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# A PHOTOGRAMMETRIC SURVEY USING KNOWLEDGE REPRESENTATION ON THE ARPENTEUR WEB-BASED PHOTOGRAMMETRIC WORKSTATION

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## ABSTRACT

ARPENTEUR is an application for digital photogrammetry mainly dedicated to architecture (Architectural Photogrammetry Network Tool for Education and Research). One can freely access ARPENTEUR via the internet (<http://moma.gamsau.archi.fr> or <http://photogeo.u-strasbg.fr>). Usual steps of inner and outer orientation are implemented in order to generate a photogrammetric stereomodel.

ARPENTEUR has been developed thanks to the collaboration of two complementary research laboratories : the group "Photogrammetry and Geomatics" of ENSAIS-LERGECE's laboratory (Strasbourg, France) and the Gamsau-MAP CNRS laboratory (CNRS : French National Body for Scientific Research) located in school of Architecture (Marseille, France).

This paper focuses on a new approach of photogrammetric surveying in which formalised architectural knowledge is a prerequisite to the measurement process. The first step of the survey is therefore a rigorous analysis of the architectural corpus used in the building. All the architectural elements which are expected to be measured are defined and organised in a hierarchy of concepts and formalised using the Java™ object language capabilities.

The purpose of the photogrammetric measurement is then to inform the architectural geometrical model with data such as location, orientation and dimension. Each architectural element considered is given within its definition a redundant set of geometrical primitives that can be observed on its surface. These primitives appear as a geometrical interpretation of the architectural element's morphology. Depending on the case study's specificity, one can choose to measure a subset of these primitives. Unmeasured data (occluded zone on a picture, ...) should be generated by the system using both theoretical model and measured data.

We propose an experimentation of this process on the old town hall tower, in Kraków (Poland). Images used in the system were taken with a point and shoot digital camera. The experimentation focuses the neo-gothic addition to the original XIVth century tower. Elements considered therefore correspond to a reconstruction based on a historical analysis of Kraków's gothic urban corpus.

The model resulting from the survey process can be visualised either on the internet-oriented VRML plug-ins, or inside the Microstation™ software.

## 1. INTRODUCTION

A LERGECE-GAMSAU common research project was initiated after the 1997 Goteborg CIPA symposium with the objective of building up a web-accessible photogrammetric tool dedicated to architectural survey. Principles and motivations for the research are as follows:

- Software for Education and Research: developing a software using Java™ is particularly convenient when teams working in several places use different platforms (here Windows NT and Unix platforms located in Strasbourg and Marseille).
- A web tool dedicated to architectural survey: ARPENTEUR has the benefit of the two partner laboratories expertise in the field of close range photogrammetry and architectural knowledge representation in a survey process.

- A simple photogrammetric system for archeologists, architects and photogrammetrists. Typically we think that the members of CIPA (International Committee for Architectural Photogrammetry) can take benefits by using a digital photogrammetric workstation on the web.

An introduction to the ARPENTEUR in its purely photogrammetric aspects was proposed to the community of photogrammetrists in two previous ISPRS meetings (Hakodate and Thessaloniki, [Drap, P., Grussenmeyer, P., 1998 & 1999]). We introduce in this paper a first experiment on the interaction between the ARPENTEUR survey tool and a theoretical architectural model. The objective is therefore to connect relevant aspects of the architectural knowledge to a photogrammetric restitution tool. We state that surveying a building is a different problem than surveying for instance a car and that therefore the

survey process could be more relevant if taking into consideration a specific knowledge of the domain.

## 2. THE ARPELITEUR SOFTWARE PACKAGE

This software package is, in a pure photogrammetric point of view, particularly dedicated to terrestrial applications, although aerial photogrammetric projects based on small format images are also possible. ARPELITEUR (figure 2) is a web based software package (made as an applet) utilising HTTP and FTP protocols. The photogrammetric adjustment and image processing routines are written in JAVA™.

### 2.1 The photogrammetric functions

The procedures and solutions available from the definition of the model to the stereoplotting module are summarised in figure 3.

The required files are:

- image files B/W or colour GIF files,
- control point file (points in X, Y, and/or Z)
- camera definition file

Both software packages use the same functions and only the user interface is a little different. The photogrammetric developments refer to the methods published in [Albertz, 1989 ; Kraus, 1994, 1997] . In addition to the standard orientation steps, we also propose an absolute orientation made without control points. We define a local co-ordinate system by measuring particular points on the model (plumb lines, wall corners), and a scaling of the model by measuring some distances on the object.

