ORTHOPHOTO IMAGING AND GIS FOR SEABED VISUALIZATION AND UNDERWATER ARCHAEOLOGY

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Abstract: We present here the first step of an interdisciplinary work dealing with underwater photogrammetry and archaeological data management. In the framework of a phd project we develop a set of tools from underwater data capture to 3D underwater GIS for archaeological excavation. The phd project, managed by Julien Seinturier, is monitored by Odile Papini for the data fusion aspect and Pierre Drap for the underwater photogrammetrical aspect. The project is financed together by the French Region PACA and the COMEX firm, specialized in underwater exploration.

In this paper we present the first step experimentation on and underwater archaeological site in Corsica managed by the DRASSM and excavated under the scientific responsibility of Franca Cibecchini.

After a brief archaeological presentation of the site we'll start by a description of the photogrammetric survey phase, made during the excavation, in the same time that a traditional manual survey make thanks to the shallowness site aspect. The first step is an orthophoto production. Buoys and scale bar are present on the site in order to permit orientation an model scale.

If the orthophoto produced can't replace completely the manual survey made in situe, (this kind of survey is, in the same time, an archaeological interpretation made by the expert in the best situation of observation) the archaeologist can have a lot of benefit using this kind of representation. The orthophoto is a photogrammetric product, easy to obtain once the photogrammetric orientation is done and considering a more or less plane seabed, enough accurate for a first site representation. Moreover, due to the small scale photograph the orthophoto generation carry out a lot of very interesting huge quantities of qualitative detail.

Then we will present the way to use this site representation as an interface to the database, managing all the site archaeological data, from the artefact representation and localization to the bibliography and iconography linked.

The two dimension of this stratigraphy approach allowed us the use of traditional and free GIS software as GeoTools and SVG GIS package. For each step of the excavation, referring to a different deepness of the same site, we can produce a 2D representation used as a database interface.

The next step presented here, yet under development, is the data management in term of coherence, abstract theoretical model and data fusion. The artefact are carried out of the seabed and then analysed in laboratory month after the excavation process. So we have for each object, several information coming from different medium, for example underwater photogrammetry and direct observation in laboratory, we have to develop a strategy to merge these different data often obtained from different accuracy measure system.

The last but not the least step of this project is developed with the Comex firm. We plan to develop an integrated photogrammetric tool, using a ROV, digital camera and video control, in order to be able to make this kind of survey completely diver less.

KEY WORDS: Under Water Archaeology, Close range Photogrammetry, Seabed visualization, Information System.

1. The wreck

The wreck was discovered in 1962 by sportive divers in shallow waters (around. 3-4 m), in front of the beach of Cala Rossa, on the Northern side of the gulf of Porto Vecchio, (south-east Corsica). The divers recovered most of the visible material, only Greco-italic amphorae, without doing a real excavation. B.Liou ([Liou, 1975]) carried out a rapid survey in 1974, which brought to light some other Greco-italic amphorae, one Punic amphora and some fragments of tableware. The importance of the site already emerged from these first discoveries. This is one of the few wrecks belonging to the III century B.C. with a main cargo composed of Greco-italic amphorae bearing many graffiti in archaic Latin.

Due to the importance of this site, the French DRASSM decided to invest in further archaeological searches. From October 2003 a real archaeological excavation took place, directed by H. Bernard (DRASSM) and by F. Cibecchini.

The excavation covered a main area of 16 m^2, a rectangle of 4 x 6 m, divided in 24 squares of 1 x 1 m with SW / NE direction.

This particular situation of the sea bottom, with a strong dispersion of fragmented materials mixed with tree branches and stones, could be explained by rather violent floods of the near Ozu torrent.

The exact origin of the wreck is not yet clear: we still need the results of the minero-petrographic analysis of the fabric, as well as further information from the next archaeological campaign (October 2004).

The cargo seems to be more heterogeneous than we believed up to now, consisting of ceramics from the central Thyrenic coast of Italy together with other ceramics probably from the Punic world (Carthage, the Hiberic Peninsula or Sicily). The chronology of the wreck seems to be confirmed in the second half of the III century B.C., most likely in the last quarter of the century.

