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# FROM UNDERWATER PHOTOGRAMMETRY TO A WEB INTEGRATED DOCUMENTATION SYSTEM: THE CASE OF THE 'GRAND RIBAUD F' ETRUSCAN WRECK

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## Abstract

The interdisciplinary work we present here is aimed principally at administering diverse types of information collected during an archaeological excavation using a single data management system. The approach is global, from the consultation of three-dimensional data to simple textual data to the addition of data captured by a digital photogrammetry system called l'Arpenteur [Surveyor], which is fully integrated to the data management system.

We are using an object formalisation of the manipulated archaeological data using JAVA 1.3, the language chosen for all developments, from the digital photogrammetry tool to the three-dimensional model generator (VRML or JAVA 3D) used as a navigation interface in the database.

Following a brief introduction to the archaeological context, and the special aspects of the excavation due to the great depth of the shipwreck, we will then present the existing system and explain the problems encountered. Not all of them have yet been resolved, such as the translation of objects to and from the relational DBMS, the revision of data coming from different sources, and the automatic generation of three-dimensional models as a navigation interface.

## 1 INTRODUCTION

The management of data is one of the major problems encountered during an archaeological excavation, and presents many types of obstacles:

- The characteristics of the manipulated data are very different, let alone the vital multimedia aspects, and the use of diverse and sophisticated technologies, the latter which poses even more management, presentation, and analysis difficulties;
- Many people are likely to consult the data simultaneously and will possibly update the data;
- These data are likely to change as time goes by, as a result of updates, error checking, and the modification of modeling hypotheses.

The objectives of the work presented here are the synthesis, analysis, and diffusion of knowledge about the excavation at any given moment via the creation of a Web interface. The originality of the proposed system resides principally in its dynamic presentation in a Web site, of three main components: (i) a database management system ; (ii) a three-dimensional model ; and (iii) a digital photogrammetry tool. The link between these three components is realized, from the conceptual point-of-view, by modeling with the aid of computer tools relying on the object oriented approach (using JAVA 1.3), of a body of objects manipulated by the archaeologist. This computerized approach unites the exchange between the different forms of expression of the objects under study and ensures the coherence between these different expressions (three-dimensional representations ; text ; DBMS management ; and assistance for the user during photogrammetric measurement). The state of progress of this work is presented on the following Web site : <http://GrandRibaudF.gamsau.archi.fr><sup>1</sup>

After a brief introduction to data management systems used in archaeology, and a description of the archaeological context of the Grand Ribaud Etruscan Wreck, we will introduce the photogrammetry tool l'Arpenteur and its use during the photogrammetry work . Then we will discuss its implications for the archaeological data management system described here. We will then discuss the document system and its basis : object modeling of the body of information to be studied, the mechanism for managing incomplete data, and the implications of photogrammetry measurements and the use of generated three-dimensional models as a navigation interface for the database. Then we will present the technical choices that were made (connection between the relational object models, three-dimensional visualisation using VRML or JAVA 3D, and information exchange in JAVA-RMI,<sup>2</sup> Servlet and Php4).

<sup>1</sup> Grand Ribaud is a small coastal island, not far from Toulon, south of France, where many wrecks of different origins have been found. They have each been assigned an identifying letter, which in the present case is Grand Ribaud F.

<sup>2</sup> RMI, Remote Method Invocation.. RMI's are a SUN solution integrated with JAVA 1.1 for the management of distributed objects. PHP is a script language interpreted by the server. The rumour that suggest that PHP is an acronym for "People Hate Pearl" would appear to be false ! It actually means "Personal Home Page" or even more recursive acronym "PHP Hypertext Processor".

These technical choices concern the tools widely and freely used over the Internet to make the system accessible to as many people as possible. We will end with a look at the research directions that this project will follow.

## 2 THE PROJECT CONTEXT

### 2.1 Archaeological Data Management Systems

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, that is to say 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 is then set-up.

### 2.2 The Experience of the Grand Ribaud Etruscan Wreck

The Etruscan wreck discovered in 2000 by Mr. H.G. Delauze (COMEX, a French commercial salvage and diving company) has been dated to the between the 6<sup>th</sup> and 5<sup>th</sup> century B.C. and sits in 60 metres (197 feet) of water off the coast of Toulon, France. The archaeological interest in this wreck is considerable because only three wrecks of this type are known and all had been robbed before being studied archaeologically. A first campaign took place in October 2000 with the help of COMEX who made available their exploration vessel Minibex, their submarine *Rémora 2000* and a remotely operated vehicle (ROV).

