

Heritage Boat Specifications Extraction from 3D Laser Scanning

Kleanthis Xenitidis¹, Stamatis Chatzistamatis², Christos-Nikolaos Anagnostopoulos², Vassilios Mardiris¹, Dimitrios Makris³

¹ *Eastern Macedonia and Thrace Institute of Technology, Digital Forensics and Data Management Research Lab, 65404 Kavala, Greece*

² *University of the Aegean, Department of Cultural Technology and Communication, 81100 Mytilene, Greece*

³ *Kingston University, Digital Imaging Research Centre, Penrhyn Road, Kingston upon Thames, Surrey KT1 2EE, UK*

Abstract – The adaptation of advanced technology is changing the way cultural heritage is being conducted nowadays, and maritime cultural heritage is no exception. Greece has a rich history in the marine section, and many boats are proclaimed from the Ministry of Culture as Cultural Heritage Monuments. The use of modern technology, like total stations and 3D laser scanning, has narrowly been used for the documentation and study of maritime heritage contexts to date, and this is always done by using commercial software for the extraction of the specifications. In this paper, we propose an automated method for extracting heritage boat specifications from point clouds delivered from 3D laser scanning of heritage boats. The proposed method is implemented from scratch, and there is no need for the use of any commercial software. Our approach is scale-invariant and can be used with the same reliability for larger heritage boats or ships providing precise measurements on surfaces from the acquired 3D models.

I. INTRODUCTION

Maritime Heritage is by essence a branch of heritage that is of significant importance, because ships and boats have always been the medium of goods and knowledge [1]. Curating heritage boats can be difficult because they are complex structures and usually large [2]. The complexity of this kind of artefacts justifies the use of modern technologies for the documentation and enables new assessments that are not possible with traditional methods, but also a higher precision [3].

Over the last two decades, projects using different methods flourished all over the world to document digitally historical ships and boats. 3D laser scanning is one of that method which offers a multifaceted means of recording and studying boats. In this paper, we describe the application of 3D laser scanning in specifying characteristics of heritage boats. The proposed technique,

is scale-invariant, and although it is tested only at one boat, can be applied to boats and ships of any size.

II. RELATED WORK

In recent times, maritime heritage documentation strategies have been considerably improved using advanced acquisition systems. The people needed for the documentation process are much fewer providing at the same time a more objective way of measuring. Several initiatives show the direction using mainly three different technologies [1]:

- Coordinate Measurement Machines, such as a Faro Arm [3]
- Total Station Theodolite [4], and
- Laser Scanners [5].

One of the most remarkable projects that used laser scanners for the documentation of heritage boats is “The Traditional Boats of Ireland Project” [6], where a comprehensive survey of Ireland’s traditional water craft took place. The other remarkable project was “LaScanMar” [7], or Laser Scanning Maritime, where the project was conceived out of a need to satisfy a lack of 3D digital recording and documentation for maritime heritage preservation, specifically boats for which there were neither plans nor recorded information. During all the above projects, the specifications extraction is done by commercial software and specifically a plug-in for Rhinoceros, known as Orca 3D [8], which enables detailed analysis of the 3D model.

III. THE TEST BOAT

The boat that is studied in this paper is named “Evangelistria” (Fig. 1). It is a traditional type of boat that has not been preserved anymore. The history of “Evangelistria” starts from Old Phocaea in Asia Minor in the late 19th century. Owned by Panayiotis

Charalambous family, the boat was used for transporting salt in the salt marshes in the area [9]. It is said that Eleftherios Venizelos (1864-1936), seven times prime minister of Greece, got on this boat when he visited Mytilene, Lesvos Island, Greece in 1916 [9].



Fig. 1. The "Evangelistria" boat

Recognizing the historical value on "Evangelistria", the Ministry of Culture proclaimed it a Cultural Heritage Monument. Since 2006, it has been displayed in the Atrium of the Department of Marine Sciences at the University of the Aegean in Greece.

