Full XML documentation from photogrammetric survey to 3D visualization. The case study of shawbak in jordan.

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FULL XML DOCUMENTATION FROM PHOTOGRAMMETRIC SURVEY TO 3D VISUALIZATION. THE CASE STUDY OF SHAWBAK CASTLE IN JORDAN

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ABSTRACT:

The paper presents an interdisciplinary project dealing with survey and documentation in medieval archaeology. The project is led by two scientific partners: the CNRS MAP-GAMSAU of Marseilles (France) responsible for the photogrammetric survey and the web documentation, and the "Dipartimento di Studi storici e Geografici" (DSSG) of the University of Florence (Italy) responsible for the archaeological research. The case study is the Castle of Shawbak, traditionally known in historical reports as the "Crac de Montréal" in Jordan.

2D and 3D models generation from photogrammetric data, user friendly matching of measurements and archaeological knowledge, XML usage as standard language for the whole project are the main innovative and interesting issues of this research. More details on the above will be given in the present document.

- In the Survey stage two photogrammetric packages have been used. Photomodeler ™ is used to make the orientation, several hundred of photographs have to be oriented and this software is easy to use for archaeologists as well. Besides, ARPENTEUR (**AR**chitectural **P**hotogramm**E**try **N**etwork **T**ool for **E**d**U**cation and **R**esearch) is used to generate a survey linked to archaeological data. A set of tools has been specifically developed in ARPENTEUR, based on correlation process and archaeological knowledge, in order to simplify the plotting stage and make it easy for a non-photogrammetrist.
- The geometry of 3D models of measured objects, such as ashlars blocs and/or stratigraphic units, is achieved through archaeological knowledge (several patterns of extrusion, mapping from photographs) and a set of textual data related to archaeological analyses. The main purpose is the production of geometrical models that can work as interface to access the textual/archaeological dataset.
- The geographical distance between the two partners was actually the first reason for developing an XML based web platform aimed at exchange and update the generated models. Due to the complexity of the matter, several interfaces have been developed in order to create (purpose) a dynamic link between 2D or 3D representations and textual data. The general format for all the data in this project is XML. 2D images and vectors are generated in SVG (Scalable Vector Graphic is a XML representation for 2D data); 3D models are generated in X3D which is the XML upgrade of VRML; archaeological data are formalized in XML standard and the web site developed as an exchange platform is also entirely written in XML and XSL.

This project is still under development and not yet fulfilled. After two photogrammetric campaigns in Jordan the first results are available on the web site: http://piccard.gamsau.archi.fr/Shawbak/

1. INTRODUCTION

This paper is devoted to the presentation of a method of photogrammetric survey and documentation applied to the medieval archaeology case study of the Castle of Shawbak (Crac de Montréal) in Jordan. This work is the outcome of the cooperation between the Marseilles *Map-gamsau*, CNRS laboratory (France), and the *Dipartimento di Studi storici e Geografici* of the University of Florence (Italy).

The methodological frame is organised in four steps:

1) Global computer aided photogrammetric orientation, presently achieved by Photomodeler™. This first step produces oriented photographs and ortho-rectified photos comparable to those used in traditional surveys of architectural complexes.

2) 3D survey of all the blocs/units in each wall. This step can be a long lasting one since it is not possible to automate the plotting, due to the erosion of building materials forbidding any systematic treatments. Moreover the knowledge of the archaeologists is needed for the interpretation of the photographs.

Figure 1. the Castle of Shawbak, Jordan.

To solve the above issues a method has been developed allowing the archaeologist to make a reliable 3D measurement with only one photograph. This method (I-MAGE standing for Image processing and Measure Assisted by GEometrical primitive) developed in 2001 [Drap, Grussenmeyer, Gaillard, 2001] allows to 'hide' to the archaeologist's eye a number of photogrammetric details during the plotting.

3) Editing of 3D measured data and archaeological data. During the plotting (see step 2) the archaeologists are allowed to insert textual archaeological information while performing the 3D survey. XML formalization of both 3D result and associated records makes indeed possible extensive data querying by a 3D representation in X3D or VRML and/or by interactive maps/elevations of analysed walls formatted in SVG.

