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3D MODELING OF CULTURAL HERITAGE OBJECTS WITH A STRUCTURED LIGHT SYSTEM

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ABSTRACT

3D modeling of cultural heritage objects is an expanding application area. The selection of the right technology is very important and strictly related to the project requirements, budget and user's experience. The triangulation based active sensors, e.g. structured light systems are used for many kinds of 3D object reconstruction tasks and in particular for 3D recording of cultural heritage objects. This study presents the experiences in the results of two such projects in which a close-range structured light system is used for the 3D digitization. The paper includes the essential steps of the 3D object modeling pipeline, i.e. digitization, registration, surface triangulation, editing, texture mapping and visualization. The capabilities of the used hardware and software are addressed. Particular emphasis is given to a coded structured light system as an option for data acquisition.

KEYWORDS: active sensors, 3D point cloud, scanning, registration, surface triangulation, visualization

1. INTRODUCTION

Active sensors, based on coherent (laser) and non-coherent light, are used for many kinds of 3D reconstruction tasks and recently very much for 3D recording and documentation of cultural heritage objects. They have become a very common source of documentation data in recent years, in particular for non-expert users, as they provide range data of surfaces automatically in high resolution and accuracy. Compared to passive image-based approaches (Remondino and El-Hakim, 2006), active sensors provide directly and quickly 3D information of the surveyed object in form of range data (point clouds). Active sensors are suitable for different scales and objects. While the recording devices are still relatively expensive, important progress has been made in recent years towards an efficient processing and analysis of range data.

Structured light systems consist of one (or more) camera(s) and an active light source, which illuminates the object with a known pattern of light sequence. Based on the triangulation principle, the 3D object coordinates can be recovered in 1-2 seconds with a potential accuracy of 50 microns or even better.

This paper reports about two projects where a coded structured light system (optoTOP-HE™ and optoTOP-SE™, Breuckmann GmbH) is used for the precise 3D digitization of cultural heritage objects. It includes all essential steps of the 3D object modeling pipeline from data acquisition to 3D visualization. The first study is the 3D modeling of a part of a marble Herakles statue, named "Weary Herakles" (Figure 1a), which is on display in the Antalya Museum (Turkey), digitized with an optoTOP-HE system. The second study is about the 3D modeling of a Khmer head sculpture (Figure 1b), which is in the collection of Museum Rietberg Zurich (Switzerland), digitized using an optoTOP-SE sensor.

The 3D modeling pipeline of the Weary Herakles (Akca et al., 2006a; 2006b) and the Khmer head (Akca et al., 2007) projects have already been published elsewhere. This paper presents the both projects in a complete form, explains the processing steps from the technology perspective, moreover, gives a comparative evaluation of the used hardware and software tools.

Figure 1. (a) The Weary Herakles statue in the Antalya Museum. (b) The Khmer head sculpture in Museum Rietberg Zurich.

The next chapter introduces the scanner with the emphasis on working principle and technical specifications. The following third and fourth chapters explain the data acquisition and modeling workflow of the Weary Herakles and the Khmer head projects, respectively. The fifth chapter addresses the capabilities and the limitations of the used hardware and software. A comparison of the used reverse engineering software (Geomagic Studio™ and Poly-Works™) is also reported.

2. DATA ACQUISITION SYSTEM

2.1. Coded Structured Light System

The key feature of a structured light system is the replacement of one of the cameras with an active light source, which illuminates the object with a known pattern. This solves the correspondence problem in a direct way. Many variants of the active light principle exist (Beraldin, 2004; Blais, 2004).

The coded structured light technique is based on a unique codification of each light token projected onto object. When a token is detected in the image, the correspondence is directly solved by the de-codification. It requires a complex light projection system. There exist many codification methods (Salvi et al., 2004; Dipanda and Woo, 2005). The time-multiplexing, also called temporal codification, with a combined Gray code and phase shifting is the mostly employed technique. The op-toTOP-HE and optoTOP-SE sensors use the same technique.