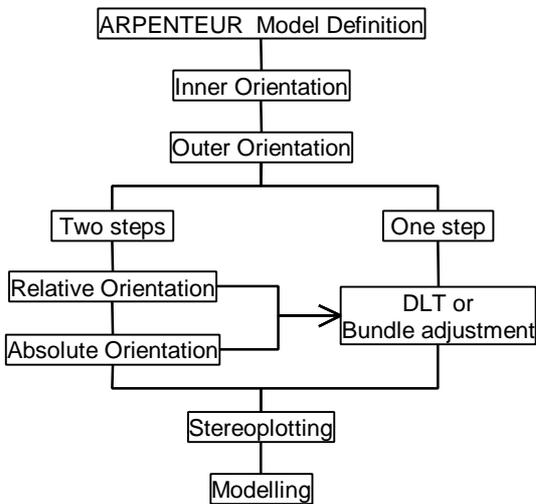


Figure 1. Overview of the photogrammetric functions in ARPELITEUR

### 2.2 Platform

ARPELITEUR can be used locally as an application. In principle, executing a software in JAVA™ requires a little more time than one written in C++ native code. The differences established for the examples processed until now are not significant. But ARPELITEUR is rather developed to be used as an applet. In that case the software is operational from any platform supporting a web browser using a required level of JAVA™ (e.g. JDK

1.1.7). Presently we are testing with Netscape Communicator 4.6 on PC platform and SUN station.



Figure 2. ARPELITEUR's main frame.

### 2.3 Internet access

The software is accessible via the internet network and a web browser. We use three kinds of servers to offer the service. Using ARPELITEUR (figure 2) means three steps :

- Registration: The HTTP server allows the free creation of a personalised workspace by a registration page. You have an access to example projects. Once you are registered you have access to the whole capability of ARPELITEUR.
- Using ARPELITEUR with your own project: Of course you can use your own project. You have a specific access to your workspace via an FTP server directly accessible through the main windows. The FTP server allows you to read and write files on your workspace, so you can put your images, camera definition file, ground control point file on the server and get the output text files generated by the system.

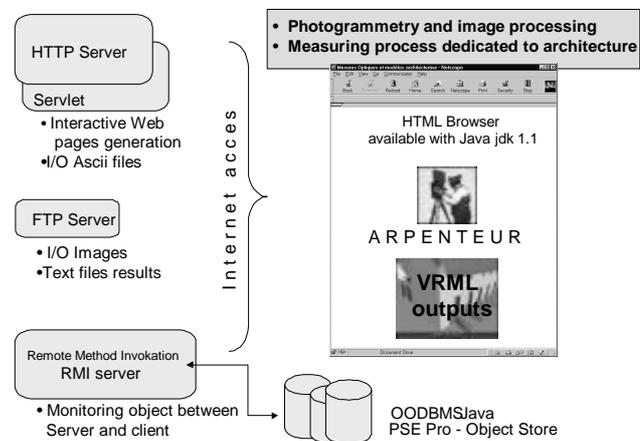


Figure 3. ARPELITEUR's project synoptic scheme.

- Getting the results

ARPENTEUR is an applet using a lot of Java classes. That means that the process is running on the client computer; the JAVA™ security restrictions do not allow an applet to write files on the client disk neither on the server disk. To solve this problem we develop a Java application server, running on the server machine and dedicated to saving files on the disk. All the result files, the orientation reports and the plotting files are written in your workspace by this Java application server after connection with the client.

### 2.4 VrmI output

VRML for Virtual Reality Modeling Language, is a platform independant interpreted language dedicated to the visualisation of 3D scenes inside a standard web browser. All objects manipulated by ARPENTEUR who implement a VRML interface are enabled to visualise their instance created through the survey process. This allows a direct monitoring of the scene from within the applet.

Measured points, controls points, geometrical primitives and architectural objects measured can therefore be visualised during the successive steps of the survey (once the absolute orientation is done).

JAVA™ / VRML interaction is used in order to allow the user to retrieve data from an object in the scene by a mouse click on its VRML representation.

## 3. THE ARCHITECTURAL MODEL

### 3.1 Object paradigm

The object-oriented programming languages give an opportunity to formalise and handle models of complex knowledge fields. The field of knowledge is split into elementary concepts structured through refinements of classes. The object-oriented programming approach lets us gather generic objects into hierarchies of elements that share common properties, behaviours or attributes. Each property added gives a birth to a new generic element that is more specialised, therefore placed lower in the hierarchy.

