MODELLING OF AN ANCIENT BRONZE SUSPENSION HEAD BY MEANS OF REVERSE ENGINEERING TECHNIQUE

Assoc. Prof. K. Efstathiou,
Dr. Eng. Em. Varitis,
Assist. Prof. G. Mansour,
Dipl.-Eng. C. Efstathiou
Laboratory for Machine Tools and Manufacturing Engineering, Mechanical Engineering Department,
Aristoteles University of Thessaloniki, Greece

ABSTRACT

In recent years, reverse engineering technique is used in the field of archaeology to model the geometry of archaeological findings. Modelling of ancient objects is a demanding process due to fragility. In this paper a non destructive method which combines Computer Tomography and 3D Laser scanner for modelling metallic objects with composite geometry and thick walls in presented. Several ancient objects are modelled to verify the accuracy and the reliability of the proposed method and a characteristic example of a suspension head found in the Greek city of Dion is presented.

KEYWORDS: Computer Tomography, Laser scanner, Modelling, Reverse Engineering

1. Introduction

Reverse Engineering (RE) is an emerging technology that plays a promising role as a data acquisition for object modelling. Using devices such as 3D laser scanner, Computer Tomography (CT) and Coordinate Measuring Machine (CMM), point data are acquired from the surface of specimens and with appropriate processing the 3D model is created.

Reverse engineering is now widely used in multiple applications, such as manufacturing, industrial design, automotive and jewelry design and reproduction. In recent years, a large number of applications in other fields as, medicine, geology, and especially archaeology have been reported. The use of reverse engineering techniques in archaeology has several benefits. The creation of 3D models of ancient objects is a vital factor in the legacy and heritage of prehistory. Virtual reality approach creates a background for producing virtual museums and virtual sites of the past [1]. Virtual museums creation provides the possibility for everyone, to visit these virtual places and explore the ancient findings.

Moreover, the 3D model of archaeological objects, which can be produced by a reverse engineering technique, is necessary for archeologists and researchers to investigate the objects themselves. The investigation results reveal invaluable information about the design and forming or manufacturing process [2] of these objects in the antiquity. Finally, the 3D models could be used for manufacturing precise copies of the ancient objects by employing modern rapid prototyping techniques [3].

For all these reasons it is easy to understand the significant effect of RE in archaeology for modelling archaeological findings. The aim of this paper is to present a non-contact method for modelling metallic ancient object by means of reverse engineering techniques, which is based on Computer Tomographies and 3D laser scanning measurements.

2. State of the art

3D modelling of archaeological findings is a demanding process which comprises several restrictions. Due to the value and fragility of the archaeological findings, a non-contact technique is necessary to be applied to avoid any damage. Moreover the internal parts or features of the findings must be recorded for further investigation of the forming process in the antiquity, as already mentioned.

3D laser or optical scanners is a technique used in many cases for modelling ancient objects [4, 5]. In Figure 1, a laser scanner is presented. According to its basic principle a 3D reconstruction is based on object image acquisition in stripe structural light or laser while the object is rotating around a vertical axis in a machine table. A set of cameras is used for the whole surface reconstruction. The 3D coordinate measuring method is carried out provided that the plane of projected structural light and the rotation axis of turntable are known. This technique is applied on objects regardless of their material. However, non-contact scanners employ light within the data capture process. This creates problems when the light impinges on shiny surfaces, and hence some surfaces must be prepared with a temporary coating of fine powder before the scanning process. Furthermore, laser and optical scanners collect geometric data only for the external surface of the objects. Another non-contact technique is X-Ray computer tomography. Computer tomography is often encountered in industry, medicine and in other sectors. A computer guided tomography and its working principle is presented in the Figure 2. The tomography consists of two main units, the source of radiation producing the X-rays (Roentgen) and the detector. The specimen was rotated appropriately within the device and multiple tomographies were performed at successive revolving positions. The method is based on the measurement of the X-radiation absorption by the object in various directions. The reconstruction of the external and internal object surfaces was generated by a data computer analysis, when a satisfactory number of topographies were conducted. In this way, the 3D external and internal object geometry is possible to be visualized and partial or full sections, at any position of its geometry, to be obtained. This technique could be used to record geometry of ceramic, wooden, and marble objects [6]. In case of metallic objects, with thick walls and composite geometry, the X-ray could not penetrate the whole thickness of the object and the resulting measurement data file has errors [3]. Only metallic objects with thin walls and non composite geometry could be recorded successfully as presented in many cases in the literature [7].