A Gray code is a binary numeral system where two successive values differ in only one digit, i.e. 000, 001, 010, 011, … in natural (plain) binary codes, and 000, 001, 011, 010, … in Gray binary codes. It was invented and patented by Frank Gray (Gray, 1953) in Bell Labs. For the case of coded structured light systems it is superior to the natural binary codification, since it resolves the ambiguity better at the edges of consecutive patterns (Figure 2a and 2b).

A sequence of Gray coded binary fringe patterns is projected onto the object (Figure 2c). This divides the object into a number of 2^n sections, where n is the number of pattern sequences, e.g. 128 sections for n=7. Thus each pixel is associated with a codeword, which is the sequence of 0s and 1s obtained from the n patterns. The codeword establishes the correspondences relating the image pixels to the pro-jector stripe numbers. The object space point coordinates are calculated using the spatial intersection provided that system calibration is known. All pixels belonging to the same stripe in the highest frequency pattern share the same codeword. This limits the resolution to half the size of the finest pattern.

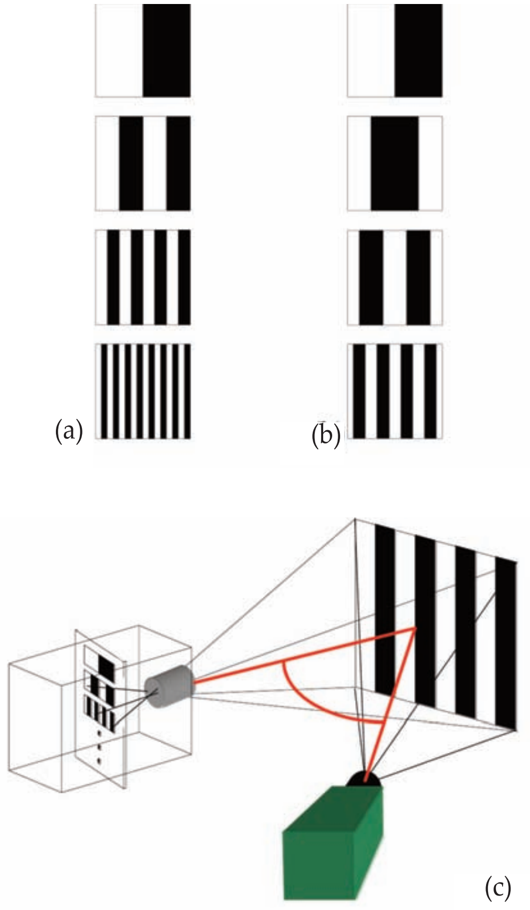


Figure 2. (a) Natural (plain) binary code. (b) Gray binary code. (c) Setup of a fringe projection system (courtesy of B. Breuckmann).

An additional periodical pattern is projected several times by shifting it in one direction in order to increase the resolution of the system. For each camera pixel the corresponding projector stripe number with sub-stripe accuracy is yielded by a phase shift method (Gühring, 2001; Pribanic et al., 2010).

2.2. Breuckmann optoTOP-HE and optoTOP-SE

The optoTOP-HE (High End) system (Figure 3), as a high definition topometrical 3D-scanner, allows the 3-dimensional digitization of objects with high resolution and accuracy. The optoTOP-HE system uses special projection patterns with a combined Gray code and phase shift technique, which guarantees an unambiguous determination of the recorded 3D data with highest accuracy (Breuckmann, 2003). The time for a single scan takes about 1 second for a 1.4 mega pixel camera. The sensor of the optoTOP-HE system can be scaled for a wide range of Field of Views (FOV), by changing the baseline distance and/or lenses, typically between a few centimeters up to several meters. Thus, the specifications of the sensor can be adapted to the special demands of a given measuring task.

The optoTOP-SE (Special Edition) series are the identical systems. The major difference is that the optoTOP–SE sensors have only three different FOV cases with a fixed 300 mm base length. More details of the both systems are given in Table 1.

