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Towards Spatio-Temporal 3D Visualization of an Underwater Archaeological Excavation: The Case of the Late Bronze Age Shipwreck of Modi

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This paper refers to the challenge of creating a simplified 3D platform that will serve as an interactive tool for the archaeologist during excavation and interpretation of an underwater archaeological site, as well as presentation material for the non-scientific, interested user, utilizing 3D visualizations and animations of the excavation phases. The ongoing underwater excavation of the Late Bronze Age shipwreck of Modi (Poros)[1], triggered the idea and served as a test case for the generation of the platform.

Key words
3D platform, underwater photogrammetry, underwater excavation, cultural heritage, 3D visualization, 3D modelling, shipwreck.

Image-based 3D modeling can be an excellent method for the recording, documentation, and visualization of an underwater archaeological site. However, its application in underwater excavations — especially of shipwrecks — is of outmost importance, since these sites, are very often composed of an indistinct terrain, on which assemblages of finds or structural elements are to be recorded with special care to record their geometry, their association to other finds, and to their position within the whole site (spatio), all in the constantly changing (temporal) environment of the destructive process of excavation.

Among the research interests of the documentation team was the examination of the possibilities and limitations of the implementation of image-based 4D documentation of an entire underwater excavation and its impact on the workflow and the post-excavation processing. The main objective was the generation of a platform that would integrate semantic, time, and descriptive information, into 3D models, in order to create advanced *spatio-temporal* representations of the excavated site.

The Test Case site

The underwater excavation of the Late Bronze Age shipwreck off the island of Modi (Poros), began in 2009, and is, to this day, an ongoing interdisciplinary research project, carried out by the Hellenic Institute of Marine Archaeology[2], under the direction of the archaeologist Christos S. Agouridis. The shipwreck is located on the northern, steep, rocky bottom, off the islet of Modi, SE of the island of Poros, in the Argosaronic gulf, at a depth of 24–37 m.

The ceramic cargo of the wreck is dated to the Late Helladic III period (13th – 12th century BC) and comprises an assemblage of large transport vessels (pithoi, jars, and hydrias), some of them surviving intact and most of them in fragmentary condition.

The excavation of the site presented great difficulties from the very beginning. The morphology of the seabed is extremely rugged (Fig. 1). The site is covered with rocks, which rolled down from higher levels of the underwater site as well as from the land. Finds were heavily fixed to the seabed with hard marine concretions around them (Fig. 2). A lot of time and effort was spent detaching finds, making the documentation of the process very demanding in terms of detail and constant strict archiving, in this very complicated terrain. The stratigraphy of the site consists of four main layers, found on the entire shipwreck site, without easily recognizable boundaries.

Documentation work in the field

Careful planning and management of the documentation of excavation work, involved a specially designed database[3] and the implementation of parallel surveying methods, in the early research periods of 2005–2007 (SHARPS, trilateration, photogrammetry), resulting in the uniform application of photogrammetry in combination with 3D modeling from then on.

The aim of the documentation work soon became the integration of semantic, time, and descriptive information, into the 3D models of the excavation site, which were produced daily, after detailed archiving of both archaeological information, surveying results, and 3D models, during field work.

In order to achieve that, a number of steps were taken, involving at first, the exact positioning of the site and the creation of a local, fixed coordinate system. A network of fixed control points, in the form of a grid, was established in the whole of the wreck-site, from the first excavation period in 2009.

The next important step was to model the terrain of the site in 3D, as geomorphologic data yield important information for the archaeologists and is vital for a realistic visualization. In each area that was excavated, photogrammetry was used on a daily basis to provide an accurate and detailed 3D tracking of the changes that occurred in the excavation trench. An image dataset was collected every day and after its photogrammetric processing, a detailed, textured 3D surface model – geo-referenced mesh – was exported in compatible 3D file formats (Fig. 3). Additionally, for the requirements of everyday documentation, 2D vector drawings, and an ortho-photomosaic of the trench, were produced. (Figs 4 & 5).

