LASER SCANNER RELIEFS OF SELECTED ARCHEOLOGICAL STRUCTURES IN THE SUBMERGED BAIAE (NAPLES)

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Commission V

KEY WORDS: Scuba Laser scanner documentation, Baiae, Underwater cultural heritage

ABSTRACT:

In 2011 the ISCR (Rome), in the frame of the Project Restoring Underwater directed by Barbara Davide Petriaggi, started to test Naumacos Laser Scanner I, designed by Gabriele Gomez de Ayala, in order to document the restoration of a room paved with opus sectile probably part of the Bath of Punta Epitaffio (Underwater Park of Baiae – Marine Protected Area, Naples).

The experimentation conducted in Baiae by ISCR has shown the effectiveness of the Laser Scanner; this method also allowed to considerably reduce times and costs of underwater surveying. Moreover, the 3D relief obtained, has the characteristic of being geometrically (accuracy is sub-millimetric) and chromatically faithful to the reconstructed structure, as well as being exportable in various forms and usable in several contexts. From 2011 to 2013 the evolution of the instrument Naumacos Laser Scanner 3 was developed and tested in the restoration work of the Villa con ingresso a protiro, where three structures were documented in 3D (a paved with black and white mosaic decorated with hexagons and peltae, a very fragmentary black and white mosaic and a stone artefact. This paper shows the results of this documentation campaign and it underlines the prominent role in documentation and in museum display of Underwater Cultural Heritage played by the three-dimensional laser scanning survey. This technique also contributes to the increase of the value of scientific dissemination.

1. INTRODUCTION

The use of laser scanners for 3D acquisition is commonplace on dry land and is now also entering the field of underwater archaeology.

3D laser scanning delivers more precise results than 3D photogrammetry, but requires instruments that are still relatively costly. It uses a family of technologies, each of which has been tuned to meet the requirements of acquiring objects of different types, from the smallest, such as coins, to entire topographical areas or buildings. Scanners of this kind allow the rapid automatic acquisition of the position of thousands of points, known as point clouds. These define the surface of an object or a site, producing a 3D model that can be rendered for visualisation. The scanning pipeline consists of various phases, the first of which is the acquisition of the geometrical shape of the object, which can require scanning from many different directions. This is followed by alignment or registration, which allows the different scans to be merged automatically into a 3D model. Appropriate software, some of which is available free, is also required to process the data produced by the hardware.

The systems available to locate and map underwater archaeological sites (on and within the seabed) are essentially the multi-beam systems (sidescan sonar, sub-bottom profilers, magnetometers, and single and multibeam echosounders) and the interpretation of stereoscopic pictures.

The first group of tools produce a 3D graphic representation of the seabed morphology, particularly suitable to the geological study of the conformity of the seabeds and underwater canyons and to the localization of archaeological sites (wrecks, isolated items or archaeological structures); the second system produces a 3D model through the interpretation of stereoscopic pictures by means of particular software created for this kind of use (available freeware) that interprets the pictures in order to obtain a 3D model roughly like the original one (Canciani, Gambogi et alii 2002; Petriaggi, Davide 2010, Mahon, Pizarro et alii 2011; Diamanti, Georgopoulos et alii 2011; Gearhart 2011).

In 2010/2011 the ISCR, in the frame of the project Restoring Underwater directed by Barbara Davide Petriaggi (http://www.iscr.beniculturali.it/pagina.cfm?usz=1&uid=69&id=pro=4), started a collaboration with Naumacos Underwater Archaeology (Gabriele Gomez de Ayala) to develop underwater three-dimensional scanning systems.