4) Data fusion. Data fusion tools have been developed to produce 3D models (i.e. of blocks) based both on material data, measured by the operator, and the theoretical archaeological knowledge (i.e. the one used to infer the extrusion pattern to be applied to the walled blocks in order to generate 3D models [Drap, Hartmann-Virnich, Grussenmeyer. 2000]). Fusion problem of incomplete data are also to be considered since the blocks and the stratigraphic units can be measured partially from various points of view by different operators, in different places and times.

2. ARCHAEOLOGY OF AN OVERSEAS FEUDAL SOCIETY

2.1 Territorial organization in the Petra region (Jordan) during Crusader Age.

The University of Florence archaeological mission – within a general research programme on the structural aspects of Mediterranean feudal society's lifestyles – has been committing since 1986 to a project dealing with stratigraphic investigations aimed to analyze features and forms of the Crusader "incastellamento" in the premises of the Lordship of *Oultre Jordan* in the 12th Century.

The inquiry is meant to collect (and interpret) material data on the "*caractères originaux*" of the first period of the Crusaders' occupation in the Holy Land, in the setting where these documents are better preserved and readable from a stratigraphic point of view: modern Jordan ([Vannini *et al.* 2002]). The whole medieval fortified system of the 'lordship' – set up in an very short time, within the first 20 years of 12th century - and the whole region, were indeed completely abandoned by the Crusaders after the battle of Hattin (in year 1187, when the entire Latin Kingdom army was defeated by Salah al Din). Moreover, apart from some exceptions, these fortifications were no more occupied as such (a non military re-use of al-Wu'Ayra castle has been documented by recent archaeological excavation at the site).

The castle of Shawbak represents one of the above exceptions. Located aproximately 25 km north of Petra, the archaeological-monumental area of the *castrum* of Mons Regalis/Shawbak - one of the best preserved rural medieval settlements in the entire Middle East - occupies a strategic position in the major road system connecting the Dead Sea and Damascus to the Red Sea, Cairo and the Arabian peninsula.

The fortified settlement, crowning a limestone relief, dominates a nearby village and represents one of the few examples of a Crusader castle inherited as a military stronghold by the Ayyubids after the Europeans' defeat of Hattin in 1187. The citadel is encircled by a complex and uninterrupted defensive system of almost perfectly elliptical shape (175 x 90 m), composed of three curtain walls (at least in 12th century) and interspersed with abutting towers and ramparts dating from Crusader to Mamaluks' ages.

The walled circuit, due in its basic layout to the will of king Baldwin I in year 1115, had been defending since the beginning the centres of secular and ecclesiastical power, together with a settlement of remarkable dimensions. Moreover Arabic sources recorded also a second (and larger) fortified settlement located on the eastern slope of the hill of the castle.

The site of Shawbak is to be considered an extraordinary archaeological-monumental area that holds the possibility to be fully explored stratigraphically. It is characterised by a very readable archaeological stratification that can be interpreted through the methods of recent Italian 'light archaeology'. A consistent material archive spanning over at least 1600 years, from Roman- Byzantine age (structures belonging to these periods have been recognised thanks to recent archaeological investigation [Vannini Nucciotti 2003]) through Crusader-Ayyubid, Mameluk and Ottoman periods.

2.2 Light Archaeology.

University of Florence's research operates at a territorial scale, through surface and upstanding structures' stratigraphy, computational archaeology, and archaeometry, also resorting to sondages and to open area excavations on sample areas.

The archaeology of upstanding structures, developed in Italy in the late 1980s (i.e. [Brogiolo 1988]), aims at interpreting architectural complexes as stratigraphic formations similar, from a theoretical point of view, to any other archaeological deposit. Buildings can thus be analysed not only through the conceptual devices derived from a 'history of architecture' perspective, whose primary tool is typology. Archaeological Stratigraphy ([Harris 1989]) can indeed be used to study and interpret architecture since the theory of the stratigraphic units (being those, trivially speaking, the material results of past human and natural actions whose marks are still readable in the material record) can be recalled to answer for the development of any building from its origin until its present-day state.

Such a methodology stands at the core of so called 'Light Archaeology', a realm in which the team of Medieval Archaeologists of the University of Florence holds an internationally recognised expertise. A direct outcome of 'light' procedures in archaeology is the production of large and complex datasets, whose management can overcome the possibilities of available GIS software. In particular, working with 'heavily' three-dimensional objects such as architectural complexes, the archaeologists' primary need is to find a suitable tool able to gather, analyse and display all different kinds of data (text, raster, vector etc.) within a geo-referenced system that could ultimately allow spatial analyses. That's how the whole 'thing' started.

