Archaeological 3D Modelling using digital photogrammetry and Expert System.

The case study of Etruscan amphorae

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Abstract

The present paper focuses on a new tool dedicated to the survey and the representation of archaeological and architectural heritage. The tool is based on a photogrammetric process related to an expert system that handles a knowledge base coming from the field of the archaeological or architectural expertise.

The system was tested on an archaeological field: the Etruscan amphora, Py4. The presence of a great number of amphorae on the site of *Grand Ribaud F,* the Etruscan wreck located in *Hyères*, France, together with the archaeologist's survey needs of the wreck, led us to the development of the system. We add also a persistence mechanism for the data, structured in XML.

The project is articulated in several phases:

- Development of the theoretical model: for each identified object, a geometrical description offers a whole of geometrical primitives, which are the only objects to be potentially measured, and a theoretical representation of the object.
- Being photogrammetric measurement highly incomplete (the object is seen only partially or is in part deteriorated), the Expert System determines the best strategy to inform all the geometrical parameters of the studied object, starting from taken measurements and the default data as defined in the architectural model and the geometrical model.
- The resulting object is thus based on a theoretical model, dimensioned more or less partially by a photogrammetric measurement. At the time of the exploitation of the photographs the operator can choose the number of attributes of the object which are regarded as relevant to measure. The choice of attributes is revisable in time, for example at the time of a second series of measurements. The system can be used to position in space some objects of catalogue after a scale phase. If measurement is more complete, in addition to positioning in space, the system allows to analyse how the measurements vary from the theoretical model and, by there, to study these deformations or the erosion. These, in turn, allow one to question the initial model.

The whole of the developments of the project is written in Java and uses the expert system Jess, available on the WEB.

1 INTRODUCTION

This project deals with archaeological survey in order to obtain a 3D model of the excavation during the different phases of the process. We focus our approach on the photogrammetric survey of artefacts made according to an a priori geometrical model which is obvious for contemporaneous industrial objects but in some case already possible with old production such as Roman or Etruscan Amphorae.

We developed a photogrammetric tool based on the idea of a process driven by the knowledge related to the domain. In archaeology as well as in architecture the goal is to allow the domain Expert to use its knowledge to achieve the desired goal. The results may be plotted documents, files devoted to visualization, or a data base.

For this purpose, the system supplies the Expert with a complete set of tools that allow him to formulate hypotheses related to his field of investigation, which lead to a simplification of the measuring process. Among others, for instance, the creation of a corpus figuring the present objects in the field of investigation.

The latest development of the project, which is presented here, relates to integrating measured data with a theoretical model in order to obtain a complete representation of an object partially measured. The way to merge the different data are formalized in logical rules and for each instance measured, an expert system, fully integrated in the photogrammetric software determines a set of operations needed for the geometrical computation.

The project was developed around an underwater archaeological application: the *Grand Ribaud F* Etruscan deep ship wreck discovered in 1999 in *Hyères*, France. The wreck is of high archaeological interest for both its cargo and its state of conservation. It is about 2600 years old and it contain nearly 1500 amphorae. A web site allows access to all the excavation data. (http://GrandRibaudF.gamsau.archi.fr)

2 GENERAL CONTEXT

2.1 The arpenteur project

The ARPENTEUR project (**AR**chitectural **P**hotogramm**E**try **N**etwork **T**ool for **E**d**U**cation and **R**esearch) started in 1998. In the past years, the project became both a WEB-based tool and a traditional software running in Java on several platforms. (Windows, Linux). It has been regularly completed and updated according to the evolution of the Java Development Kit proposed by SUN™.

ARPENTEUR is a simple photogrammetric tool devoted to architectural report. In this way of thinking, we would like to offer a simple and efficient tool for archaeologists and architects to use, which does not require an important photogrammetric knowledge or expertise.

Once the first orientation step is performed by a photogrammetrist at least for photogrammetric model control and validation, the measuring step, made with the ARPENTEUR software, can be performed under the field expert responsibility, archaeologist or architect.

2.2 The Etruscan wreck

Among ancient navigators, the Etruscans were the first, in the sixth century B.C., to create an efficient trade network on the south coast of Gaul. Until recently, however, only two pillaged Etruscan wrecks were known to be in the French Mediterranean sea. The discovery by COMEX (a French commercial diving company) in 1999 of a wreck loaded with Etruscan amphorae and a general cargo, situated in more than sixty meters of water off the island of *Grand Ribaud* (*Hyères*, France), has brought to light important new data on archaic period trade and history.