The experiments were conducted in the Underwater Park of Baiae – Marine Protected Area, Naples. Here the ISCR is directing the project Restoring Underwater devoted to tests tools, materials and methods to restore and in situ protect underwater archaeological structures and underwater Cultural Heritage. Restoring underwater was designed in 2001 by Roberto Petriaggi who directed the restoration works in Torre Astura (Rome), Baiae and in other underwater archaeological sites in Italy (Petriaggi, 2004; Petriaggi, Mancinelli, 2004; Petriaggi 2005; Petriaggi, Davide 2010; 2012; Petriaggi, Davide Petriaggi, 2015). The ISCR Unit of underwater archaeology in the past years have focused its efforts to test 3D documentation systems, as the three-dimensional survey of the sarcophagi of the wreck off San Pietro in Bevagna (Taranto) using ScubaScan system by Menci Software (Petriaggi, Davide 2010) or participating to the 3D documentation campaigns conducted with Università della Calabria (Gallo et alii 2012.; Bruno et alii, 2013).

The scanners developed in Baiae by Gabriele Gomez de Ayala and ISCR, object of this paper, produce, as we describe below, dense point clouds for the elaboration of 3D models with submillimetric resolution, simultaneously extrapolating from surface texture information and digital images. The equipment uses on-board GPS to orient the 3D images in order to assemble 3D composites of large areas, aligning the different individual scans in post-production using a system of optical targets.

In Italy another example of underwater laser scanner is tested by ENEA Frascati’s Laser Vision Lab that is perfecting an underwater laser scanner called RE-VUE (Remote Viewing in Underwater Environments) which can be used at depths of up to 400 metres. (Further information and a bibliography is available at...
The Villa con ingresso a Protiro.

The second 3D documentation campaign was conducted in the Villa con ingresso a Protiro. This villa is one of the many villae maritimae along the lacus baianus. It has two clearly defined areas: the residential quarters and the baths. Between them lies a rectangular area probably a garden area. Here a statue, similar in style to the Aphrodite of the Gardens by Alcamenes, was recovered and is now housed in the Archaeological Museum of Campi Flegrei. The prothyrum was framed by a pair of columns and two long stone seats. The vestibule, with doorways to the ostiarius or gate-keeper's lodge, led to the atrium, whose walls were lined with marble panels, as were those of adjoining areas, many of which had mosaic flooring. A room at the north-east corner of the atrium with a mosaic of black and white tesserae with geometrical motifs (_hexagons and pseudo-emblema with circles and peltae_) was restored by ISCR and 3D documented using laser scanner (Fig.2). A large hall with a 10.37 metres wide apse lies to the south of the atrium. This was probably not part of the original design.

This mosaic lies inside a rectangular room measuring 4.77 metres by 5.55. The mosaic consists of a background of white tesserae with ornamental motifs created using a double line of black tesserae. The principal motif is a series of hexagons covering the whole floor, with a square of four black tesserae at the centre of each hexagon. Black tesserae also make up the double border around the edges. The central section is a pseudo-emblema consisting of four circles enclosed by a large square, with four peltae inside each circle. Three equidistant solid black equilateral triangles lie between the circles inside each side of the square. There is a quincunx (the five-spot motif on six-sided dice) at the centre of each circle. The point of each pelta terminates in a small flower with three heart-shaped petals separated by a central dot. The remaining space between the four circles contains a small square enclosing a cruciform floral motif with a central dot. The floral motif has lobed petals with arrowhead tips. The mosaic dates back to the second century BC. Together with this mosaic, the 3D documentation involved also a very fragmentary black and white mosaic (Fig. 3 A) and a stone artefact probably a threshold of a sliding door (Fig. 3 B).

In particular, for these purposes, 3D relief has been very helpful to study the differential degradation of the mosaic tesserae and also to well document the shape and the mode of operation of a stone artefacts identified as a threshold of a sliding door (BDP).
3. THE 3D LASER SCANNER DOCUMENTATION

The first laser scanner developed and used to document the opus sectile room was based on laser line and triangulation for the calculation of the point cloud (Fig. 4 - 6). The first version of the system was mounted on a frame (Fig. 7). The frame allowed to know the exact position of the scanner among the area to be scanned.

Fig. 4 - The opus sectile floor: 3D results (ISCR Archive)

In another phase of development, a portable scanning system was developed, based on infrared laser light structured. The system is operated by the diver simply framing the area to be scanned as a video camera. It can also be placed in front of the area to be scanned and activated, the system begins scanning rotating on its axis (Fig. 8).

