, see Appleton and Lovet 2005, Carlwright et. al. 2004. Recently, there are a number of 3D GIS visualization systems developed to assist in collaborative planning processes, both in urban and rural contexts (Bishop et al. 2005; Pettit et al. 2004). Lovett (2005), explain related literature for future planning scenarios and referred to it as "futurescapes". Some has developed their own system that that can interactively communicate with the user/planner/expert based on certain planning scenarios and also referred to as landscape visualization (MacFarlane et al. 2005)

Several techniques can be used to build 3D modeling, which are explored by the author in several applications such as building accurate 3-D model for two of our University Campuses, the Yarmouk University (in Irbid City) , and the Balqa Applied University (in Salt city).and also for the Artemis temple in Jerash City, see Al-Hanbali et. al. 2006a, b and c and Al-hanbali et. al. 2005. Digital Photogrammetry techniques is used to build three-Dimensional Modeling as one of the most suitable and efficient technologies for producing fast accurate geographic data sources, see Wolf 2000, Koelbl 2005 and Atkinson 1996. It optimizes 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.

However, there is a need to build suitable 3D model with less time consuming tasks, less expenses, and faster techniques, based on sacrificing accuracy and precision. This is becoming feasible as implemented in this work, especially, with the new evolvement of GIS software development, technology, fast processors, and digital devices tools. 3D modeling is becoming more feasible and requires much less time and effort using suitable procedures such as discussed and implemented in this paper.

The objective of this work is to demonstrate the usefulness of three-dimensional modeling, and explore the capabilities of current technologies and off-the-shelf software such ArcGIS via pilot projects. The paper explain the various techniques used to build up context-procedure for 3d models texture mapping visualization within GIS environment as a tool for spatial planning, decision making and tourist applications. The paper concludes by discussing the lessons learnt in undertaking a cross-disciplinary software approach to developing and applying 3D texture visualization within GIS environment and offering some future directions in the application of 3D geographical visualization.

2. Objectives:

The main objective of 3d modeling and texture mapping is to build suitable procedure for documentation of cultural heritage objects and thus to serves as a tool to make information accessible for: documentary and research tourism applications for any interested persons who can investigate the object without going to the site. The result of the documentation has to include not only the graphical knowledge but also some nongraphical information such as objects' history, conservation status and owners

Nowadays, the techniques based on the use of the Digital Photogrammetry and GIS help us to solve with success the necessary 3D models with texture mapping, on which all the implied professionals in this topic can lean on and make their performances. In addition to, the elaboration of so architectural surveying, the techniques allow us not only to edit some plans with a high degree of graphic precision and metric accuracy, but also to detect all those defects or structural and constructive degenerations that cause the minimum deformations or alterations in the formal state of the building.

Also, these technologies highlight on the conventional techniques in being an open system that allows the gradual incorporation of new applications or studies as these they leave applying. As conclusion one can affirm that the digital Photogrammetry and the GIS provide a group of advantages and benefits in the architectural tasks impossible to obtain with such an efficiency, velocity and economy by means of other procedures. Different queries on 3D model of object can be done by linking graphical and attribute data.

Al Hussein Public Parks project is one of the landmarks in Amman. The Parks include a cultural village, sports fields, memorial building, historical passageway, decorated gardens, amphitheater, circular yard, automobile museum, children museum, Traffic Park, and walls and gates. Such projects aim at showcasing our cultural heritage once it's been reformulated and then presented in a contemporary way. The project contains sites that embody the goal of preserving the architectural heritage and emphasize esthetics. Figure 1 illustrates the parks geographic location and the landscape.



Figure 1:(a) Park location on Jordan Map(b) Photo of Al-Hussein National Parks

The main idea of the Historical Passageway is an attempt to explore the cultural content and to present a chronological timelines for the region, with its rich history, beginning with the stone age and on to the iron, copper and bronze ages. The Passageway also depicts past civilizations and peoples. The mural, which stretches some 488 meters

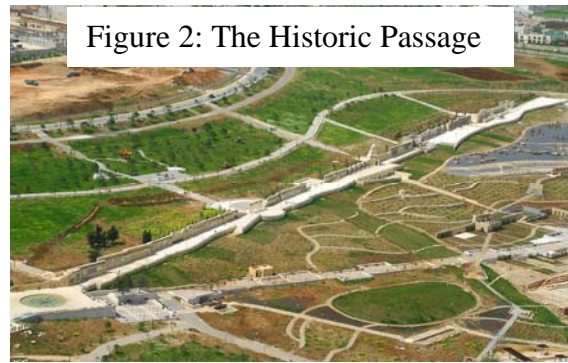


Figure 2: The Historic Passage

(see Figure 2), has been divided into slides of various lengths corresponding to the historic period to which it refers. The creation of each slide was inspired by the historical events and characters of a particular period. Stones of all shapes and sizes have been used as a main building element. Marble, granite, iron, bronze, ceramic tile and pottery have also been used. This made it possible to create the needed diversity while maintaining the thematic link. As far as Mastabas are concerned, different types of material and various colors were used as appropriate for each historical period.