Fig. 1 The amphorae lying on the sea bed, after the discovery of the wreck, August 2000.

A first survey of the wreck was conducted in October 2000, and a second in August 2001, both directed by DRASSM (the French Department of Underwater Archaeological Research) using its research vessel *Archéonaute*. Logistic support also came from COMEX, which provided its vessel *Minibex*, submersible *Rémora 2000*, remotely operated vehicle *Super Achille*, and prop-washer *Blaster*. In addition, the project was assisted by the French National Centre for Scientific Research (MAP-gamsau laboratory). By building on experience gained over nearly fifteen years of work on deep sites, this project allowed further testing and development of new methods, particularly those which do not require divers. In this respect, especially noteworthy are the photogrammetric recording of the visible remains we undertook as well as a test excavation of the central section of the site by gentle prop-washing. These evaluations have confirmed the importance and excellent state of preservation of the wreck, loaded with nearly 1500 amphorae in several layers, stacked bronze basins and disks, coarse Etruscan wares, and high-quality Greek ceramics.

Fig. 2 Amphorae lying on the sea bed, with a buoys for a reference to vertical and a rule for scaling.

The study of the artefacts already allowed us to advance some hypotheses about the origin of the amphorae, which all belong to Type Py 4 categorized by M. Py in a 1974 study of imports to the French ports of Vaunage and Villevielle [Py, 1974]. Although this type seems to be relatively standardized, on the *Grand Ribaud F* wreck there were in fact at least four different *sizes* of the same *shape*. The remains of vine branches and wear marks on the amphorae show that they were secured by dunnage and securely attached to each other by thin ropes. The examination of the amphora clay shows homogenous production, characteristic of southern Etruria.

While exploiting advanced technologies and technical innovations, it also helps to lay the foundations of a new form of underwater archaeology: one in which divers completely leave their place to remotely controlled devices, given that saturation diving is expensive and increasingly inappropriate for careful excavations on deep-water sites. It is our wish that our site, transformed for the time being into a real experimental laboratory, will permit new technologies to work for the benefit of historical and archaeological research.

2.3 Digital Photogrammetry

The wreck is resting at a depth of 60 meters ; even if divers are able to go to that depth, the work is very difficult and potentially dangerous. A diver can not stay more than about ten minutes at this depth and to establish a topographic map under those conditions would be near to impossible. We took a light digital photogrammetry method by using a non-metric digital camera, mounted in a waterproof housing attached to a bar on COMEX's submarine *Rémora 2000*. For a light presentation of the underwater photogrammetric method you can refer to [Drap, Long, Durand, Grussenmeyer, 2001-A], [GrandRibaudF, 2000] and more generally to [cipa-uwp, 2002].

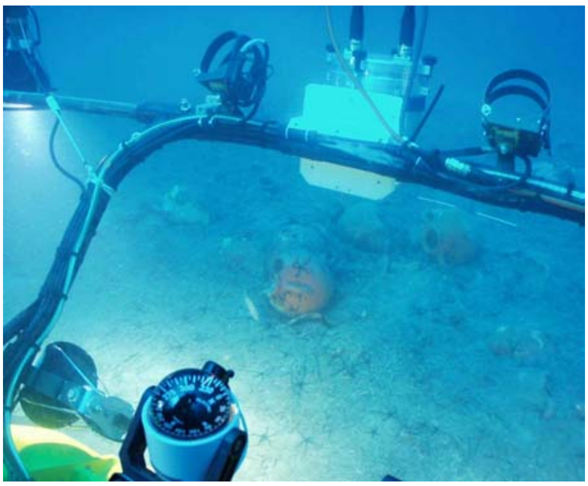

Fig. 3 Interior view of the submarine. The camera is inside the white waterproof housing mounted on a bar outside the submarine. The optical axis is vertical.

2.4 What the archaeologist needs ?

For many years Geographic Information Systems have become common tools for archaeologists who see in this technology the alliance between the huge amount of information collected in the field and graphical representation which supports the analysis. The GIS graphical representations most often originate from cartography, this means merging vectors, images, and symbology in 2D visualization tools. The old culture of chart reading (see Christian Jacob's book on this subject, [Jacob, 1992]) is very useful in the use of GIS and probably one of the obstacles in the way of a truly 3D GIS. As a matter of fact, even without the realistic representation, the strength of the GIS is linked to the symbolic cartographic representation of the data offering a synthetic expression of the data analysis.

