INTEGRATION OF MULTI-SOURCE SPATIAL INFORMATION AND XML INFORMATION SYSTEM IN UNDERWATER ARCHAEOLOGY

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ABSTRACT

We present the first stage of an interdisciplinary project devoted to the survey and the documentation of underwater archaeological excavation. The case study is the excavation driven by the DRASSM at the beach of the Catalans in Marseille. The excavation and peripheral work is sponsored by the city of Marseille in coordination with DRASSM and 2ASM association (Association Archéologie Sous-Marine). This paper is structured in three parts:
The eccentric archaeological context: at 200 meters from the beach, in Marseilles downtown, we found the remain of an ancient Greek city probably due to dredging from the old harbour. Sculpture, architectonic pieces, amphorae, vessel, etc. have been close to the beach for centuries and were discovered only last year by Pierre Giustiniani, president of the 2ASM.
The extent of this excavation (on about 500m by 300m) makes it impossible to carry out a simple photogrammetric survey. The survey process was done merging several 3D sources. In this project we use multibeam sonar data to produce bathymetric data and sonar with signal penetration into the seabed. These two acoustic approaches allow to make a seabed map and to locate important architectonic blocs even yet under the seabed. In this area we chose some place to make a standard archaeological excavation with an underwater photogrammetric survey.
One of the main objectives of this work is the artefact analysis and documentation. The survey produces two data types: artefacts registration and 3D models used generally as an interface to the archaeological data. We developed a web information system, fully XML (SVG and X3D for the graphic part, and XML for the database) in order to manage the objects, strongly heterogeneous, carried out of the water during this excavation. ISA-PX (for Information System for Archaeology using Photogrammetry and XML) allows archaeologists to update the database on the web with a visual 2D or 3D control of the artefact position in the site.
The first results of a campaign led in last fall will soon be available on the web site http://www.2asm.net/Catalans/

1. INTRODUCTION

1.1 Presentation

We present in this paper the first results of the underwater archaeological excavation made at the Catalans beach, in Marseilles, France. The excavation and peripheral work are sponsored by the city of Marseilles in coordination with DRASSM and 2ASM association (Association Archéologie Sous-Marine). [Catalans, 2005]
After a brief presentation of the archaeological interest of this site, two aspects will be developed:
The geometrical data fusion resulting from the diversity of the approaches used to make the survey (sonar and photogrammetry).and the link between the survey and the archaeological data structured in XML and accessible from a Web site.
Due to the large area of this excavation (on about 500m by 300m) it was impossible to make a traditional photogrammetric survey. The survey process was achieved merging several 3D sources at different scales. We use multibeam sonar data to produce bathymetric map and sonar with signal penetration into the seabed. These two acoustic approaches allow to make a seabed map and to locate important architectonic blocks even yet under the seabed. In this area we choose some specific zones to make standard archaeological excavation with an underwater photogrammetric survey. A GPS is used to ensure a common reference system for all the surveys.

Figure 1. Site map: Catalans beach and the dam.

The second important aspect of this project is the online archaeological artefact documentation. We developed a web information system, fully XML (SVG and X3D for the graphic part, and XML for the database) in order to manage the objects, removed from the water during this excavation. ISA-PX (standing for Information System for Archaeology using Photogrammetry and XML) allows archaeologists to update the database on the web with a visual 2D or 3D control of the artefact position on the site.
The system allows virtual navigation in the site and access to the objects documentation.
The first results of a campaign led in last fall will soon be available on the web site http://www.2asm.net/Catalans/

