A MERGING DATA TOOL FOR KNOWLEDGE BASED PHOTOGRAMMETRY: THE CASE STUDY OF THE CASTLE OF SHAWBAK, JORDAN

J. Seinturier[1], P. Drap[1], O. Papini[3], G. Vannini[2], M. Nuccioti[2]

[1]MAP, umr CNRS 694, Ecole d'Architecture de Marseille, France (Pierre.drap, Julien.Seinturier)@gamsau.archi.fr
[2]Dipartimento di Studi storici e Geografici dell'Università degli Studi, Florence, Italy (vannini, nuccioti)@unifi.it
[3]Université du Sud Toulon Var, La Garde, France (papini@univ-tln.fr)

KEY WORDS: Archaeology, Automation, Interactive, Internet/Web, Survey

ABSTRACT

The present paper addresses an approach for merging heritage survey and archaeological knowledge. The theoretical framework is the integration between photogrammetric survey and documentation process, practically used in different archaeological excavation. Merging surveyed geometries and knowledge is a complex task. Many variables have to be considered during the process of merging. Photogrammetric survey results and knowledge can be actually seen as information. Information is sorted by source. A source is a set of information provided by the operators involved in the excavation process. Such operators can be archaeologists, photogrammetrists, or any other researcher (i.e. a topographist) involved in the study. The merging process involves the verification of the consistency of different sources and the aggregation of all the information from the sources into a global result. Each source, respectively each operator, owns a personal representation of his knowledge domain, a photogrammetrist uses geometrical primitive and 3D representations of the object surveyed, an archaeologist has a textual and semantic representation of the objects. Merging together all these sets of information needs a tool which can be easily operated by most of the participants in the research and which can furthermore manage the 'multiple knowledge' on the surveyed object. This tool, called Ametist, an acronym standing for Arpenteur ManagEment Tool for Interactive Survey Treatment, uses a simple interface for displaying results and knowledge in various form (textual, 2D map, 3D scene, XML). This tool can make an automatic merging of the "multiple knowledge" and its merge engine can solve conflicts (object identification mismatch, measure of an object taken several times, spatial collisions etc.). When conflicts cannot automatically be solved the application can report about inconsistency errors and ask a user to manually correct the information involved. As inconsistency can be present in any information, all operators have to be able to use the interface. The tool provides a simple easy to use interface. This document will first address the concept of knowledge based photogrammetry (with ARPENTEUR) and then deal with a presentation of 'Ametist'. Finally, a real case study will be considered to highlight the first results of such a system in the frame of a French Italian scientific partnership with the "Dipartimento di Studi storici e Geografici" of the University of Florence, in charge of the archaeological research. The selected case study is the Castle of Shawbak, in Jordan, known in medieval written sources as the "Crac de Montréal".

1 INTRODUCTION

The Arpenteur project provides a framework for knowledge based photogrammetric survey. It has been used several times during archaeological excavation as for instance at Aleyrac abbey [Drap, Hartmann-Virnich, Grussenmeyer. 2000]. In this paper, we present a new extension of the Arpenteur project: "Ametist", an acronym standing for **A**rpenteur **M**anag**E**ment **T**ool for **I**nteractive **S**urvey **T**reatment. It is a new part of the project which provides an easy to use system of survey management. This application can perform various posts-processing treatments on data issued from Arpenteur. Operations include data verification, merging different data sources or export data in various formats (such as XML and in the near future VRML). This paper first presents the archaeological research at the site of Shawbak, Jordan. Then a brief description of the Arpenteur knowledge based photogrammetry project is also provided. An introduction of Ametist will follow also addressing the issue of the Arpenteur data merging. Finally an overview of the results gathered on the first experimentation will be given, together with future research perspectives.

2 THE ARCHAEOLOGICAL CONTEXT

The archaeological study is led by the *Dipartimento di Studi storici e Geografici* of the University of Florence, Italy. The work in Shawbak is part of a wider research aimed at analysing the structural aspects of feudal society all over the Mediterranean basin through a sampling strategy based on 'historical regions' to define spatial contexts.

One such a region is actually the Trans-Jordan of Crusader-Ayyubid age, organised according to western European standards between year 1100 and 1187 (when the Crusader settlement was abruptly dismantled after the defeat suffered by the army of the Latin Kingdom of Jesrusalem).

The settling strategies adopted in the area by king Baldwin I and his followers resulted in the building of large rural fortified settlements (similar to the ones contemporarily created by the feudal aristocracies in southern France or in Italy) located on a line connecting present-day Amman to the red sea.