If the 2D representation is sufficient to demonstrate the archaeological work concerning an urban scale or larger, applied to a period for which traces of the elevations do not exist, it is far from being the same when one is studying a building, or in this present case, a ship. The need for a 3D representation is then of first importance and the global understanding of the study revolved around that kind of representation. The context of this work concentrates in only one tool, a data management system, a 3D visualization system, a 3D measuring tool, and an object modelization of the study area are then set-up.

2.5 Taxonomy Elaboration

The document management system proposed in this work is relying upon the hypothesis of the existence a theoretical model of the archaeological objects studied. From the amphorae to the ship we can suggest a theoretical model for these objects. The purpose of this model is to describe on the object typology, work which has been done since 1899 by Heinrich Dressel in his classification of amphorae, as well as a group of relations describing the behaviour and relationship of these objects between each other.

All of the amphorae[1] from the wreck are of Etruscan origin and have the same shape as amphorae described by Mr. Py (type 4), [Py, 1974] in a study of the imports to Vaunage and Villevielle (Gard, France). Eleven years later, Gras and Slaska completed this initial classification by proposing a typology of amphorae from Southern Etruria. The type Py 4 and its variants have been included in the EMD group. [Py, 1974]. Generally, our amphorae have a standard shape. They have a bulging shape profile with an almond shaped edge immediately above the bulge, leaving no room for a neck. In some cases, the base of the lip is underlined by a thin, well-defined groove. In terms used by Gras, the bottom is flat but thin and shaped. Its profile is sometimes more oval than round. The handles are high, regular and well curved. We will see that this homogeneous production, which in all likelihood originated from the same workshop or series of workshops, does have a few noticeable variations even though all of our examples are perfectly contemporaneous. The homogeneity of the ship's cargo, without any Greek amphorae, but only very standardized Py 4 type amphorae from the same production centre, shows us that the ship carried a homogenous cargo.

This regularity in the production of the amphorae allows us to use a modelling approach and to formalize this knowledge into a hierarchy of objects sharing the same properties and structured according to the Object paradigm. The amphorae from the wreck, for the time being, have been grouped into four sub-classes of the Py 4 type amphorae according to morphological considerations.

3 DIFFERENTS SOURCES

3.1 Description of the multiple data sources problem

In this context, the measurement and the management of the amphorae of this wreck

[1] The amphora chronology Py 4 and the Greek ceramic discovered on the site tell us that the wreck occurred between 525 and 480 B.C.

are based on three strongly incomplete data sources. The first represents the theoretical model of the amphora. It contains the geometric standards necessary to the chart of the amphorae, definition of the form, default values concerning the characteristic sizes of these objects. These data evolve with each addition of new instance in the base. The second source is fed by the photogrammetric measurement taken on the objects by using the photographs made during the excavations. Information of the third source comes from the measurements made in laboratories on the amphorae, once gone up on the surface. In this work we won't use these data sources.

3.2 The first source : a theoretical model

This source represents the expert knowledge of the archaeologists in his graphic expression (S1). It is about a model resulting from observation from the amphorae. The objects are represented by classes which gather information of various nature: the geometrical description of the objects in the form of a whole of geometrical attributes, the description of the possible facts (possible observations and measurements on the objects) and the description of the rules of calculation used to evaluate the geometrical attributes using the observations carried out.

The diversity of the objects handled by the archaeologist and the geometric complexity of their surfaces led us to search for stable morphological characteristics of the objects where diagnostic measurements could be taken. These diagnostic characteristics are also described in the model.

A series of simple geometric primitives are used to approximate these morphological characteristics and are used as an interface between the photogrammetric measurement and the underlying model.

The geometrical description of the class makes up a list of attributes, definition of the position and orientation (translation, rotation matrix) and definition of the geometrical characteristics: height, diameter of the collar, diameter of the paunch, etc. For each attribute representing the geometrical characteristics of the object the value of the class attribute is the average value of the attributes of the already observed instance of this class.