It should be noted that the mural contains a number of sculptures, decorations, paintings and metallic formations that were contributed by a number of local artists of various artistic schools. (see <http://www.ammancity.gov.jo/english/project/p4.asp>)

King Hussein Mosque seems like an Islamic castle, plain design magnificence since it simulates distinct Islamic architecture style and compose between modernity and originality in the Islamic patterns on walls, vaults, arches and floors to be one of witnesses that remind of Hashemite interest in mosques structure. Al-Hussein Bin Talal mosque is constructed by an order from the



Figure 3: King Hussein

second great king Abdullah to co memorial the great departed on an area of **60000 m²** and the building area is about **8000 m²**. The mihrab is an Islamic piece of art made excellently by students of traditional Islamic art faculty in **Al-Balqa Applied University** whom used Walnut and Oak wood in magical manner as shown Figure 3.

Because of the special importance of the Historic Passageway and King Hussein Mosque, they were chosen for our research work to build detailed and proper 3D models with very detailed and true texture mapping within a GIS environment. In addition, 3D virtual reality with over all texture was generated for the parks within the same GIS environment. ArcGIS/ArcScene is the software used as the 3D GIS environment.

Figures 4, 5a, and 5b illustrate the resultant 3D modeling of the Parks with Texture mapping.

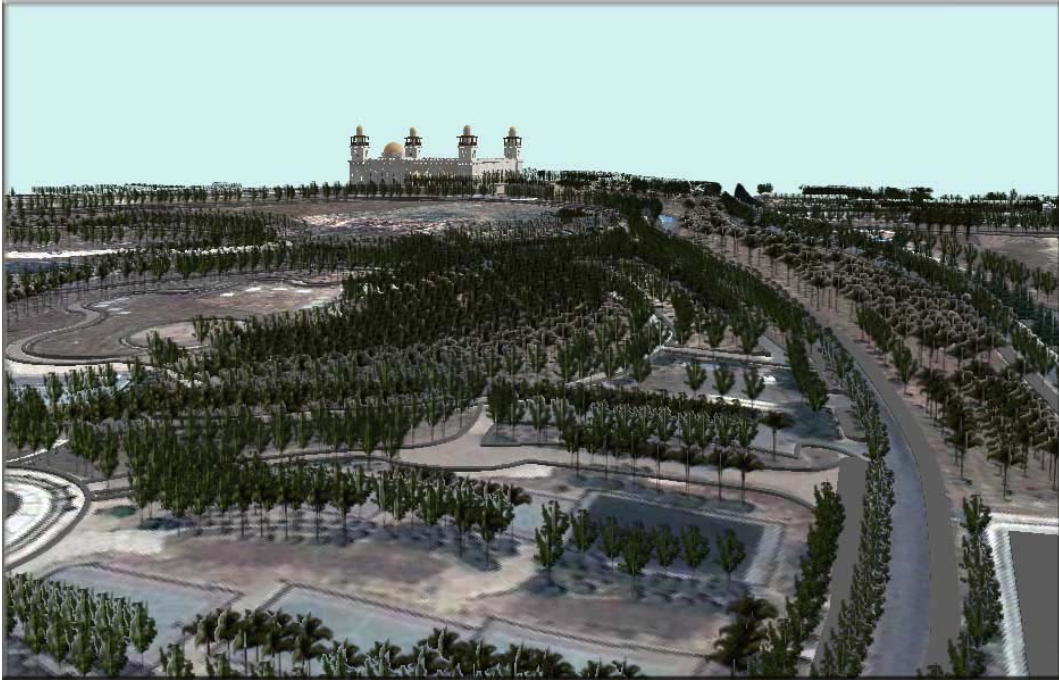


Figure 4: 3D modeling with texture mapping of King Hussein Parks.