2. The previous expérience

This work is part of a trans-disciplinary work initiated five years ago between several research institutes dealing with archaeology (DRASSM), photogrammetry (MAP and ENSAIS), computer science (SIS in Toulon) and a private company dedicated in underwater exploration (Comex). During several campaigns we have resolved a set of problems in order to proceed to a photogrammetric survey in very deep water as well as in shallow water. In particular this work uses tools and methods developed during the Grand Ribaud F excavation, managed by Luc Long (DRASSM) ([Drap et alii, 2001-B] and [Drap et alii, 2003])

2.1 Photogrammetric Orientation

The survey phase was done as an aerial photogrammetry but without any control points.

Curiously one of the main difficulties was that the wreck was in shallow water. The depth was approximately four meters and the photographer-diver was near the surface which is really problematic for the stability.

The selected method was to minimize the time of intervention. A set of rulers to put the model in scale and several buoys for vertical reference. (The buoys were made with some perforated table tennis balls- fig 1).

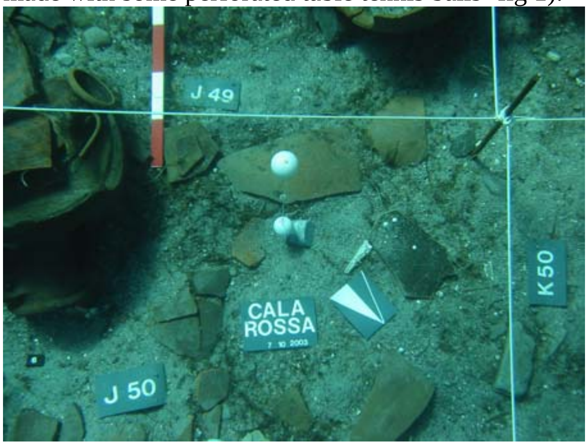

Fig.1. *Seabed photograph extract from photogrammetric strip. Ph. F. Cibecchini.*

2.2 The calibration process

The camera calibration in multimedia photogrammetry is a problem already identified since almost 50 years ([ASP, 1980] p. 838). You can refer to [Maas, 2000] to have an overview of the state of art of this field. The problem is not obvious, the light beam refraction through the different dioptre (water, glass, air) introduce a refraction error which is impossible to express as a function of the image plane coordinate alone.

A lot of authors give some solution more or less simple, usually with iterative process, in order to solve this problem. [Kwon, Lindley, 2000.] [Maas, 2000], [Justin et alii, 2002]. Even if Hans-Gerd Mass give a solution simplified it refers always to a 'standard case' of multimedia photogrammetry : only three media, an object in liquid, a plan-parallel transparent plane making the separation between the object and the sensor located in air.

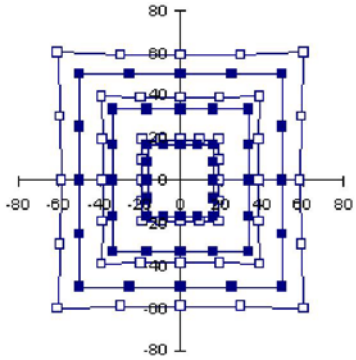

Fig. 2. Refracted and non refracted coordinate of measured point on three square rims [Kwon, 1998]

[Kwon, 1998] gives a representation of this distortion as a pin-cushion distortion in a particular case: a set of control points are marked on a plane, the control plane is parallel to the image plane and the camera axis passes through the center of the control plane. In these conditions we have a distortion represented in Figure 2

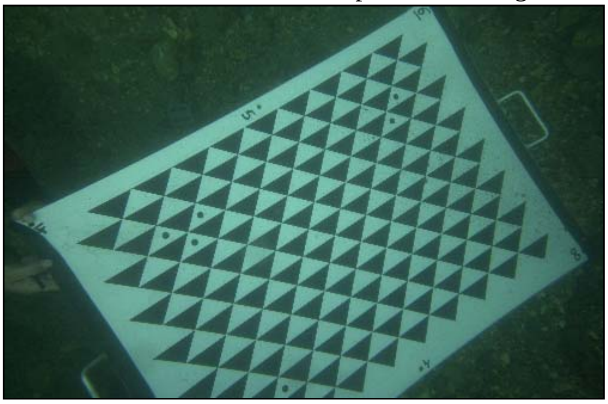

Fig. 3. Photograph for calibration process with Photomodeler. Calibration grig lend by Comex.