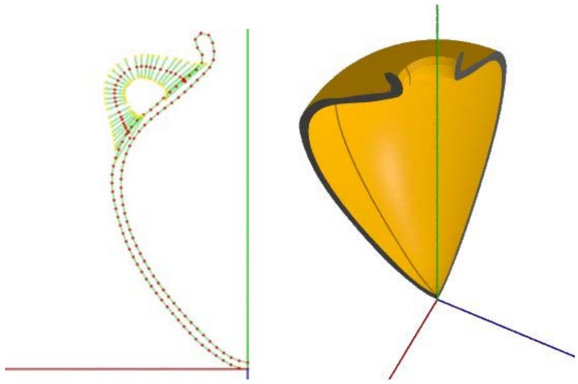

Fig. 4 Two steps of the elaboration of the Etruscan amphora theoretical model[2]

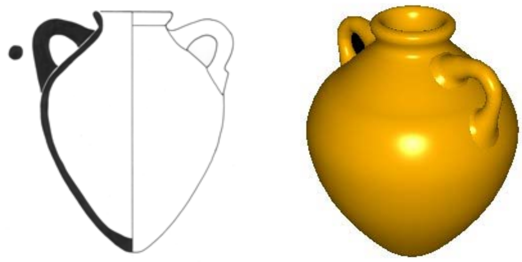

Fig. 5 On the left part, the graphical model designed until now by archaeologists, on the right part a CAD interpretation of this model.

The description of the facts specifies the existence or the absence of information observed, for example the existence of points measured on the collar or on the bottom, the facts can also represent the presence of deduced information, as the existence of a circle calculated on the points measured on the collar.

The calculation rules are elaborated by the photogrammetrist. These allow, according to facts and to the attributes values to calculate parameters related to the objects, for example, rule N: *If there are points on the bottom of the amphora and the calculation of the circle of the collar has to converge, then axis OZ of the amphora will be determined by the bipoint (barycentre of the*

[2] 3D model written in POV-ray, thanks to M. Jacques Zoller

points of the bottom, centre circle of the points of the collar).

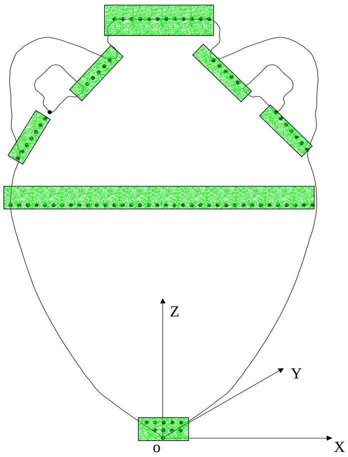

Fig. 6 The five zones where the photogrammetric measure can be done on the amphora in order to obtain facts.

These rules of calculation are used by the Expert System which is, in this project, the mechanism of deduction. It should be noted that information of this first data source is evolutionary, each new amphora modifies the values of the attributes of this source. In addition the rules of calculations, which represent the expert knowledge of the photogrammetrist, can vary from one photogrammetrist to another. The information contained in source 1 of data exceeds the geometrical aspects, indeed it enters in the definition of the "model" a set of non-graphic data (Bibliography, iconography) which will not be approached in this article.

3.3 The second source : underwater photogrammetric survey

The second data source (S2) comes from photogrammetric measurements made using the photographs taken on the site. This information is of three types: position and orientation of the photographs in the set of axis of the site, position and orientation of the identified and measured amphorae, determination of some morphological attributes. For each amphora observed on at least two photographs, the archaeologist identifies the class of the amphora and chooses a class suggested in files XML representing the first data source (S1). An instance is created with a single identifier, as from this moment measurements can be made according to the amphora description. Measure can be done only on the set of geometrical primitives defined in the model as support measurement. This information is strongly incomplete because the amphorae are seen only partially on the photograph, in addition much of them are already broken. The role of the Expert System and the deduction phase will be to supplement these observations and after fusion of the sources S1 and S2 to propose a complete model of each instance.

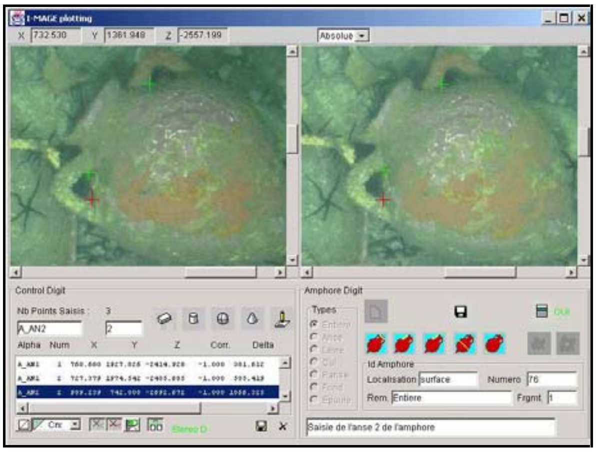

Fig. 7 Photogrammetric Digit module dedicated to amphora survey. Only five particular zones are allowed for the measurment.