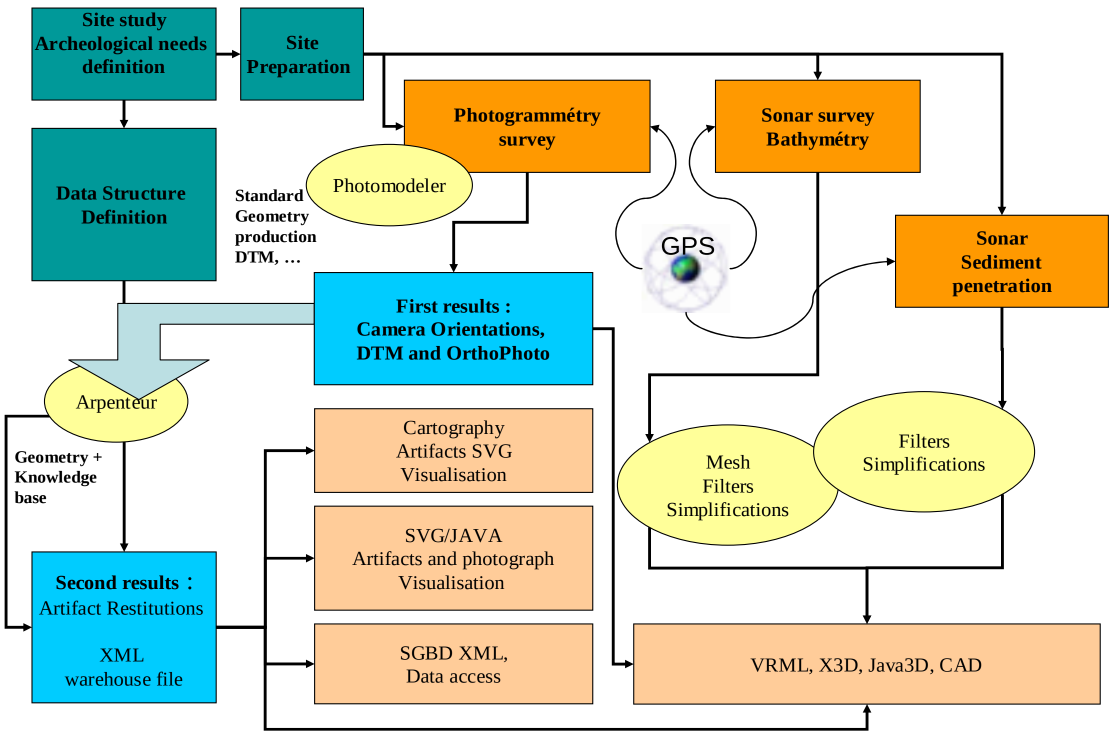

Figure 2. Survey synoptic schema.

2. UNDERWATER PHOTOGRAMMETRY

Some ship wrecks excavations with photogrammetric survey and three-dimensional restitutions have already been carried out in France since 1975. It was initially the case of the wreck carrying Roman amphorae called *la Madrague de Giens*, then in 1986; on the site *Grand Ribaud D*, with a cargo of dolia ([Hesnard, 1988]) and another wreck with a limestone blocks cargo, the *Carry-le-Rouet* (Long, 1988]).
Underwater stereo photogrammetry was already largely developed in the 1990s, with the help of various submarines, using semi-metric or metric film-based cameras. It was in particular the case in 1993 of the Roman wreck *Plage d'Arles 4*, 662 m depth, then the case of the vessel *La Lune*, lost in 1664 by 88 m depth, near Toulon. Lately, in 1996 the method was improved, out of the bay of Marseilles, on the Roman wreck *Sud-Caveaux 1*, at a depth of 64 m [Long 1998]. However, in 1964, the submarine Asherah, with the financial support of the National Geographic Society, had inaugurated in Turkey, at a depth of 35 m, the first stereoscopic survey, on the Byzantine wreck *Yassi Ada 2* [Bass 1970; Bass, Rosencrantz 1973]. This kind of survey can be done today in only one day at a depth that can reach 6000 m (intervention limit of the submarine Nautile, IFREMER). The campaign needs a first phase for equipping the site with scale bar and buoys for the vertical orientation. The photogrammetric orientation is performed by bundle adjustment with digital photographs.
The authors have already work on this problematic, in particular on *the Grand Ribaud F* Etruscan wreck [Drap, Seinturier, Long, 2003], [Drap, Long, 2005].