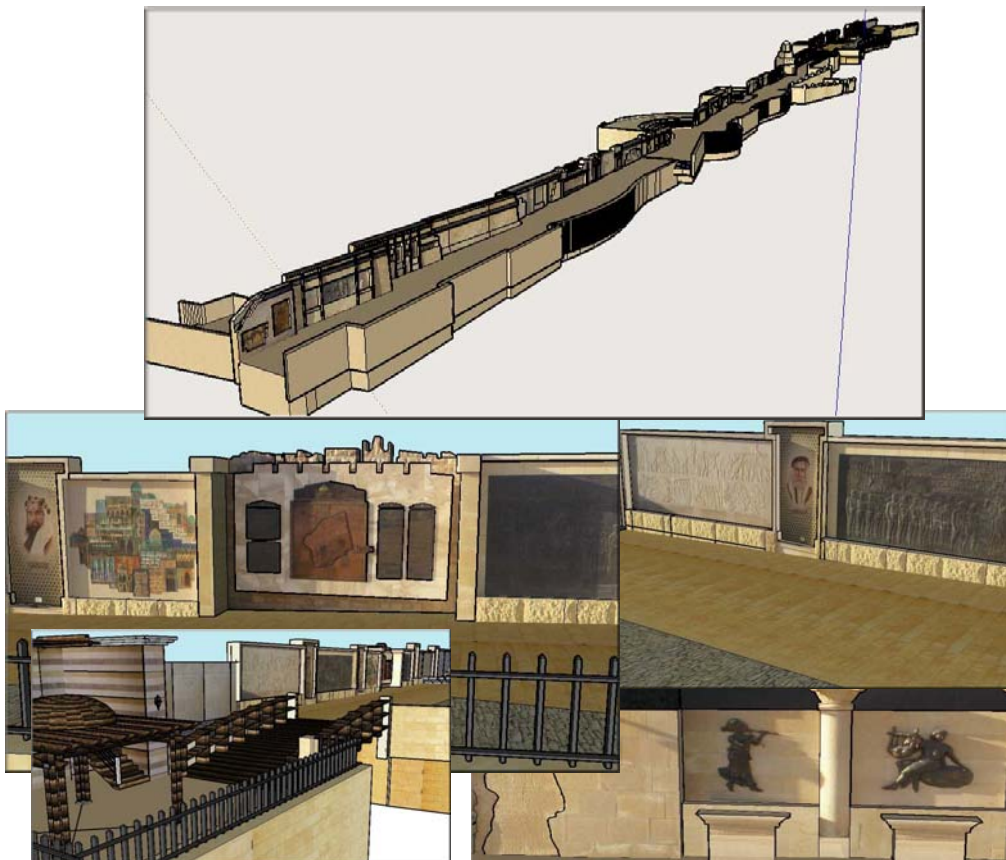


Figure 5a: 3D modeling with texture mapping of the Historic Passage.



King Hussein Mosque

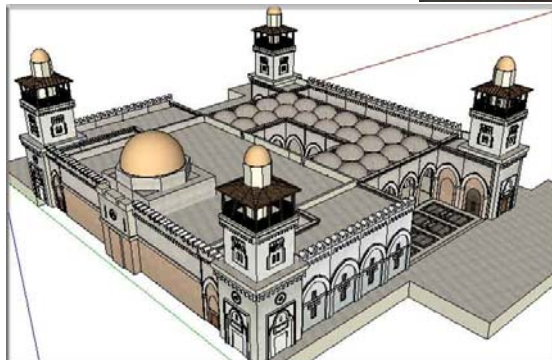


Figure 5b: 3D modeling with texture mapping of King Hussein Parks Mosque.

The following sections detailed methodology related to each phase discussed and explained through the implementation of such procedure via pilot project named 3D GIS Visualization for King Hussein Parks in Amman City.

3. Methodology and Project Planning:

The following are the implementation steps required to build a true reality 3D GIS model with texture mapping that is implemented for King Hussein Parks.

1. Data Modeling:

- **Data collection** of all available geospatial database and attribute data wither it is
 - AutoCAD files (or a CAD formats data), like 2D and 3D CAD files available from the blue-prints and construction drawings.
 - Raster imagery such as Quickbird and Ikonos for the area of interest,
 - Paper- and scanned-tourist maps of the area,
 - Attribute database and documentations related to the parks information.

- **GIS Data Modeling:** This is an important step to define all required geospatial databases including vector and raster classes and their relationship classes based on the defined objectives of the project. This will draft what is required and missing to build the required GIS data-model.
2. **Data Measurements, Processing and Preparation:** to build the required 2D and 3D GIS information system.
- **Data measurements and Capturing:** In this process the following are some important data measurements:
 - Ground control point for the area using GPS,
 - Survey measurements of the area of interest using Total Station
 - Building heights and reference points to provide proper scaling for required 3D objects,
 - Stereo images of objects to build 3D models,
 - Photos of required texture to be used as filters later on to build texture to 3D models.
 - **Data Processing and Preparations:** In this process the following are some important processing steps:
 - Build Orthophotos for the area of interest (PCI and SOCET SET are used),
 - Build terrain and DTM to build 3D view of the Orthophotos (AutoCAD and ArcGIS are used),
 - Digitize the Orthophoto to build all required 2D vector layers according to the GIS data-model, also add to it their attribute data (ArcMap is used),
 - Append all detailed-CAD files to these digitized sets to build and scale it to proper dimensions (ArcMap is used),
 - Build relational database within the GIS data-model layers (ArcMap and ArcEditor are used),
 - Build height dimension for 2D GIS vector layers as attributes based on the GIS data-mode (ArcMap is used),
 - Edit capture photos to remove any un-needed feature in the photos before using it as a filter for added texture (Photoshop 8 is used).
3. **Build 3D model** of all the needed features based on required details and available spatial data and also according to the GIS data-model design. The following are the important implemented cases:
- **Case I Simple 3D shape geometry:** in this case the 2D layer was built and the height dimension was determined either by direct survey measurements or taken from CAD drawings. The 3D model can be built directly in the 3D GIS software environment. The shape appears like 3D blocks shapes (ArcScene software is used).
 - **Case II 3D CAD Model is available:** in this case, the dimensions have to be verified by scaling it with the built 2D layer and also via survey measurements. Final 3D model is then verified and georeferenced to