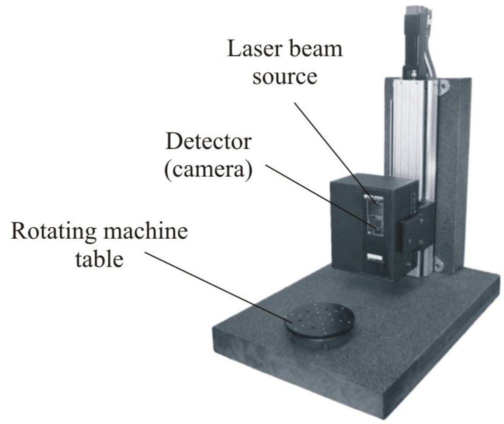

Fig.1 3D laser scanner.

In paper [3],it is presented a modelling method of archaeological metallic object based on point clouds and polygon model procedure which is the classic modelling method applied in reverse engineering applications. The scanning device is computer tomography and because of the object composite geometry the resulting measurement data enclosed defect regions. According to this method the following procedure is performed to model the final geometry. The measurement data file, which contains points coordinates of the object surface, is imported in appropriate software for further manipulation. Through the processing steps the final model of the object is created. Due to the fact that the measurement file has several defect regions, this method requires the combination of complicate manipulations and time consuming actions such as noise filtering, filling of holes, surface smoothing in the deformation to be applied.

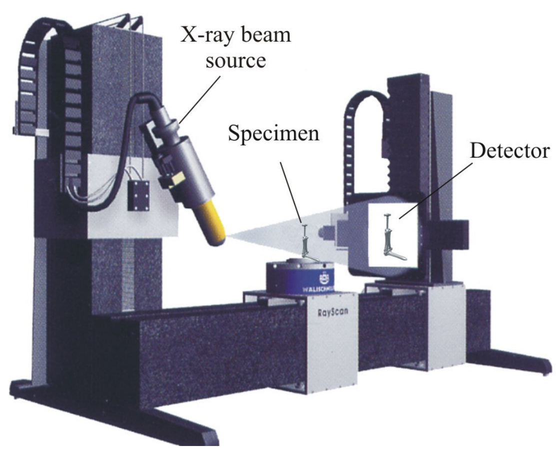

Fig. 2 Industrial Computer Tomography.

3. The proposed method

In the present paper a method for modelling metallic archaeological objects with composite geometry is applied. The object is scanned using two different techniques of measurements, a computer tomography and a laser scanner. The final geometry is generated by the conjunction of these techniques. The measurement file of computer tomography contains information for the external and internal surface of the object in low quality. On the other hand the external surface of the object is recorded successfully by the laser scanner. The measurement files are represented by a point cloud. In order to align the models, the registration of these files is performed by means of a hybrid algorithm [8] and then the file of computer tomography superimposed to the file of laser scanner. Furthermore, the 3D polygon models (STL files) are generated by a polygonisation process. Then, the regions, which have been recorded better, of each model, are isolated and then combined for the generation of the final model of the object. This procedure is performed in suitable software.

The workflow of this method is presented in the Figure 3. It is obvious, from the diagram, that the point cloud and polygon model procedure used in [3] have been replaced by an automatic registration algorithm and suitable processing which is not complicated and does not require user's expertise. The proposed method needs less time than the classic reverse engineering method and has been tested successfully in several applications [9].

4. Application of the proposed method

The proposed method is applied in a bronze suspension head of a Roman time passenger carriage, which is shown in Figure 4, found during excavation in Dion, a prominent archaeological site in Northern Greece.

The cabin (see lower part of figure 4) is carried by leather belts bound to suspension heads on wooden poles reinforced by metal plates, fixed on the frame of the carriage. The suspension heads had two finger-shaped extrusions forming closed rings on their front and rear side (see view A of the figure 4), where the leather belts were hitched.

The complete solid geometry of the suspension head was recorded by computer tomography to avoid any damage of the prototype and also record invisible internal geometrical features.