3. ARCHAEOLOGICAL CONTEXT

Less than 300 meters away from one of the most famous beaches in Marseilles, ancient Greek and Roman vestiges were discovered in October 2004 during the underwater excavation of the "Anse of the Catalans". The operation was led by the DRASSM (Department of Subaqueous and Underwater Archaeological Research) with L'Archéonaute, the means of the 2ASM association, the Map-Gamsau (CNRS, Luminy) laboratory and the financial supports from the city and through its Workshop of Cultural Heritage (*Atelier du Patrimoine*).
At the very time the works were being undertaken, the inventor Pierre Giustianini located the vestiges of two marble statues that have been successfully excavated. The first piece consisting of a foot fitted of a finely chiselled sandal, belongs to a female character who must have been at least 1.5 meters high. The second one corresponds to a headless bust representing Dionysos or more likely Apollon, one of the guardian divinity of Marseilles. The hardly noticeable swaying walk, the suggested discrete muscular bulk added to the curls on the right shoulder confer the character an effeminate and youthful aspect which brings him closer to the Hellenistic representations.
During a previous mission of the DRASSM in the same area, in 2001, a little brass statue representing Apollon had been removed from the sludge, among numerous fragments of ceramics and amphorae.
Besides, explored in 2004 at a depth ranging from 8 m to 15 m, the Catalans area includes a number of architectonic blocks and drums of fluted columns, some of which stem from Greece and were part of one or several buildings of small or average size, private or public (peristyle, gantry, small temple...). One can notice some bases and Tuscan capitals, drums of columns, blocks of base, flagstones but perhaps also some elements of pediment bases. The Tuscan columns, through the way they were turned on the lathe and through the addition of a portion of barrels at the base, refer to the late Hellenistic technique, well attested in Provence in the 2nd and 1st centuries BC.
These items, all damaged owing to their long submarine stay and the action of lithophage organisms, are so scattered and fragmented that their presence cannot be accounted for by a ship

loading. Too heavy to be related to a ship ballast and not practical enough to be used for anchoring, they are furthermore located too far away from the edge to come from a coastal site. Regarding these points, there exists no historical nor archaeological source providing evidence of any occupation of the littoral in that area, in the Antique epoch, except a few sepultures (punt and round tiles) noticed in 1863 and 1895.

The assumption that best accounts for these discoveries brings us back to the dredging of Marseilles' harbour since the Roman epoch and until the modern ages. As it was the case with the horn of the antique harbour discovered in 1969 while the Stock Exchange Building was being built, the quays were probably made of materials stemming from Greek monuments that had been used as quarries during the whole Antiquity.

The more recent searches of the Jules Verne and Ville-neuve-Bargemon squares enabled us to assess the great scope of dredgings during the Roman epoch in the Lacydon (old harbour of Marseilles) and at the same time, to find some vestiges of dredges that were abandoned in the 1st and 2nd century BC.

First deposited in the "remblai hellénistique" of the Stock Exchange area, the sediments and debris resulting from the cleaning out of the harbour were subsequently removed further toward the open sea by the Romans, particularly in the Catalans area, located at the way out of the harbour.

Well sheltered in windy weather, this area is well-known in the medieval and modern archives as the "quartier des infirmeries" or "quartier Saint Lambert". It long constituted the privileged receptacle for deposits resulting from the dredgings that have been regularly repeated since the XVI th century.

For this reason, the rich terracotta ware recorded around the blocks and fragments of statues belongs to three distinct periods : the Hellenic period, the late Antiquity and the modern epoch (XVIth – XVIII th centuries).

During the search, a certain number of areas that were relatively rich in archaeological furniture, were spotted and then marked out with buoys by means of a flexible gridding used as a groundwork for the removal of the sludge performed with our suction pump.

The items, meticulously excavated and *in situ* numbered, were then registered by photogrammetry. At the same time, a 3.4 meter-deep sounding had been introduced down to the rocky substrate. It provides archaeologists with knowledge about the sedimentation and stratigraphy of the area. Besides, a series of aerial snapshots, triggered from an helium balloon, visually registers the position of relevant blocks indicated at the surfaced of the sea with numbered buoys.

These elements were afterwards all more precisely registered by means of a GPS receiver.

Finally, the whole site, which altogether covers an area of several hectares, was prospected with an echosounder for sediment layers, which is capable of detecting buried blocks under the upper sediment layer.

The significant number of anomalies that has been recorded up to now have not been checked on the field yet, which allows us to imagine the richness of the area.