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To solve this problem in standard condition (normal camera housing, cheap software for digital photogrammetry) it wasn't possible to use this academic way. It was not possible to modify the colinearity equation in PhotoModeler and here was no possibility to get a professional housing for our cheap camera (Canon Ixus 300) The housing we used was from Canon and had a special lens for which the calculation assume water in the object space. The use of wide angle was then possible. In these condition, according the approximate pin-cushion distortion model from [Kwon, 1998] and keeping in mind that for this kind of a survey we weren't dealing with millimetres in term of precision, we decide to use a very simple way to calibrate the camera : the PhotoModeler calibration module. (fig.3)

We just considered the set housing-camera rigid and undeformable and we made a calibration as if we were in air. The pin-cushion distortion is here modelized by focal length variation (increase) and radial distortion.

3. A new Medium

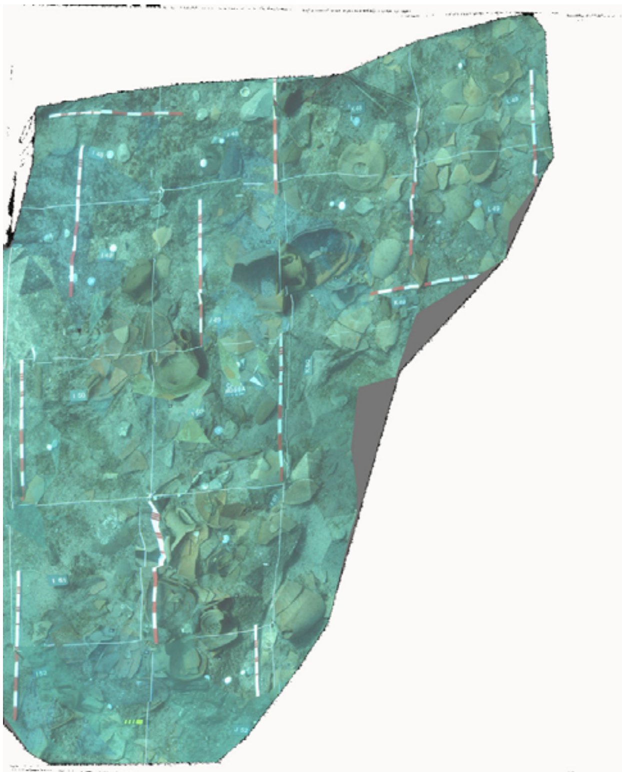

Fig. 4. OrthoPhoto generated by Photomodeler™ after the orientation phase. Scaled document, we can see all the amphorae pieces represented in the fig. 5.

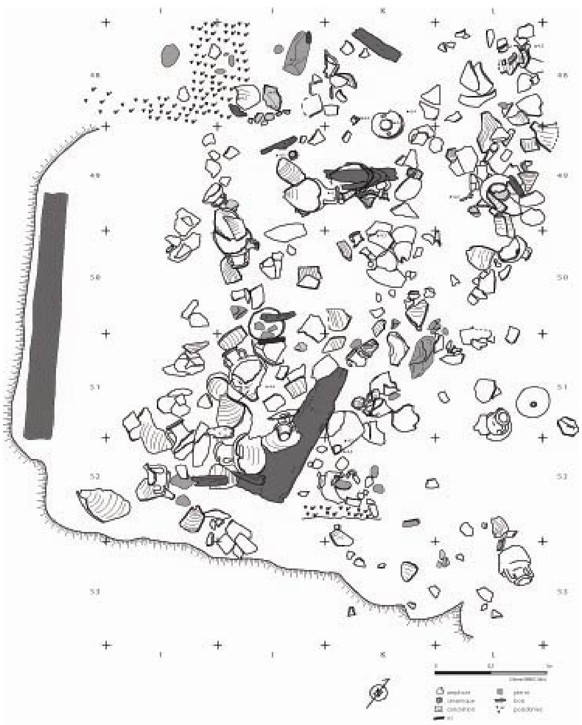

Fig. 5. Map of the wreck made *in situ* by the divers.

For archaeologist, and especially underwater archaeologist, digital photogrammetry is considered as a new technology, not really easy to use and producing document which are not easy to read.

