HIGH RESOLUTION TEXTURED MODELS FOR ENGINEERING APPLICATIONS

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ABSTRACT:

Three dimensional textured modeling is a process that during the few last years is gaining ground in monument documentation, visualization and dissemination. The combination of a variety of data acquisition technologies, to photogrammetric processes and computer graphic methods has certainly been fruitful. Low-resolution 3D models are frequently used for information dissemination about monuments, e.g., via web-pages in the form of a VRML model. However, the creation, publication and interaction with high resolution 3D textured models are still rather challenging and cumbersome tasks. It is certain that a high-resolution textured 3D model, produced so as to guarantee a given level of accuracy, would be an invaluable tool for applications involving restoration, preservation and monitoring of monuments. To this end, the main objective of this paper is to present the basic steps of a workflow for the creation of a high resolution textured model as it was applied for the monument of Zalongon, a 15m tall and 18m long complex of sculptures. Examples of how engineers interacted with the final model for the required restoration actions are also presented. Finally, publication issues are addressed with a short investigation on various viewers and formats.

1. INTRODUCTION

During the last twenty years the development of methods for object and scene modeling, among a variety of other applications, has encouraged a significant improvement in historical monument documentation, visualization, dissemination, preservation and monitoring. The 3D model production from images can be achieved by using various methods and techniques, which besides digital photogrammetry also include shape from shading (single image technique), photometry, stereopsis and video approach (Remontino & El-Hakim, 2006; Ioannidis & Georgopoulos, 2007; Said et al, 2009). Low-resolution 3D models are broadly widespread, mainly in the form of VRML models in web pages. However, the production of high-resolution textured 3D models, which guarantee a given level of accuracy, although since several years it has provided some very good outputs (Beraldin et al, 2000 & 2002; Bernardini, 2001; Ioannidis & Tsakiri, 2003) is still a challenging task with an ongoing research interest for various issues. In many occasions accurate 3D models become significant tools for applications involving monument restoration or preservation; e.g., engineers would be greatly facilitated if, given a three-dimensional textured model, they could make their own sections, interactively measure distances, areas or volumes, annotate the 3D model or, in a more advanced level affect the actual model surface.

The main objective of this paper is to present a method for the creation of a high resolution model and to investigate in which ways engineers are able to interact with textured 3D data through various programs. The related research is carried out for the 3D textured model that was created for the monument of Zalongon, a complex of sculptures, 15m tall and 18m long, built in the late 1950's and located on top of an 80m high cliff in Epeiros region, north-western Greece (Figure 1). The monument commemorates the sacrifice of the Souli village women, who in 1803 preferred death from humiliation by the conqueror. They chose to dance over the top of a steep cliff. The restoration work that is currently carried out involves cleaning the object surface, the extraction and replacement of large pieces that have suffered damages from weather and are deteriorating rather quickly, and the completion of parts that have been destroyed by frost. The detailed geometric documentation of the current situation of the monument included the production of 2D drawings, including orthophotos and accurate 3D models.

Figure 1. View of the front side of the monument of Zalongon

The first section of this paper is dedicated to the data acquisition process and is combined with a brief presentation of 2D drawings that were also created for the project. The second