4 DATA FUSION

Obtaining an amphora 3D representation requires a merge of photogrammetric measurements (S2) and theoretical model (S1). The technique that we use consists in supplementing photogrammetric measurements by the theoretical model. These two data sources give information on the remarkable zones of the amphorae, defined by an archaeologist (lip, belly, handles, back, see Fig. 6). It is obvious that the difficulty of the source merge consists in finding at which time to use a source or the other. The solution used by our system is the recourse to propositional logic to formalize the knowledge contained in the two sources and how to use it. The merging method is provided by an inference on the logic formalization of the sources which generates actions to be achieved. Finally the merge is carried out according to the actions. We can divide the work in three steps.

4.1 Step one: Built of a Knowledge Base (KB)

A Knowledge Base is a logical formalization of the data present in S1 and S2 : the facts base from (S2), the rules base and the default values from (S1). Let us see how to build KB by building the facts base then the rules base.

The first goal is to build a facts base providing information of the data present in S1 and S2. For that, with each data coming from a source, a fact in the knowledge base is associated. Conversely, if a fact is present in the knowledge base then the associated data is in the corresponding source and can be accessed and used. This is a simply application of closed world assumption, frequently used in data base domain. From here we will use the term *fact* to indicate an object of the knowledge base or the data corresponding, ambiguity being corrected by the context. Here is a knowledge base built example.

Example: Let’s assume that S1 contains theoretical height and a theoretical belly radius for an amphora and S2 contains photogrammetric measurements on belly and one of the handles. The knowledge base KB will contain S1height, S1bellyradius, S2belly, S2handle1. Each fact determine the existence of a data in a specified source.

The second goal is to supplement the knowledge base with base rules which indicate how to merge the sources. The rules use facts of the knowledge base to generate new ones, representing the needed actions for merging. A rule can be described as a *if* .. *then* bloc, for example:

if fact1 and fact2 then action3.

4.2 Step two: Sources merge

Once the knowledge base is built, a system allowing the fact base saturation must be set up. The computation of new facts, called saturation of the knowledge base, has to be done. For this, we use a forward chaining inference engine: JESS (Java Expert System Shell) [Jess, 2001]. The forward chaining inference consists of choosing a rule where all the premises are in the facts base and start it. The start of a rule adds its facts of conclusion to the base then returns to the rule choice step. When there is no rule in the base that can be triggered off, the saturation of the knowledge base is complete and the inference is finished. The difficulty is to choose the rule to start with, JESS uses the well known RETE algorithm which can find the best rule matching the facts present in the base. You can find more information about RETE in [McWhirter, 2001]. At the end of the forward chaining inference, the knowledge base contains new facts which represent actions to do to achieve the sources merging. The use of JESS is only possible by using a wrapper between the knowledge base, written in a XML file, and JAVA objects used by JESS. This wrapper is made of a XML parser which feeds two JAVA managers: a formulas manager containing the rules and a facts manager. We can start a JESS inference by giving the two managers to it. Once JESS job is done, the fact manager contains the initial facts and the inferred facts from the saturation.

4.3 Step three: merging with action

The whole project is written in Java and rules and facts are stored in XML files. The Expert System Jess, fully integrated in the project produces a set of facts (the fact manager) in order to give the best way to compute the object according to the measures and the theoretical model. Step three is the bridge between the set of facts produced by Jess and the set of actions that have to be done with the amphora instance to obtain the right geometrical attribute. From the implementation point of view, the instances are Java instances and calling the Expert System is calling a generic method named *logicalRestitution*() which uses as input a fact manager and produces an action Manager.