Figure 1: A selection of the archaeological sample used to achieve an actual knowledge of the material aspects of feudal society's lifestyles across the Mediterranean basin. All projects are part of the Strategic Research Progamme 'The Mediterranean feudal society: archaeological profiles' supported and directed by the University of Florence.

Such a display of economic and military means was indeed justified with the attempt to control the most important road system of the Arab world (connecting Damascus to Cairo and to the desert 'higways' leading to the Arabian peninsula), and had the ultimately effect to bring back to life the historic frontier of Roman empire: the so-called *limes arabicus*.

The area spanning from the ancient city of Petra and the site of Shawbak can be considered a real keystone for the Crusaders' project, as can be easily demonstrated by the early interests and the specific instructions given by the king himself to organise a settling system right there.
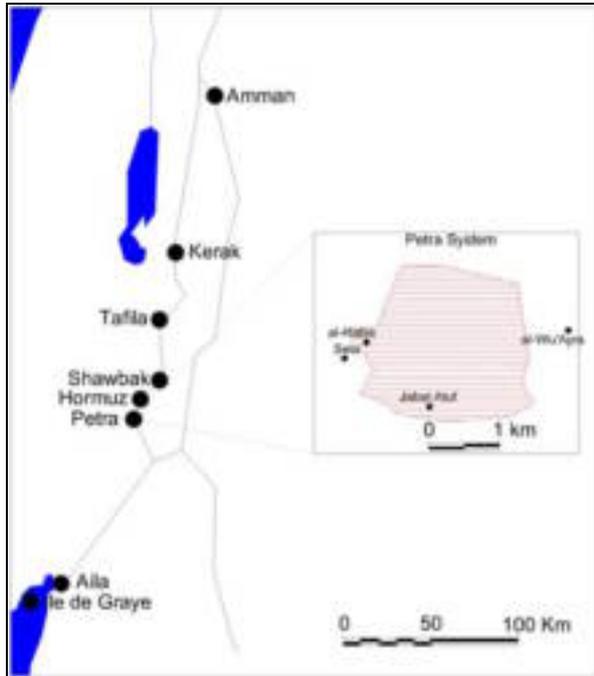

Figure 2: A schematic view of the European settling system in Transjordan at the beginning of 12th century

The area encloses in fact a number of fortified villages, known in written sources as *castra*, literally castles. All of them, except one, are concentrated inside (or in the near vicinity of) the urban area of ancient Petra. Two of them (al-Wu'Ayra and al-Habis) have been widely investigated in previous years by means of traditional and 'light' archaeological means (see [Drap et alii, 2005] for further details), while a third is currently under study: the castle of Shawbak.

Located approximately 25 km north of Petra, the archaeological-monumental site of *Mons Regalis*/Shawbak can be considered one of the best preserved rural medieval settlements in the entire Middle East. Its key characteristics include a relevant time-spanning readable stratigraphy (from Roman to Othoman periods), an astonishingly well preserved nucleus of still standing medieval historical buildings and (connected with the above) a primary role played over the centuries by the castle (from Crusader age) in the political and military control of the whole Transjordan.

Archaeological readings at the site encountered since the beginning a number of problems relating to data management. In particular it was required to find a suitable solution that allowed to gather, edit and query in real-time a very large amount of data belonging to different documentary series (i.e. archaeological textual records, archaeological survey, architectural plans/elevations, 3D digital terrain models etc.) so as to maximize the possibilities of historical interpretation.

Knowledge based photogrammetry appeared to provide an extremely valuable solution for the envisaged archaeological needs.

Figure 3: The Shawbak castle

3   KNOWLEDGE BASED PHOTOGRAMMETRY

3.1 The Arpenteur project

The ARPENTEUR project (**AR**chitectural **P**hotogramm**E**try **N**etwork **T**ool for **Ed**Ucation and **R**esearch) started in 1998 by Pierre Drap, Pierre Grussenmeyer [Drap, Grussenmeyer, 2000]. In the past years, the project became both a WEB-based tool and 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[TM].

Arpenteur is a photogrammetric project devoted to architectural survey that offers a simple and efficient tool for archaeologists and architects and that does not require a deep knowledge or expertise in photogrammetry.

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 with the help of experienced researchers of other domains of knowledge, archaeologist or architect.

Examples can be consulted at http://www.arpenteur.net.

