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3D MODELING OF THE WEARY HERAKLES STATUE

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ABSTRACT:

A Herakles statue, named “Weary Herakles” and located in the Antalya Museum, Turkey was scanned by a Breuckmann structural light system. The work comprises all the necessary steps of the 3D object modeling pipeline, i.e. digitization, registration, surface wrapping, editing and visualization. 3D documentation and visualization of cultural heritage objects is an expanding application area. This paper presents the capabilities of some of the current technology in this field.

1. INTRODUCTION

A part of a Herakles statue, named “Weary Herakles” and located in the Antalya Museum, Turkey was scanned by a structured light system. This is a statue of the Greek demi-god Herakles, which dates back to the 2nd century AD. 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 (MFA). The lower part was found by Prof. Dr. Jale Inan (1981, 1992) in 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 1). According to the mythology Herakles is the symbol of power. He killed the Nemean lion, which was a nuisance in Greece. He used the skin of the lion as armor.

Because of the Turkish laws, the government has asked for restitution of the upper half so that the two fragments can be joined. The MFA has refused to consider Turkish petition. In 1992, casts of the two fragments were placed together. They were found to match perfectly. The MFA says the statue may have broken in ancient times, and the upper torso may have been taken from Turkey before Turkish law established state ownership of archaeological finds (Gizzarelli, 2006).

The digitization of the lower part of the statue was done in September 2005 in the Antalya Museum with a Breuckmann[1] opto*TOP*-HE structured light system. The system was kindly provided by the Turkish reseller InfoTRON[2], Istanbul.

The project was conducted in cooperation with InfoTRON Co. (Turkey), Breuckmann GmbH (Germany), the Division of Photogrammetry of Yildiz Technical University (Turkey), and

Figure 1. The Weary Herakles statue in the Antalya Museum

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1 http://www.breuckmann.com
2 http://www.infotron.com.tr

the Group of Photogrammetry and Remote Sensing of ETH Zurich (Switzerland). Further information can be found on the project webpage[3].

Totally 67 scans were acquired in order to fully cover the statue. Individual local point clouds were registered into a common coordinate system by use of an in-house developed method, called Least Squares 3D matching (Gruen and Akca, 2005). The surface modeling was performed in Geomagic Studio (a commercial 3D modeling software). The final 3D model contains approximately 5 million triangles. Nearly the same results were obtained by using the corresponding functions of the Breuckmann system.

3D documentation and visualization of cultural heritage objects is an expanding application area. This paper covers all the necessary steps of the 3D object modeling pipeline, and presents the gained experiences.

2. DATA ACQUISITION

2.1 Structural Light System

The opto*TOP*-HE system, as a high definition topometrical 3D-scanner, allows the 3-dimensional digitization of art objects and paintings with high resolution and accuracy. Optionally, the texture and/or colour of the object can be recorded, offering a one-to-one correspondence of 3D-coordinate and colour information.

Topometrical scanners (Figure 2) are based on the principal of optical triangulation using structured light: A special projection unit projects a fringe pattern or a sequence of patterns onto the object. A digital camera records the image of the object together with the projected fringes. For the technical details we refer to Breuckmann (1993, 2003).

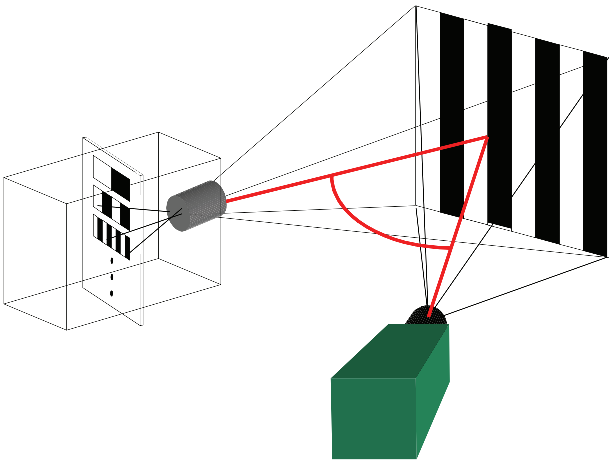


Figure 2. Setup of a topometrical 3D-scanner

2.2 The Scanner : Breuckmann opto*TOP*-HE

The opto*TOP*-HE system (Figure 3) uses special projection patterns with a combined GrayCode / phaseshift technique, which guarantees an unambiguous determination of the recorded 3D data with highest accuracy.

The time for a single scan takes about 1 second for a 1.4 MPixel camera and a few seconds for high definition cameras with 4-8 MPixel. Different scans can be directly aligned by means of the 3D geometry of the digitized object without using any additional markers.