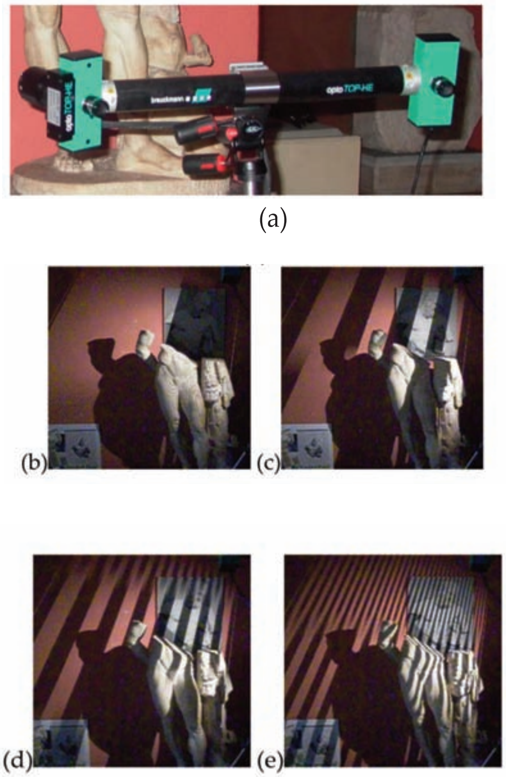


Figure 3. (a) The optoTOP-HE sensor. (b-d) The first 4 fringe projections of a scan of the optoTOP-HE sensor.

Table 1. Technical specifications of the used optoTOP-HE and optoTOP-SE sensors.

	optoTOP-HE	optoTOP-SE
Field of View (mm)	480 x 360	400 x 315
Depth of View (mm)	320	260
Acquisition time (sec)	<1	<1
Weight (kg)	2-3	2-3
Digitization (points)	1280 x 1024 (1)	1280 x 1024
Base length (mm)	600	300
Triangulation angle (deg)	30	30
Projector pattern	128 order sinus	128 order sinus
Lamp	100W halogen	100W halogen
Lateral resolution (μm)	~350	~300
Feature accuracy (relative)(2)	1/15000	1/10000
Feature accuracy (μm)	~45	~50

(1) *Current optoTOP-HE version has a dimension of 1384 x 1036 points.*

(2) *According to image diagonal.*

3. WEARY HERAKLES PROJECT

The Weary Herakles is a marble statue of the Greek demigod Herakles, which dates back to the 2nd century AD (Figure 1a and Figure 4a). It is a copy of an original bronze statue of Herakles sculptured about 330-320 BC by the Greek master Lysippos of Sikyon. Many artisans devoted their skills to replicating this original around that period. This particular example was probably carved in the Hadrianic or Antonine (Roman) period. The version is identified as the “Herakles Farnese” type on the basis of its similarity to a more complete copy (Figure 4b) in the Naples National Archaeological Mu-seum (Italy).

In Greek mythology Herakles (or Heracles) was the demigod son of Zeus (Jupiter or Jove, the Roman name) and the mortal Alcmene. In Roman mythology he was called Hercules. He was one of the greatest of the mythical heroes, best known for his superhuman strength and many stories are told of his life. He was made to perform twelve great tasks, called The Twelve Labours of Herakles and became a god. The first task was strangling the Nemean Lion, which was terrorizing the countryside around Nemea. He killed the lion and used the skin of the lion as armor. In ancient art he is mostly portrayed nude and leaning (hence "Weary Herakles") with the lion's skin near him.

Figure 4. (a) Weary Herakles statue split to upper and lower parts, (b) "Herakles Farnese" type located in Naples.

The statue was broken in two parts (Figure 4a). We do not know when and by whom it was done. The upper half was first seen in the USA in the early 1980s. It is currently to be found at the Boston Museum of Fine Arts. The lower part was found by Prof. Jale Inan (Inan, 1992) at an excavation site in Perge (Antalya, Turkey) in 1980. It is now on display in the Antalya Museum, along with a photograph of the top half (Figure 1a).

According to the Turkish law, Turkish antiques have been state property since Ottoman times 1906. The Turkish government has asked for hand-over of the upper half so that the two fragments can be joined. The Boston Museum has refused to consider the Turkish petition. In 1992, casts of the two fragments were placed together. They were found to match perfectly. The Boston Museum says the statue may have been broken in ancient times, and the upper torso may have been taken from Turkey before the Turkish law established state ownership of archaeological finds (Rose and Acar, 1995; Brodie, 2003).