The project main objective is founded on the idea of a process guided by knowledge related to one's personal field of study. The results can be shown as documents (XML), visual file (SVG, VRML, X3D) or as a body destined to database. For this purpose, the system makes a set of tools available to the experts and allows them to formulate hypotheses and the corresponding measurements related to their field of investigation.

3.2 Stone by stone survey

The stone by stone survey of the castle is the first step of the Italian – French collaboration (see [Drap et alii. 2005] for a more detailed presentation on the matter). The archaeologist and the photogrammetrist define together a theoretical model of the objects to be measured. In case of a bloc, the theoretical model is an extruded polyhedron, as we see in the figure 4 and 5:

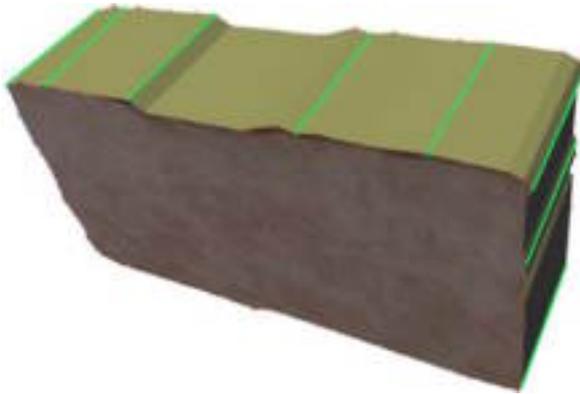*Figure4: A block perimeter easured with Arpenteur*

:

Figure 5: The Figure 4 block, after extrusion and mapping: in VRML

However, when wall masonry is not destroyed, the photogrammetry operator can only see one face of a block (i.e. ashlar). The archaeological knowledge of the blocks used for the construction of the castle enables to generate a 3D model of the real object. As the blocks are box shaped, and as the visible face of a block is almost planar, a 3D model can be generated by extruding the visible face with computed vector. The depth of extrusion is established through the archaeological knowledge of the real objects.

With the semi-automated computation of 3D representation of objects, non photogrammetrist final users have performed the stone by stone survey of a selected samples of walls of the castle (please refer to [Drap et alii, 2005] for further details).

3.3 Archaeological needs

This first experiment has shown new needs for the archaeologists. The first of which is the verification of data generated during the survey. When Arpenteur is used, errors may occur. These errors are of various kinds: Points badly plotted, bad identifiers assigned to objects, incomplete documentation, bad attribute values, and finally software errors. The project has to provide a simple way for verifying surveyed data allowing to modify them in any given case. The second need comes from the number of operators involved in the survey. On very large surveys, as it is the case in Shawbak, a joined group activity is required also for plotting. Different operators have to be able to work from distant locations simultaneously but, when the time comes for merging the whole dataset, the results of operators can conflict. The surveyor needs then a tool for merging all the intermediate results into the final result.

The third need is the management of a large amount of data.

During a survey, Arpenteur produces a lot of information in various formats. Information has to be processed for a later use, according to the wish of the archaeologists. A management tool that can be used by archaeologists is so necessary.

These three needs require specific solutions. Some of them have already be used in the framework of underwater archaeology and can be used also in the present case study. (Drap, P., Seinturier, J., Long, L., 2003,)

4 DATA MERGING

The data aggregation is a complex problem. In most of the cases, a simple aggregation is not efficient because inconsistencies are presents in the different results and generate conflicts. These conflicts are due to two principal causes. As already pointed out a survey can be made by different users also distant in space from one another. This circumstance can facilitate errors in naming the surveyed entities (i.e. two separate entities can be given the same 'ID' or two different IDs may be given to the same entity, as the case would be for an angular ashlar block visible and surveyed on two different wall faces by two different operators) Secondly, a site can be surveyed during a long time span. The time difference between observation and survey can produce conflicts (i.e. due to site modifications as destructions/rebuilding etc.).
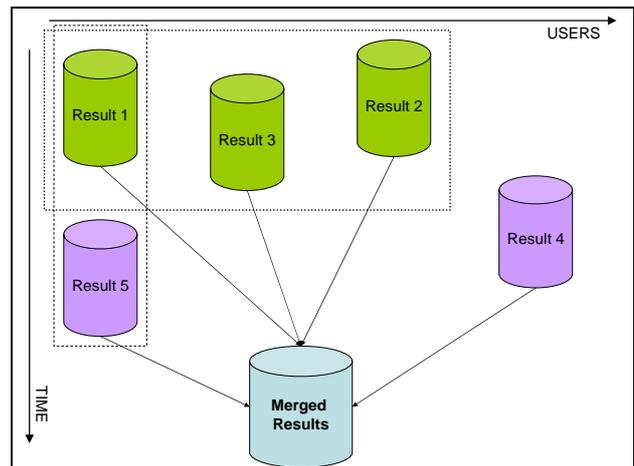