Steps to the generation of the Platform

The Surface models

Before being imported into 3D modeling software, each geo-referenced mesh needed to be edited regarding its geometry and texture. In the course of this operation, a group of meshes was developed that were updated daily, with two or three levels of detail for each mesh. The amount of detail can be adjusted depending on the distance of the camera, in order to avoid the difficulty of manipulating high detail polygonal meshes.

'Noise' carried into the built mesh from the acquired data set and areas corrupted by lack of information were cleaned through an editing operation and decimating process, with the use of Zbrush. After being imported in 3Ds Max software, as FBX or Obj file formats, each mesh was accurately placed using its co-ordinates. In this trial state of the process, outline editing was carried out in order for the daily meshes to have a clean border, related to former and forthcoming meshes.

Applying textures to the 3D model, based on the images taken from photogrammetry, was done through Substance Designer, which is node-based. It allows the texture information to be taken from the photogrammetry in a flexible manner, improving performance by reducing memory cost. The 3D model was also refined through Substance Painter, to fill hidden holes in the texture.

The last step was to import the FBX file formats, from 3Ds Max, into a game engine, such as Unity or Unreal, and develop an interactive 3D environment, integrating semantic information of finds, numbering, depths of excavation, layers, materials, and stratigraphy.

The Finds

Due to the difficulty of documenting the finds on site in high resolution, each find, that was lifted to the surface, was photographed after a basic conservation procedure (cleaning, restoration), and a detailed 3D model of it was created (Fig. 6). A reconstructed mesh of each find was built and edited, in order to acquire closed geometry, so it could be imported into the 3D base of the site. If a 3D model of a find could not be produced, a theoretical model was built, according to archaeological references. Each find's exact location *in situ*, could be defined by the underwater photogrammetric model.

Results – Future work

The need for the generation of a constantly changing 3D navigation platform, has been a persisting idea for a few years, but was considered due to the complexity of the site and the amount of information accumulated in the excavation's database that could be brought to life through this process. A trial presentation of this platform was created in order to become the base for future work as well support further funding for its final design and construction.

Following the line of work described above, the platform was created with the use of an interactive 3D browsing engine. It can serve as a navigating 3D tool, that gives the opportunity to archaeologists to perform complex modeling tasks and watch the different phases of the excavation– as this approach allows better handling of rotations of models with millions of polygons – using the 3D model of the excavation site, with no special computer skills required.

The platform allows the user:

- To navigate freely in the 3D model of the entire wreck-site or choose a certain trench.
- To slice the 3D model of the wreck-site or a trench, at specific dates of the excavation, extracting 2D plan views and section views of the model (Figs 7, 8, 9).
- To see pop-up windows over finds, which carry minimal information for each one.
- To link directly to the archaeological log of the project, in order to study further details of the finds, as all finds visible at that instant, will appear with a link tag (Fig. 11).
- To see more detailed information on the finds as a second tag will link to a 3D model of the find, with details such as, dimensions, origin, date, etc., which have been recorded during the project (Fig.10, 11,12,13).

The next goal of this ongoing work is the visualization and animation of all excavation phases in layers, for the whole wreck-site and the annotation of all elements, using the information stored in the excavation's database. The implementation of this 4D Platform in future research periods, as well as other underwater excavation projects, can serve as a tool during excavation (through the creation of fully updated, daily 2D plans that are an essential tool in underwater archaeology), as a means, for the interpretation and planning of further excavation of the site, and finally, as a way for a non-scientific user to experience the underwater excavation in its totality and appreciate the effort made for the investigation and preservation of underwater cultural heritage.

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Captions

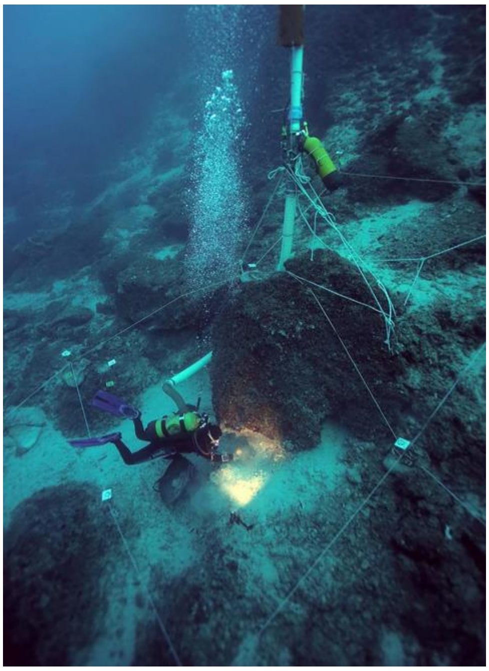


Fig. 1: The shipwreck is located at a steep, sloped bottom with extremely rugged morphology. ©H.I.M.A.