Since both parts are unfortunately separated geographically, our aim was to record and model both the lower and the upper part and bring these partial models together in the computer, so that at least there the complete statue could be seen, appreciated and analyzed. With the help of the Turkish authorities and the Antalya Museum we were able to complete our work on the lower part, but access to the Boston Museum was denied. The digitization of the lower part of the statue was done in the Antalya Museum with a Breuckmann (http://www.breuckmann.com) optoTOP-HE coded structured light system. The system was kindly provided by the Turkish reseller InfoTRON Co.

(http://www.infotron.com.tr), Istanbul.

3.1. Scanning in the Antalya Museum

The scanning campaign was completed in one and a half days of work. The statue is around 1.1 meters in height. The whole object was covered with 56 scans of the first day work. The remaining 11 scans of the second day were for filling the data holes and occlusion areas. Totally 83.75 million points were acquired in 67 scan files. The average point spacing is 0.5 millimeter.

The optoTOP-HE is an instantaneous 3D digitization system, which enables the acquisition of one point cloud in nearly less than one second. However, orienting the scanner and planning the scan overlay needs careful preparation (Figure 5), especially for this kind of object with many concave and hidden parts. Due to the sensitivity of the sensor to ambient light, special attention was paid to environment lighting conditions. Two ceiling halogen lamps looking at the statue were turned off.

Figure 5. Preparation for a scan in the Antalya Museum

3.2. Point Cloud Registration

The pairwise registration was done by use of an in-house developed method, called Least Squares 3D Surface Matching (LS3D) (Gruen and Akca, 2005; Akca, 2010). The mathematical model is a generalization of the Least Squares image matching method, in particular the method given by Gruen (Gruen, 1985). It provides mechanisms for internal quality control and the capability of matching of multi-resolution and multi-quality data sets.

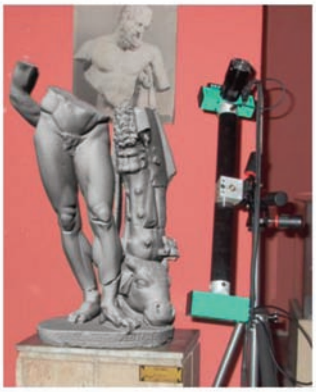
The pairwise LS3D matchings were run on every overlapping pairs (totally 234) and the matched point correspondences were saved to separate files. The average of the sigma naught (standard deviation of 3D discrepancy) values was 81 microns. In the successive global registration step, all these files were passed to a block adjustment by independent models procedure, which is a well-known orientation procedure in photogrammetry. It concluded with 47 micron a posteriori sigma naught value.

3.3. Point Cloud Editing

After the registration, all scan files were merged as one XYZ file, discarding the scanner detected blunders. This file totally contains 36.2 million points. The file was imported to Geomagic Studio™ version 6 (Raindrop Geomagic Inc., USA). All the editing procedures were carried out in Geomagic Studio. The data set was further cropped to include only the area of interest (AOI), i.e. deleting the background wall or other non relevant parts, concluding with 33.9 million points. A low level noise reduction was applied.

3.4. Surface Triangulation and Editing

As a first attempt, the surface mesh generation was performed at the original data resolution. The operation could not be succeeded, since the memory request of the software exceeded the physical memory limit of 2 GB of the computer. Therefore, the number of points was reduced to 9.0 million by applying a subsampling procedure based on curvature information. This operation eliminates points in flat regions but preserves points in high-curvature regions to maintain detail.



(a)

Surface triangulation concluded with 5 million triangles. Because of the complexity of the statue and occlusions, some inner concave parts could not be seen by the scanner. This resulted in several data holes on the triangulated surface. They were interactively filled by use of the corresponding functions of Geomagic Studio. In the final 3D model, we were able to achieve a high level of realism (Figure 6). The main portion of the editing effort was dedicated to the hole filling. It is a tedious work which takes the longest time among all steps of the project.