Figura 6: Overview of the merging process

Time conflicts and the user conflicts can be simultaneous. In figure 6 the left rectangle shows two results provided by a single user at two different times. The second rectangle shows three results given by three different users. The two rectangles are intersecting because the two conflicts have to be solved at the same time. In the Shawbak context, the stone by stone survey illustrates these conflicts. Let's take the simple example of block restitution. During a single user's restitution, the operator can have plotted twice or more times the same block since he/she sees it from different point of views on different photographs. At the end, results contain different identifiers for a same item. Items may also have been measured by one or more users with the same identifier. Only one item has to be chosen in the merged result. As seen before time interferes with restitution too. All these problems can be combined. For these reasons an historic record of the item and the traceability of the merges is therefore a needed requirement for the system. A formal expression of the consistency of the results is needed. A first approach of formal representation has been studied in the framework of underwater archaeological excavation survey and will be applied in the near future to the Shawbak case.

4.1 Consistency of the results

The consistency verification is the first step of the merging. This step is critical because it must detect the conflicts between results. Conflicts are separated in two groups: The attribute conflicts and the spatial conflicts. The first group contains the conflicts relative to items description or documentation. A survey result must respect some constraints on the items attributes. For example, two item must not have the same identifier. If they do, a conflict is detected. The source of the conflict can be the redundancy of an item in different results or an error in the identification of an item. The second group is composed of the spatial conflicts. As Arpenteur provide 3D representation of real items, spatial constraints can be used. For example in a stone by stone survey, the 3D representations of two blocs must not intersect (a standard measurement error is anyway considered for neighbour blocks). The two items in figure 8 are violating this constraints, a conflict must be detected because they represent the same block. Detection of spatial constraints violation is not easy due to the complexity of the algorithms used and the number of items. The conflicts are expressed as rules. Once the conflicts are detected, rules are generated. A rule is expressed in the form:

If item 1,…, item n violate C then conflict C detected

Where "C" is a constraint. The conflict detection provides groups of items for each constraint violated. The merge aims to choose one item from each group. The tool here presented is still under development and aims at providing a simple attribute merging that will be enhanced by new merging techniques dedicated to spatial conflicts.

4.2 Ametist

Ametist, has been designed to provide Arpenteur users with a way to manage all the data produced by the software. This new tool covers the three domain of Arpenteur: Photogrammetric measurement, 3D representation and documentation. The graphic interface (designed to be user-friendly) proposes a global view of the photographs used during the photogrammetric measurement, a workspace which can display representation of the survey and a set of forms for the documentation. The figure 7 shows the Ametist graphic user interface.

As the software can read the XML output from Arpenteur software, users can control the output of Arpenteur as often as needed. Moreover, the user can modify some attributes directly from the interface. A second need is the large amount of data processing capability. The software has to be fast and stable, even if hundreds of items are surveyed
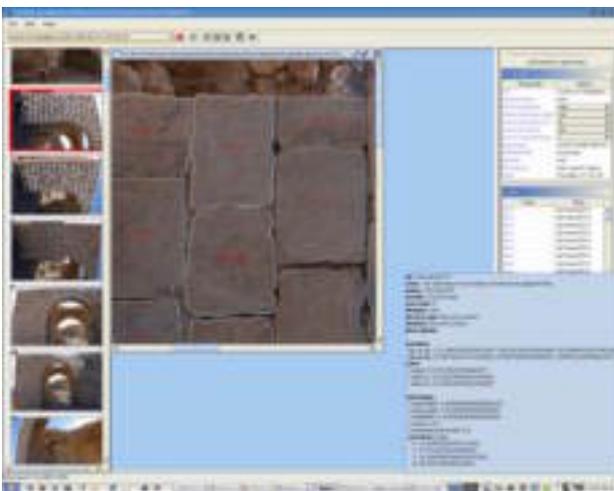

Figure 7: The user interface with a photograph and an item

tooltip.

Ametist is a Java application. Since Java 1.4, the Graphical User Interface is fast and stable and is a good base for a strong graphic application. The application is developed for displaying a large amount of high resolution photographs and is therefore based on the Java Advanced Imagery (JAI) toolkit. The primary need is nonetheless the merging of several results: a most complex task indeed.