The principal objective of the October 2000 project was to obtain digital photogrammetric coverage to record the actual state of the wreck and to allow the creation of a site plan and a 3D reconstruction using simultaneously the observed data, and archaeological sources and hypotheses.

#### Digital Photogrammetry

The wreck is resting at a depth of 60 metres ; 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 adopted 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*.

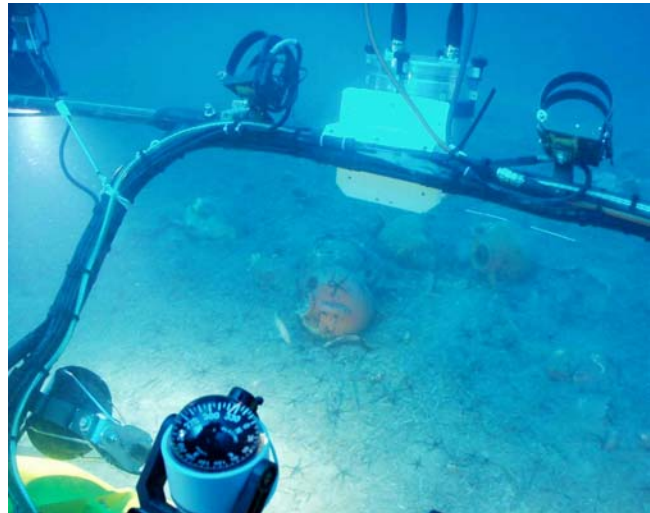


Figure 1: Interior view of the submarine. The camera is inside the white waterproof housing mounted on a bar outside the submarine. The optical axis is vertical.

#### The First Photogrammetric Results

A total of sixty-one pictures have been oriented, with seven rulers to put them in scale and two buoys for vertical reference. The orientation relative to north is approximated. More than one thousand points were recorded and were used to generate a digital terrain model.

The initial results allows us to display the bottom, to locate the numbered amphoras that were brought to the surface by archaeologists as well as the different positions of the submarine when the images were recorded. The overall precision of the bundle calculation (a calculation of the positions and orientations of images in the same coordinate system of the sixty-one images is within 2.5cm).

### 2.3 The ARPENTEUR Project

ARPENTEUR (meaning ARchitectural PhotogrammEtry Network Tool for EdUcation and Research) is a set of software tools developed in collaboration with the LERGEC laboratory of ENSAIS in Strasbourg, France. These tools are based on the notion network use and rely on the HTTP and FTP communication techniques. Examples can be consulted on the Internet site <http://arpenteur.gamsau.archi.fr>.

The main justifications for the project are as follows :

- As is the case with education and research software, the JAVA™ development language gives a tool and a technology allowing teams working on different sites and systems far apart a practical means for work and exchange.
- As a tool dedicated to architecture, ARPENTEUR benefits from the expertise of two teams in the fields of close-up photogrammetry and the representation of architectural information.
- As a tool dedicated to photogrammetry, ARPENTEUR is a simple system and should be considered as a light photogrammetry system, light meaning easy to use as well as there being no requirement for heavy equipment.

The integration of these objectives in the same group rests upon two technical and conceptual choices. The first is in the use of the digital images obtained with a digital camera that are now commercially available which give adequate definition. These images also allow the software tools user to make many tasks automatic. Finally, they allow the total integration of the process from the images to final results like 3D visualization in CAO-DAO 3D software.

This integration is put to profit to serve another choice, conceptual, founded on the idea of a process guided by the information related to the field. Concerning both architecture and archaeology, the goal is to allow experts to use their knowledge to produce results which ideally meet their wishes. The results can be shown as documents, visual files, or as a body destined for a database. For this purpose the system gives experts a group of tools which permit them to express hypotheses related to their field of investigation, hypotheses that lead to easier measurement process. Between these, for example, the creation of a body representing the objects in their field of investigation.

As a benefit of those choices the ARPENTEUR looks like a tool developed for professional architects and archaeologists with minimal intervention from the photogrammetry expert.