The computer tomography employed for the recording of the suspension head's geometry had a power of 250 KVA and a recording resolution precision of 10 μm. However, due to the object's relatively high thickness of the object, the X-rays could not fully penetrate it, which resulted in incomplete description of the object's geometry by the acquired data. As it can be seen on the upper left side of Figure 5, various geometric irregularities appeared on the surface of the object, not consistent with its true form.

For this reason the external geometry of the suspension head was scanned with a laser scanner. The object was scanned from several

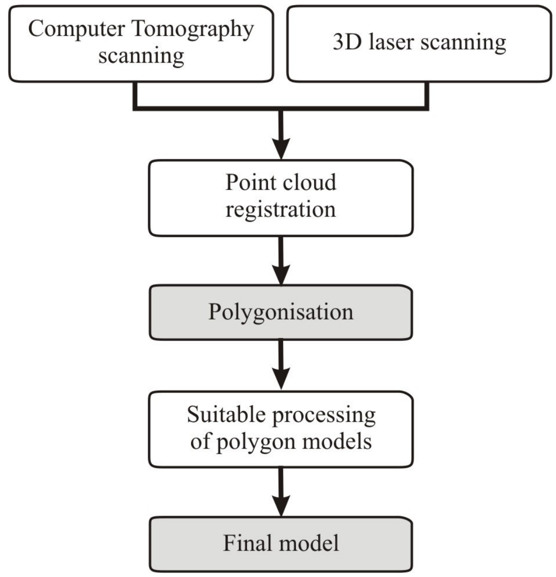

Fig. 3 Workflow of proposed method for modelling metallic ancient objects.

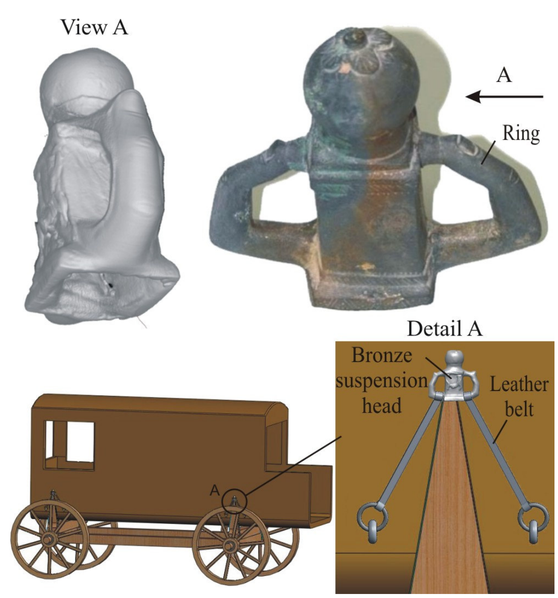

Fig. 4 The suspension head and the passenger carriage.

angles, by two laser beams and the related geometrical data were recorded and displayed on a computer monitor. The complete external geometry of the suspension head was determined at a digitalization accuracy level of 90 μm. However, some regions in the geometry of the object were recorded by laser scanner with less precision than the computer tomography. The external geometry of the suspension head is shown in the right upper part of Figure 5.

The measurement data of the computer tomography and laser scanner were aligned by a registration hybrid algorithm and is presented in the middle of the Figure 5. Afterwards, in suitable software, the parts of each of the two STL files that were given better the geometry of the suspension head, were isolated and then combined for the creation of the final STL file. The final 3D model of the suspension head is presented in the lower part of the Figure 5.

5. Conclusions

In the present paper, a method for modelling metallic archaeological findings with composite geometry is presented. The object is scanned by a computer tomography and a laser scanner. The measurement files of these techniques are aligned by a registration hybrid algorithm and then, by means of suitable processing, the final 3D model of the object is generated. The proposed method does not require user's expertise and consumes less time than the classic reverse engineering method. Finally, the method has been tested successfully, in several applications and leads to high accuracy results.

6. References

[1] **Rees M.,** *Rapid Prototyping and Art,* Rapid Prototyping Journal, Vol. 5, No. 4 (1999), pp.154-160.

[2] **Bouzakis K.-D., Pantermalis D., Efstathiou K., Varitis E., Michailidis N., Sagris D., Mavroudis I., Vasteli K., Kastner J., Salaberger D.,** *Design and manufacturing aspects of a vaginal speculum of antiquity, as investigated by computer tomographies,* Journal of Archaeological Science, 35 (2008), pp.633-642.

