

MEASUREMENT AND 3D MODELLING OF AN ANCIENT MEASURING DEVICE: NIPPUR CUBIT ROD

Z. Duran, U. Aydar

ITU, Civil Engineering Faculty, 80626 Maslak Istanbul, Turkey – (duranza, aydaru)@itu.edu.tr

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ABSTRACT:

For all think surveys of archaeological sites it is of utmost importance to recognize the fact that (nearly) all ancient buildings and towns are established according to an obviously normed set of precise non-metric ancient length units (cubit/foot or pechys /pous-units). Throughout the history, mankind constructed different kind of structures and monument, that we call them all as Cultural Heritage. To understand the features, location and relationship between these monuments it is needed to determine a common measurements unit at their equivalent that are used today. 3D documentation and visualization of Cultural Heritage objects is an expanding application area. The selection of the right technology for these kinds of applications is very important and strictly related to the project requirements, budget and user's experience.

In this paper, the studies of precise measurement, 3D modeling and documentation of Nippur Cubit will be presented. For these purposes, close-range photogrammetry and laser scanning technology were applied.

1. INTRODUCTION

For all think surveys of archaeological sites it is of utmost importance to recognize the fact that (nearly) all ancient buildings and towns are established according to an obviously normed set of precise non-metric ancient length units (cubit/foot or pechys/pous-units) (Lelgemann, 2004). Throughout the history, mankind constructed different kind of structures and monument, that we call them all as Cultural Heritage. To understand the features, location and relationship between these monuments it is needed to determine a common measurements unit at their equivalent that are used today.

In order to provide an overview the ancient length units are separated in the sequel into several groups only according to their mutual relations. The first known standard measure of length was a heavy copper bar, unearthed at Nippur on the Euphrates River dating from about 2650 B.C. It is marked with four large units, each divided into 16 smaller units, much like feet and inches. It's generally admitted by the contemporary metrologists that the Roman foot is directly deduced from the Nippur cubit measure, since the Egyptians, at the beginning of the 3rd millennium BC, shared the old Sumerian Nippur measure of 30 digits into 28 digits. $518 \div 28 = 18,5$ mm. $18,5 \times 16 = 296$ mm. This ancient measuring device is nowadays exposed in the Archeological Museum of Istanbul, Turkey (Figure 1).



Figure 1. Original Photograph of the Nippur at the Museum

In this paper, the studies of precise measurement, 3D modeling and documentation of Nippur Cubit will be presented. For these purposes, close-range photogrammetry and laser scanning technology were applied.

2. PHOTOGRAMMETRIC IMAGE ACQUISITION AND DATA PROCESSING

Due to new developments in semi-conductor and sensor technology and due to increasingly economical and efficient computer performance, architectural photogrammetry has developed into a fully digital technology in the last years. Since the beginning of the 1990's digital cameras with resolutions that are comparable with film-based Medium Format cameras have been available. During the 1980's and the 1990's detailed facade drawings were still produced at a scale of 1:50 to 1:100 using photographs from film-based cameras and by analogue and analytical photogrammetry. These elevations were used by architects and for the preservation of historical monuments. However, today complete and detailed 3D object reconstruction is increasingly performed by methods of digital architectural photogrammetry (Kersten Th. et al, 2004).

Photogrammetry deals since many years with the 3D reconstruction of objects from one or more images. It provides for accurate sensor calibration and object modeling using analog or digital imageries, it is very portable and many commercial software is available for image processing and 3D modeling.

Close range photogrammetry was selected for obtaining precise measures and 3D model of ancient Nippur Cubit which is the first known measuring device of the earth. After the photogrammetric evaluation the cubit was also modeled by laser scanner technology in order to make a comparison of these two techniques.

In this study Olympus C 5050 non-metric digital camera was used for taking the photographs. Before taking the photographs

the calibration of the camera has been done by test field calibration method (Figure 2). This stable test field takes place at the Laboratory of Photogrammetry in ITU and contains 37 control points. The coordinates of control points of the test field are measured in periodically in case of any changes.

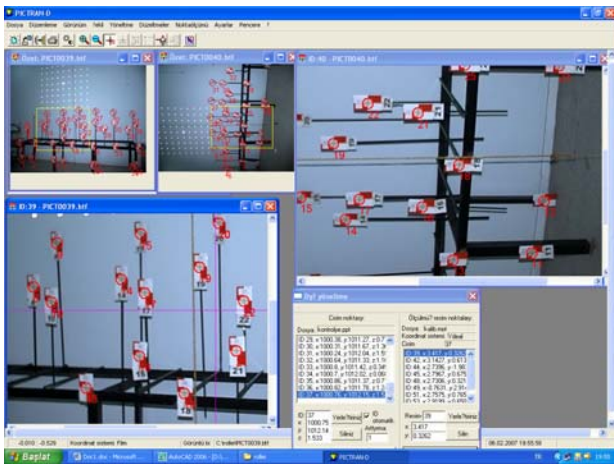


Figure 2. Calibration of the camera

Since the Nippur Cubit is a very valuable cultural heritage and is forbidden to be moved outside of the museum, a precise and stable control point's frame was used. This precise stable control point's frame contains 12 control points. Before the study the control points were measured by Pentax PCS total station and the coordinates of the points were calculated precisely. The object was located into the frame and small marks were stuck on the object to be used as tie points (Figure 3.) The objects were recorded photogrammetrically by multi image triangulation mode, 15 images were taken around the objects.