Fig. 2: Finds heavily grounded to the seabed. ©H.I.M.A.

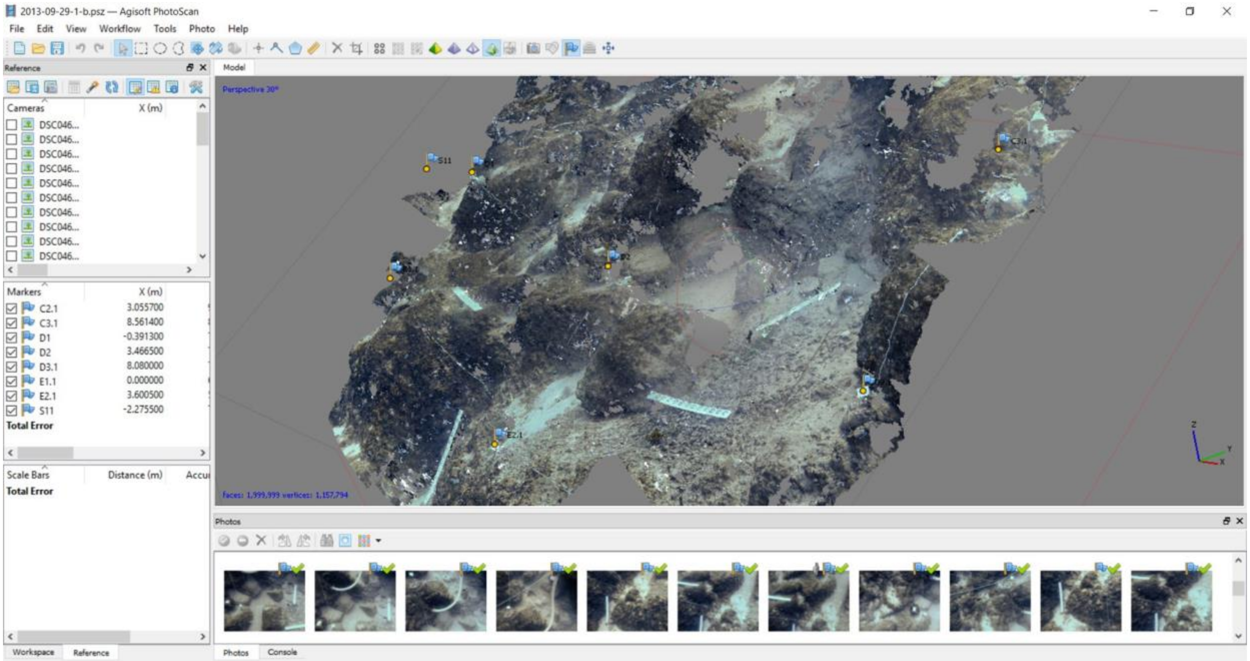
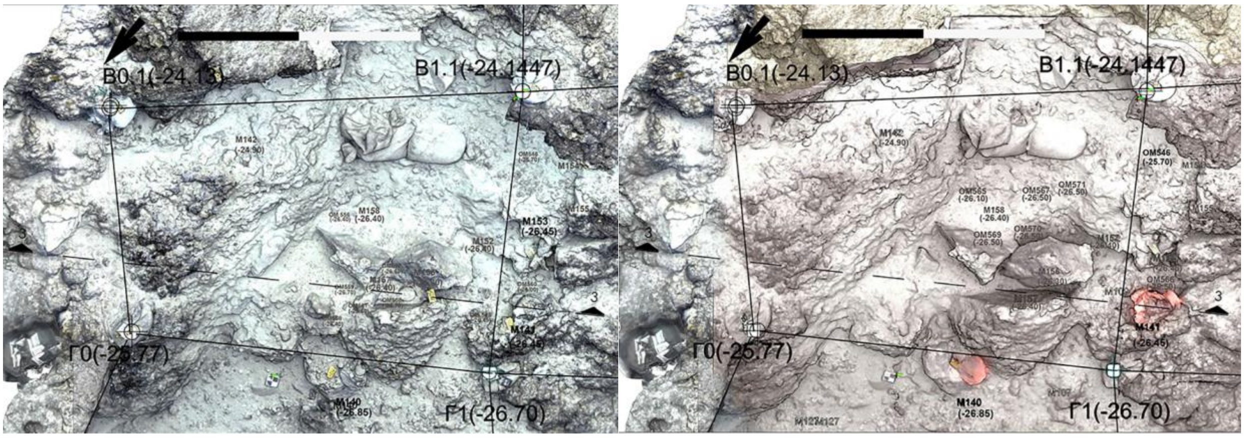