The sensor of the opto*TOP*-HE system can be scaled for a wide range of Field of Views (FOV), 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. For the high definition digitization of the Weary Herakles a sensor with a 1.4 MPixel camera and a FOV of about 480x360 millimeters has been used, resulting in a lateral resolution of approximately 360 microns and a depth resolution of about 20 microns.

Figure 3. The opto*TOP*-HE sensor

The corresponding software supports the most important strategies for the alignment and registration of point clouds. It also offers a bundle of postprocessing functions, e.g. for the generation of a combined polygon mesh (merging), calculation of cross-sections, data reduction/compression, filtering and hole filling. The recorded 3D data may be visualized in shaded form, optionally with overlapping texture or colour information, and stored in standardized file formats (e.g. STL, PLY, WRL, DXF).

2.3 Scanning in the Antalya Museum

The scanning campaign had been completed in one and 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 83.75M points were acquired in 67 scan files. The average point spacing is 0.5 millimeters.

The opto*TOP*-HE is an instantaneous 3D digitization system, which means that the acquisition of one point cloud is done in nearly less than one second. However, orienting the scanner and planning the scan overlay needs careful preparation (Figure 4),

[3] http://www.photogrammetry.ethz.ch/research/herakles/

especially for this kind of object with many concave and hidden parts.

(a)

(b)

Figure 4. (a) Preparation for scanning, (b) scanning

3. POSTPROCESSING WORKFLOW

The following processing steps were carried out from the raw point clouds to 3D visualization:

- Registration
  + Pairwise registration
  + Global registration
- Point cloud editing
  + Cropping the area of interest
  + Noise reduction
  + Down-sampling
- Surface wrapping and editing
- Visualization

3.1 Point Cloud Registration

3.1.1 Pairwise Registration with Least Squares 3D Surface Matching: The pairwise registration was done by use of an in-house developed method, called Least Squares 3D Surface Matching (LS3D) (Gruen and Akca, 2005).

The LS3D estimates the transformation parameters between two or more fully 3D surfaces, using the Generalized Gauss-Markoff model, minimizing the sum of squares of the Euclidean distances between the surfaces. This formulation gives the opportunity of matching arbitrarily oriented 3D surfaces simultaneously, without using explicit tie points. The geometric relationship between the conjugate surfaces is defined as a 7-parameter 3D similarity transformation. This parameter space can be extended or reduced, as the situation demands it. The unknown transformation parameters are treated as stochastic quantities using proper a priori weights.

The mathematical model is a generalization of the Least Squares image matching method, in particular the method given by Gruen (1985). It provides mechanisms for internal quality control and capability of matching of multi-resolution/-quality data sets. For details we refer to Gruen and Akca (2005).

Totally 234 consecutive matching processes were performed using the LS3D matching method. In all cases the solution was found. No divergence or failure case occurred. The average of the sigma naught values is 81 microns.

3.1.2 Global registration: The first scan was selected as the reference, which defines the datum of the common coordinate system. Since multiple overlaps exist among the point clouds, there is need for a global registration, which distributes the residuals evenly among all the scans, and also considers the closure condition, i.e. matching of the last scan to the first one. For this purpose we used the block adjustment by independent models solution, which was formerly proposed for global registration of laser scanner point clouds, but for the case of retro-reflective targets as tie points (Scaioni and Forlani, 2003).

In the LS3D matching processes, the final correspondences were saved to separate files. The number of tie points was thinned out by selecting of every 24th correspondence. Then all these files were given as input to the block adjustment by independent models software BAM7, which is an in-house software based on a 7-parameter 3D similarity transformation. It was run in the rigid body transformation mode by fixing the scale factor to unity. The block adjustment concluded with 47 microns *a posteriori* sigma value in 4 iterations.