Until now the map produced by archaeologist are established in situ, diving. This method carried out two kind of problems: accuracy and time consuming. Photogrammetry and ortho photo should be an answer but we have to deal with another component: history and symbology. A design made by an expert is an interpretation of the scene, readable easily by other expert of the domain. An ortho photo, even if it is more accurate, if it give a lot of qualitative data is a document without interpretation, without knowledge.

If we want the archaeologist to use this kind of document we have to insert knowledge inside, this is the main part of our actual work and we present here our actual state of development in this direction.

4. Knowledge and Photogrammetry

Since almost 10 years we are working on a link between photogrammetry and knowledge through the Arpenteur project. Arpenteur, as **AR**chitectural **P**hotogramm**E**try **N**etwork **T**ool for **E**d**U**cation and **R**esearch is a set of software tools developed in the frame of the MAP research Group, a laboratory of the French National Research Council (CNRS). These tools are web based and rely on IP communication techniques. Examples can be consulted at http://www.arpenteur.net.

The project main objective is founded on the idea of a process guided by the information related to the studied field. Concerning archaeology, the goal is to allow experts to use their knowledge to produce results which ideally meet their wishes. [Barceló, 2000] The results can be shown as documents, visual files, or as a body destined for a database. For this purpose the system makes a set of tools available to the experts and allows them to formulate hypothesis and the corresponding measurements related to their field of investigation. As an example, we can consider the creation of a *corpus* representing the objects in their field of investigation.

In order to minimize the photogrammetric expertise during the plotting phase, the use of knowledge is made in three different steps in the photogrammetric data processing.

4.1 The first step: geometrical knowledge

Geometrical knowledge of the surveyed scene can be used in order to help the homologous point determination. In this context the I-MAGE process (as **I**mage processing and **M**easure **A**ssisted by **GE**ometrical primitive) (Drap, Grussenmeyer, Gaillard, 2001) is a convenient help for the user. After the manual measurement of some points on the object-surface, the user can focus his attention on the semantic way, observing only one picture when the system makes automatically 3D measurements.

4.2 The second step: archaeological knowledge

The second step is using archaeological knowledge to obtain a complete representation of a measured artefact. This work, published last year, (Pierre Drap, Julien Seinturier, Luc Long. 2003), is managed in three phases:

1) 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.

2) As photogrammetric measurements are highly incomplete (the object is seen only partially or may be deteriorated), an Expert System determines the best strategy to inform all the geometrical parameters of the studied object, starting from the measurement process and handling the default data as defined in the archaeological model and the geometrical model. The expert System used is Jess, for more details you can refer to (Jess, 2001)

3) The resulting object is thus based on a theoretical model, dimensioned more or less partially by a photogrammetric measurement. During the exploitation of the photographs the operator can choose the number of attributes of the object which are relevant to measure. The choice of attributes is revisable in time, as for example during a second series of measurements. The system can be used to position in space some objects from a catalogue after a scaling process. For an extended measurement process, in addition to positioning in space, the system allows analysing how the measurements vary from the theoretical model (e.g. deformations or erosion). After all the system allows checking the model relevance.

This approach has been used in underwater archaeological surveys, during the excavation of the Grand Ribaud F Etruscan wreck with more than 1500 amphorae of the same typology. (Grand Ribaud F, 2000-2004)

4.3 The third step: knowledge to manage results

In an archaeological context, a lot of data is produced from various sources. Heterogeneity is one of the main problems of this kind of applications. It can be found at several levels from the given data to the target format. We mainly focus on three kinds of heterogeneity due to multiple data sources, differences between objects of study and changes between versions.

4.3.1 Heterogeneous data sources

The first kind of heterogeneity comes from the differences between data sources. In our application, they can be divided in two main families whether they are calculated or produced by an expert. The first ones are often well structured (i.e. vector or matrices) whereas the second ones are less structured (natural language). We call them semi-structured data and it is important that they can be more structured than full text. We are dealing with multimedia data, mainly pictures and semi-structured text.

That is why the data model must provide a way to federate heterogeneous data across multiple data sources. The user must be provided with a unified view of data.