4. THE SURVEY METHOD

4.1 Sonar

We used a multibeam sonar, GeoSwath with a 250 Khz frequency, set up by Maritech company[1]. This sonar is designed for swallow water (up to a depth of 200 meters) and was developed with respect of the IHO standards (*IHO Standards for Hydrographic Surveys).*

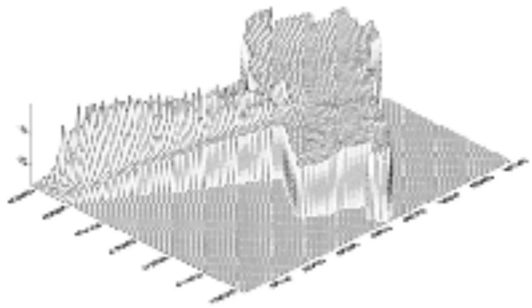

Figure 3. Interpoled grid based on sonar measurement.

Figure 4. Bathymery, mesh and color class visualized in Microstation / terramodeler.

The georeferencing of the sonar measurements was done by GPS with DGPS MAX from Omnistar Company[2].. The goal of this survey was to obtain a bathymetric map of the studied area in order to geo-reference the photogrammetric survey of the excavated zones.

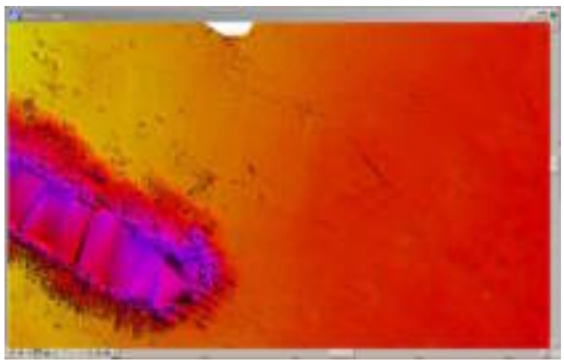

Figure 5. Detail of Figure 4.

[1]MARITECH company, Rue St Joseph, 83310 Grimaud, France
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[2] http://www.omnistar.com/

4.2 Sonar, sediment penetration

4.2.1 Archaeological needs: Regarding the site extent and the seabed sediments, the expertise could not be carried out but by means acoustic survey techniques. The echosounder for sediment layers makes it possible to record the seabed layers density differences. This technique was used and improved by the marine geologists and the tankers in order to obtain stratigraphic statements at considerable depths. In archaeology, where the study generally occurs in shallow water with a relatively small size on surface and thickness (from ship wreck to the isolated object), this process has not always reached a very good resolution. However, since the first experiments combining seismic detection and wrecks, detection progress has contributed to adapt this kind of tool to a finer detection. To serve this purpose, the Association Archéologie Sous-Marine (2ASM) elected an engineer in acoustics (Philippe Plantevin, SOACSY company 3) to proceed with the analysis of part of the site, and to define, considering the encountered difficulties, which shallow water sediment layers system will be relevant in our future research in front of Marseilles.

4.2.2 Technical choice: The echosounder used was shallow water sediment layers KNUDSEN[4] with a NEPTUNE 12 kHz[5] transducer.

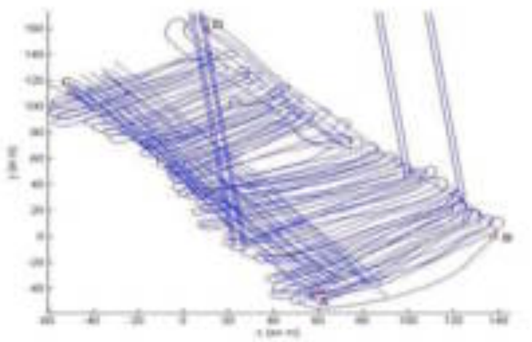

Figure 6. Echosounder profil trajectory. Document from Soacsy.

The georeferencing of the sonar measurements was also achieved by means of a DGPS MAX from Omnistar
The theoretical vertical resolution of the echosounder is about 50 cm until a depth of 20 of meters under the sediment.
This approach starts to be used successfully in underwater archaeology. The reader can refer to the work of Foley and Mindell [Foley, Mindell, 2002] to see a very interesting application of it.