Since the architectural heritage clearly reveals elements of permanence and of variability, the knowledge to be represented and handled features both stable concepts (the roofing, the opening, etc.) and their historical variations. A thorough investigation of each of this evolution's steps is needed by specialists of architecture and conservation in order to identify and organise sets of non-ambiguous objects that we call architectural entities. In addition to the architectural entity hierarchy approach of the building, we have developed a "grouping" mechanism that is used when applying the underlying model to fields of experiments. A grammar based on the JAVA grammar allows a textual description of the field of experiment in which the building is seen as a set of entities and of relations linking them to one another. A compiler uses this textual description to represent the building as a collection of instances of the theoretical model's classes.

The ARPENTEUR interface to this compiler gives a possibility to choose, modify or create a script in which the building is described. Following the compilation phase, the interface gives a direct access to the instances generated through the process and by a messaging mechanism allows the user to visualise the VRML representation or to get information on the model's instances data.

### 3.2 Corpus organisation: The Architectural classes

Architectural concepts are described as entities, réseaux (arrays), attributes and relations and are gathered in the ItemTopos hierarchy. Elements of a building will be described as entities providing that they meet two requirements:

- An entity is a unique " object " identified by a single element of the vocabulary.
- An entity has an obvious role in the physical structure of the building.

Architectural entities, structured by the inheritance of class mechanism are analysed from the point of view of intention. This means isolating object categories for which similarities of structure or behaviour can be observed.

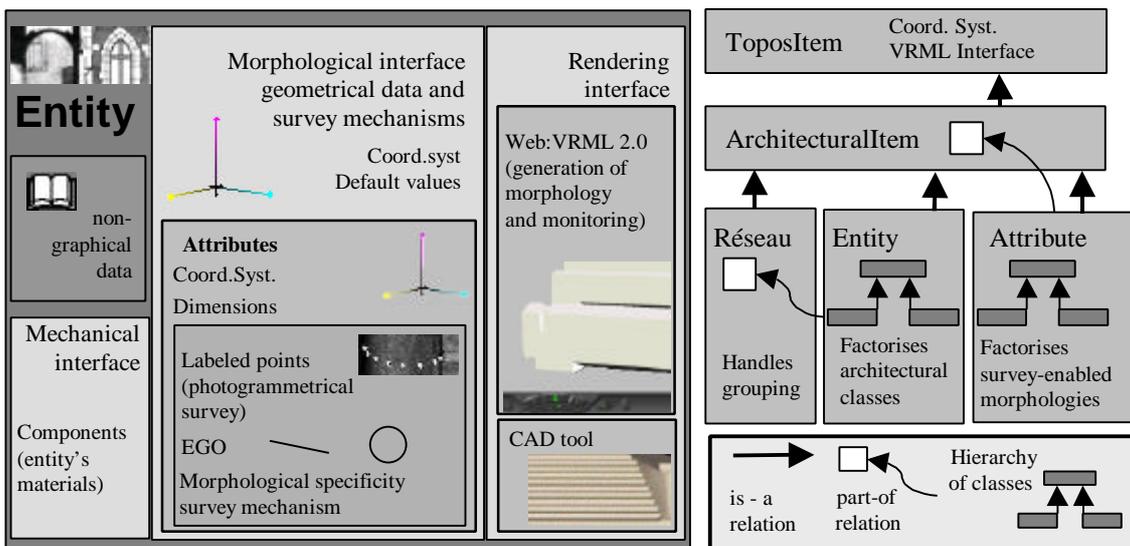


Figure 4. Architectural entity structure.

Once the properties of the architectural entity are described (both nature and behaviour) the relations between entities are formalised in order to organise the building. Attributes are items of vocabulary that correspond to a morphological specificity of one or several entities.

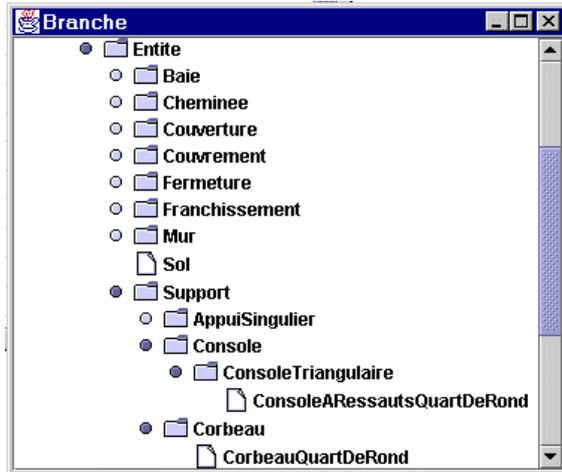


Figure 5. Architectural entities partial hierarchy.