3. THE PHOTOGRAMMETRIC CAMPAIGN

Figure 2. Shawbak, plan of the site with indication of archaeologically analysed buildings.

The photogrammetric campaign was held in November 2004 and was aimed at surveying the fortified gates CF3 and CF5. (see Figure 2). Raw data of this campaign include: 743 photographs, 234 oriented photographs, 5325 3D points calculated, 100 control points and 10 working days for an archaeologist to make the orientation with Photomodeler. The archaeological team uses two Leica laser total stations that, in a previous field season, were employed to lay out a local reference system for the entire site.

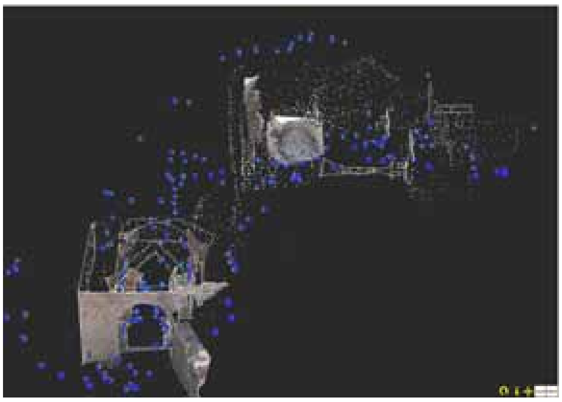

Figure 3. Camera positions calculated by Photomodeler.

The traditional survey, with a good accuracy (according to the control points) was used as a starting point for the photogrammetric programme.

4. MEASURING BLOCKS AND STRATIGRAPHIC UNITS

4.1 Pre existing method

Traditionally the archaeologists employed rectified photographs to make a stone by stone survey and define the boundaries of stratigraphic units (in vector graphic), whose relative chronology allow understanding the building phases of analysed structures. The first aim of the photogrammetric process has therefore involved the creation of ortho-rectified images, actually of a greater accuracy than those created by previously used practices.

Figure 4. Stratigraphic units identified on orthophoto (CF 5).

A first set of orthophoto was therefore produced to guarantee the continuity of the archaeological documentation.

4.2 New proposal

Beyond this standard orthophoto production and in order to provide a new tool for the archaeologists, the final goal was to produce a stone by stone survey, using (on the operator's side) only one photograph but providing a fully 3D survey. One old experiment on medieval architecture survey [Drap, Hartmann-Virnich, Grussenmeyer. 2000] and one on light survey of the measurement process that allowed non-photogrammetrists to use the system (I-MAGE process see figure 5) ([Drap, Grussenmeyer, Gaillard, 2001]) were assembled in order to produce an integrated tool.

The resulting system could therefore allow an operator to perform a 3D survey working only one image. The result is a set of 3D blocks, extruded accordingly to a vector of extrusion perpendicular to the average plan of the studied wall. The depth of extrusion is left to the operator choice (an archaeologist able to resort to his/her specific knowledge of the artefact) during the plotting phase.

4.3 The I-MAGE method

The I-MAGE process has been designed to help during the measuring process in photogrammetric surveys. Users can make a 3D measurement using one single photograph, without altering result precision. Key specifications can be summarized as follows.

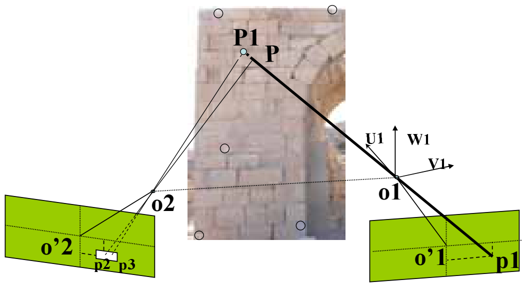

Figure 5. The I-MAGE process.

4.3.1 Computing a 3D point:

The I-MAGE method relies on 5 steps (figure 5):

1) A plane Π is computed using a set of 3D point. Here the target

2) A point P can be computed from one image by intersection of an image ray (p1, O1) and the geometric primitive here the plane.

3) P is projected as p2 onto the second image;

4) The point p2 is used as approximate position to initiate the area based correlation process;

5) The point p3 is the result of the correlation; p1 and its homologous p3 are used for the computation of the 3D coordinates of P1.