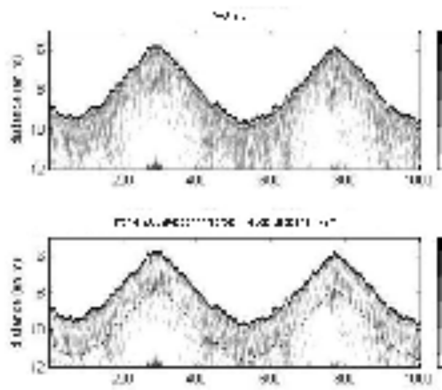

Figure 7. Echosounder result on shallow water sediment layers. Profile N° 23. Document form Soacsy.

4.2.3 Future work: Efforts are underway to try to develop an interpolation tool to merge two sonar grids of any kind (based on a rectangular, triangular or polygonal network): given a certain meshed surface and a certain flat grid, the problem is to interpolate the Z values of this second grid. Indeed, interpolation between two rectangular grids is quite easy to perform, but the problem is a bit more complex when the mesh is polygonal. Moreover, it could be interesting to try to establish a map, 2D or 3D, of the anomalies detected by the echosounder, so that the measurements are easier to interpret.

4.3 Photogrammetry

Several photogrammetric surveys were carried out on different specific areas of interest where archaeological artefacts could be located. These sites are far smaller in size than the area covered by the sonar.

4.3.1 Field work: The photographs were taken during the excavation by divers who took care not to bother archaeologists: the total diving time was then efficiently reduced.
We used a Nikon D100 contained in an IKELITE underwater housing, and two external flashlights to cope with reduced light. The photographs were taken within a 2-3m distance from the objects. We defined several strips for each site, but we also took convergent photographs of some particular artefacts (ex: columns) when we thought it was relevant to do so.

4.3.2 Post-processing: The EOS PhotoModeler software was used to calibrate the camera and build 3D models of the studied artefacts.
As for the underwater calibration, the latter was performed by means of PhotoModeler's calibration grid. Actually, considering that the errors due to refraction could be (experimentally) taken into account in the commonly used polynomial distortion correction turns out to give good results [Drap, Long, 2005].
VRML models of the archaeological artefacts were produced:

[3]SOACSY, CO/CEEI-Provence. Domaine du Petit Arbois – BP 88, 13545 Aix en Provence cedex 4
[4] http://www.knudsenengineering.com/
[5] http://www.neptune-sonar.co.uk/t119.asp

Figure 7. VRML representation from the photogrammetric survey of a particular zone of the Catalans site (Zone 3)

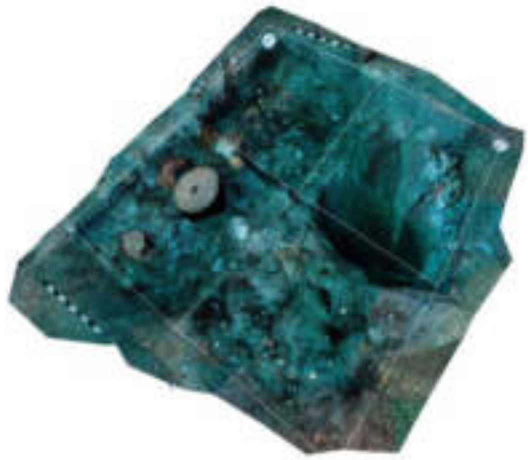

Figure 8. Another VRML representation of a particular zone of the Catalans site (Zone 8), including the gridding settled by archaeologists

Orthophotos of the modelled sites were produced in PhotoModeler as well.

5. DATA FUSION

5.1 Merging different sonar data sources

The data acquired by both sonar sensors was geo-referenced in the WGS 84 system, by means of the same DGPS MAX receiver. We used IGN's CIRCE2000 coordinates transformation software to transform the geographic coordinates into planimetric UTM 31 coordinates. Once meshed, the point clouds could be visualized in the CAD software MicroStation V8.0. As for the merging operation, we computed the theoretical sub-sea depth of points acquired by the echosounder by interpolation in the bathymetric grid; added to the sub-bottom depth, it gave us the sub-sea depth of each point.