IV. 3D LASER SCANNING OF THE BOAT

For the 3D laser scanning survey, the team took into consideration the guidelines that are suggested from English Heritage Handbook [10] and more specific ones that are suggested from Ireland's Heritage Council [11]. The team used a phase-based Faro Focus^{3D} laser scanner with associated equipment such as spheres and checkerboard targets (Fig. 2).



Fig. 2. Part of the survey setup

The survey process involved levelling the scanner on a tripod at a location with a clear view of the desired section of the boat. Seven targets were placed within its view, three spheres and four checkerboard targets, and a single scan initiated. The selected resolution was at 1/8 on the Focus^{3D} laser scanner. That resolution records a

point every 6mm at a distance of 5m. The selected quality was 4x, which means that every point was fired four times by the laser scanner for more accurate z-value. On completion, a total number of seven individual scans were carried out, six around the boat and one inside the boat. The spheres were scanned by six scans, enabling the individual scans to be registered together automatically with maximum 1mm error. The checkerboard targets were used to register the outside of the boat scans with the one inside. The post-processing phase included the cleaning of scans from the noise and the creation of the point cloud that represents only the 3D model of the boat (Fig. 3). At the last step of the post-processing phase, the checkerboard targets were used as control points for testing the accuracy and precision of the final model.

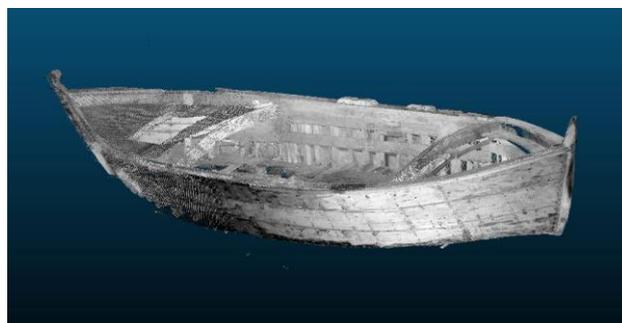


Fig. 3. The 3D model of the boat

V. SPECIFICATIONS EXTRACTION

The specifications extraction is the following step of our approach. The extraction is fully automated, with software that is written in Python programming language. The 3D point cloud $A = (X, Y, Z)$, which represents the boat, is positioned in an orthonormal coordinate system, according to the following rules:

- **X-axis** – longitudinal with 0 at stem and positive towards the stern
- **Y-axis** – transverse with 0 at the centerline and positive outwards
- **Z-axis** – vertical with 0 at the waterline and positive upwards

The waterline is established from known data such as photographic material representing the boat in the water, as well as from markings such as marks on the original boat.

The next step that takes place is the reconstruction of the boat. The boat's hull is reconstructed using B-spline curves. In order to achieve the reconstruction, the point cloud A was separated into $N = 50$ longitudinal slices A_i , described by the following formula:

$$A_i = \left\{ \begin{array}{l} (x, y, z) \in A, \\ \frac{i}{N} \cdot \max(X) \leq x \leq \frac{i+1}{N} \cdot \max(X) \end{array} \right\} \quad (1)$$

for $i = 0, \dots, N-1$.

Consequently, each slice A_i has been projected into yz-plane:

$$A_i^p = \left\{ (y, z) \in \square^2, (x, y, z) \in A_i \right\} \quad (2)$$

so that a 2D B-spline curve C_i can approximate it. The approximation of each set of points A_i^p for $i = 0, \dots, N-1$ has been implemented using the algorithm described in [12]. Consequently, each curve C_i has been positioned into the 3D space in the longitudinal plane:

$$x = \frac{2i+1}{2} \cdot \frac{\max(X)}{N} \quad (3)$$

Example of the longitudinal plane of four of the calculated curves is shown in Fig. 4 and a drawing of the reconstructed boat with curves is shown in Fig. 5.

