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HAL Id: halshs-00264008

https://shs.hal.science/halshs-00264008

Submitted on 20 May 2008

# PRESENTATION OF THE WEB BASED ARPENTEUR TOOLS: TOWARDS A PHOTOGRAMMETRY BASED HERITAGE INFORMATION SYSTEM

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**Commission VI, WG VI/2-4**

**ABSTRACT:**

The paper presents the current state of the ARPENTEUR project (**AR**chitectural **P**hotogramm**E**try **N**etwork **T**ool for **EdU**cation and **R**esearch), and principally the new photogrammetric module, the 3D measuring and modelling module including an automatic DSM densification tool and the formalization of photogrammetric data in XML.

This JAVA[TM] based package has been proposed as a WEB tool since 1998. It is now also available as standard software running on Windows or Linux platforms.

Several significant ideas are supporting this project:

- The photogrammetric module has been based on the orientation of couples of images (not necessarily stereo pairs, and not necessarily from metric cameras) and well known steps of interior and exterior orientation. Image processing functions from the Java Advanced Imaging Library as well as an area based correlation method for the measurements of homologous points are included.

- A semi-automated Primitive Measurement Method called **I-MAGE** (**I**mage processing and **M**easure **A**ssisted by **GE**ometrical primitive) has been proposed for the geometric measurement of 3D model. This method is based on the coupling of image correlation and geometric primitive computation as planes, cylinders, cones and sphere shapes of the object. Five methods of generating DSM automatically are completing the previous modules. These methods based on feature point extraction techniques, well known in aerial photogrammetry, have been adapted to close range projects in Arpenteur. Encouraging results have been obtained.

- The last important point is the choice of XML to formalize object data, as well as photogrammetric data. Automatic links are generated between the 3D representation of the measured object and the XML formalization of the photogrammetric, dimensional and more general semantic data of a project. As the data in XML can be parsed and queried, the links between textual data and graphical representation can be considered as the first step towards an information system dedicated to architecture and archaeology.

## 1. INTRODUCTION

We present in this paper the latest development of the Arpenteur package. ARPENTEUR (as **AR**chitectural **P**hotogramm**E**try **N**etwork **T**ool for **EdU**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 current version presented in this paper remains a web-based photogrammetric tool strongly supported by a link between photogrammetry and the knowledge of the studied field (frequently archaeology or architecture).

Arpenteur is developed in Java 1.4 using the library JAI (Java Advanced Imaging 1.1) and Java3D for 3D visualization. To have access to the result presentation module, a SVG plug-in is required. All this products are available for free from SUN and Adobe web sites.

During the last years we have developed our collaboration with underwater archaeologists and the development presented in this paper has been made in this framework.

## 2. ARPENTEUR

As a tool dedicated to archaeology and architecture, ARPENTEUR benefits from the expertise of two teams working in the field of close range photogrammetry and representation of architectural information.

The main objective in a project is founded on the idea of a process guided by the information related to the studied field. Concerning architecture and 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.

Finally, ARPENTEUR looks like a tool developed for professional architects and archaeologists with minimal intervention of the photogrammetry expert.

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.

## 2.1 The first step: geometrical knowledge

Geometrical knowledge can be used in order to help the homologous point determination. We know that in the field of architectural or archaeological photogrammetry we can often have a geometrical approximation of the measured surface. 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. In this paper we present namely DSM tools based both on a surface approximation and on image processing considerations.

## 2.2 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), the 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 architectural 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)

## 2.3 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.

### 2.3.1 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.

### 2.3.2 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.

### 2.3.3 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.

### 2.3.4 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.

## 3. AUTOMATIC GENERATION OF 3D MEASURES

Whereas in aerial photogrammetry automatic generation of DSM is becoming mastered, it remains a research topic in close range photogrammetry because of the greater complexity of the scenes. A relevant result can be obtained provided that a pre-existing network of 3D-measures is to be densified. With the aim of measuring new points automatically, two multi-images approaches have been explored: on the one hand the area-based matching and on the other one the feature-based matching.

Five different steps follow the previous principles considering simple algorithms based on one approach to algorithms that combine both. All these methods have been implemented in ARPENTEUR and complete the I-MAGE module.

### 3.1 The first phase: Roma, 3-D Automatic Measurement Principles

ROMA, **R**epresentation of **O**riented **M**odel for **A**rpenteur, is the first tool built on the I-MAGE method developed in the framework of the Arpenteur Project (Drap, Grussenmeyer, Gaillard, 2001). Roma allows automatic measurement using a set of oriented photographs and a mesh visible on these photographs.