### 3 A DEDICATED DATA MANAGEMENT SYSTEM

The roots of this project reside in the link between many tools and the elaboration of this link through a semantic approach of the objects to be measured and shown. Measurement, representation, and management are articulated around a common model formalized from the « Object » point-of-view and implemented in JAVA 1.3. The measurement and representation phases take advantage of this common model by putting in place of a default value mechanism allowing to take complete measurements of the object by using jointly a group of measurements and the generic properties of the type of object studied.

#### 3.1 System Structure and Document Management

The project is presented on an Internet site (<http://GrandRibaudF.gamsau.archi.fr>) which offers at the same time a work interface for archaeologists and a presentation medium of the excavation for the public at large. Access to the data generated by the DMS can be consulted using the VRML interface and in modification / adding mode by the text interface, protected by restricted access. This work is also taking place in the problematic of data management thru the Internet, formalized in the GIS in the work of Kritin Leukert [Leukert, 2000].

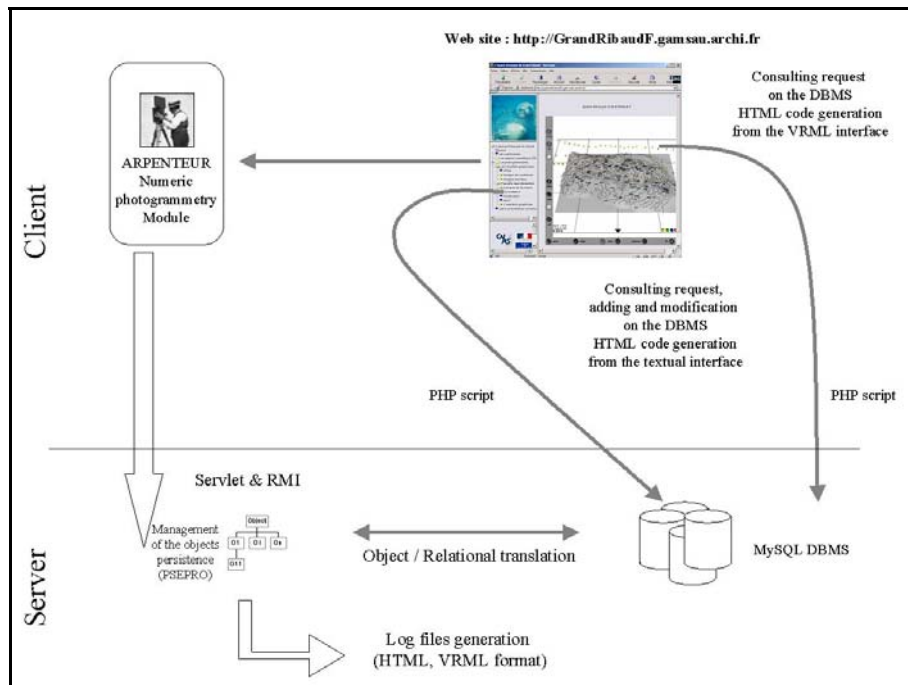


Figure 2: Synoptic Diagram of the document management system from the excavation of the Grand Ribaud Wreck.

#### 3.2 Elaboration of a Specific Body

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

## Amphora Typology

All of the amphorae<sup>3</sup> from the wreck are of Etruscan origin and have the same shape as amphorae individualized by Py and Py in 1974 (type 4) in a study of the imports to Vaunage and Villevielle (Gard). 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. (See [Py, 1972]; [Py and Py, 1974]; and [Py, 1985]; and also the work of Sourisseau, 1997). 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 modeling 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.

### 3.3 Measurement, representation and request linked to a body of objects

The representation and measuring tools must manage a group of objects and their relations. In fact, it is not easy to see the difference between the static behaviour of an object (not considering state and time) and the dynamic behaviour (linked to state and changing with time) [Braux, Noyé, 2000]. As is the case with measurement problems (default value mechanism, extrapolation of non-measured data) or representation problems (expressing the morphology with VRML or Java 3D), the object's behaviour is generically defined with an interface (a Java method) and every object uses, according to the situation, the specified method.

Using this object programming approach has allowed us to make the modeled object's behaviour easily dynamic and also allows us to generate graphical representations in different format using shared interfaces.