- its exact position on map (AutoCAD and Sketch up softwares are used).
- **Case III Only 2D layer is available:** in this case close range Photogrammetry is used to build 3D wire mesh of the required object(s) using the captured stereo imagery during the data capturing step (Photomodeler and SOCET SET softwares are used).
 - **Case IV some parts are available in 2D and others in 3D:** combination of case II and III is used, but it is very important to use a consistent reference system to merge all 3D into one object (Sketch up software works well in this case).
4. **Build a 3D GIS model with all relational spatial data base** that correspond to the 3D model. There are several techniques to insert the built up 3D models from step 3 within the 3D GIS environment as following:
- **The 3D GIS environment** in our case is the **ArcScene** environment of the ArcGIS software. Datum for providing reference base-height for any inserted point, 2D or 3D objects.
 - **Case I Simple 3D shape geometry:** in this case ArcScene build the 3D model directly using the 2D vector layer with the added height information as part of the layer attribute for each feature in the layer, or added directly as a constant height for all features in the layer. DTM is also specified as the base-height for all layers.
 - **Case II 3D CAD Model is available:** in this case, if the CAD software has the capability to export the 3D model file into 3D shape file, then it can be inserted directly into the ArcScene environment. If not the file can be imported into Sketch up software, where it will be exported into proper format for ArcScene. It is important to note that complex 3D models should be split as much as possible to smaller objects in order to be able to export it easily into the environment using the geodatabase format. Our practice found that the best scenario is to use Sketch up software. You can better control your split objects since the export formats are geodatabase. Also, it is important to georeference the model to its exact position in ArcScene before exporting it.
 - **Case III Only 2D layer is available:** in this case the close range Photogrammetry such as Photomodeler or other Photogrammetry software such as SOCET SET or Z/I can export the 3D model to 3D CAD model or shape file. Our recommendation is to convert the models to CAD format then exporting them to Sketch up software and repeat the same as described above.
 - **Case IV some parts are available in 2D and others in 3D:** combination of case II and III is used, but it is very important to use a consistent reference system to merge all 3D into one object (Sketch up software works well in this case).
 - **Up till this step all added 3D models in ArcScene can take one texture tile which is normally color coding based on symbol definitions and object classes.**

5. **Texture Mapping:** appending to all facets of the 3D features the true texture is very essential to simulate reality and thus provide the user/planner with true scene that can help in making better decisions. The following are the options and scenarios one can follow:
- **Use the Orthophoto with added DTM** as a base-height to provide true texture of the earth and ground surface for the area of interest.
 - **Append/stitch texture to built up 3D models** using the following options:
 - **Orthophoto Accurate Texture Mapping:** One needs to build Orthophotos of all the faces of the objects. Use these images as filters to append/stitch these to the 3D CAD model surfaces using Sketch up or 3D MAX softwares.
 - **Direct photo Texture Mapping:** It is important when capturing the photos for the model surfaces to make the line of site of the camera axis as perpendicular as possible to the surface of interest. Then use these photos as filters to append/stitch these to the 3D CAD model surfaces using Sketch up or 3D MAX softwares.
 - **In both cases,** the best way to export the 3D model with texture is through exporting all models to Sketch up software and then exporting it in geodatabase format to ArcScene software.
 - **Export the built up 3D model object with texture as point-symbols.** Sketch up software is designed to work perfectly in case of:
 - The object is designed to provide general attributes of the whole building for example
 - The object is very complex and can't be exported as true 3D model with texture,
 - The objects are standard and are very similar in shape such as Villas compounds,
 - Built using other softwares such as **Sketch-up or 3D Max.**
 - **Use of Color/texture tiles as a common texture for 3D similar models** objects can be implemented for classification/coding scheme as a simple texture mapping applications, which can be done within the GIS environment and provide very useful results.

The resultant 3D reality model Offer flexible and interactive visual decision support system for data management. The following section is the direct implementation results of the above discussed methodology for various applications that are related to the conducted pilot project named 3D GIS Visualization for King Hussein Parks in Amman City.

4. Three Dimensional GIS Modeling & Texture Mapping Applications

4.1 Virtual city Modeling

Municipalities are becoming more and more interested in virtual city modeling. This trend coincides with the need to better understand the related

problems/issues visually that is a reflect of true reality. With increase size of population, better city planning is to manage the third dimension to provide the decision making process more eyes and prospective to see reality. Environmental issues for example such as studying noise and pollution effects in city, have to be based on 3D studies rather than 2D prospective. Along this track, a pilot project for an area of interest to build 3D model for Amman city, Jordan, using simple approach. The approach followed in this Application is based on building 3d model based on 2D vector layers and the height attribute using color-coding texture mapping classifications, see Al-hanbali et. al. 2006a. Figure 6 illustrates clips from a 3D virtual reality an animation generated for Al-Hussien area in Amman City, zooming from 3D Jordan going down to Amman then to Al-Hussien area. Where real tracks using PDA with GPS are imported as GIS files, then adding these track files to ArcScene environment, showed a nice 3D virtual environment of the area.