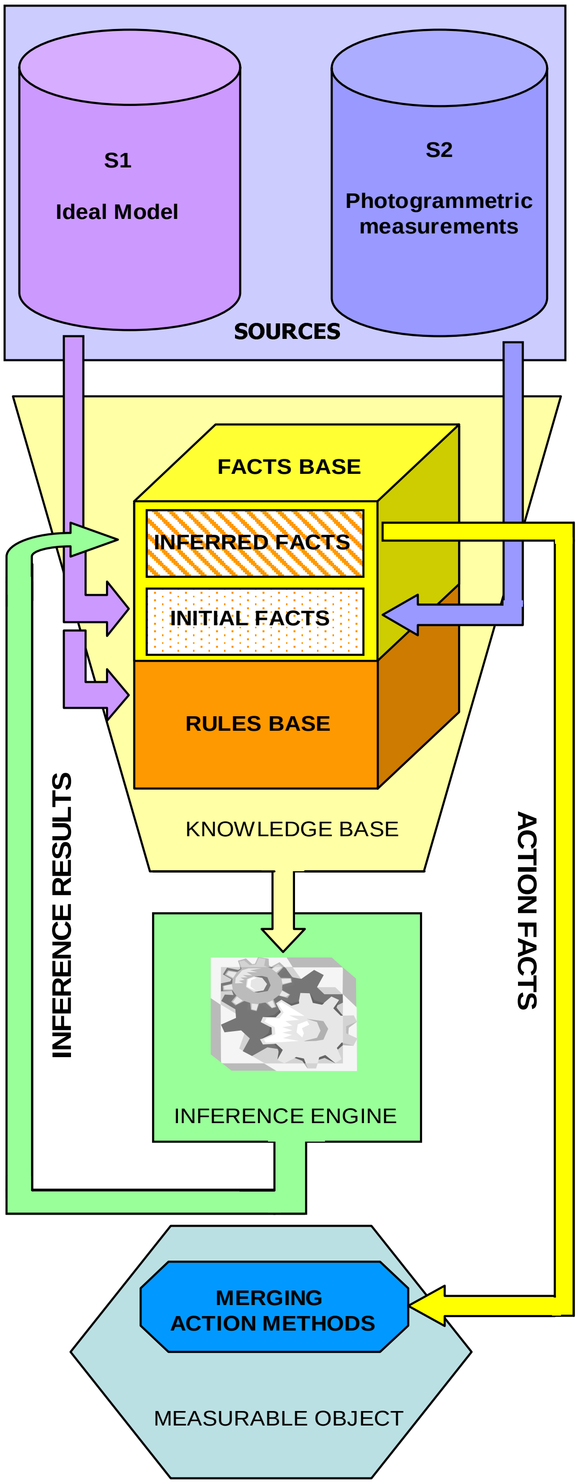

Fig. 8 From data sources to full object representation: Synoptic scheme of Expert System.

An action, in this context, is a simple Java object that memorizes by java-reflection the method name to be used.

The underlying principle is that all the measurable objects in the hierarchy have a set of elementary methods to monitor basic geometrical actions such as barycentre computation, translation, rotation and so on. All elementary actions have an homologous fact described in the theoretical model (source S1) and produced by interpretation of the fact manager fed by the Expert System.

5 RESULTS

This approach enables us to obtain, in spite of a partial vision of the amphorae, a representation of the cargo relatively close to what it was. We get two kinds of results, a textual form, structured in XML and a set of graphical representations, directly generated from the java object: a VRML and a MicroStation™ representation.

5.1 Textual results

The textual results are stored in XML files. They are accessible from automatically generated VRML representations.

We made this choice because XML provides a great flexibility in the data formalization and allows a very interesting data/presentation independence. Some situations have to present by different ways the produced results. For example, we can publish a HTML file from XML results with appropriate XSL transformations and distribute it on a website or use it as a simple report paper.

These XML files manage all information which we have on the measured and calculated objects: the photographs on which they are visible, characteristics geometrical calculated or inferred by the Expert System, the list of the facts, measured, calculated or inferred, the various remarks made by the archaeologists, etc. The bond between the generated chart and this information is also used to be able to ensure itself of the origin of a geometrical attribute. Indeed, the geometrical representations of the objects, after inference of the Expert System, are "theoretical". They correspond to a perfect object dimensioned by measurement because the possible missing parts were supplemented by the mechanism of inference. It is thus significant to be able to reach numerical information about the object, from its chart, and to be able to know if an attribute was calculated or inferred from the theoretical model.

5.2 Graphical results

All the data surveyed are formalized in XML files which are, in fact, the only result of the plotting phase. We parse the XML file in order to generate automatically 3D representation using VRML or MicroStation™ formalism. These graphical representations are actually different points of view on the results.

Fig. 9 A cut elevation east-west of the excavation. Visualized with MicroStation™.