For objects based on geometric primitives (planes, cylinders, cone, or sphere shapes), image correlation and the geometry of the object can be combined in order to calculate 3D points. This I-MAGE method is based on five steps, assuming that the first one is that a geometric primitive has been measured from a set of 3D points visible on at least two images (Figure 5).

Many architectural features can be approximated by a combination of geometric primitives. The parameters of so-called architectural features are part of the basic data required for the modeling process. The object is first reduced to geometric primitives such as plane, cylinder, cone, or sphere shapes.

The I-MAGE process is available with several geometrical primitive: Plane, Cylinder and Sphere.

During the plotting phase generic modeling possibilities are available using, if desired, the I-MAGE process; meaning that one can combine traditional plotting (one image after another, with the possible help of correlation) and I-MAGE process that give you a 3-D with one photo digitized.

This Semi-automated Primitive Measurement Method is a useful tool for fast object-modeling. It is interactive, as the operator follows and analyses the results of adjustments directly on the images. For archaeologists, architects or civil engineers, the object-geometry parameters given by the process make the interpretation of the object-building available for several computer-assisted applications.

4.3.2 Several way to use I-MAGE

The first goal was to make a tool easy to use and efficient, able to produce at least the same type of result than the traditional orthophoto plotting.

I-MAGE process can be use in two different modes.

The first one, shown on figure 5, produces real 3D points, based on correlation process and with a good precision. The point precision is of course depending on the local contrast on the photograph. This type of result can be used to evaluate, for instance, the wall planarity. But as measurements are normally made on the stone edge, often broken, with shadow and perspective difference from one photograph to another, it can be difficult to take a lot of good 3D points on the block perimeter.

However archaeologists do not generally need to evaluate the wall planarity; if the correlation process is not used in the I-MAGE process the resulting point is always projected on the primitive. This way of operating is actually very similar to a 'simple' survey based on a ortho-rectified photo but generates points projected in 3D on the measured plane.

In the present case study, both methods were used.

4.4 3D blocks

I-MAGE process was also used to produce 3D models of building blocks (i.e. ashlars) based on the only observable face.

The morphology of each ashlar block is expressed as a polyhedron with two parallel sides, or faces. In most of the cases only one side is visible, sometimes two, rarely three. The survey process can inform about the dimensions of one face, then the entire polyhedron is computed accordingly to the architectural entity's morphology (extrude vector) and the data provided by the archaeologist (depth, shape …).

Computing an extrusion vector can be easy in the case where the architectural entity's morphology is obvious; during a wall survey for example an extrusion vector can be computed by a minor square adjustment of a plane around the survey zone. In our case it's the plane used in the I-MAGE. In this case where the entity's geometrical properties are simple, the extrusion vector is calculated before the survey phase and the block is extruded directly from the measured points. In the case of the survey of an arch the extrusion should be radial and needs the geometrical features of the entity (intrados, radius, axis).

This approach for measuring blocks was already published in a VAST congress [Drap, Hartmann-Virnich, Grussenmeyer. 2000] and has been combined with the I-MAGE process in order to obtain an integrated tool.

5. PUBLICATION

5.1 3D expression CAD, VRML and X3D

Measurement and extrusion provide the morphologic attribute of the 3D model representing the block. This model is able to express the block morphology with different formalism to satisfy the various user's needs.

Currently we can generate binary cad files readable by Bentley Microstation, or textual files in VRML and X3D format.

The produced geometry is, of course, linked with external archaeological data.

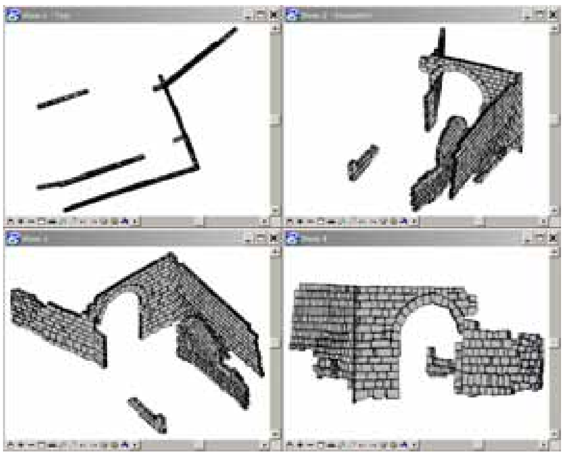

Figure 6. CAD generation of the measured blocks. (Bentley Microstation)