Arrays are groups of entities and relations chosen in order to represent one specific combination. Typical example of arrays is any type of the Roman or Greek column. They consist of generally three entities aligned according to each order's rules (base, shaft, capital).

### 3.3 Textual formalization

A script based on our "LaDemarche" script language defines how a given set of entities is organised in an array (réseau), and visualised in a scene. A first version of La Demarche, developed in 1997 with C++, had a strong drawback: its static aspect. As a grammar, it used a lexical analyser (LEX) and was therefore given a finite vocabulary after compilation. By choosing to develop in JAVA we could transform this language into a dynamic one that allows the integration of new concepts without compilation. With the introduction in the Java language of the metaclass mechanism it is possible to link the name of a class with its computer representation. It is therefore possible to gain access to each of the object's methods without writing tokens in a predefined dictionary.

We have also introduced in "LaDemarche" the notion of mutable object, not implemented in Java but formalised in UML (Unified Modelling Language). Any instance of an object owns properties (attributes and behaviour) given by its class type. These properties, even though their actual content may vary during the instance's life, cannot disappear, and neither can new properties, not defined inside the class, appear. The addition of new attributes inside an instance implies a change of class type. This is not implemented neither in C++ nor in JAVA. Moreover, a mutation between sister classes cannot be done without facing the risk of an information loss (properties loss). We have therefore preferred implementing mutation in a restricted meaning : refinement of classes. The refinement operation allows the instance of a given class A to mute into an instance

of a class derived from class A. We are therefore sure that after this operation all the attributes of the mutating instance will be informed. New attributes described in the derived class are given default values. This approach can prove useful when dealing with a group of architectural objects to be handled inside a common control structure. For example we group the ten beams (Solives) of a ceiling of which two are side beams (Muriere):

```

Solve ensSolve[10];
a 10 Solives array
ensSolve[0].refinement(Muriere);
instance 0 is refined into a Muriere
ensSolve[9].refinement(Muriere);
instance 9 is refined into a Muriere

```

This "LaDemarche" script defines a polymorph array of 10 Solive type objects of which two are Muriere type objects.

### 3.4 Interaction with survey

Surveying an instance of the architectural model is a process in which, when following our approach, the goal to achieve is informing the instance of its architectural dimensions (width, radius, etc..) position and orientation. Each architectural entity is provided with a redundant set of geometrical primitives corresponding to their morphological specificity. Each primitive is provided with a self-calculation mechanism member of the EGO class hierarchy in charge of finding inside a given group of points the geometrical attributes of the primitive. Each point surveyed is therefore labelled as "belonging" to a given instance of the theoretical model. The architectural survey process inside ARPENTEUR starts with choosing what entity (what type of entity) is to be surveyed. The user can then choose inside the definition of the entity what particular morphological aspect (what primitive supporting the morphology) he will measure.

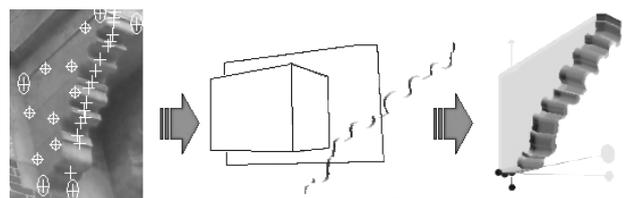


Figure 6. Three survey steps of console. Labelled points, bounding box, projection plane and moulded profile, Console

The result of these steps is a "LaDemarche" script in which the entities measured are described, and that can be updated in order to add new instances issued from a theoretical analysis of the building (typically adding "clones" of a measured objects in an ordered composition such as an archway of unseen or destroyed objects).

#### 4. THE CASE STUDY OF TOWN HALL IN KRAKOW

##### 4.1 Context of the architectural study

The GAMSU-MAP CNRS laboratory (Marseilles, France), specialised in the use of computer techniques, and the HAIKZ institute of Kraków's faculty of architecture, specialised in conservation, have initiated a research and exchanges program supported by a POLONIUM Franco-polish funding, named ARKIW, aiming at investigating the architectural evolutions of Kraków's main market square during its eight centuries of history. Multidisciplinarity is a central aspect of this research, and the enabling of distant web access to all the computer developments a necessity. The architectural model is here positioned to serve as a junction between the concepts and methods of the computer scientist, and the knowledge and practice of the conservatorist.