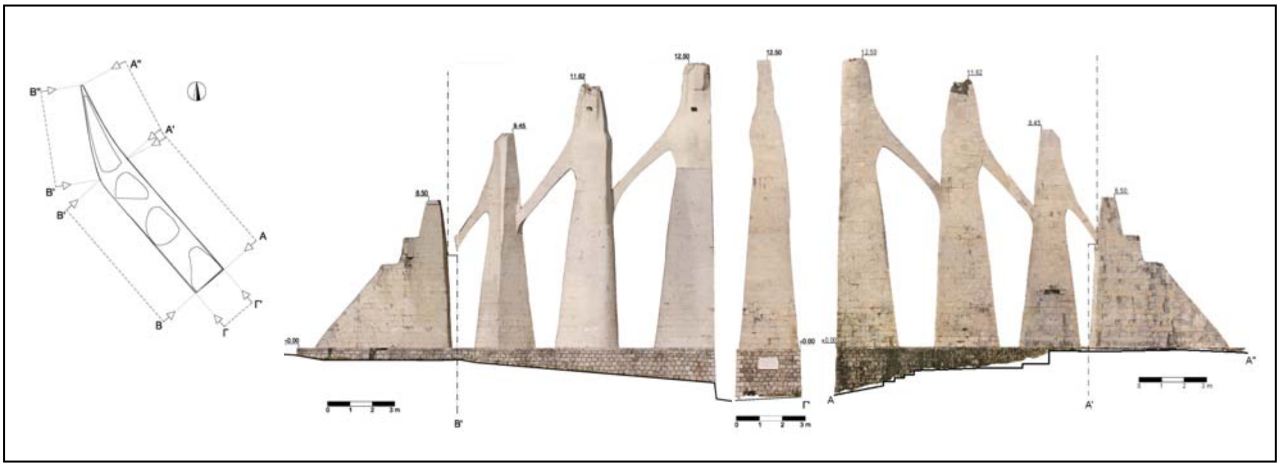

Figure 2. Left: A horizontal drawing that displays the five vertical levels that were chosen for the othroprojection; Right: the final orthophoto-mosaics

section is dedicated to the workflow for the creation of the 3D textured model, whereas the third is a presentation of the interaction of the engineers with the model during the restoration process. The fourth section addresses publication issues with a presentation of various viewers and formats.

2. DATA ACQUISITION, PREPARATION AND 2D PRODUCTS

The data required to build high resolution 3D textured models include, 3D scans, geodetic measurements and a significant number of images. The equipment used in this case was a time-of-flight terrestrial laser scanner, the Leica HDS 2500, two total stations, TOPCON GPT7003i and PENTAX R323N, and a 8MP digital camera, CANON MARK II, with numerous lenses available. For the survey of the monument a 12 station geodetic network was established in the surrounding area. A total of 761 points were measured, i.e. 148 points for the survey of the surrounding area, 327 control points, another 144 points of detail and 99 points for a horizontal section near the basis of the monument. Also, 16 scans were acquired from 9 scanner setups and 16 reflective targets were placed and measured for the registration process and for the integration of the scanner data into the geodetic reference system. Finally, 239 images were also acquired for metric purposes. The adjustment of the geodetic network and the calculation of the geodetically acquired points were carried out in Tachymetria© software achieving a maximum standard deviation of 5mm. For the production of 2D drawings (1 topographic drawing, 3 façade line drawings and one horizontal section) Autodesk's AutoCAD Civil 3D was used. Topcon's Image Master™ was used for the photogrammetric orientation of the images. For the production of the 60 orthoimages, which fully cover all the non flat surfaces of the monument, Topcon's Image Master™ and Intergraph's Image Station™ were used, whereas, SISCAM's ARCHIS 2D™ was used for the creation of 8 rectified images, for the flat surfaces. A total of 5 orthophoto-mosaics were assembled and processed with Adobe Photoshop CS2. In Figure 2, a horizontal drawing displays the five vertical levels that were chosen for the othroprojection and the final orthophoto-mosaics.

3. THREE DIMENSIONAL PROCESSING AND TEXTURE MAPPING

The monument of Zalongon, being a complex of 7 free-form figures -of which four form a separate complex- at a distance less than 4m from the edge of the cliff, is certainly an application beyond the ordinary. For the creation of the surface of the 3D model all of the original scans were registered into a common reference system by applying a method that was developed by the authors (Valanis & Ioannidis, 2008). By this method, the integration of the processing scans was made, although no special targets were included and characteristic points were impossible to identify between overlapping scans.

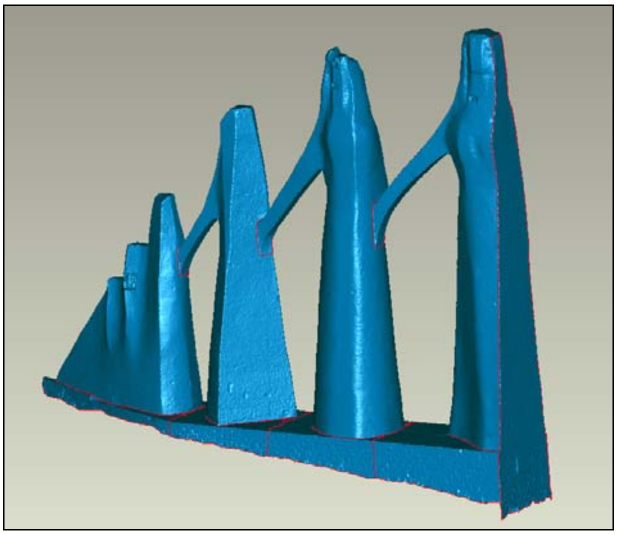

Figure 3. The complete 3D model surface, cut for the texture mapping process.