Fig. 3 Photogrammetric processing for the extraction of a detailed, textured 3D, geo-referenced surface model. Photoscan processing by E. Diamanti, ©H.I.M.A.



Figs 4, 5: The excavation trench of two consequent days of the 2016 research period in plan views extracted from the 3D model, by G. Farazis, ©H.I.M.A.

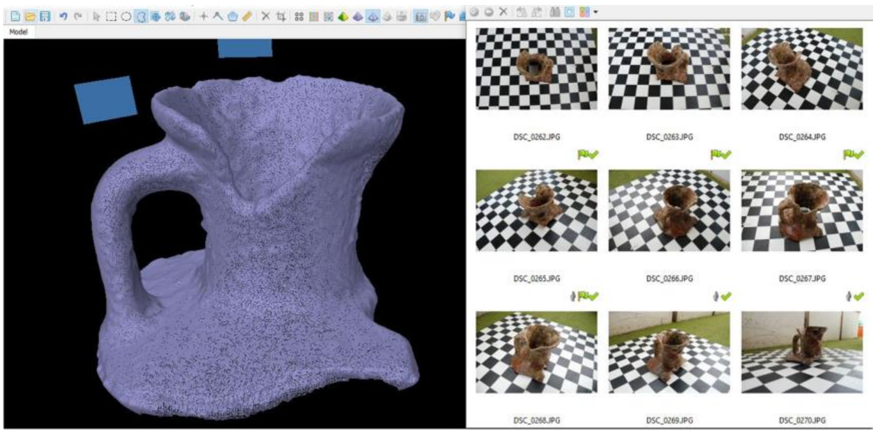
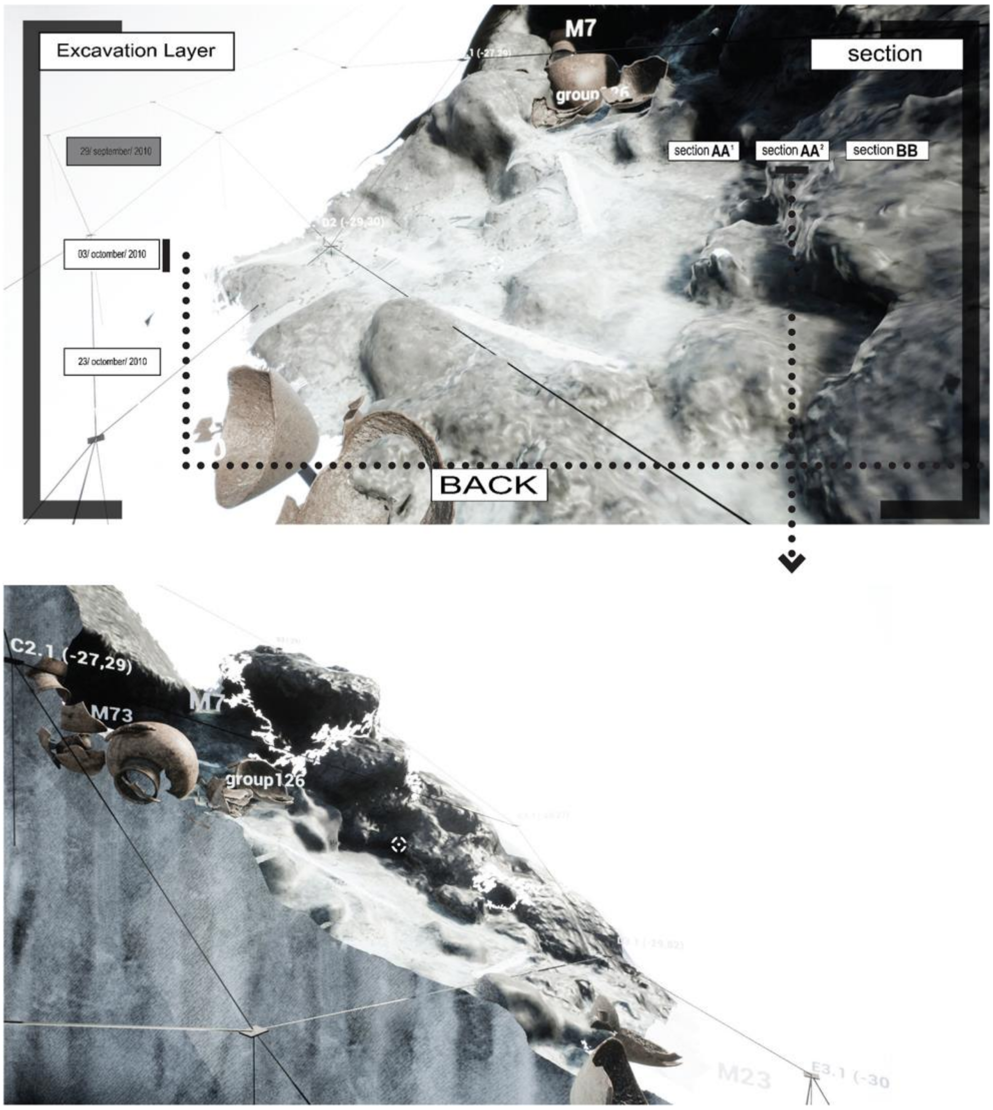