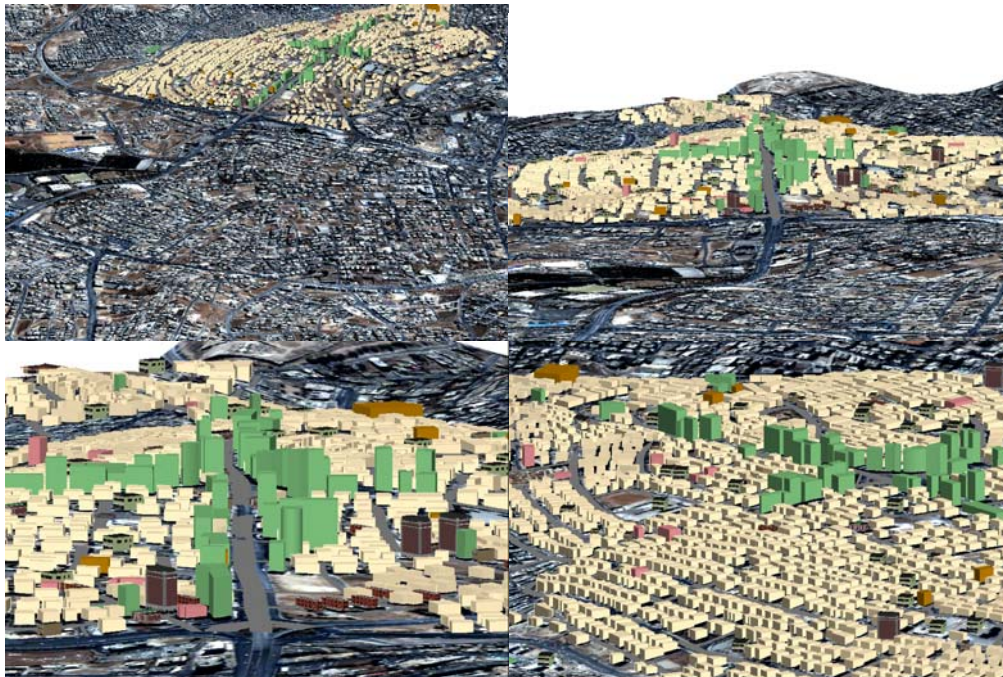


Figure 6: 3D modeling with color-coding texture mapping of Al-Hussein area.

4.2 3D Spatial Analysis

4.2.1 Cadastral Applications:

Asset management in Cadastral application is directly affected by 3D generation. Most of our residential and commercial areas are utilizing the space in 3D, and thus, it is becoming a necessity to model this space to allow 3D spatial analysis scenarios. There are many factors that affects the land valuation process are directly or indirectly related to 3D. For example, Topography and permitted number of floors are directly related to 3D modeling and thus it is becoming a necessity. To model this, a pilot project for a very commercial area in Amman City called Al-Gardens was carried out to

show the real value of 3D possible spatial analyses one can conduct in 3D environment, by building the 3d model based on 2D vector layers and the height attribute using color-coding texture mapping classifications (Figure 7). The software used in this work is the ArcScene/ArcMap of the ESRI software.

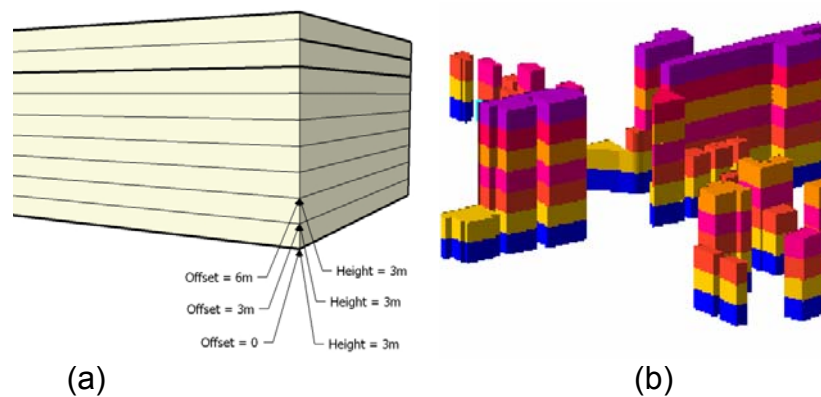


Figure 7: (a) The offset height for each floor level, which is 3 meter each. (b) Classifying buildings and floors using color scheme.

One example of a performed 3D spatial analysis is illustrated in Figure 7. The resultant query is to select all available offices, at the third, fourth or fifth floors with an area of 80-100 m² and a price range of 60000-70000 JD. See Saleh and Al-Jabra 2006 for more scenarios.

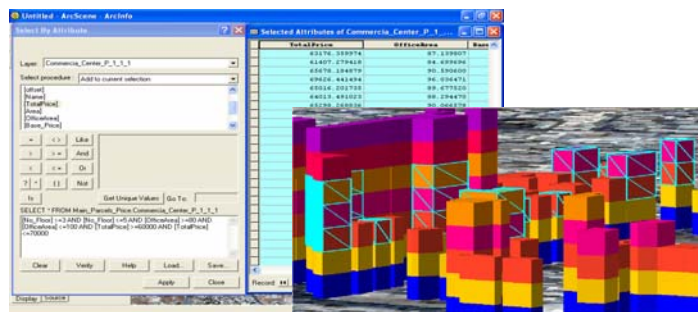


Figure 7c: 3D spatial analysis to select all available office, at the third, fourth or fifth floors with an area of 80-100 m² and a price range of 60000-70000 JD.

4.2.1 University Campus:

As an example, one scenario is illustrated in Figure 8. In the case a fire breaks down in the Chemical labs Supply building, what are the affected neighborhood buildings and what are the safe buildings and the safe floors of the affected buildings? Also, it can be illustrated with different zone colors from deadly (red color), to dangerous (yellow color) to warning (gray color) areas. The illustrated spatial query shows the answer in two and three dimensional environments and can be with animated virtual reality, see Al-Hanbali et. al. 2006a and 2006c. The difference between 2D and 3D made the problem easily visualized to provide very solid base to take immediate actions that is almost impossible to do without it. The feasibility of this type of analysis opens new era of applications.