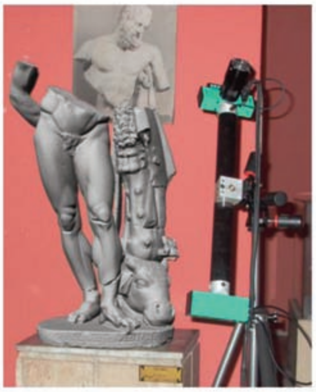
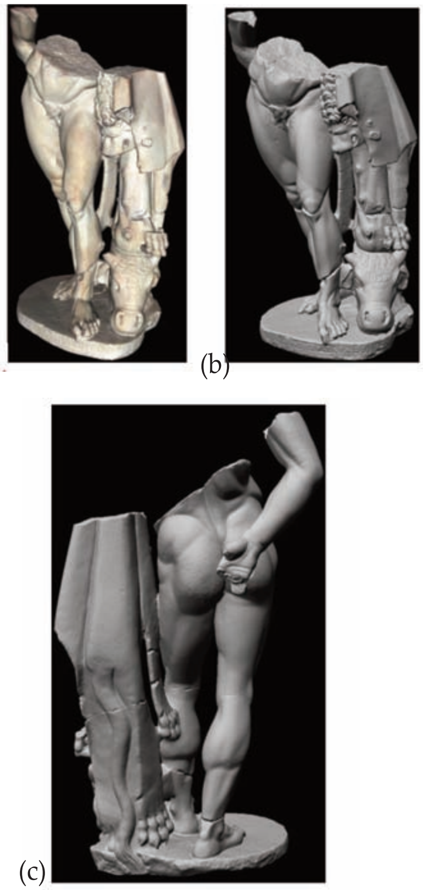

(b)

Figure 6. (a) Picture of the Herakles statue and (b) its back-projected 3D model.

3.5. Texture Mapping and Visualization

Separately taken images, with a 4 mega pixel CCD Leica Digilux 1 camera, were used for the texture mapping. The Weaver module of the VCLab's 3D Scanning Tool (ISTI-CNR, Pisa, Italy) was used here. The VCLab's Tool is a bundle of modules, which comprise the fundamental steps of the 3D modeling. The algorithmic details of the software can be found in Callieri et al (2003).

The visualization of the final model was done with the IMView module of PolyWorks™ version 9 (InnovMetric Software Inc., Canada). It gives a better shading than Geomagic Studio. The textured 3D model was visualized with the viewer of the VCLab's Tool (Figure 7).


(a) (b)

(c)

Figure 7. Frontal view of the texture mapped 3D model (a), frontal view (b) and back view (c) of the grey shaded 3D model.

4. KHMER HEAD PROJECT

The earliest examples of Buddhist art on the mainland of Southeast Asia date from the 4th and 5th centuries and emerged under the influence of Indian and Sri Lankan art. During the 6th century the Khmer people established themselves in the fertile tropical plains of Cambodia, and as the dominating power in South-east Asia in the 12th and 13th centuries. They built the stunning group of temples at Angkor. The Khmer rulers supported both Hinduism, displayed most magnificently at Angkor Wat, and Buddhism whose most important monument is the Bayon temple at Angkor Thom.

A bodhisattva head from the late 12th or early 13th century carved in the Bayon style was scanned in Museum Rietberg Zurich (Figure 1b).

It is Lokeshvara or Avalokiteshvara, the "Lord of compassion who looks down (on the suffering of the world)", an emanation of the Buddha Amitabha as demonstrated by the seated Buddha on his hair ornament. His serene expression and transcendent smile convey better than any words the sublime essence of the Buddhist teachings (Museum Rietberg, 2006).

4.1. Data Acquisition in Museum Rietberg Zurich

The head is made of sandstone and 28 centimeters in height. The data acquisition was done in Museum Rietberg Zurich. A Breuckmann OptoTOP-SE fringe projection system was used for this purpose (Figure 8). The scanning and imaging took four hours on site work. The head was covered with 18 point clouds, totally 23.6 million points.

Figure 8. Scanning in Museum Rietberg Zurich.