4.3.2 Dealing with objects specificity

The second kind of heterogeneity comes from the differences between studied objects, for instance between amphora and parts of amphora or even between amphorae themselves. Many data come from pictures, thus if not enough pictures are available, some pieces of information can be missing. Another problem comes from the fact that some objects may be incomplete (i.e. broken amphorae).

The data model must also provide tools to express variations between objects from the same class and different level of details in the description of an object.

4.3.3 Temporal heterogeneity

And last but not least, we have to deal with changes. The changes can take place at several levels from values to data structure. For instance, the values can change between underwater and surface measurements; this kind of changes can be managed with modern database systems. But in our application, the classification of data (i.e. relation between families of objects) and the inner structure of those objects depend on the knowledge of experts and this knowledge can change when new measures are done. The data model must provide an easy way to change the schema of data and application build on top of it must be able to deal with change.

4.3.4 Using XML for modelling photogrammetric Data

For all the reasons presented in the previews sections we have chosen XML as our data model. XML is *de facto* the standard for federation and exchange of data between heterogeneous applications. We use SVG (SVG, 2001) to generate a *view* on the result and to visualize the data fusion operation. This will be described in section 4 of this paper.

5. Data Storage and publication

5.1 General description of the data and goals

ARPENTEUR allows the user to produce data relative to a photogrammetric survey. Information coming from the knowledge of the measured objects and the site is added with these data. The communication between measured data and information on the survey is of primary importance in such a system, and provides a synthesis of all information available in a survey. It makes it also possible to check the results in a visual way, and allows an automatic check of the data coherence. The format of data storage must thus answer these concepts, but it must also be integrated perfectly into the ARPENTEUR package. For that it must allow the publication of data on the Web, but also to be simple of installation and use.

5.2 SVG Publication

SVG Format (Scalable Vector Graphics) is the standard of the W3C for the publication of graphic interfaces. This format based on XML is visible thanks to a specific visualization tool, developed for many operating systems and freely usable. For specification and example you can visit the web site (SVG, 2001). A SVG file is a file in XML containing information of all kind, geometrical information being able to be posted and with which one can interact. In ARPENTEUR, SVG files are used to provide a first level interaction with the user. We speak about first level interaction because the user can choose information to display but without possibilities of modification. The interface of SVG visualization is in two parts. The first part gathers the photographs used for the photogrammetric statement. The points raised for each measured item are shown on these photographs. By selecting a group of points, the user can then activate one item. The second part of the interface contains all information on one activated item. This second part depends on the type of item and gathers photogrammetric information, measurements but also characteristics defined by the archaeologists or any other expert. The first advantage of this interface of SVG visualization is that all actors of the survey can check the coherence of the data. Indeed, the photogrammetrist can check the points measured on the photographs, whereas the archaeologist can check the coherence of the data suitable for item (natural, observations...).

At the technical level, the use of this interface requires a Web browser and a SVG plug-in (for example the Adobe one). This interface is thus convenient. Moreover, although being a format of representation rather heavy, the performances of SVG interfaces are very satisfactory, even for important surveys. It is also possible, thanks to the two modes of publication of the present results, to have an automatic web publication of the results.