After all the scans were registered the data were transformed to the geodetic reference system, by means of the geodetic coordinates of the reflective targets in Leica's Cyclone™ software. A total of 16 million points of less than 2 cm resolution resulted into a moderate resolution 3D mesh of 700,000 polygons with an average edge length of 3 cm as demanded by the project specifications. The 3D meshing and the required editing were carried out in Raindrop Geomagic

Studio 9™. For the texture modeling process, this data was reduced to a 10% with adaptive algorithms that retain a greater density in areas of interest (details, curvature change, etc). At this stage, the surface was cut into pieces so as to facilitate the next steps of the process and improve the texture mapping results. The final model as it was cut initially is displayed in Figure 3.

After the surface was prepared for the texture mapping process it was exported in dxf format and imported in Topcon's Image Master. As already mentioned a total of 327 digital images of the monument were acquired. The best of those images were selected and imported into Image Master along with the coordinates of the acquired control points. Stereopairs were formed between consequent images and control points were measured where visible along with appropriately selected tie points. It must be noted that the complex form of the monument, was documented with a non-trivial configuration of images acquired first from the ground and later on from a scaffolding that was built for the restoration process. All of the measurements were introduced in a bundle adjustment process. The performance of the software was considered to be quite satisfactory for this rather difficult data configuration. In Figure 4, a snapshot of the program environment after the bundle adjustment presents a 3D view of the constellation of the images only for the tallest figure of the monument. At this point it is worth mentioning that the software provides a matching algorithm that yields particularly impressive results for close range data. The algorithm was tested on the data for a very high density (5 mm) and the quality of the resulting mesh was beyond the ordinary with great detail but the creation of a suitable model for the complete surface would require a great deal of editing. However, during the texture modeling process, the already prepared original model was used.

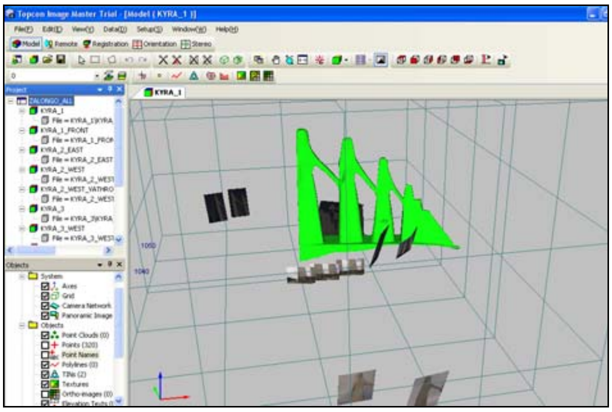

Figure 4. 3D view of the constellation of some of the images after the bundle adjustment.

As already mentioned when working with texture mapping, a way to facilitate the process and obtain results is to work on parts of the model. This is because through Image Master, when a texture map is created, the result is a rendered image of the textured model from a selected view and not a developed image of the textured surface of the model. This means that areas that are not visible in a view are poorly mapped. Of course the software provides functions that enable texture mapping of the complete surface by choosing multiple images. Figure 5 presents a snapshot of the program during the texture mapping process and the result for part of the model. However, models produced in this way always present problems such as tone differences, stretched areas, gaps etc, that are difficult or even impossible to edit and correct for. A way to bypass this problem is to work on parts of the model. For each part one has to create multiple texture maps from different images. In this way, the resulting texture maps for a part of the surface that are created from different images can be combined and adjusted in an image processing software such as Photoshop in the same way that photomosaics are processed. The difficulty in this process lies with the fact that the resulting text files of the 3D models must be merged and combined manually.

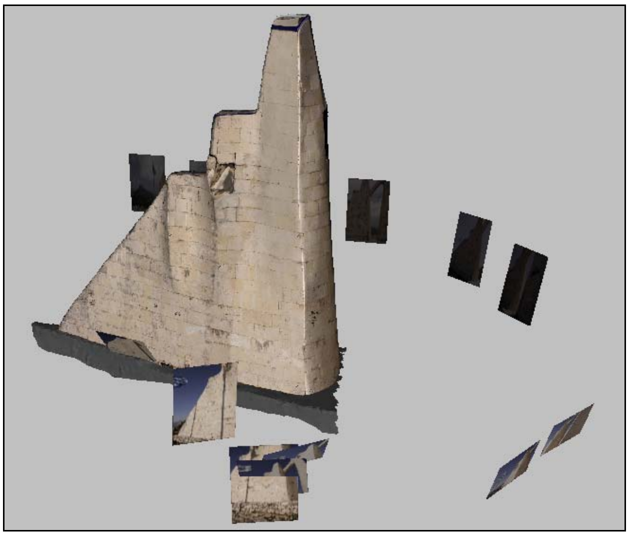

Figure 5. A snapshot of the program during the texture mapping process and a result for part of the model