4.2. Point Cloud Registration

The point cloud registration was done again with the LS3D surface matching method. 52 pairwise LS3D matchings for all overlaps gave an average sigma naught value of 60 microns. The global registration with the block adjustment by independent models solution concluded with 28 microns sigma naught value.

4.3. Surface Triangulation and Editing

The surface modeling was done by use of two commercial packages, namely Geomagic Studio (version 11) and PolyWorks (version 10). The aim was to compare the capabilities of both software. The registered point clouds were imported in the proper file formats. Accordingly, the registration steps were skipped in both software. Both software packages have different processing pipelines (Table 2).

Geomagic Studio offers fully automatic data import functionality provided that data is given in one of the appropriate point cloud formats. Totally 18 point clouds were imported, merged into one, which gave a very dense (denser than 50 microns inter-point distance at some locations) point cloud. After discarding the no-data or scanner signed erroneous points and points belonging to background and other non relevant objects, 3.2 million points remained.

Table 2. Modeling workflows in Geomagic Studio and PolyWorks.

Geomagic Studio	PolyWorks
Importing point clouds	Importing point clouds
Point cloud merging	Surface triangulation
Defining the AOI	Surface merging
Noise reduction	Defining the AOI
Down sampling	Surface editing
Surface triangulation	
Surface editing	

The noise reduction ensures that points coming from different views in different quality will finally have the similar signal-to-noise ratio. Here a slight (low level) noise reduction was applied. After this step, the model contains highly redundant points coming from the multiple views. A curvature based subsampling procedure was performed, reducing the number of points to 1.9 million.

The surface triangulation in Geomagic Studio is fully 3D and automatic, with limited user interaction. Hence, the resulting meshes usually have topological errors and holes. On the other hand, it can preserve the high frequency details of the object geometry successfully by considering all points in one processing sweep. In general, surface triangulation quality is highly related to the point density and homogeneity.

PolyWorks has a significantly different workflow. Each step is represented as a module inside the package. Data import is not automatically performed. Each point cloud is individually imported, subsequently converted to the surface form by applying a 2.5D triangulation, similar to the terrain modeling case. Therefore, the user should interactively rotate the point cloud to a position where the viewing angle is close to the one at the acquisition instant. It substantially reduces the topological errors. On the opposite side, such a stepwise surface generation strategy does not utilize all the available information properly. For example, there might be some object parts with thin point distributions in individual views, whereas the combination of all views together provides a good solution.

In the next step, separate surfaces were merged as one manifold using the IMMerge module. This part is highly automated, and additionally offers a noise reduction option. During the process, triangulation is also optimized especially at the overlapping regions by associating dense triangles to high curvature areas and sparse at flat areas.

The IMEdit module offers many surface editing functions, e.g. cropping the AOI, filling the data holes, correcting the wrong triangles, boundary cleaning, etc. However, it is less flexible and user friendly than Geomagic Studio.

The resulting models from both software packages meet the project requirements. The PolyWorks model (0.6 million triangles) has substantially less number of triangles than the Geomagic model (3.9 million triangles), thus having a better and optimized triangulation algorithm (Figure 9). However, the model from Geomagic Studio preserves the small details and structures slightly better than the model of PolyWorks.