[3] **Bouzakis K.-D., Pantermalis D., Efstathiou K., Varitis E., Michailidis N., Mavroudis I.,** *Archaeological objects solid geometry determination based on computer tomographies, digital photography and appropriate processing of the related data*, 2nd International Conference on Manufacturing Engineering (ICMEN) and EUREKA Brokerage Event (2005), Greece, pp. 675-694.

[4] **Chikatsu H., Anaj T., Hatano K.,** *Real-time ortho imaging and surface modelling for archeological artifacts,* Optical 3D Measurement Techniques IV, Edited by A.Gruen, O.Kuhbler, Zurich (1997), pp. 19-26.

[5] **Vladimir A. Knyaz, Sergey Yu. Zheltov,** *Vision based technique for photorealistic 3D reconstruction of historical items,* Geospatial Applications Papers, Archaeology (2001), www.gisdevelopment.net/application/archaeology/index.htm.

[6] **Jansen R., Koens H., Neeft C., Stoker J.,** *Scenes from the Past: CT in the Archaeologic of Ancient Greek Ceramics,* RadioGraphics 21 (2001), pp 315-321.

[7] **Rossi M., Casali, F., Chirco P., Morigi M.P., Nava E., Querzola E., Zanarini M.,** *X-ray 3D Computer Tomography of Bronze Archaeological Samples,* IEEE Transaction on Nuclear Science, 46 (1999), pp 897-903.

[8] **Mansour G., Mitsi S., Sagris D., Varitis E.,** *Optimization of point clouds registration by means of a hybrid algorithm*, The Annals of "Dunarea de Jos" University of Galati, Fascicle XIV, Mech. Engineering, Year XI, ISSN 1224-5615 (2005), pp 5-10.

[9] **Varitis Em.,** *Modelling and reconstruction of ancient objects by means of Reverse Engineering and Rapid Prototyping,* Doctoral dissertation, Aristoteles University of Thessaloniki (2009).

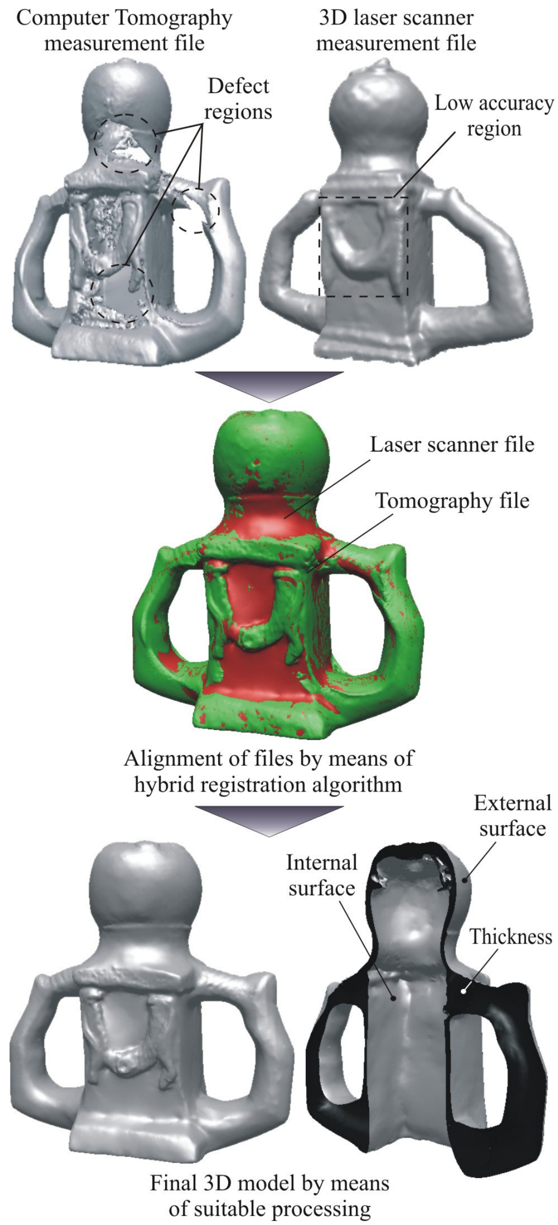

Fig. 5 Final 3D model of a suspension head created by proposed method.