Figure 3. Example of the taking photographs at the museum

4.1 Photogrammetric Data Processing

The determination of the orientations of each photo was performed by multi image triangulation. To connect all photos in an overall triangulation photo block, all control points and selected natural tie points were measured manually in the digital images. In Fig. 4 the image point measurements for tie and control points are illustrated exemplarily using the software PICTRAN D from TechNet GmbH, Berlin Germany.

All manual measurements were performed in PICTRAN D as

points, lines or polygons. The superimposition of the epipolar lines in the images after measurement of each point (Fig. 4) offers significant support to the operator in finding the points quickly and in avoiding point mistakes. The 3D point coordinates of each measured point were determined by spatial intersection and the standard deviation of each point was shown in the user interface for online quality control.

The digitized 3D points were then transferred for further CAD processing to AutoCAD via the DXF interface. The wire frame model of the Nippur rod was obtained and then the model was exported in the AutoCAD (Figure 5).



Figure 4. Photogrammetric evaluation steps at PICTRAN

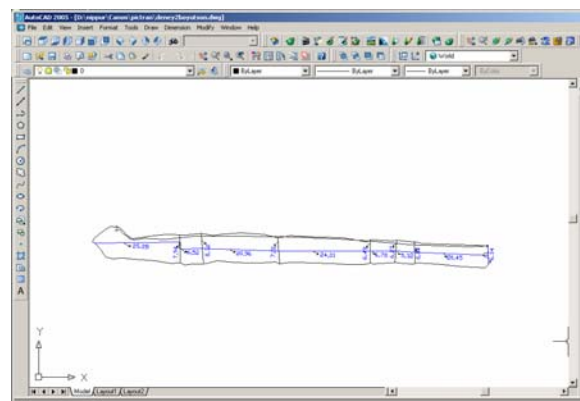


Figure 5. CAD Drawing of the object obtaining from PICTRAN

Three-dimensional photo-models help us to understand spatial objects, even if they are not accessible for us. Using photo-models from existing objects can make it easier for us to understand complex spatial structures (Toz and Duran, 2004). For the visualization purposes some images of the object were evaluated in the Photomodeler software which is low-cost photogrammetric software (Figure 6). After the evaluation the final 3D Model of the object was obtained.



Figure 6. Photogrammetric Evaluation Step and 3D model of Nippur cubit Rod at Photomodeler

5. Structured Light System

Structured light is the projection of a light pattern (plane, grid, or more complex shape) at a known angle onto an object. This technique can be very useful for imaging and acquiring dimensional information. The most often used light pattern is generated by fanning out a light beam into a sheet-of-light. When a sheet-of-light intersects with an object, a bright line of light can be seen on the surface of the object. By viewing this line of light from an angle, the observed distortions in the line can be translated into height variations.

Scanning the object with the light constructs 3-D information about the shape of the object. This is the basic principle behind depth perception for machines, or 3D machine vision. In this case, structured lighting is sometimes described as active triangulation.

At the second part of the study, the object was scanned by Breuckmann (<http://www.breuckmann.com>) StereoSCAN^{3D} Structured Light System. The digitization of the object was done in January 2008 in the Archeological Museum of Istanbul, Turkey with a Breuckmann StereoSCAN^{3D} structured light

system. The system was kindly provided by the Turkish reseller InfoTRON Co. (<http://www.infotron.com.tr>), Istanbul.

5.1 The Scanner: Breuckmann StereoSCAN^{3D}

StereoSCAN^{3D} (Fig. 7a), is one of the latest generation high definition topometrical 3D-scanner of Breuckmann that allows the 3-dimensional digitization of art objects and paintings with high resolution and accuracy. StereoSCAN 3D consists of a fully integrated combination of Breuckmann patented MPT (Miniature Projection Technique) projection unit and 2 high resolution digital cameras which are asymmetrically positioned at either side of the projector. This configuration enables maximum performance with regard to flexibility and precision. Due to the asymmetrical camera set-up, three different triangulation angles (10°, 20° and 30°) (Fig. 7b), are implemented. By this way, even areas which are otherwise difficult to capture, can be reliably assessed. Easily exchangeable objectives ensure fast switching between different measurement areas.



Figure 7a and 7b. Breuckmann StereoSCAN^{3D} and Camera Setup

5.2 Point-Cloud Alignment

The alignment of point-clouds that were recorded from different standpoints was carried out by using Optocat software of Breuckmann scanner. The first scan was taken as reference scan that defines the datum and the adjacent scans were aligned with respect to this one. Optocat uses index marks which are common in both scans for alignment step. For the creation of index marks, special targets were stuck on the object and their 3D co-ordinates were obtained by photogrammetric method using Aicon Photogrammetric Software (Fig. 8). Also the scaling was done by placing special rods near the object before taking the images.