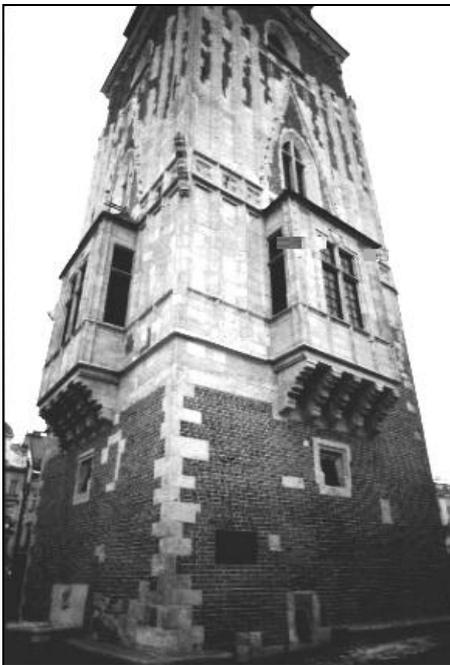


Figure 7. Town Hall, Krakow.

Kraków's old town hall is an exemplary case study in which the expertise of historians or conservatorists meets architects and surveyors. The actual corpus we have decided to focus on for the experimentation presented in this paper is the bow-window and its consoles. This element is part of the early sixties conservatory intervention on the tower due to Prof. W.ZIN (HAIKZ WA PK). Reconstruction of those consoles is based after original gothic remains and thoroughly documented, consequently it appears as a promising experimentation ground.

##### 4.2 The mouldings problem

As previously mentioned, an architectural entity embeds in its definition geometrical primitives computed through the EGO mechanisms and corresponding to a morphological specificity of the entity. An entity whose morphology includes a profile made of successive mouldings could be handled as a set of independent mouldings to which geometrical primitives correspond

(circles or planes in the case of our consoles). We would then measure points on the surface of each moulding until the whole profile would be informed. Quite obviously this approach would require an investment in time for the operator of the survey that is not satisfactory. We have therefore implemented a particular survey mechanism dedicated to the measurement of moulded profiles in which survey includes only:

- Survey of two control points per moulding corresponding to the start and end points of the moulding's curve.
- Qualification of the moulding (according to a predetermined typology).

Instances of the moulded profile class can be embedded in an entity (such as the consoles in this experimentation). Their definition includes the survey mechanism. They embed a list of individual mouldings, defined by a curve typology and two points, and informed by the survey mechanism.

##### 4.3 The survey – model cycle

Since we survey instances of an architectural model, elements represented in the final scene correspond to a theoretical definition of architectural objects. Consequently both entities that have been measured as previously mentioned and new instances of theoretical model, chosen as a result of an architectural analysis of the building, will be represented in the same space, the space of the photogrammetric control points.

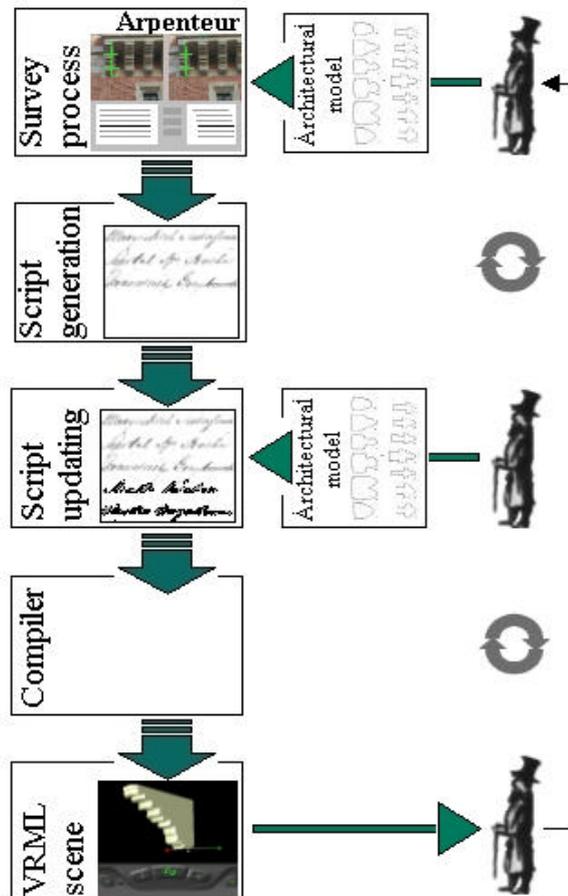


Figure 8. Survey and theoretical updating of the architectural objects

Intervention on the set of measured objects is possible as soon as a "LaDemarche" script has been generated. New entities can be added and the result visualised for validation. A new survey cycle can be launched in which objects added to the script as well as already measured objects can be surveyed totally or partially.