### 3.4 The link with Photogrammetry

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 measurement can have two purposes:

- Object orientation and position determination within the overall coordinate system of the wreck site, where the general morphology of the objects is familiar to us. In the present case, the measuring module is for measuring four types of amphorae found on the wreck: PY4-GRF1 through PY4-GRF4. The measurement specificity of those class relies on the fact that only the default values change, while the general proportions stay the same.
- Measurements which provide the position and orientation calculation of the amphorae can also serve to determine their intrinsic characteristics, data which are generally measured by another method when the amphorae are brought to the surface. Conflict detection between the photogrammetric measure and these external data is put in place without a decision being taken by the system. This raises the delicate question of data revision problems and the detection of errors, upon which we are planning to work in the future. On this subject see the work of Zhongchao Shi [Shi, 2000].

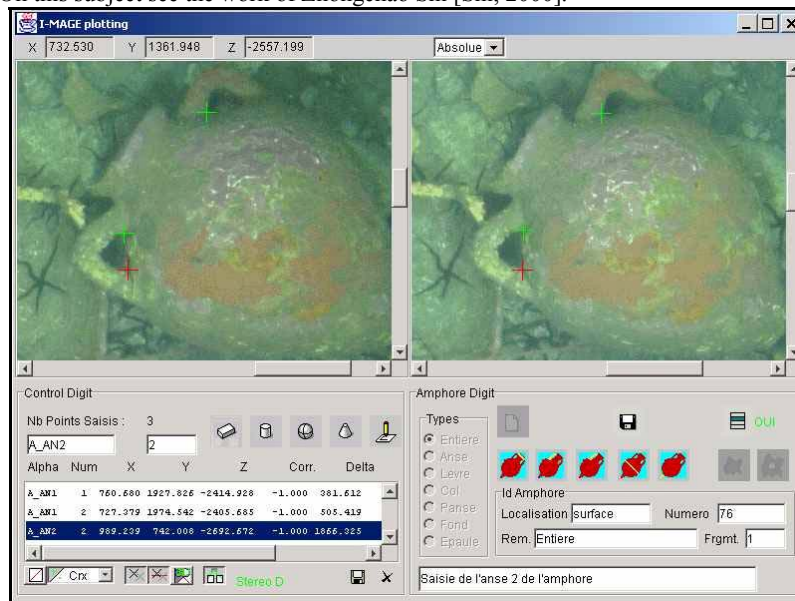


Figure 6: The Amphora capturing interface in Arpenteur.

The capturing is done according to a theoretical model and is linked to a remote database.

<sup>3</sup> 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.

The photogrammetric measurement is supported by some strategic points on the amphora (Figure 7). Five areas are used to redundantly define the amphora coordinate system definition parameters. If measurements to certain parts of the amphora are impossible, the coordinate system determination mechanism uses relationships between amphorae (if they exist) or default values. The inference problem of values relying upon incomplete data or data that needs to be re-evaluated is frequent in archaeology. We can consult, with interest, the work of Claire Reeler who uses fuzzy logic to formalize this uncertainty [Reeler, 1996-1; Reeler, 1996-2].

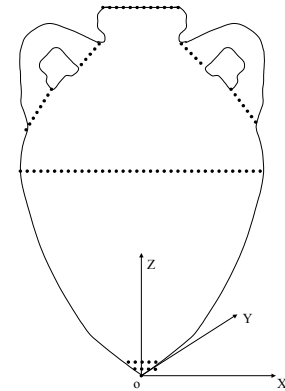


Figure 7: Location of areas which support the photogrammetric measurement of the amphorae.

### 3.5 Generation of Three Dimensional Models as Request Interfaces

As we were able to see on Figure 3, the problem of the representation of the wreck and its cargo becomes obvious when viewed in a three-dimensional format.

At present, only one surface covering has been completed (during the October 2000 excavation campaign) but future campaigns (the last one has taken place in July 2001) will show the bottom layers of amphorae, presently estimated to be three, and the hull structure itself. The three-dimensional visualization system will allow simultaneous graphic representation of archaeological hypotheses about the lading of the amphorae and the structure of the ship. Further, it will allow the user to interrogate the database about any amphora shown and the type of relationships that they have between each other.