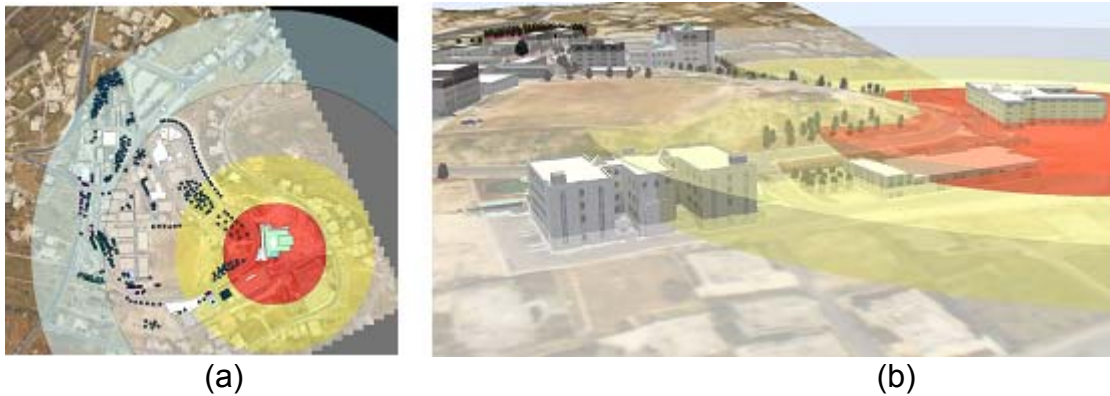


Figure 8: Three-Dimensional Spatial analysis with Virtual Reality Animation results. (a) 2D view. (b) 3D view.

4.3 OrthoPhoto Texture Mapping

In archaeological documentation of monument, accuracy of exact shape and texture is very important. For example, one conducted project is to generate true texture and a virtual reality model for the Artemis Temple, in ancient Jerash City, which will be basis for accurate documentation for monument resurrection (reverse engineering) See Al-hanbali et. al. 2006b for more details.. In order to do that, accurate surface wire-mish is generated using Close Range Photogrammetry Techniques. Then for each facet (a triangle) an orthophoto is generated from the resected/triangulated stereo images. The software used for this modeling is the Photomodeler software. After ward, using 3D Max Studio, all images are stitched to their surfaces since the orthophoto is georeferenced in the same coordinate system as the wire-mish model. The final result is illustrated in Figure 9 and 10.

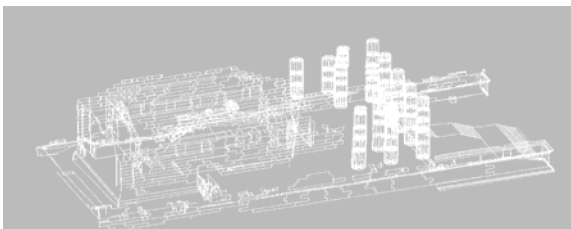


Figure 9: Wire mesh model of the Artemis Temple.



Figure 10: Adding orthphoto images as texture to the CAD model.

4.4 Direct Photo-Shots Texture Mapping for King Hussein Parks

In this case texture mapping can be made using special software like Sketch-up to stitch directly taken photo-shots of the building sides using a digital camera with suitable resolution. In order to have good results though, the camera axes should be as perpendicular to the view as much as possible. Also, there should be no abstractions between the camera and the object. If there is, one can edit the image using image processing software such as PHOTOSHOP to remove these effects, see Figure 11.



Figure 11: Image processing techniques is used to remove the trees from the image.

As discussed in section three, it is important to build 2D GIS vector layers with height information as attribute to be used as the reference systems for adding all needed 3D models with texture mapping, see Figure 12.

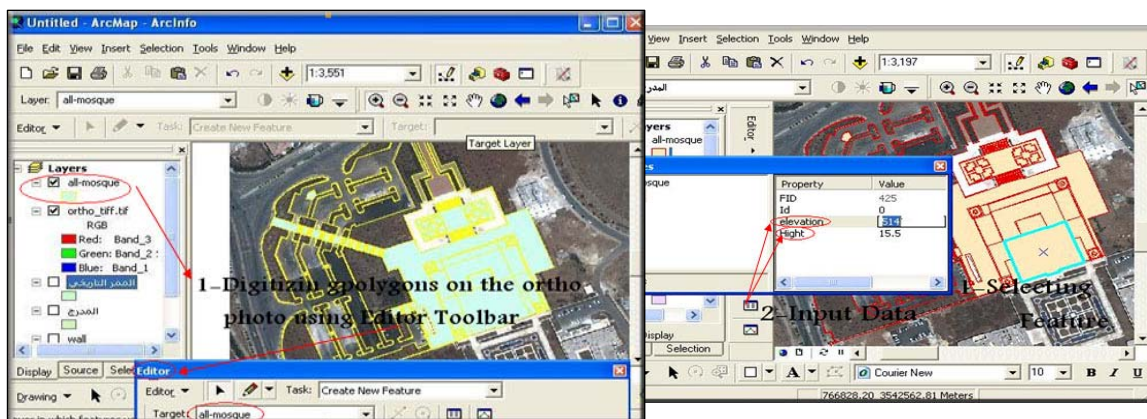


Figure 12a: Building a Vector Data with height attributes for King Hussein Mosque.