#### 4.4 The photogrammetric survey

Pictures were made in November 1998 in Kraków, using a Kodak DCS260 digital camera. The purpose of our survey was not an exhaustive restitution of the tower but an experimentation of a new survey approach. Therefore we used a non-metric camera, taking stereo pairs from the ground at a distance of 20m from the tower. The photogrammetric model is scaled on control points obtained from several plans used for architectural investigations.

#### 4.5 Stereo Plotting and Results

The stereo plotting phase is monitored by the architectural model's internal structure. Each point measured is identified as a point of a predefined geometrical element embedded in the architectural entity being measured.

Regarding to our experimentation, we have surveyed a five-units set of consoles by measuring :

- a set of points to define the profile itself.
- a set of points for the global box (position and orientation in space),
- a set of points to define the profile projection plane,

After the computational phase integrating these data the position and orientation of the console is computed then the least square plane. Finally the profile is generated according to its formal description (which is accessible from the ARPENTEUR stereo plotting frame).

After these steps we have obtained instances of architectural entities which are measured in the control point referential. We can then start the complementary phase process since a textual description of all measured architectural objects has been generated.

By updating this textual description, we can insert new objects (instances of the theoretical model) regardless of measurement phases.

In this experimentation we only inserted the floor of the bow-window that the consoles support.

After recompilation of the textual description both measured elements and added ones are shown in the VRML output. The VRML representation is always linked with the photogrammetric space, thus they can measure new points so as to check the relevancy of his additions.