4. INTERACTING WITH 3D MODELS

Engineers who are involved in restoration are greatly facilitated if they can interact with a 3D model and immediately obtain various kinds of information by measuring various distances, areas, volumes, by creating cross-sections, outlines or even by formulating and adding missing parts. Most of the functionalities listed in the above are provided by software similar to Image Master and Geomagic where the user is able to select an entire 3D model or just a part and perform any of these tasks. However, in cases where the formulation and addition of 3D data is desired different methods and algorithms are required. This was also the case for the monument of Zalongon, where the upper parts of the two tallest figures were almost destroyed. In this case although the area of interest was acquired by the laser scanner, the amount and quality of information was not considered to be adequate and these areas where photogrammetrically processed in detail with special images acquired from a close distance, when the scaffoldings were built. The images where imported in Image Station and a bundle adjustment with a great number of control and tie points was carried out. From the oriented models, point data and breaklines were acquired in order to record in detail the problematic areas. Two main categories of data were extracted, namely the part of the surface that was healthy and would be retained and the broken part that was recorded only in order to help reconstruct what was missing. This information was specially processed in Geomagic Studio. Initially, surfaces were created for the two categories of points and the new ones surfaces were used to replace the old laser scanner data. From the combined surface, and for the two destroyed heads, approximately 2 m height data (measuring from the top down) was retained. These surfaces were modeled with patches that were created manually, in order to closely follow the basic lines of the sculpture. These patches were used for the creation of grids and in a final step NURBS models were produced for these areas.

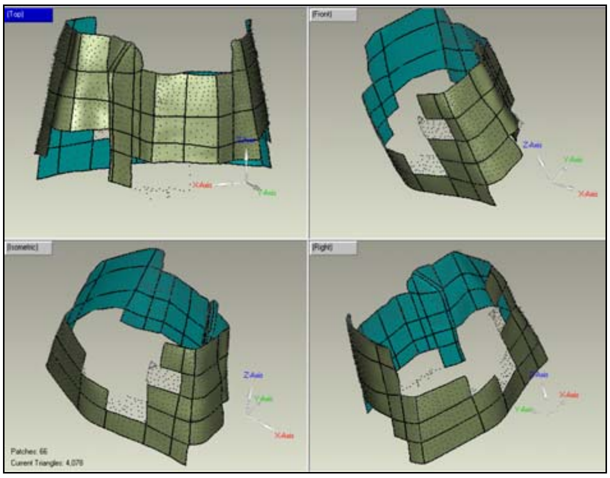

Figure 6. Patches created in Geomagic around a destroyed area

In Figure 6 the NURBS patches that were created for the second form head are presented as this was the worst of the two cases. The NURBS data were afterwards imported in the Rhinoceros 4.0 SR6™ of Robert McNeel and Associates software. Rhinoceros is a NURBS modeling software that enables the user to work in 3D and create all kinds of 3D data. As presented in Figure 7, based on the patches created in Geomagic, the authors created 3D curves, patches, surfaces that would help complete the model. Through this software the user is provided with such functionalities that enable the creation of data, e.g., by applying constraints of continuity, extending existing features, extruding objects etc.

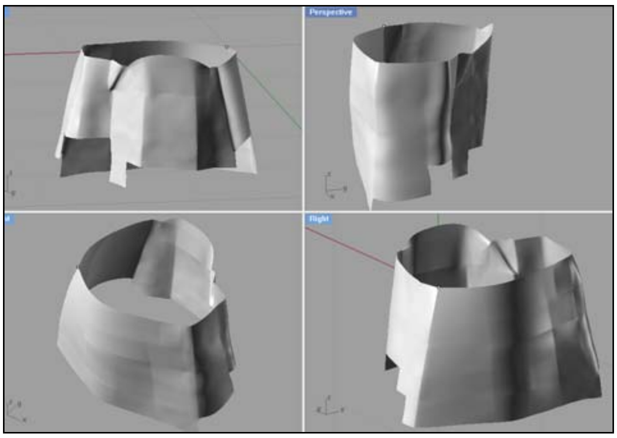

Figure 7. Partial restoration of the destroyed surface in Rhinoceros software

Efforts were also made to completely restore the original surface in Rhinoceros. However, in order to obtain a better result, another approach was preferred by the committee that was in charge of the restoration process. The partially completed surfaces were used for the creation of analogue models of a scale 1:5 and an artist, a sculptor, was assigned with the task of completing the forms based on the existing model and old photographs and sketches of the original sculptor.