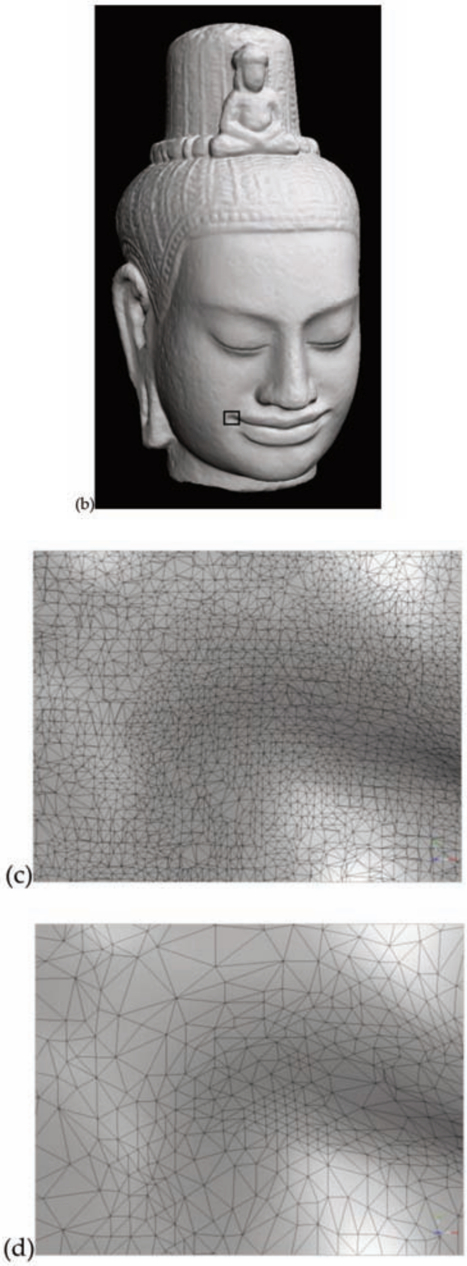


Figure 9. Shaded view of the final 3D models generated with Geomagic Studio (a) and with PolyWorks (b).Zoom-in to the left side of the lip: the different mesh-es produced by Geomagic Studio (c) and PolyWorks (d).

4.4. Texture Mapping

The digital images of the Khmer head were acquired with a photographer type of professional illumination system consisting of two diffuse lights on a tripod (Figure 10). The system was used to reduce the radiometric differences between the images and shadow effects at the complex parts and object silhouettes. Images were taken with a Sony DSC-W30 6 mega-pixel digital camera. The 3D model generated with PolyWorks was used for the texture mapping.

Figure 10. The special illumination system used in Museum Rietberg Zurich

Internal and external orientations of the images were computed using a photogrammetric bundle adjustment with self-calibration. The object space coordinate system was defined as the coordinate system of the 3D model. The common points were interactively identified both in digital images of the camera and in the intensity images of the scanner.

An in-house developed texture mapping method was employed for generating the photorealistic 3D model (Akca et al., 2007; Hanusch, 2008). In this method, the 3D geometric model and the images (together with their orientation values) are used to conduct a visibility analysis for every camera position. The triangles of the geometric model are back-projected into the images, and there the intersected and overlaid ones are searched. Partly occluded triangles are subdivided and re-meshed into fully visible or fully occluded triangles. The resultant list of visible triangles is used to calculate the texture coordinates of every vertex of the mesh. The underlying algorithm uses a "best viewing angle" criterion to evaluate the optimal texture for every triangle.

The final textured model consists of around 295000 vertices and 585000 facets (Figure 11). It is possible to visualize this model in a standard rendering software, but the navigation does not work fluently due to data size, even on computers with high quality graphic cards, memory and processing power. To cope with the problem, we decided to use a special rendering software: the open source software "Blender". It is an adequate software package to handle the huge number of triangles to produce high quality images and movies.

Figure 11. (a) The picture of the Khmer head , and (b) its texture mapped 3D model.

5. CAPABILITIES OF THE USED HARDWARE AND SOFTWARE

The optoTOP-HE and optoTOP-SE sensors as a coded light projection system meet the project requirements satisfactorily. They have some distinctive advantages over the triangulation-based laser systems (Table 3).

The use of incoherent light reduces speckle noise and provides better surface smoothness (Blais, 2004). Furthermore, it does not penetrate into the object surface, unlike laser light whose penetration property is well known, e.g. for marble (Godin et al., 2001). All these reasons make the system a suitable choice for the cultural heritage applications. On the other hand, the coded light systems are very sensitive to ambient light, requiring almost darkness during the acquisition. Nevertheless, new developments and advances in digital projectors allow 3D data acquisition also under normal light conditions.

Table 3. Triangulation based systems: Laser light versus coded light

	Laser	Coded light
Weight and price	Identical	Identical
Data acquisition speed		Faster
Sensitivity to ambient light	Less	
Speckle noise		Less
Penetration into object surface		No
Imaging for texture mapping		Yes
Depth of view	Larger	
Eye safety		Better
Geometry-colour information registration	N/A	N/A

The last item of Table 3, geometry-colour information registration, is a property only available in the modern laser 3D scanning systems. They use the same laser beam to capture both the geometry and the colour information, simultaneously.