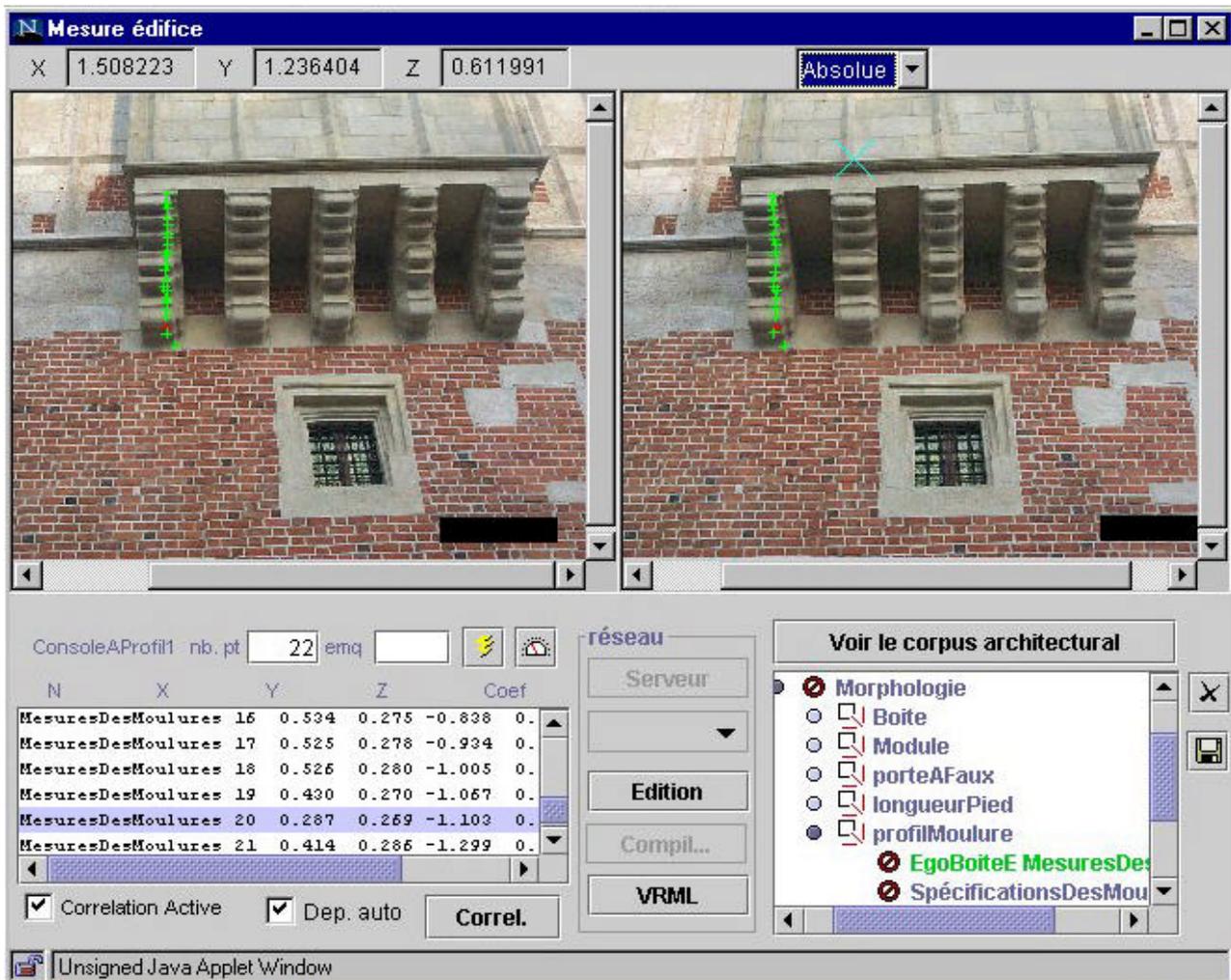


Figure 9. A Profile survey inside the Arpenteur tool

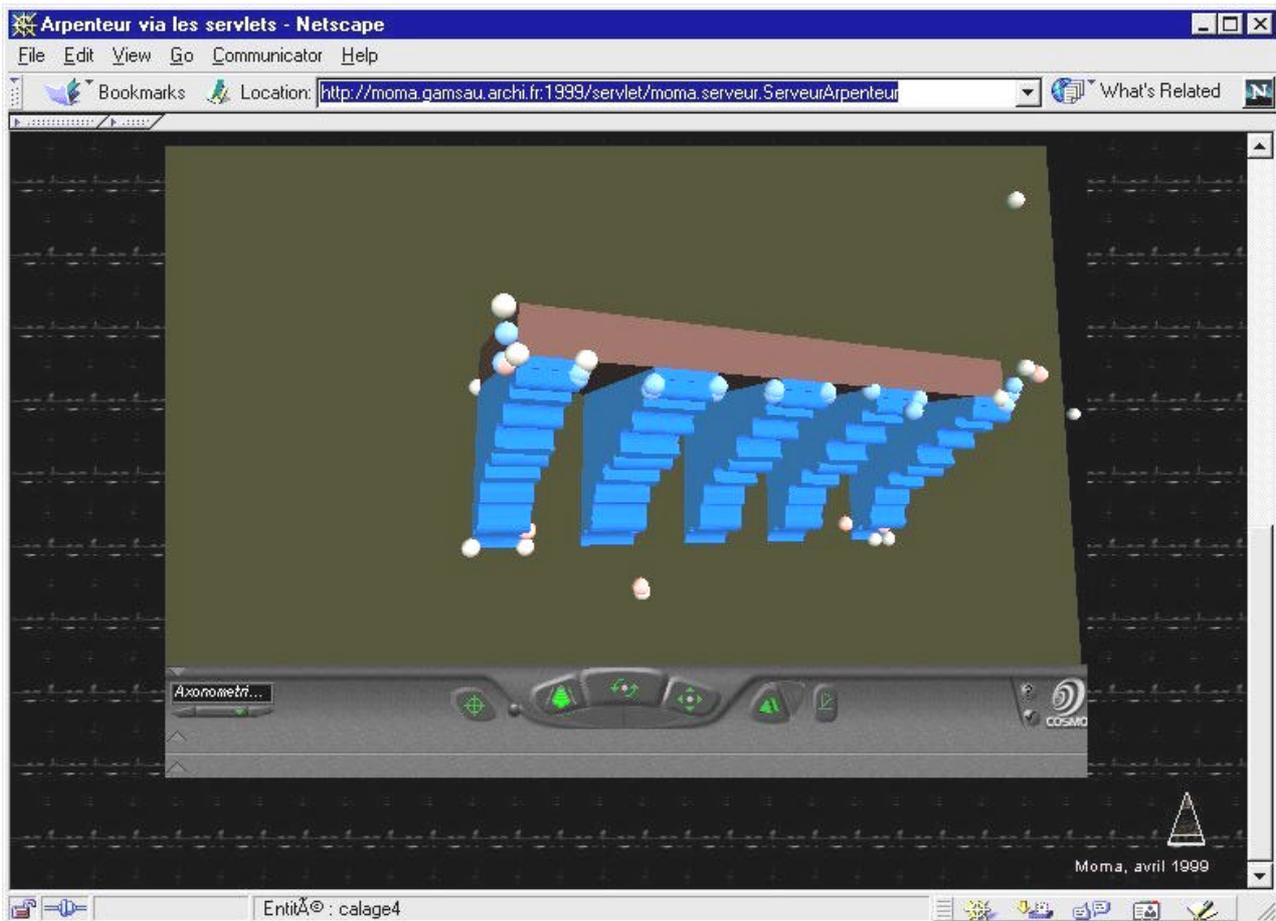


Figure 10. VRML output of the control points, of the five measured consoles and of the floor's bounding box added inside the script. Control points were measured on the floor's face cornice not shown on the VRML representation of the floor's bounding box.

## 5. CLOSING REMARKS

### 5.1 A photogrammetric workstation on the web

ARPENTEUR software packages are developed in the frame of the CIPA WG3 « simple methods for architectural photogrammetry ». Many messages addressed to the CIPA Mailing List are requests on simple and low cost photogrammetric systems. We think that such software packages can help to introduce the photogrammetric techniques to the world cultural heritage working community. The fast development of digital cameras facilitates the field work. Digital images combined with simple photogrammetric systems is a solution for documenting and modelling objects, especially if the digital photogrammetric workstation is available on the web. The proposed tools are also suitable for cooperation, education and research. ARPENTEUR is freely accessible via the Internet at: <http://moma.gamsau.archi.fr> or <http://photogeo.u-strasbg.fr>

### 5.2 A tool dedicated to architectural survey

Beyond being a photogrammetric tool, ARPENTEUR is dedicated to the dimensional analysis of an architectural model. ARPENTEUR can then be considered as an objectivisation tool for architectural modelling. It

therefore brings to the fore an original approach in which questions addressed concern photogrammetrists as well as archaeologists, architects, computer scientists or conservationists.

### 5.3 Acknowledgements

Pictures were made with a digital camera kindly lent by Department of Photogrammetry and Remote Sensing Informatics, AGH Kraków. We therefore thank Prof. Józef J. Jachimski, national CIPA delegate for Poland, and his team for their kind support.

The Kraków experiment was made possible thanks to the support of a Franco-polish POLONIUM research program linking the GAMSAU laboratory to the HAIKZ institute of Kraków's faculty of architecture (WA PK). We would like to thank Prof. A.Kadluczka, Dr M.Lukacz, Dr J.Czubinski, Mgr I.Dudek for their expertise in this experiment.