The new plaster models were scanned with an XYZRGB SL2™ structured light scanner and the data acquired were registered in the GSI™ software. In Figure 8 the XYZRGB scanner setup is presented; the system comprises of off-the-shelf components: a common LCD projector in order to project the alternating patterns of light onto the object, two DSLR cameras independently mounted on a rigid base, which sits on top of a sturdy photographic tripod, and a laptop.

Figure 8. XYZRGB™ structured light scanner setup for the acquisition of data for the plaster model

The final mesh was exported, appropriately scaled and registered with the original laser scanner data in Geomagic. In Figure 9 the new surface model is presented in combination with the original photogrammetric and laser scanner data.

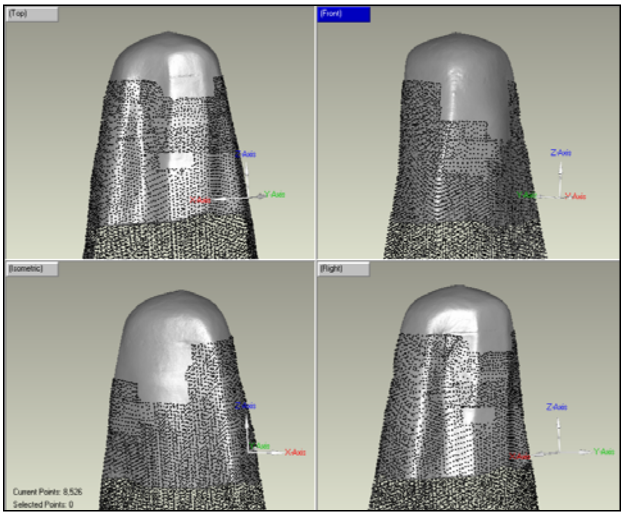

Figure 9. The new surface model integrated with the original photogrammetric and laser scanner data

5. THREE DIMENSIONAL PUBLICATION AND SHARING

Three dimensional publication and sharing is currently an area where a great deal of work is being done. Various state of the art formats such as the X3D and the Collada are developed and designed so as to carry as much information as possible in a straightforward fashion. These formats allow reference to external files enable annotations, but are suitable for low-resolution and clean CAD-like models. Other formats such as VRML and OBJ are more popular as they can carry significant volumes of information and are easier to share since the use of these formats is quite widespread. Regarding web publishing, the authors have employed Cosmoplayer and Cortona, two rather old plug-ins for internet browsers that nevertheless enable sharing of VRML files over the web in an easy and efficient manner. A significant number of programs and viewers are also available currently on the internet and some of those are distributed freely and are open source; e.g., Objviewer, a viewer for OBJ files or SwirlViewer, a viewer for VRML, X3D, Collada, 3DS, OBJ, PLY and STL formats. However, most of the viewers available are not suitable for high resolution textured data and do not provide other functionality. Another effort worth mentioning is the Adobe Acrobat Pro Extended™ version that enables the publication of 3D data in PDF format. This is a very useful application since the user can easily access and view a 3D model and measure distances or add 3D comments. However, the texture of a 3D model is presented in a poor way because of bad lighting applied by the program. In general, and to the extent of the authors experience and knowledge it is still difficult to share 3D information that is not in the VRML format with the vast majority of the users over the web.

6. CONCLUSIONS

In order to create 3D textured models that sustain a certain level of accuracy, the application of advanced data acquisition and processing techniques is required. For the object of this study, the monument of Zalongon, geodetic, photogrammetric, scanning, programming, surfacing, modeling, texturing and mosaicing processes have been combined. The creation of high resolution textured 3D models is undoubtedly a non-trivial task. In order to effectively share and interact with large volumes of data in most cases specialized commercial software is required. But even in the case of commercial software it is impossible to retain texture information during all of the stages of processing. Especially for high polygon textured models, publication and sharing over the web is still a major issue. A rather popular solution is to create low polygon models with rich texture that is also enhanced during the rendering process. However if the models need to be textured with their actual color, texture modeling is no longer a trivial task. Also, issues of interoperability between the data acquisition and the various processing software still introduce difficulties in the process. Nevertheless, it is certain that high resolution textured models are going to be invaluable in monument restoration and monitoring in the future.

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