ROMA uses a simplified geometrical model, i.e. a surface mesh, image correlation and oriented photographs to determine 3D points visible on photographs and included in the mesh.
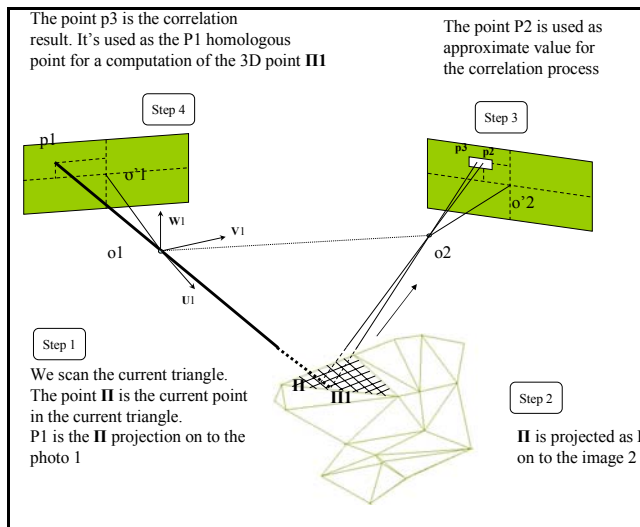


Figure 1. Principles of ROMA

We use four steps in this Semi-automated Primitive Measurement Method, considering that a mesh has been measured and computed from a set of 3-D points visible on at least two images:

✓ For each triangle of the mesh we scan triangle and get point ∏. Each point ∏ is projected as p1 on to the photograph 1;

✓ ∏ is projected as p2 onto the second image;

✓ Point p2 is used as an approximate position to initiate the area based correlation process with p1;

✓ Point p3 is the result of the correlation; p1 and its homologous p3 are used for the computation of the 3-D co-ordinates of ∏1.

This first implemented algorithm generates automatically regularly 3D-points through area-based matching. Initially a set of points was measured by the user. This collection of points is triangulated and the regular scanning of the 3D-surface of each triangle provides theoretical 3D-points which are projected on a reference image. The semi-automated Primitive Measurement process called I-MAGE supplies measured 3D-points thanks to automatic correlation with other images.

As a geometric-construction-based method, it gives a regular grid but the correlation process tends to fail when it works on low-textured image zones.

## 3.2 Other Simple algorithms

On the contrary, the second algorithm uses the featured parts of images. Firstly, interest points are extracted by Harris' improved algorithm (Harris & Stephens, 1988) considered as the most efficient according to (Schmid et al. 2000). Then the homologous points of the reference image interest points are searched among other images. But the correlation process is limited by two geometric conditions. On the one hand, out of continuity constraint, when a point belongs to the projection of a triangle from the initial network, his homologous point must be in the projection of the same triangle in the other image. Moreover, each homologous point is checked by exchanging reference and search matrix.

To improve the number of matched points, an iterative method that applies this principle has been implemented. Indeed, corner detector can classify the points according to their degree of interest. Usually only the best points are conserved. It would not be judicious to take a larger part of points because it would raise the number of wrong matching. However we observed that if a point is repeated, his degree of interest has approximatively the same rank in the other image. Then the algorithm can match feature points progressively by rank.

## 3.3 Combined algorithms

Even though the feature-based matching is more robust than the area-based matching, it depends entirely on the repeatability of the detector. Another idea is to combine the two principles to avoid this drawback. For each triangle of the network of measures chosen by the user, a reference image is determined and the feature points are calculated in this area. Then supposing that those points lie on the 3D-triangle, their homologous points are found by correlation in the other images through the I-MAGE process.

If this method provides many successful matching, the repartition of the points can be inhomogeneous on some scenes if interest points are clustered.

A fifth algorithm is based on the same structure as the previous one but it forces the points to be regularly disposed. As in the first method, a regular set of points is created on the surface of the triangles. Then those points are projected on a reference image. But instead of matching them directly, best feature points are calculated in their neighbouring and the homologous points of these new points are searched in other images.

## 3.4 3D Viewing

In order to visualize the reconstructed surfaces of the scenes, a VRML export file can be generated. Thus, a triangulation of the 3D-points including the initial network and the collection of new measures is necessary. Since some points are too close to each other for a good viewing, a part of them is eliminated. A local optimization deletes the points which disappearance would modify the structure of the surface, according to the chosen criteria presented in (Schroeder et al., 1992). Then relevant images are projected on the triangles of the grid.

## 3.5 Results

The five implemented-algorithms have been evaluated and compared using different photographed scenes. Some objects with a well-known simple geometry visible on the photography were used to estimate the accuracy of the methods.

| Methods | Advantages | Drawbacks |
|---|---|---|
| Area-based matching | Many points Good repartition of feature points | Wrong matching on low-textured images and problematic images |
| Feature-based matching | Good precision, especially with low-textured images | Very few points |
| Iterative feature-based matching | Good precision, especially with low-textured images | More points than in the previous method |

| Combined matching | Many points | Bad repartition of feature points, clusters of points on textured area Wrong matching on problematic images |
|---|---|---|
| Regular combined matching | Many points Good repartition of feature points | Wrong matching on problematic images |

Table 1.  Results from the five methods.