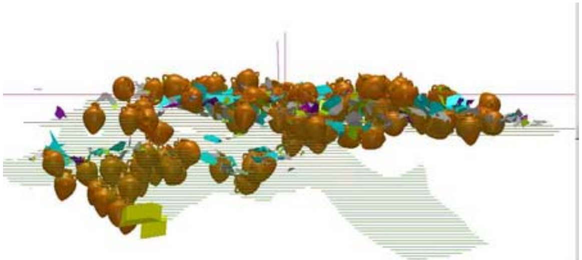

Fig. 10 A cut elevation north south of the excavation. Visualized with MicroStation™.

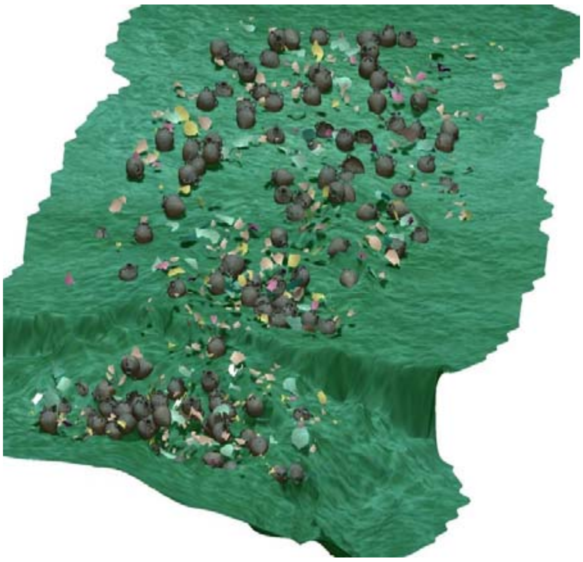

Fig. 11 A large view of the site, sea bed, excavation and amphorae as discovered. Visualized with MicroStation™.

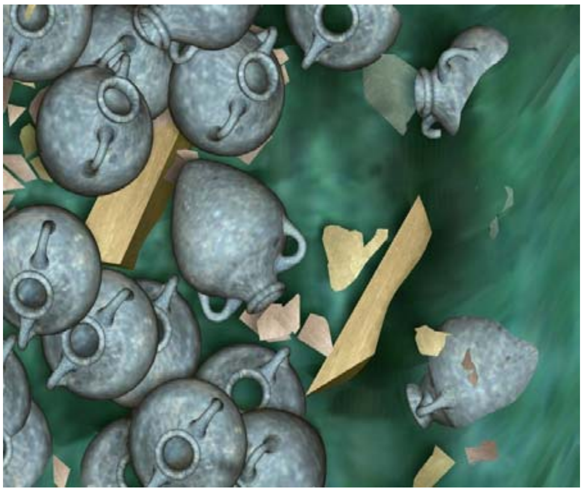

Fig. 12 A detail of the bottom cargo. We can see the wooden frames and the amphorae fitting. Visualized with MicroStation™.

5.3 Visualization and Interaction

The importance of the visualization of a three-dimensional model for archaeology at the scale of buildings needs no longer to be demonstrated. For instance, see Paul Reilly from 1990 in an article entitled “Towards a virtual archaeology” published in the *Computer Applications in Archaeology* conference proceedings in Southampton, which clearly described the interest in the elaboration of a three-dimensional model and its visualization. Since then, this aspect has largely been studied and many theoretical studies on the ‘reconstruction’ of the past have been undertaken. On this subject see the synthesis of Juan A. Barceló [Barceló, 2000].

5.3.1 The Limitations of VRML

The VRML three-dimensional imaging language is well adapted to simplified and quick visualization. Coupled with a script language such as PHP, it also allows a simple and efficient link to a relational DBMS for consultation or an XML database access. Within these limits of use, it fulfills perfectly its job and research projects which employ it, for example, the virtual museum project dedicated to the evolution of a city developed by Maria Elena Bonfigli and Antonella Guidazzoli [Bonfigli, Guidazzoli, 2000]. It is also used with a sound JAVA 2D interface, such as the educational work in the GIS from Kate Moore, Jason Dykes and Jo Wood at the University of Leicester, [Moore, Dykes, Wood, 1997].

Nevertheless, VRML suffers from a lack of portability, the fact that free and efficient viewer hasn't been developed for Unix, and especially from an enormous lack of flexibility for dynamic updating of three-dimensional models.