Figure 8. Determination of indeks marks coordinates by photogrammetric method

5.3 Point Cloud Editing

After the alignment, all scans were saved as one XYZ file and exported to Geomagic Studio. The exported file was containing 563954 points. After the exportation, a low-level noise reduction was applied. At second step, by using Curvature Sample method of Geomagic Studio, the number of total points was decreased to 201578. Curvature Sample method decreases the number of points at flat surfaces and preserves the points at curvature areas in order to maintain the details.

5.4 Surface Triangulation, Editing and Texture Mapping

Surface triangulation was carried out at Geomagic again by using the related function. Although the triangulation step ended with 448702 triangles, decimating operation was applied in order to reduce the number of triangles by taking into account the hardware limitations and texturing purpose. Decimate of polygons operation works according to two optional algorithms. In this work, shape preservation mode was chosen since the main goal was to maintain the model shape. Because of the brightness of the object surface and the light condition during the scanning, the wrapped data had a few holes. These holes were filled manually by using the related function of the software. On the hand, triangulation operation resulted with some intersecting triangles which cause deformation at topology. These intersecting triangles were repaired automatically. Geomagic Studio does not allow texturing the object by original images. For this reason, the data was exported to one another software Rapidform that provides the opportunity of texturing the object with original images. RapidForm attaches texture using point matching. After selecting 5 or more pairs of corresponding points on the texture and a polygon model, RapidForm attaches the texture to the polygonal surface based on those points.

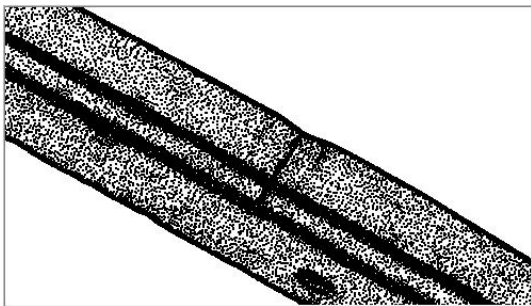


Figure 9. Point Cloud

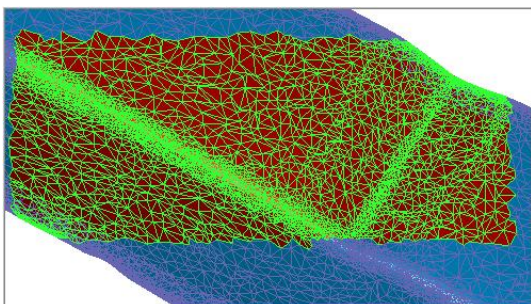


Figure 10. Triangulated Model

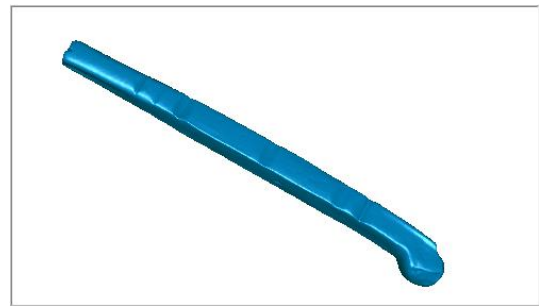


Figure 11. Shaded View



Figure 12. Textured Model by RapidForm

Table 1. Measured values on models

	1/2 Yard (Arm's length) (cm)	1 foot (cm)	14 finger (cm)
Original	25,6	27,65	24,15
Photogrammetry	25,28	27,48	24,31
Laser scanner	25,32	27,58	24,06

7. CONCLUSION

Active sensors are now have an important usage in not only the reverse engineering area for industrial products but also the documenting, 3D modelling and visualizing the art objects and architectural structures. On the other hand, close-range photogrammetry is used for years for the same purposes as an efficient and reliable method.

In this paper, the studies of measurement, 3D modelling and documentation of Nippur Cubit Rod which is the first known measuring device of the earth, were presented. For these purposes, close-range photogrammetry and high definition 3D scanning technology were applied to obtain the 3D model of the object. According to the results it is possible to say that the both methods provide efficient results. The major differences of these two techniques are in terms of processing time and automation. While scanning is much faster and represents the surface details better due to the high number of points, close-range photogrammetry is a powerful tool providing reliable results about the spatial objects measure. Also different

software packages for both techniques were used in this study for different purposes. Although each has different features individually, there is not only one software package which fulfills the all requirements in terms of texture mapping, precision and automation.

One of the most important distinctions to be made between the two techniques considered is the amount of 3D data acquired by each technique. Laser scanners acquire thousands of points over the field of view in a very short period of time. When several scans are merged, the resulting 3D point cloud gives a detailed, useable 3D model of the object's surface. A major difference with digital close range photogrammetry is the number of 3D points that can be acquired.

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