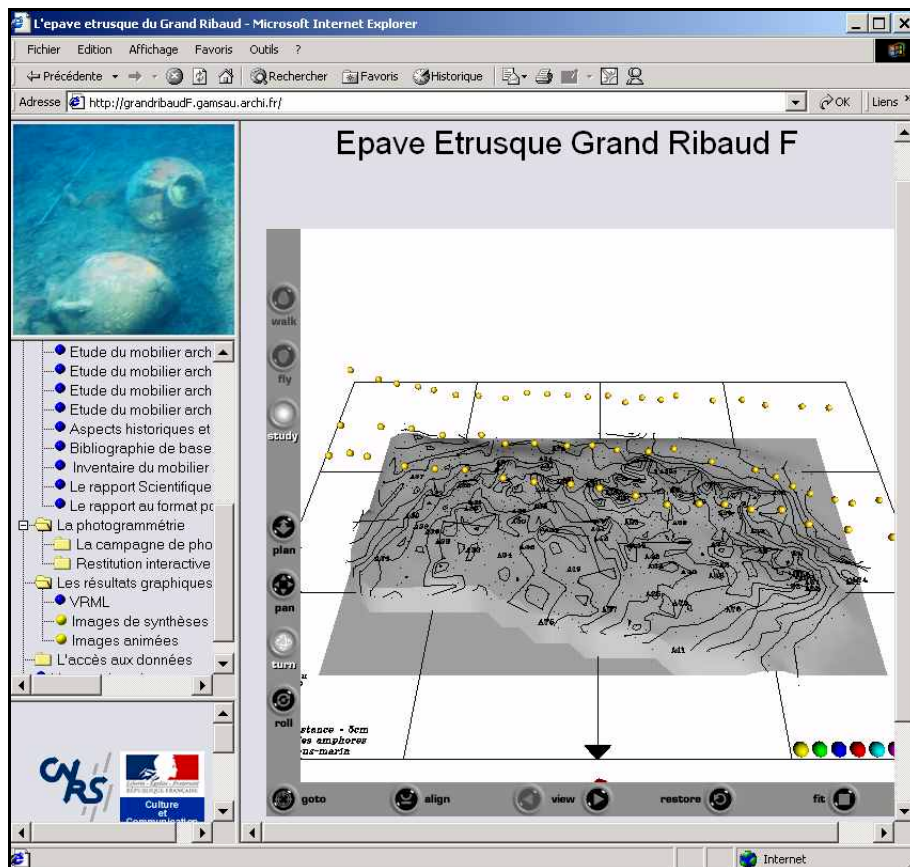


Figure 8: Visualization of the three-dimensional model of the wreck, in the current state of the excavation, VRML interface towards the database. Contour interval = 5 cm. The yellow spheres show the different positions of the submarine and allow access to the images. Eighty amphorae are shown.

## 4 INTEROPERABILITY AND TECHNICAL CHOICES

This project is part of an ongoing process. The computerization of an archaeological excavation requires a major re-evaluation of the tools and methods that have been used in the past. The project started with a request for collaboration from DRASSM to MAP for the underwater photogrammetry campaign. The opportunity for better collaboration and a more global project was taken at that time. Diverse tools, at different stages of development, already existed at MAP-gamsau [Drap & Grussenmeyer, 2000]. The questions of the link between photogrammetric survey, three-dimensional representation, and databases were already present [Drap, Hartmann-Virnich, Grussenmeyer, 2000]. The only thing left to do was to synthesize existing experience and to propose a co-operative model for the team.

The final constraint was the ownership of the software to be used. To be able to freely install the system in all of the team's laboratories and to make sure that the use of the site would not require licences, we decided to use only software that had free access over the Internet.

This project relies on the following tools:

- Web Server: Apache 3.14
- Servlet: JServ
- DBMS: MySQL
- Script language: PHP4
- Development Language: JAVA 1.3 + library JAI 1.02 (image processing for the photogrammetric aspect)
- Three-dimensional imaging formalisation language: VRML 2 et JAVA 3D

### 4.1 The DBMS

Choosing MySQL as the DBMS had major implications for the rest of the project, but to date, a final decision has not been made. The first question that the reader has the right to ask is as follows: why use a relational DBMS while the object structure is omnipresent throughout this project.

At least two reasons led us to this choice:

- The archaeologists had to be able to continue to work without having to change their habits, given that they were already familiar with the use of a relational DBMS in their earlier work. The system had to be, for them, accessible via an SQL request. The use of MySQL on a network with the manager PhpMyAdmin allowed us to resolve this problem even though it was transferring to the computer development aspect.
- On the other hand, this project started during the first excavation campaign while the class scheme was not yet set, and is still under modification. In this case, the use of a PSEPRO type object DBMS, from ObjectStore which is already used in the purely photogrammetric framework of Arpenteur gave us time coherence problems. We must ensure the permanence of the recorded observations of more than one hundred amphoras to date, and must also support structural modifications to the model improved by the ideas of the archaeologists.