Fig. 5 - The opus sectile floor: 3D results (ISCR Archive)

Fig. 6 - The opus sectile floor: 3D results (ISCR Archive)

This light and compact instrument (15 x 16 x 10 cm - 4 kg) was particularly valuable in producing an extremely precise and faithful 3D model of the original. To capture the level of detail required, the system was configured to give an accuracy of 0.05 mm at a resolution of 1,200,000 pixels. Many of the areas scanned were spatially aligned in post-production using reference points, shooting angles, solid forms and scanner metadata. The underwater scanner also captures textures which are subsequently rendered in the 3D model. These textures are acquired together with associated spatial coordinates, ensuring a perfectly faithful 3D model. Two different texture capture technologies are used, RGB point sampling and high-resolution spatially-annotated digital photography, which allows optimal results to be obtained in the variably turbid waters. For detailed scanning of larger areas, the system is configured to capture several square metres at a time, with an accuracy of 0.5/1/2mm (Davide, Petriaggi and Gomez De Ayala, 2014). A given area can be scanned from different angles with the results merged into a single 3D model later.

The upgraded version of the scanner used for the Villa con ingresso a protiro has offered a number of innovative advantages such as being able to capture surface detail in motion rather than from a fixed point (frame mounted) as was the case with the first one system.

The last system developed is based on structured light. When the light is projected on a surface it is deformed according to the shape of the surface, measuring the deformations it is possible to obtain three-dimensional data.

The system produces 30 scans per second and each scan is linked to the previous one. The accuracy depends on the needs, the system provides a centimetric to sub millimetric accuracy. The accuracy depends on the time of permanence of the system on the same place. Much more time on the same shot, the higher
resolution of the result. The system produces point clouds and it is able to generate mesh in real time depending on whether it is configured with processors on board. It can scan continuously for 90 minutes covering a large area. Contrariwise of the traditional terrestrial 3D scanner, this system can scan moving objects, it can also scan in motion itself, it doesn’t need to be calibrated nor it needs to be placed any targets for its use. The operators are free to move while scanning the area of their interest. The result is a 3D model of all the surfaces sampled, and, at the same time a 3D motion capturing. By making a complete sampling of the site it will produce a three-dimensional digital map of the superficial layer and a detailed 0.05 mm mapping of the position of the Stratigraphic Unit. During the excavation or restoration work the scan of each layer records every single event and modification of the site and its condition. In the underwater environment it is not possible to take pictures from several meters because of the light absorption and for the low visibility through the water, the same is by scanning a surface of underwater objects so it is important to make several shootings from different angles. It is very important to line up each single scan accurately to avoid the possibility to add mistakes during this phase. Follow a few photographs of the 3D survey carried out in the Villa con ingresso a protiro (Fig. 9 - 12). In this case, the accuracy is sub millimetric, because there is the need to recognize the individual mosaic tiles and monitor their erosion overtime (BDP, GDA).

4. CONCLUSIONS

The use of 3D scuba laser scanner has been useful to study, restore and document some selected underwater artefacts in Baiae (Petriaggi and Davide Petriaggi 2015:221-223; 263-264). This system produces an extremely precise and faithful 3D model of the original and for this reason it is particularly suitable for the in situ archaeological activities. These underwater sites have been an ideal setting for this system, since there are many details, small items, and a few undercuts, so they will need just few scans from different angles, and only sufficient zenith scans parallel will be necessary.
This underwater scanner is an open system, well-suited to the unpredictably changeable conditions of underwater archaeological sites. This was invaluable in the production of archaeological documentation and the planning of conservation and maintenance tasks.

The three-dimensional laser scanning survey plays a prominent role in the documentation and museum display of Underwater Cultural Heritage, increasing the value of scientific dissemination (BDP).

REFERENCES


Diamanti, E., Georgopoulos, A. and Vlachaki, F., 2011. Geometric documentation of underwater archaeological sites. In: Proceeding of the XXIII CIPA Symposium, Prague, Czech Republic, 12/16 September 2011, edited by Karel Pavelka, I-8, Prague, Czech Technical University in Prague, Faculty of Civil Engineering in cooperation with CIPA.