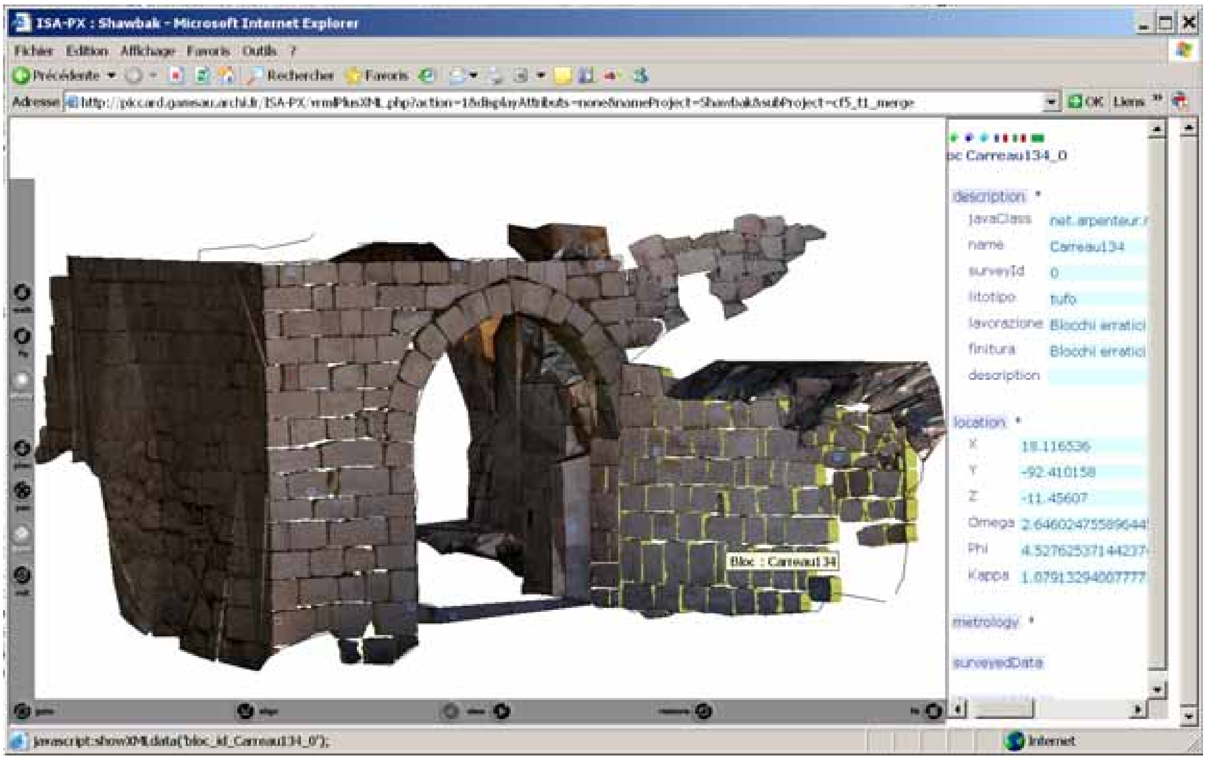

Figure 7. ISA-PX 3D interface: VRML model allow access to archaeological data.

5.2 The XML database

After objects measurement (i.e. the blocks) allowed by ARPENTEUR software, all information on that very same object is available in XML format (geometry, qualitative data, references to the photos used to measure the objects, archaeological information). How can the user have an easy and full access to the entire dataset in order to query/entry/edit it?

A specific tool called ISA-PX has been developed to achieve this goal. The authorized user has only to upload his XML file on the website of the project (i.e. http://piccard.gamsau.archi.fr/ISA-PX). After the parsing of this file, the system produces, for each object, an XML file with the relevant data. A corpus with all the values of all the attributes is also available without any action of the user. At the same time, a database (MySQL) is populated (an XML consistent system based on XQuery is currently under development).

The measurement system based on Arpenteur produces also files in SVG and X3D formats; the links with ISA-PX exists in these files (see Figure 8). These 3D description languages are not powerful enough to build a bidirectional link between ISA-PX and the 3D representation textured of the studied building. Currently these 3D representations are used as simplified interfaces between the 3D representations and the textual and iconographic data. A more generic description to enable a real interaction between these two aspects of the objects will be required shortly. Java3D seems to be the most powerful system for the task but is unfortunately too slow.