These tests lead to several conclusions described in the following table. More generally, they give encouraging results, even on problematic images (repetitive structure for example). Moreover, the experience shows that the methods do not have the same efficiency according to the nature of the scenes. And increasing the number of generated points corrupts the quality of the measures. While the implementation of a suitable algorithm is expected, the method to be applied must be chosen case by case.
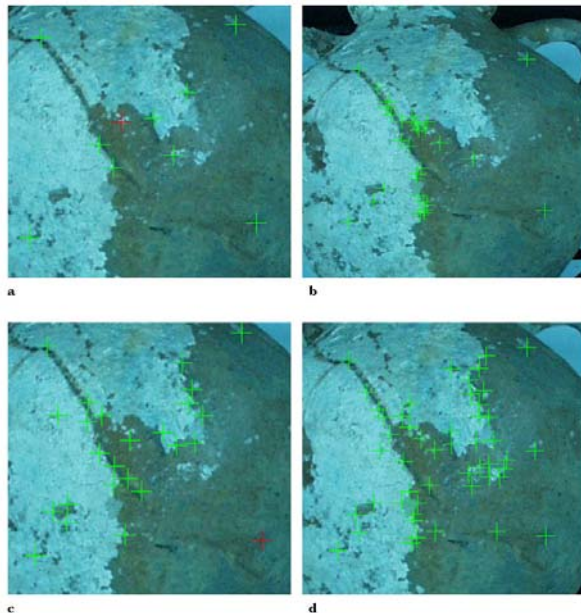


Figure 2.  Position of the new generated points.

We can see on fig. 2 the distribution of the points calculated according to the used method:
a) Iterative feature-based matching
b) Combined matching
c) Feature-based matching
d) Regular combined matching
The experimentation was done on an Etruscan amphorae coming from the excavation of the Grand Ribaud F.

**3.6  Conclusion about DSM**

Among the numerous possible applications of this process, the completion of laser measurement as presented is very useful. To survey places where laser instrumentation is too difficult to settle, classical photogrammetry is a good compromise to get automatically a dense network of measures.

**4.  DATA STORAGE AND PUBLICATION**

**4.1  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.

**4.2  XML, a standard for data storage**

The data used or produced by ARPENTEUR belong to three groups: photogrammetric statements, information on the survey and measures. The backup of these data thus requires the ability to store sorted information in classes. XML format makes it possible to create files that gather the information sorted out of tree. This is conceptually interesting. Moreover, from a practical point of view, the XML is a standard resulting from World Web Consortium (W3C) very widespread in the medium of research and in companies. You can see the W3C recommendation in (XML, 2000). XML is particularly appropriate for our application. XML has also other interesting characteristics. First of all, a file XML is a simple textual file, what allows an edition and a very simple distribution. Then, a XML file is readable without having to make specific operation (contrary to the file of data bases for example). More, the textual nature of the file makes it sensitive to compression. As XML format is introduced, we can describe its specific use in ARPENTEUR.

**4.3  XML: the core of data processing**

The choice made for the development of ARPENTEUR is to limit to the maximum the redundancy of information. The data are all stored in a single way. The use of these data then implies the treatment of XML files, being used as common core to all the chain of use and treatment of the application. Data are stored in three XML files. The first one contains the photogrammetric model of the survey, the second one contains expert knowledge necessary to the survey and the third one the photogrammetric statements and measurements, like all information relating to the survey. For example, for the survey of the excavation of a wreck, the first file contains information relating to the calibration of the diving apparatus and the orientation of the photographs. The second file contains knowledge to measure on the objects (amphorae...). The third contains the results of the photogrammetric statement, the measurements of the objects as well as the remarks and information given by the archaeologists. From these three files, all information concerning a survey is available.

**4.4  Simple data publication: XSL**

A transformation of the XML documents using XSL style sheets is carried out. See example on the W3C web site (XSL, 1999). This transformation makes it possible to visualize the majority of the data in a static way, without any possibility for the user of interacting with those. This representation allows a

fast access to all information. The utility of this simple method of publication is to allow a fast awareness and a simple overview of the results. For a more advanced use, SVG publication of the results is also possible.