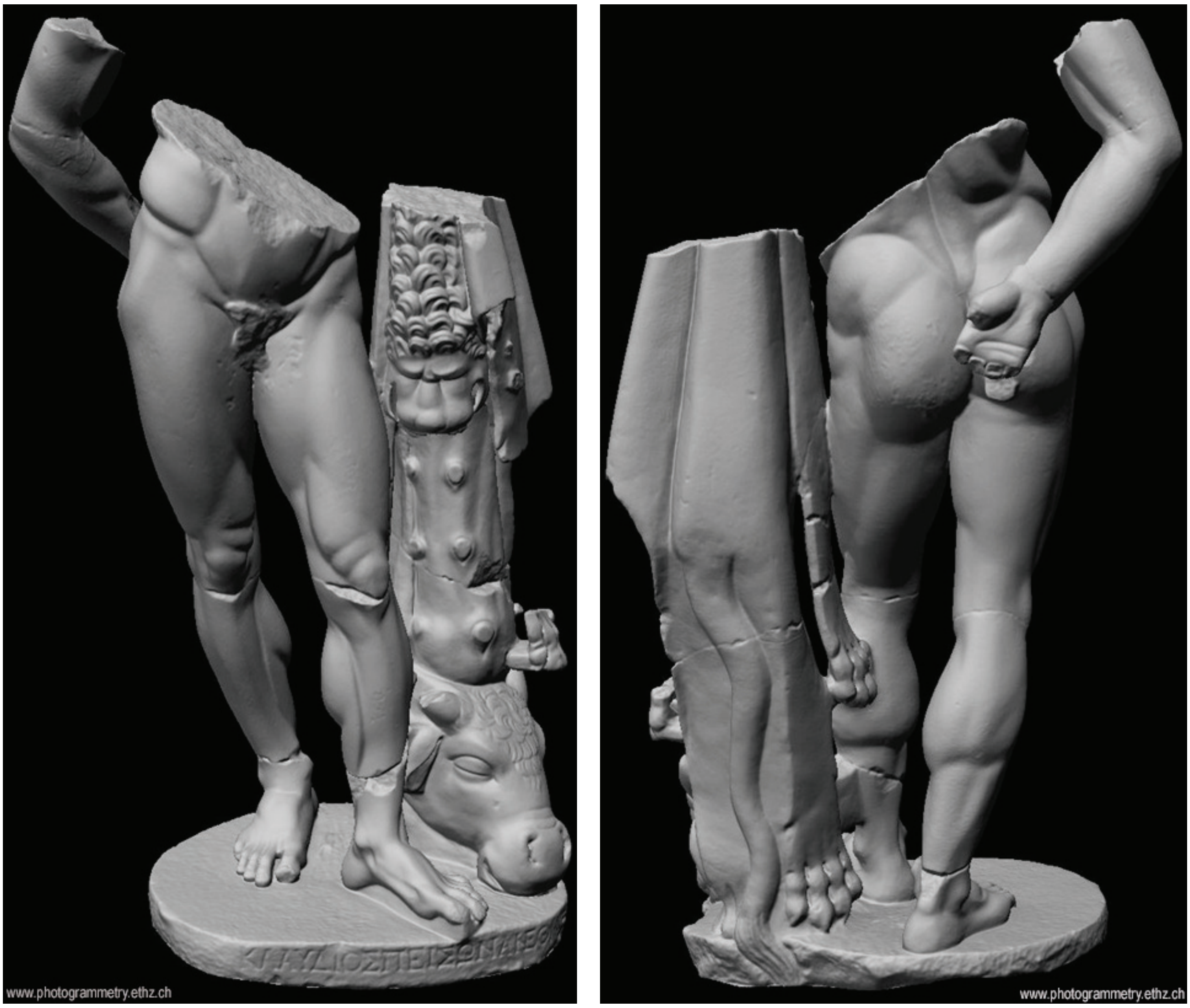
Very similar results are obtained by using the corresponding functions of the OPTOCAT software of Breuckmann scanner.

3.2 Point Cloud Editing

After the registration all scan files were merged as one XYZ file, discarding the no data points. This file totally contains 36.2 million points. The file was imported to Geomagic Studio 6 (Raindrop Geomagic), which is a commercial 3D modeling software package. The rest of the procedure was carried out in Geomagic Studio.

The data set was further cropped to include only the area of interest, i.e. deleting the background wall or other non relevant parts, concluding with 33.9 million points. A low level noise reduction was applied using the "Reduce Noise" function of Geomagic Studio.

As a first attempt the surface mesh generation was tried at the original data resolution. The operation could not be performed, since the memory request of the software exceeded the physical memory limit of 2 GB of the computer.



(a) (b)

Figure 5. (a) Frontal view of the final model, (b) back view of the final model

The number of points was reduced to 9.0 million by applying the "Curvature Sampling" function of Geomagic Studio. This operation eliminates points in flat regions but preserves points in high-curvature regions to maintain detail.

3.3 Surface Wrapping and Editing

Surface wrapping was done by setting the number of target triangles to 5 million. Because of the complexity of the statue and occlusions some inner concave parts could not be seen by the scanner. This results in several data holes on the wrapped surface. They were interactively filled with the "Fill Holes" option of the software. The final model contains 5.2 million triangles (Figure 5).

The main portion of the editing effort is for the hole filling. It is a tedious work, and takes the longest time among all the steps of the project.

4. CONCLUSIONS

Active sensors, i.e. laser scanner and structured light systems 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 the Weary Herakles statue, where a close-range structural light system is used for digitization.

The system has acquired high quality point cloud data of the statue. The numerical results of the processing are in good agreement with the system specification. The heaviest user interaction is needed in the editing steps, e.g. for filling the data holes.

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

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