The imaging is described in a file, and external links (URL to a DBMS for example) are also coded in the file. The dynamic modification of the contents of VRML imaging is a very cumbersome operation, not easily portable, and limited in its possibilities.

5.3.2 The Opening of JAVA 3D

Since the version 2 of Java (Java 1.2 and Java 1.3), a three-dimensional graphic library is available. Like VRML, JAVA 3D offers an imaging graph and a clear structure in the represented space. The JAVA 3D designers are involved in the development of VRML and offer a series of bridges and translators between these formats (mainly in VRML / JAVA3D).

Obvious advantages of JAVA 3D on VRML rest in two directions:

- JAVA 3D is a JAVA library and can therefore be used directly from the model development language. The link between the graphic representation and the model becomes then intimately close and it is possible to easily consider a bidirectional link between the model and its graphic representation, also between a persistent object manager, the acting object and its graphic representation.
- The visualization of imaging is no longer linked to a three-dimensional tool which is unusual, not really portable and no longer dependent on the JAVA 3D library on the host computer. JAVA 3D is distributed for a majority of today's computer systems.

We are currently developing a set of mechanisms, based on object approach to offer to objects a dynamic behaviour for their graphic representation. This approach will also allow visualization on the web of relations linking the objects.

6 CONCLUSION AND FUTURE DEVELOPMENTS

This work is a part of a big project which associates several teams working in various disciplines and nevertheless complementary. Team members with different backgrounds are currently working with the same XML formalism, and every team has taken a few steps towards the others to harmonize the lexicon and to establish a common language.

We developed in this project a tool to represent the archaeological assumptions of the archaeologists and to allow the visualization of scenes which are based on a minimum of measured points. The generic aspects of the development enables us to consider the extension of the process to other types of objects, in particular purely architectural objects.

The conceptual choice underlying the project led us to elaborate knowledge manipulation tools. We have joined, thanks to Jess, an inference engine to the measurable objects knowledge base in an Expert System able to assist the measure of any object providing a theoretical model as archaeological objects (like amphorae) or architectural objects. Out of the great interest lead by the performance of the inference algorithms, the use of an expert system involves a high abstraction level in the measurable object knowledge representation. For us one the most important thing is the associated knowledge. This tool allows an archaeologist expert to make a photogrammetric survey without an important photogrammetry background. The expert role is more to insert knowledge in the system than to perform geometrical survey.

6.1 XML and a patrimonial Information System

The data management, an omnipresent problem in archaeology, is dealt in two ways: the first one is purely textual and the second is based on the object geo-referential point-of-view. These two approaches are accessible on the Internet.

The three-dimensional model as an interface to the data formalized in XML allows the purely documentary data (references, observations made during the excavation, photographs) to be linked to a three-dimensional representation of the object. This graphic expression of the object relies on the data (position, orientation, dimensions) and on the generic knowledge of the object (theoretical shape, default values, relationships between various objects, facts and computation needed). The three-dimensional model, generated by the system, shows the generic model of the object, defined by the archaeologist, measured by photogrammetry and thereby a relevant interface between the user and the collected data.

In this framework of multimedia data management system, our objective is to publish the data in different ways, XML is the choice we made to federate them. Thanks to this formalism we can represent in an homogeneous way a set of very different kinds of data such as structural description of the image content, physical data, photogrammetric data.

The result data, generated in XML, allows both a simple and automatic publication of the result towards different media, and a way to elaborate a request on the whole set of data.

This work is available on the Internet http://GrandRibaudF.gamsau.archi.fr

6.2 Data evolution problems

The data evolution problem becomes crucial as soon as several measurement methods are involved, especially considering that the underlying model could evolve. For example, in our case, the number of layers of amphorae and their relative positions are still archaeological hypotheses and can change. This revision problem is clearly identified in the context of GISs [Peled, Raizman, 2000, Shi, 2000] but it remains somewhat more complex in our case.

We must manage data stemming from both photogrammetric measurements and from direct manual measurements on amphorae that were brought back to the surface. All of these measurements are incomplete and represent the same object at different moments in time. The comparison of these measurements to models based on a series of manual measurements, must allow to show the errors and eventually to think again about the model.

This work about reversible data fusion and revision, from the different data sources existing in this project has started this year thanks to a collaboration with Prof. Odile Papini, SIS laboratory, university of Toulon, France.([Benferhat, Dubois, Lagrue, Papini, 2003], [Papini, 2001])

7 REFERENCES

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