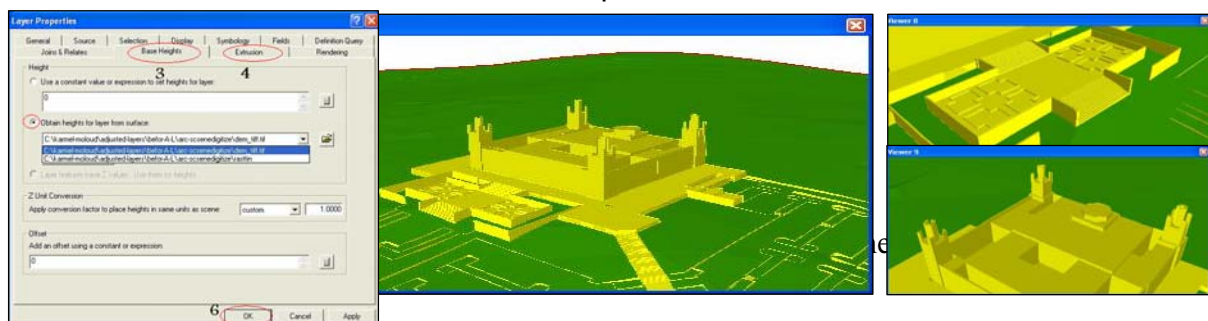


Figure 12b: Building 3D model with color texture using 2D vector layer and height information as 3D solid model for the mosque in the ArcScene environment.

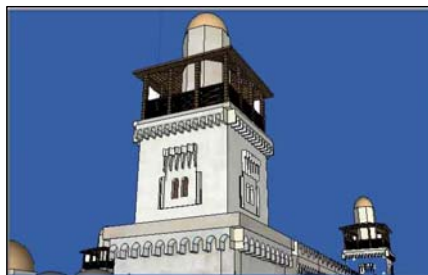
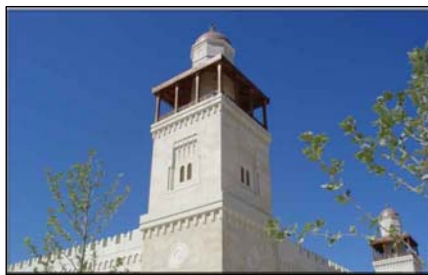
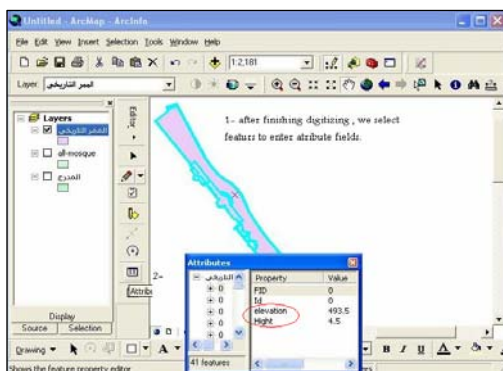
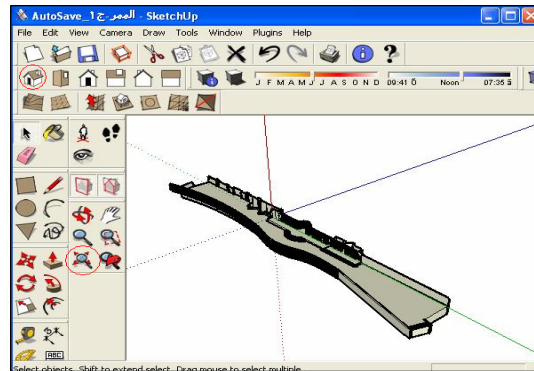


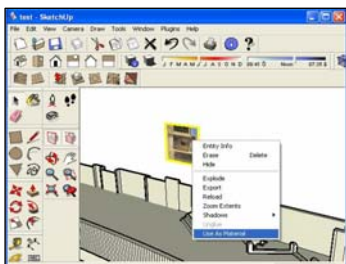
Figure 13:
True photo
and clip of the
3D model of
the Meathanah
with texture
mapping



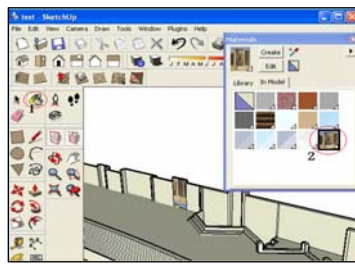
(a)



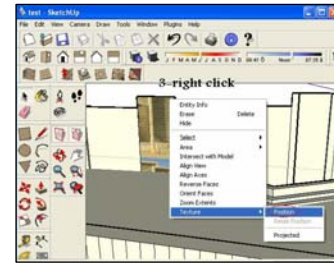
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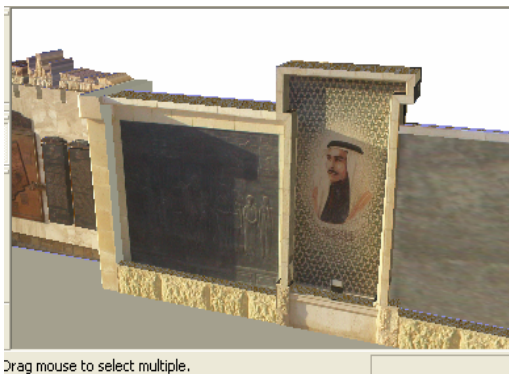
(c)



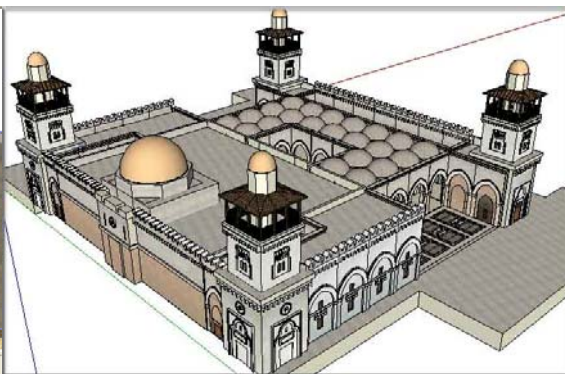
(d)



(e)



(f)



(g)

Figure 14: (a) 2D GIS layer with height info of the Historic Passage within the ArcMap software that provide a reference layer. (b) 3D CAD model imported to Sketch up software. (c) Adding image to Sketch up software. (d) Adding image as filter. (e) Stitching/appendimg image to face of interest. (e) Final results of the Historic Passage. (g) Final results of the Mosque.