We have therefore developed special classes in the Object translation (using a Java method) towards the MySQL tables relying on the standard JDBC. Much interesting work on the Object/Relational exchanges exist and shows efficient routes, for example those of Classe Priese [Prieese, 2000]. Nevertheless, we have not improved the relational DBMS scheme to keep a simple structure that could be the object of simple requests.

This solution, which has its advantages (simple use of the PHP4 as an interface script between the HTML/VRML client, the Apache server and the MySQL server) will be questioned when the excavation progresses and when the data structures are finalized.

### 4.2 Interface and Implementation

#### The Grand Ribaud Database Structure

Three types of data are itemized in the table "amphora": identification data (name, number, excavation identifier, inventory number, description, location); measurements (height, mass, volume, various diameters, number of fragments, measures of the lip); and photogrammetric data (origin, measured points, phi, omega, kappa). These data reflect the structure of the corresponding JAVA class.

#### Database Access Mechanism using the Internet

The client server sends the server an http request containing a script execution (for example : <http://GrandRibaudF.gamsau.archi.fr/chercher.php>). On the server, the request is transmitted to the Apache server. The executable PHP is launched and analyses the content of the script. It first launches a connection with the database managed by MySQL, then, for example, a selection request. The database sends back the result to the executable PHP which formats the result and creates a page in HTML format which it transmits to the Apache server.

This type of tool allows the creation of a flexible and rapid user interface. The exchange of measurement data in the photogrammetry module by Java – RMI and Servlet have performances which are obviously less interesting.

## 5 ONGOING DEVELOPMENTS

This project was the starting point of an effort to address a number of questions; new questions have arisen, so we plan on taking future developments in the following four directions:

- The management of relations between model objects and the reifying problems;
- Three-dimensional visualization as an interface to a DBMS;
- The tricky problem of data revision;

- Finally the link between the photogrammetry tool which could benefit from more two- and three-dimensional geometric information from the measured objects.

### 5.1 Visualization and Interaction

The importance of the visualization of a three-dimensional model for archaeology at the scale of buildings no longer needs 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].

#### The Limitations of VRML

The VRML three-dimensional imaging language is well adapted to simplified and quick visualisation. Coupled with a script language such as PHP, it also allows a simple and efficient link to a relational DBMS for consultation. Within these limits of utilization, 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 no free and efficient viewer has 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.

#### The Opening of JAVA 3D

Since the version 2 of Java (Java 1.2 and Java 1.3), a three-dimensional graphic library has been made 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 then becomes intimately close and it is possible to easily envisage a bidirectional link between the model and its graphic representation, also between a persistent object manager, the acting object and its graphic representation.
- The visualisation 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 series of mechanisms, based on the concept scheme (Figure \*\*) to offer to objects a dynamic behaviour for their graphic representation. This approach will also allow visualization of the web of relations linking the objects.

### 5.2 Data revision problems.

The data revision problem becomes crucial as soon as several measurement methods come into play, 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 evolve. 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 rethink the model.

## 6 CONCLUSION

The development of this new project is ongoing. The individual management elements work together and are accessible on the network. The first step of the project has been reached: teams from different backgrounds are currently working on the same tool, every team having taken a few steps towards the others to harmonize the lexicon and to establish a common language. The different modes of representation of objects handled by the archaeologists formalized with an Object language or a relational approach co-exist and the different ways a model is changed to another type are transparent for the user.

The management of data, an omnipresent problem in archaeology, is dealt with in two ways: the first is purely textual and the second is from the object geo-referential point-of-view, these two approaches being accessible over the Internet.

The first aspect, more traditional, because of its textual interface, allows classical operations on a DBMS. The georeferencing implies a point-of-view closely linked to the knowledge that we have about the handled objects. The use of a three-dimensional model as an interface to the DBMS 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 content of the database (position, orientation, dimensions) and on the generic knowledge of the object (theoretical shape, default values, relationships between diverse objects). 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 pertinent interface between the user and the DBMS.

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