5.2 Merging sonar and photogrammetry data

5.2.1 Georeferencing of photogrammetric models: We had then to integrate photogrammetry models into the sonar data, which we considered as a reference for the integration procedure[6].
A GPS navigation receiver had been embarked on the boat and used to get the planimetric coordinates of the archaeological sites, with a 5 meters accuracy. These UTM coordinates were then reported into the bathymetric sonar model in order to compute the depth of the sites using the nearest neighbours' interpolator.

5.2.2 Model orientations: Once located onto the sea bottom, the photogrammetric models had to be oriented so that they match the latter as exactly as possible, with respect of the North direction.
A ruler indicating the North had been placed on the sea bottom during field work on each site so that we could afterwards orient models toward the North.
Furthermore, for each site location, we calculated the local slope of the sea bottom in the East and North directions: that gave us the rotations to apply to our models in PhotoModeler so as to eventually make them coherent together with the sonar data.

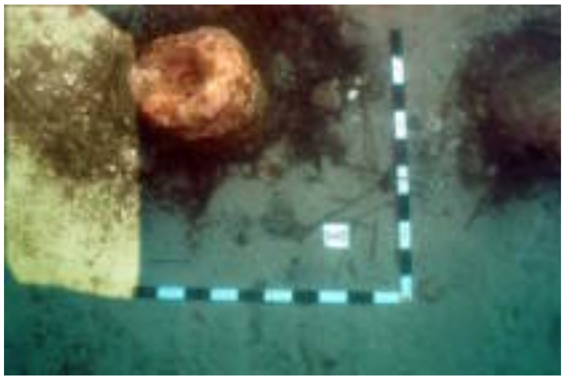

Figure 9. A ruler oriented on the site with a compass. (Catalans, zone 3)

6. DOCUMENTATION

As soon as the photographs are made and that the objects are carried out of the water, they are referred to in a data base. This operation is made by archaeologists who prepare the database schema for each family of objects and fill the base.
We proposed the XML formalism as a general choice for this documentation system used for the presented excavation (see [W3C, 2005]) ISA-PX, standing for Information System for Archaeology using Photogrammetry and XML, is a complete system integrating the standard operations on database elements but also the data consultation from a 2d or 3d graphic interface. The XML formalism allows us a great flexibility in the objects description: the diversity of objects, (the site is a dredging zone) was an important component in the choice of use the polymorphic characteristics, which is possible with the XML formalism.
Currently all the objects resulting from the 2004 campaign are present in the data base and available for consultation through a textual interface on the Web site dedicated to the excavation.

[6] Another approach consists to map photo mosaic onto a mesh computed from sonar data. This way is used by [Singh, Roman, Whitcomb, Yoerger, 2000]. We can note alsa the work of [Fusiello, Murino, 2004].

7. RESULTS

We developed a web-based navigation system to visualize VRML models of the bathymetric and photogrammetric data. A compass indicating the North was developed to help the user to navigate in the scene. Moreover, the position and orientation of the viewpoints are displayed in real-time.
Through the VRML models, the user also has access to the XML database containing all the gathered informations about the artefacts.
Once merged, the acoustic and optical measurements allow us to produce orthophoto at different scales, ranging from the site scale (by means of the bathymetric map) to the scale of the artefacts (amphoras) and their sharp details.

8. CONCLUSION

The merging of acoustic and optical data bound to be acquired at different scales is a relevant and innovative step into the integration of multi source data into an information system. This is similar to the merging of laser scanner and photogrammetry data in the case of terrestrial surveys, which is the subject of an increasing number of researches and experiments. Therefore, this study allows us to develop great prospects for the future.
Particularly, it may bring new developments on the complementarities of acoustic and optical surveying techniques, especially for the study of deep water wrecks. It may also bring about studies within the scope of the EPOCH European excellence network. [EPOCH, 2005]

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[W3C, 2005], The World Wide Web Consortium (*W3C*) develops interoperable technologies (specifications, guidelines, software, and tools) to lead the Web to its full potential. http://www.w3.org/