Sketch up software works well for texture mapping and allows to customize and duplication of any shape or repeated pattern that can be fitted to various facets, such as windows, doors and openings or special decorations on the surface/sides of a building. This procedure is useful for creating virtual reality animation for displaying and tourism applications, but can't be as accurate for archaeological documentation, see Figure 14. The software also can operate within the ArcGIS environment and ArcScene. Figure 13 illustrates two images taken for Mea'thanah of King Hussein Mosque, one is the actual photo and the other is clip of built 3D model with texture mapping.

5. Discussion

In order to achieve the objective of this research work of building 3D GIS models with texture mapping suitable for needed applications, several important issues are essential to be taken into consideration to provide satisfactory results that can be summarized as following:

- 1- Proper planning and study of the region of interest to know all needed elements of the project, to make proper GIS data model design and implementation procedures.
- 2- Data Collection and processing should be well planned so as not to duplicate any available data (*vector data, raster data*) for the region of interest, to help better execution of the GIS data model.
- 3- Photo capturing has to be properly planned and oriented to produce good results.
- 4- The evaluation process of current off-the-shelf software for 3D modeling and texture mapping is a very important step to know what are their capabilities, limitations and suitable tools that can help to better execute the modeling process.
- 5- Orthophoto, DTM, 2D GIS vector layers are very important to be prepared before hand as they all provide important reference systems for the production of seamless 3D GIS data models.
- 6- Building 3D models can be done with various methods. Depending on the applications, one should not focus on producing the most accurate model rather than what is needed and how fast and less expensive it can be produced.
- 7- Building 3D GIS with texture mapping is rather very time consuming and requires lots of talent working with several software. It requires PC with very high processing power, graphics card and RAM (at least One GB). Most important is that each model has to be split into several smaller models that can be easily exported and imported from one environment to another.

In this project, several softwares were employed and used in order to complete the required production, which are the following:

- a- **PCI Geomatica10 (OrthoEngine):** to produce Orthophoto and DTM
- b- **ArcGIS V9X GIS software:** ArcMap is used to build 2D GIS layers and data-model, in addition to ArcScene that provides suitable 3D environment
- c- **Sketch Up 5:** used to exporting and importing 3D model from and to ArcGIS depending; also used to build/complete building 3D model and finally for adding the true texture to these models.
- d- **AutoCAD (version 2004):** Used to build/complete building 3D model, measure building height, and editing of the provided CAD drawing for 3D models of the building faces.
- e- **Photoshop:** Used to edit captured photos for 3D objects to eliminate any unwanted effects in the photos, e.g. the shadow on faces, trees, baileys, and cars, human...etc.

The suggested methodology is very flexible that can be utilized and implemented for various types of projects and applications that is becoming essential in the near coming future. Especially for application similar to King Hussein Park, that can be properly modeled and illustrated for visitors and planners. This can provide very efficient tool for preserving our cultural heritage, civilization, and architecture heritage and esthetic sites. Texture mapping is now becoming feasible with lower cost and less time consuming using the new capabilities of the above mentioned software's.

6 Conclusions and Future work

This work is the result of research that explores the effective use of 3D GIS modeling in various applications. The paper illustrates the feasibility of 3D GIS modeling using off-the-shelf softwares. Several applications and procedure followed to explore the various possibilities, suitability and advantages for each application..

Virtual city modeling to build three dimensional GIS models that allow 3D spatial analysis for various applications is presented. The approach used in this work presents a simple strategy that is suitable for required spatial applications. The procedure followed is economic based on available databases and can be implemented easily to deliver quick and sufficient results. For example, what is important in Cadastral applications is not how accurate is your model rather than how presentable to satisfy the required conditions and spatial criteria. Similarly, the same is for Tourism and Navigation. Hence, the paper summarized suitable procedure that requires fewer resources (financial, instrumentation, software and human) to deliver the required 3D spatial analysis quickly.

To provide more realistic view and real virtual reality environment, two procedures to add texture mapping to the 3D objects are discussed and

compared. The first one using a close range Photogrammetry software (Photomodeler) to create 3D model and orthophotos, then using the 3D Studio and/or Sketch up softwares to produce very accurate 3D model with true texture (accuracy is within 3cm). The other discussed application is sketching directly the taken photo-shots of the a building sides to its 3D model using the sketch-up software to produce 3D model with true texture. The results were nice and little distortions were encountered and deliver good results for many applications in virtual city modeling.

The software used, showed to be very useful and sufficient for suggested applications, such as:

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

Finally more work it still required in the area of adding true texture to 3D model. It is important to define an automatic procedure for fitting available vector data such as streets to DTM and Orthophoto to build virtual 3D GIS models. More work and investigation for 3D virtual city models for cadastral applications such as adding details for

- Building Texture and Building Floors using the CAD drawing details
- Adding Attributes to these floors
- Adding streets feature based on textured captured from Orthophoto
- Populating these models on the internet through web-mapping applications.

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