4.3 First results of merging

As previously said, data merging involves result's consistency verification, and items modification. A traceability of the changes during the merging is also needed, the archaeologists have to be able to see what has been merged and for what reasons. A first practical approach has been set up for the Shawbak survey called "dynamic merging". The dynamic merging is the merging of the instantiated items. When items are instantiated, we can access and modify all information of an item: Attributes, geometry, photogrammetric data and documentation. Moreover, the modifications are taken into account immediately and can be propagated. The conflicts detection capability is maximal due to the access to all information. In case of an identifier conflict, the tool determines if this is redundancy or bad identification. In case of redundancy, only one item is kept in the final result. The choice of which item to keep is done according to an external and editable set of rules. Even if the automation of the merging is our goal, user can choose to make a manual selection among the items. The spatial conflicts are more complicated. In this work, a spatial conflict is raised if two 3D items representation are intersecting. This conflict can have two sources. First, an error in the measurement gives a bad 3D representation. In this case, the measurement of the items has to be verified and modified. Secondly, the 3D representations in conflict can be different representation of the same item. In this case, the merging has to provide a new item issued from both conflicting items information. The figure 8 illustrates a spatial conflict. The spatial conflict detection and correction is presently under development. 3D algorithm for polyhedron intersection has to be implemented. Moreover, a merging formalism and its implementation is needed in response to the conflict detection capability.
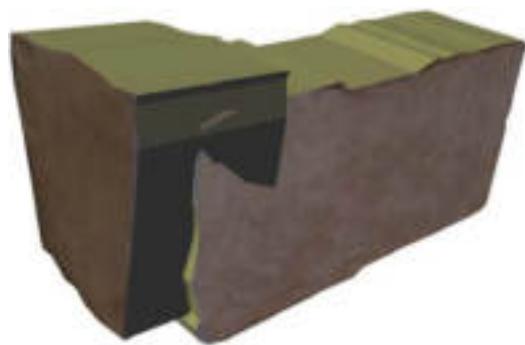

Figure 8: Spatial conflict for 2 survey of the same bloc at an angle of a wall

5 FUTURE DEVELOPPEMENTS OF THE MERGING

The merging process is complex and has to be based on a complete formalism. Moreover, the merge hast to be used in the dynamic way but also with static results (XML files, etc.).

5.1 Theoritical formalism of reversible merging

The goal of the tool is to apply theoretical results on the belief bases merging to the knowledge based photogrammetry. With Prof. Odile Papini, we have formalised a reversible framework for the belief bases merging. This work is a generalisation of the reversible revision (Papini, 2001). This framework enables to merge belief bases. The technique lies on two kind of pre orders. The first kind is the external pre-order. This is the expression of preference between the bases. For example, in the archaeological context, it can be preference between the operators involved in the survey. The second kind is the internal pre-order. Each belief base has an internal pre-order which expresses the preference between pieces of information inside the base. In a photogrammetric survey, this kind of preference can be the confidence of an operator on his results. The merging process is combining the two kinds of pre-orders into a merged pre-order which express the global preferences on all information. In our framework, the pre-orders are represented by polynomial weighting. Each piece of information is associated to a polynomial and the pre-orders are expressed by pre-orders on the polynomials. The interest of polynomial weighting is the capability to make a history of the merging. When two pieces of information are merged, their two polynomials are combined in a way which enables to retrieve the originals polynomials and so, the origin of the information. The traceability and the reversibility of the merging are guaranteed. This theoretical formalism is currently under implementation in the software. A merging engine is developed to make the reversible merging possible. Moreover, due to the generality of the theoretical formalism, the merging engine will be usable with items of different kind. This development based on a theoretical framework can be applied to other mergings.

5.2 Static representation merging

Even if the dynamic merging provide the most complete framework for a merging of the results it should be not necessary to instantiate all the items to perform a merging. Arpenteur generates static results: 3D representation as VRML / X3D files and XML files containing all the items information. The 3D representation only contains geometry. Merging of 3D expression of the results could be used for the creation of a global representation of the survey. As the files are static and only geometry is available, the merging capability is very limited. It could be also difficult to control if different items are in the same location. Finally, it is impossible to merge the non geometrical attributes of the items. The XML representation is more suitable for the merging of the results. These files are the core of the Arpenteur data and contain all information on a survey: Attribute values, documentation, photogrammetry measurements and geometric primitives for 3D representation. Even if XML representation is static, like VRML and X3D representation, the first is far more useful. As XML contains all information on a survey and on the items composing it, this representation can be used for merging item attributes or documentation. Our aim is to formalise such merging, using description logic. As all XML results have got a similar schema, the use of the Ontology Web Language (OWL) meta-description of the XML file can make the merging of static XML results possible.