The High Resolution Colour Laser Scanner is such a system developed by NRC (National Research Council of Canada). It is based on the auto-synchronized spot scanning principle (Rioux, 1994) and has been developed for digitizing a range of traditional museum objects including archaeological and ethnographic collections, paintings, small sculptures and natural history specimens in colour. The scanner, mounted on a three-axis translation system, scans a small (50-100 micron diameter) low power “white light” laser spot from a RGB laser source on the object through a synchronized laser scanning and triangulation detection system. The white laser is decomposed to its three primary components R-G-B. The 3D shape and colour are recorded simultaneously with high-resolution and in perfect registration of the XYZ and RGB components (Baribeau et al., 1992).

In its maximum resolution configuration, this system provides a spatial (X and Y) resolution of 50 micron and a depth (Z) resolution of 10 micron. This resolution is sufficient to record and examine fine brush stroke details on paintings as well as tool mark features on sculptures and archaeological objects. On a commercial basis, NRC has licensed this technology to Arius 3D (Taylor et al., 2002).

5.1. Geomagic Studio and PolyWorks software

Geomagic is a leading software company providing solutions in design, reverse engineering and inspection. The three software products (Geomagic Studio, Geomagic Qualify, and Geomagic Wrap) are mainly used in the aerospace, turbine machinery, medical devices, dental CAD/CAM, consumer products, entertainment, art, archaeology, and automotive industries. The company was founded in 1997. The headquarters office is located in Research Triangle Park, North Carolina (USA), with subsidiaries in Europe and Asia and partners worldwide.

InnovMetric is a software development company based in Quebec City, Canada, founded in 1994. The company has subsidiaries in USA, India, China, and a strategic partner (Duwe-3D

AG) in Europe. PolyWorks is the flagship product of InnovMetric, and it has been used primarily in archaeology, automotive, aeronautic, consumer goods, energy and metalworking industries as a point cloud inspection and reverse engineering solution. The core algorithms of PolyWorks have been developed in collaboration with NRC (Taylor and Beraldin, 2001; Soucy et al., 1996).

Table 4 gives a comparison of both software packages. It was prepared to a great extend based on the experiences gained in the Khmer head project where Geomagic Studio version 11 and PolyWorks version 10 were employed.

Table 4. PolyWorks versus Geomagic Studio

	PolyWorks	Geomagic
Data import	Manual	Automatic
Triangulation		
Type	2.5D	3D
Optimality	Better	
Detail preservation		Better
Topological correctness	Better	
Automatisation		Better
Editing capabilities		Better
Performance	Better	
Visualization	Better	
User friendliness		Better
Stability	Better	

Although surface digitization is a very easy and straightforward task, the surface triangulation and editing, which is the key step of the whole modeling chain, is still cumbersome and needs heavy semi-automatic or manual work. The management of large data sets is another aspect. Geomagic Studio crushed several times while filling the holes interactively, whereas PolyWorks did not. Geomagic Studio gives better details in surface geometry with the cost of large number of triangles.

Another comparison study performed on larger datasets is presented in Boehm and Pateraki (2006).

6. CONCLUSIONS

Active sensors are used for many kinds of 3D object reconstruction tasks, one important area of which is 3D documentation of cultural heritage objects. This study presents the results of 3D modeling of two cultural heritage objects, where a close-range coded structured light system was used for digitization.

The used instruments have acquired high quality point cloud data of the objects. The results of the processing (accuracy of about 50 micron and better) are in good agreement with the system specifications and project requirements. The heaviest user interaction is needed in the editing steps, e.g. for filling the data holes. We have used two commercial software packages in order to carry out the modeling step. Each software package has its own particular advantages and functions. A unique package, which fulfills all requirements with sophisticated and automatic editing capabilities, is not yet available. Usage of both packages can give the optimal modeling results. Texture mapping is another issue, which is not fully supported by either software.

Active sensing with coded structured light systems is a mature technology and allows high resolution documentation of cultural heritage objects.

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