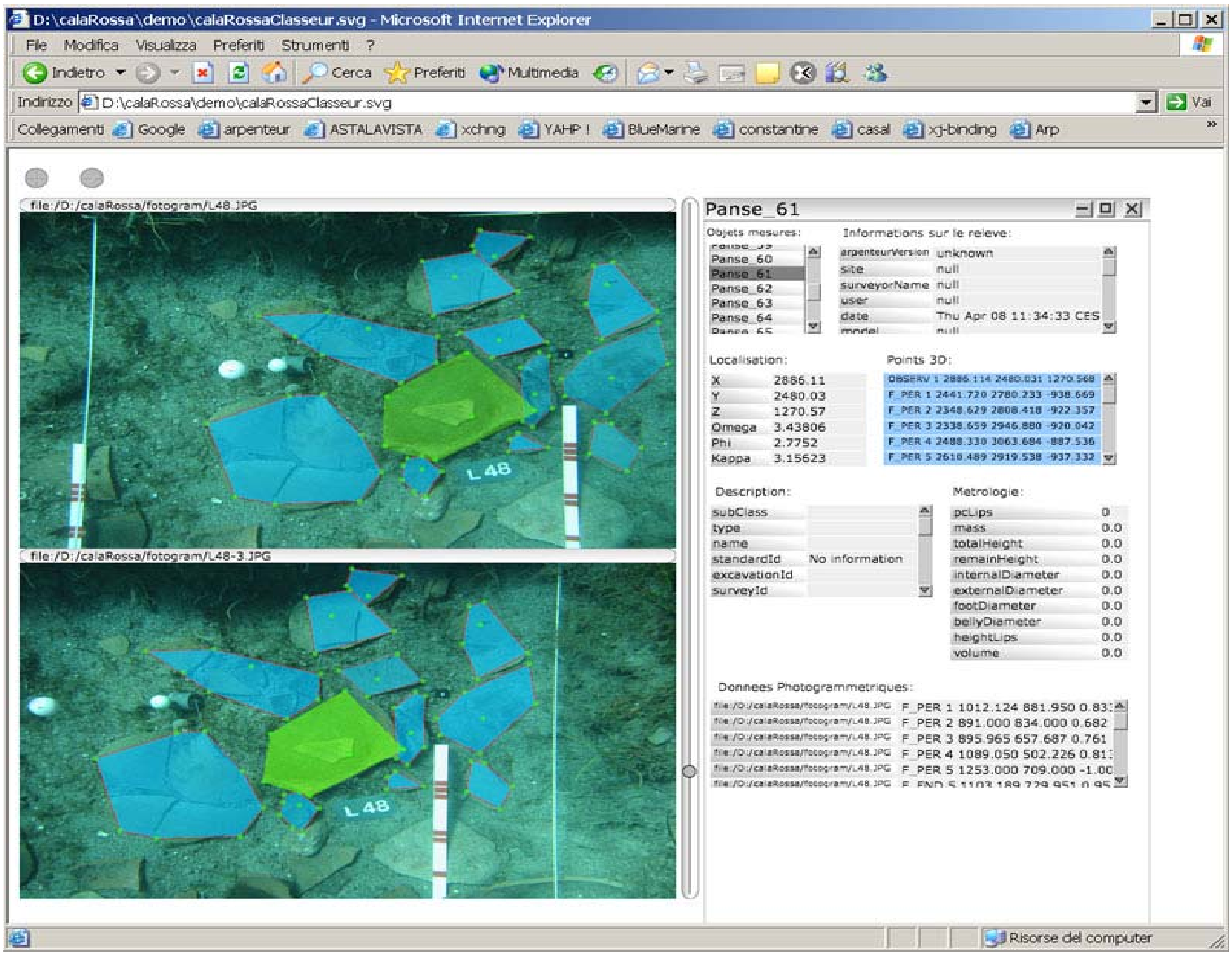

Fig. 3. Automatic SVG file generation showing both amphorae fragments and linked data. Experimentation made on the underwater "Cala Rossa" archaeological excavation in Corsica, France.

5.3 Consistency verification and data merging

Finally, XML allows us a fast access to the data. Considering this characteristic, we will be able in a future work to scan XML files and detect some inconsistencies in order to go toward an automation of some corrections, such as for example redundancy in measurements or bad classification of the objects.

The problem of data evolution becomes crucial as soon as several measurement methods are involved, or when different sources are used to establish the final data. We must manage data coming from both photogrammetric measurements and other more or less direct manual measurements. All of these measurements are incomplete and represent the same object at different time.

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

6. Conclusion and future work

The work presented here, is part of a strong collaboration between several research laboratories and a private company specialized in underwater investigation. Our goal is to produce a new tool mixing photogrammetric survey and GIS techniques tailored for archaeologists.

The new version of Arpenteur has a synthetic approach of data fusion in SVG in order to merge and clarify the results after the plotting phase.

These developments are part of the general framework and the main objective of the Arpenteur research program is to establish a link between knowledge and geometry in a simple photogrammetric tool able to be freely used by archaeologists.

Since all the data, (photo orientation and results from the plotting phase) are stored in a unique XML repository, it will be possible, in a near future, to export data in a 3D visualization tool (Java3D and X3D) and allow us a bidirectional access to non graphical data through the 3D interface. The work presented here is the first step to a photogrammetry based Information System dedicated to archaeology and architecture.

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