5.3 Shawbak excavation survey

At this time, the first merged results of the survey contain 825 blocks measured. Two final users, Elisa Pruno in Italy and Laure Lopez, in France are working on the photogrammetric measurements. The figure 9 shows a first VRML 3D representation of the excavation.

Figure 9: 3D representation of the gate of the castle of Shawbak

6 CONCLUSION

We have presented the use of a new data management tool for archaeological photogrammetric survey. The first results for the Shawbak archaeological photogrammetric survey have shown the need for it. The software here presented partially succeeded in filling a part of the need. Its simple interface can be used by non specialists. The merging capability of results makes the creation of global results easier. However, multiple enhancements are underway. The implementation of the reversible framework for the merging and the development of new geometric algorithms will open new ways for a more efficient resolution of conflicts and a quicker computation.

REFERENCES

Reference from journals
[Drap, Grussenmeyer, 2000], Pierre Drap, PierreGrussenmeyer. A digital photogrammetric workstation on the web. Journal of Photogrammetry and Remote Sensing, 55(1): 48-58., 2000.

Reference from other literature
[Brogiolo, 1988] Gian Piero Brogiolo, "Archeologia dell'edilizia storica", Como (Italy).

[Drap et alii, 2005] Pierre Drap, Anne Durand, Julien Seinturier, Guido Vannini, Michele Nucciotti, "Full XML documentation from Photogrammetric survey to 3D visualization. The case study of shawbak castle in Jordan." CIPA 2005 International Symposium, Torino, Italy September 26th, October 1st, 2005.

[Drap et alii, 2004] Pierre Drap, Pierre Grussenmeyer, Pierre-Yves Curtinot , Juien Seinturier, Gilles Gaillard , «Presentation of the web based ARPENTEUR tools: towards a Photogrammetry based Heritage Information System. », ISPRS XXth CONGRESS, Turkey, Istanbul, 12-23 July 2004.

[Drap, Grussenmeyer, Gaillard, 2001] Pierre Drap, Pierre Grussenmeyer, Gilles Gaillard, "Simple photogrammetric methods with arpenteur. 3-d plotting and orthoimage generation : the I-MAGE process." CIPA 2001 International Symposium, Potsdam University (Germany) September 18 - 21, 2001.

[Drap, Hartmann-Virnich, Grussenmeyer. 2000] Pierre Drap, Andreas Hartmann-Virnich, Pierre Grussenmeyer. "Photogrammetric stone-by-stone survey and archaeological knowledge, an application on the romanesque priory church notre-dame d'aleyrac". VAST - Euroconference on Virtual Archaeology, Arezzo (Italy) 24-25 Novembre 2000.

[Drap; Seinturier, Long, 2003], Pierre Drap, Julien Seinturier, Luc Long, , Archaeological 3D modelling using digital photogrammetry and Expert System. The case study of Etruscan amphorae, The Sixth International Conference On Computer Graphics and Artificial Intelligence, Limoges, France, May

2003

[Papini, 2001], Odile Papini, Iterated revision operations stemming from history of an agent's obserations, Frontier of belief revision M-A Williams and H. Rott eds, Applied logic series, 22, Kluwer Academic publishers, pp. 279-301

[Harris, 1989] Edward Harris, "Principles of Archaeological Stratigraphy" (second ed.), London, Academic Press, 1989.

[Vannini, Nucciotti 2003] Guido Vannini, Michele Nucciotti, "Fondazione e riuso dei luoghi forti nella Transgiordania crociata. La messa a punto di un sistema territoriale di controllo della valle di Petra", SAMI 2003, Firenze, Insegna del Giglio, 2003, pp. 520 – 525.

[Vannini et al. 2002] Guido Vannini, Michele Nucciotti, Cristina Tonghini, Andrea Vanni Desideri, "Medieval Petra. Archaeology of Crusader-Ayyubid fortified settlements in Trans-Jordan", in AA. VV. "Civilisations of the Past, dialogue of the present: Italian Research mission in Jordan", Amman (Jordan), 2002, pp. 181 – 199.

ACKNOWLEDGEMENTS