Fig. 6: The 3D image-based reconstruction of find M137, for the insertion of its model in the 3D model of the excavation site. Photoscan Prosessing by E. Diamanti, ©H.I.M.A.



Figs 7, 8: Free navigation in the 3D model of the wreck and selection to aquire a 2D view of the excavating trench, at a selected date, on the A-A axis. 3D engine trial generation by G. Farazis, ©H.I.M.A.

Fig. 9: 2D view of the excavating trench, at the same selected date, on the B-B axis. 3D engine trial generation by G. Farazis, ©H.I.M.A..

Fig. 10: Pop-up windows over artifacts carry minimal information for each one. From the navigation in the previous instance of the 3D model artifact M7 was selected and a link with more detailed information appeared on the screen. A second tag on the find links to a revolving 3D model as well as to the corresponding page of the database, photos of the find in situ and after conservation and details such as, dimensions, origin, date. 3D engine trial generation by G. Farazis, ©H.I.M.A.

Fig. 11: Link to the database of the excavation, ©H.I.M.A.

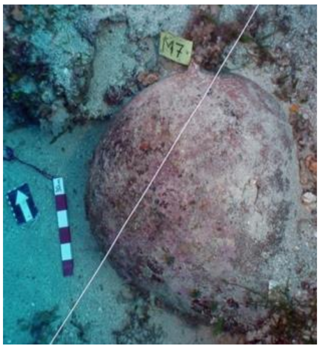
 

Fig. 12, 13: Link to photos of M7 in situ and after conservation, ©H.I.M.A.

Endnotes

1 Carried out by the Hellenic Institute of Marine Archaeology (H.I.M.A.) under the direction of the archaeologist Christos S. Agourides.

2 The Hellenic Institute of Marine Archaeology (H.I.M.A.) is a private, non-profit organization, founded in 1973, whose aim is to undertake marine archaeological research under the supervision or in cooperation with the Greek Ministry of Culture. It has over 100 members, with diverse academic credentials, all of whom work on a voluntary basis.

3 Especially designed for the project by Bruce Hartzler with the collaboration of Myrto Michalis, archaeologists, members of H.I.M.A.