Finally, a cartographic approach was also developed. For the three-dimensional complex objects pertaining to the case study the latter approach was limited to the study of walls or group of walls that can be charted on the same projection plane, like in a more traditional work based on orthophotos. Given the above conditions, the system produces a graphical representation of the complete group in SVG format (see below)

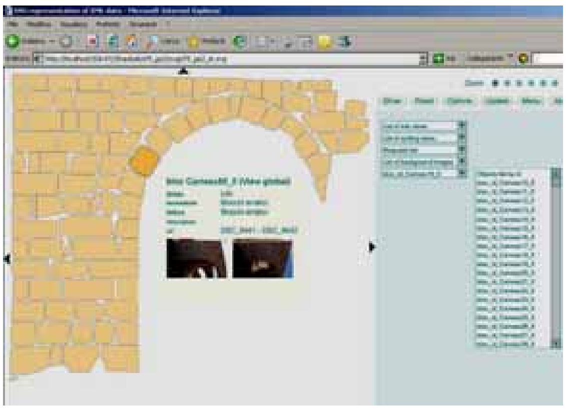

Figure 8. ISA-PX SVG interface.

As the case may be (i.e. in order to exploit the user's habits), a 2D representation can indeed be more suitable for the archaeological work than a fully 3D one. SVG (Scalable Vector Graphic), an open source format developed by the W3C, was chosen because of its multi-platform and full compliance with XML specifications. Besides, SVG provides many useful pros such as: dynamic and interactive manipulations, objects grouping by specific marks and zooming without deformation, since all objects are described in vector graphics.

The above potentialities of SVG were used by building a representation which gives quick access to the dataset by means of templates defined by the user: archaeological templates, photographic templates, typological templates etc.

5.3 Revising and updating

To look at the data is the first step in the analysis of a dataset. To go further on, the archaeologist needs to entry/edit them.

- Update of the textual data:

  - the corpus can be used to correct some basic errors (misspelling, simple inconsistencies, etc.)

  - through the graphic interfaces in SVG or VRML, the user can directly modify the selected object

  - new measurements can be added to implement changes in the shape (degradation or restoration) of the measured and referenced object.

- Revising

The conceptual model used to describe the objects can change during the time of the study, according for example to new archaeological knowledge. The user can modify accordingly the tree structure of the dataset describing the object model.

6. CONCLUSION AND FUTURE WORK

The work presented here is the first result of collaboration between the two transalpine units. It shows the feasibility of the program and will be used as a basis for future developments.

As regards architectural and archaeological analysis, three essential issues of this project are to be pointed out:
- the easy method for direct measuring of structural elements. The I-MAGE process (standing for "**I**mage processing and **M**easure **A**ssisted by **GE**ometrical primitive"), already published in 2001, [Drap, Grussenmeyer, Gaillard 2001], is a useful device for the user and this time implemented in a specific module dedicated to the Shawbak survey. After having measured some points on the object-surface, the system is set up to let the user focus his attention on semantics, considering pictures one by one, while the system automatically completes 3D measurements.

- The link between the scene representation in 2D or 3D and a XML database. This second feature allows combining a representation of the architecture itself to the database serving as a tool for the analysis of its units. A full XML choice for textual and graphical representation will allows a relevant interaction.

The use of a three-dimensional model as a user-interface to the data formalized in XML allows linking the purely documentary data (references, observations made during the excavation, photographs) to a 3D representation of the object. This graphical expression of the object relies on geometrical data (position, orientation, dimensions) as well as on 'knowledge' of the object (theoretical shape, default values, relationships between diverse objects). The 3D model, produced by the system, shows the generic model of the object, defined by the archaeologists, and measured by photogrammetry and thereby becomes a relevant interface between the user and the collected data.

- The third point is the use of architectural knowledge in order to perform the measurement process: knowledge is used to get a 3D model of each block by extrude and data fusion.

Finally the data access through the Internet and the XML formalism allow us to work in the direction of updating and revising data from their 2D or 3D representation, in this way we are working on 3D Patrimonial Information System. Among the next stages we have thought re-using all the data already gathered for 10 years by the archaeologists on two-dimensional documents (measure on orthophoto) and of converting them into data readable by ISA-PX..

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