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## 6. PERSPECTIVES

### 6.1 Extending the link between architectural model and surveying

Informing an architectural entity of its position orientation and dimensions is up to now a contextual

process. Each architectural entity has its specific survey interface that has to be analysed in order to retrieve the architectural information. We are currently working on a more generic approach of the survey process.

Up to now measured points belong to geometrical objects who define the morphology of an architectural entity. Another development on which we are focusing on is a global affectation of those points in order to implement a one to several relation between a point and entities. For example in this experimentation points measured on the top face of the consoles also inform the floor of the bow-window.

A better readability of the architectural model's contents inside ARPENTEUR's user interface is also to be studied.

## 6.2 The architectural model monitoring an image analysis : a help in the survey process

Up to now we take benefit of a knowledge of the 3D morphology of architectural objets measured in order to monitor the survey process. The operator's choices are guided by a description of possible geometrical objects to be found on the entity being measured.

We plan to use this same approach, that is integrating a knowledge of the objects to measure, in the first steps of the survey process. We plan to use image analysis in order to implement pattern matching mechanisms on architectural objects of which the shape in perspective projection is known since defined in the model. We consider this step as a helpful tool for the survey operator.

In the present version of ARPENTEUR we have implemented image filters in collaboration with the Laboratoire Signal et Image (Ecole Nationale Supérieure de Physique de Marseille) in order to check the feasibility of writing such algorithms in the JAVA programming language. For example we plan to use this approach in measuring ashlar blocks masonry.

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