### 4.5 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.
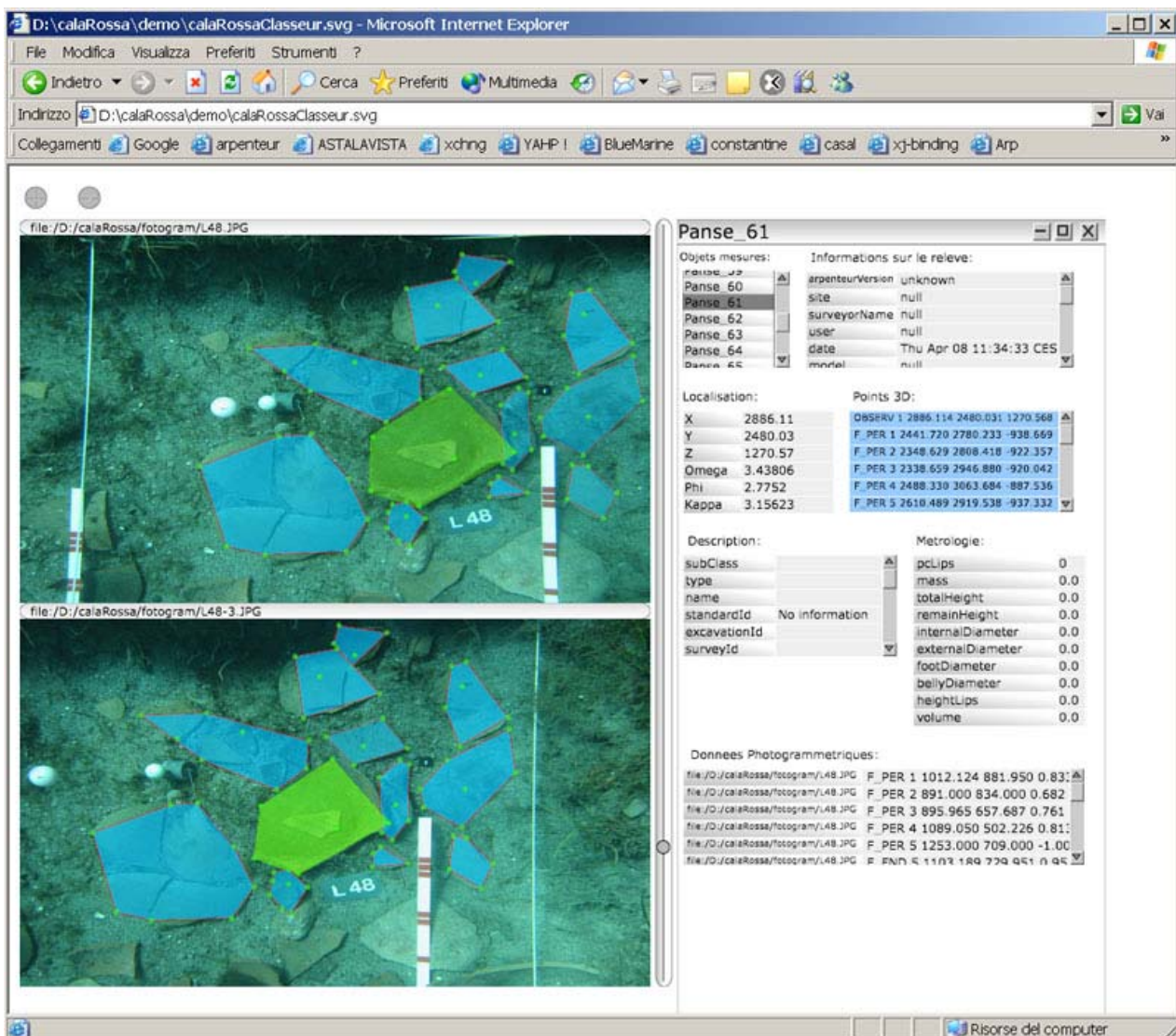


Figure 3.  Automatic SVG file generation showing both amphorae fragments and linked data.
Experimentation made on the underwater "Cala Rossa" archaeological excavation in Corsica, France.

### 4.6 Web publication

Formats used (XML, XSL, SVG) for the storage and the publication of the data are strongly Web oriented. It is possible to create Web publications of information relative to a survey by setting up on a server a Web server as well as a server allowing the processing of data in XML (like Apache Tomcat for example). The use of a server has two advantages. First one allows a large audience to display the results of a survey and thus to facilitate the access to the data. Second one is to allow teams working in various places on the same survey in openness (as within the framework of international collaborations).

### 4.7 Consistency verification and data merging

Finally, XML allows 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 (Odile Papini, 2001).

### 5. CONCLUSION AND FUTURE WORK

In this new version of Arpenteur we have presented two kinds of developments: a DSM tool, fully integrated in the measuring process of Arpenteur and a synthetic approach of data fusion in SVG in order to merge and clarify the result file after the plotting phase.

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

As 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 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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