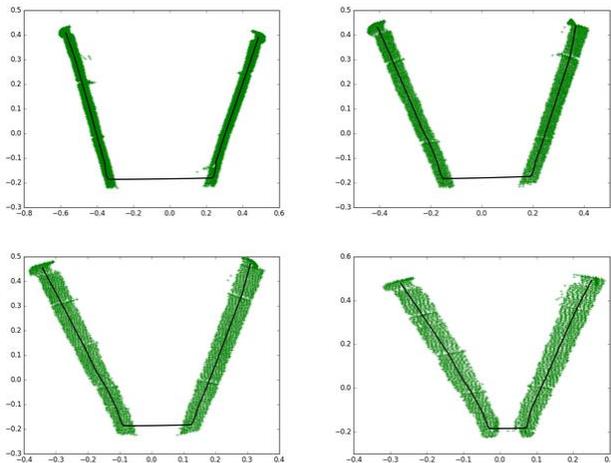


Fig. 4. Four of the calculated curves of the boat

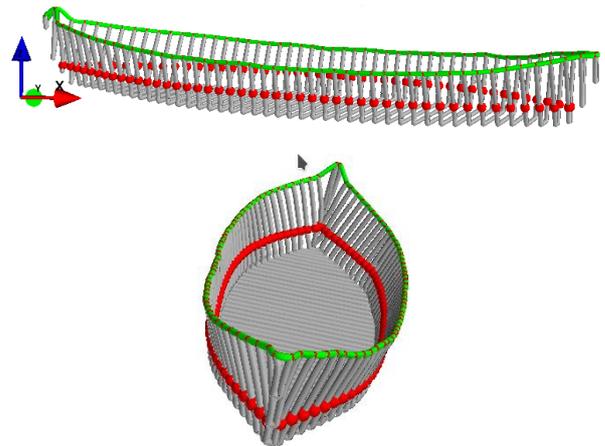


Fig. 5. The reconstructed boat with curves

Then the specifications of the boat that are calculated are (Fig. 6):

- **Loa**: the maximum length of a vessel's hull measured parallel to the waterline
- **B**: the maximum beam
- **Lpp**: the horizontal length of the waterline
- **D**: the maximum height of the boat measured perpendicular to the waterline
- **T**: the vertical distance from the deepest point of the boat to the waterline.

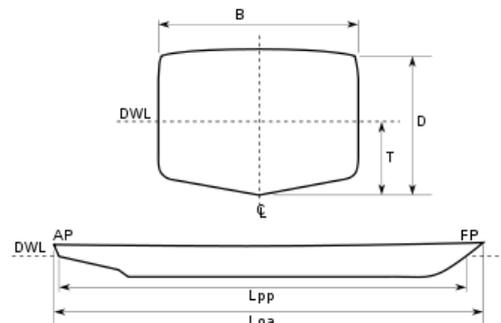


Fig. 6. Boat specifications [13]

The extracted measurements are shown at Table 1. Those measurements were evaluated and found to be accurate with hand measurements on the original boat.

Table 1. Specification measurements

Specification	Value	Figure
Loa	6.54 m	9
B	1.61 m	7
Lpp	5.99 m	9
D	1.06 m	8
T	0.25 m	8

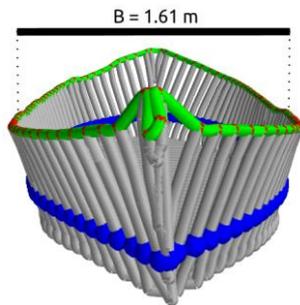


Fig. 7. *B* value

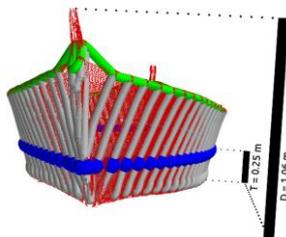


Fig. 8. *T* and *D* values

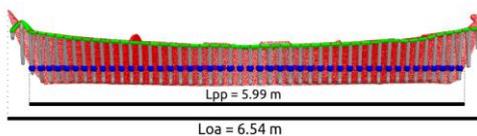


Fig. 9. *Lpp* and *Loa* values

VI. CONCLUSIONS

Our approach is scale-invariant and can be used with the same reliability for larger heritage boats or ships. Also, it can be used for boats with missing parts because the reconstruction with curves can “fill” the missing parts. The proposed approach does not need any commercial software for the processing phase, but it can calculate only specific characteristics of a heritage boat and there is a need for an extension to extract more specifications and hydrostatic data of the boat.

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