DISTRIBUTED INTERFACE FOR ARCHEOLOGICAL RESTITUTIONS.

Jean-Yves Blaise
Architect, Teacher cum researcher

Pierre Drap
CNRS researcher

Michel Florenzano
Architect, CNRS researcher, Director of the laboratory

gamsau URA CNRS n°1247
Ecole d'Architecture de Marseille-Luminy
184, av. de Luminy 13288 Marseille Cedex 09 France
Tel 33 4 91 82 71 70 Fax 33 4 91 82 71 71
email. (Jean-Yves.Blaise, Pierre.Drap, Michel.Florenzano) *@gamsau.archi.fr*
http://moma.gamsau.archi.fr

KEYS WORDS : ARCHITECTURE, MODELING, IMAGERY, KNOWLEDGE REPRESENTATION , OBJECT_ORIENTED PROGRAMMING, ANTIQUE ROME, ARCHEOLOGICAL HYPOTHESIS, VRML, WEB,

ABSTRACT :
In the field of the architectural patrimony, the building up of surveying and knowledge representation tools gives new analysis opportunities, and favour the drawing up of reconstructional hypothesis. Addressing this question, the MOMA research (**M**odels and **O**ptical **M**easurements in **A**rchitecture) implements architectural models used as a pre-requisite for the survey process. Individual objects are identified and organised following the object-oriented approach in computer science. These elementary entities gather in their definition both morphological data and patrimonial information. They are grouped into consistent sets of objects through relations stemming from the architectural vocabulary and implemented in a language developed for this purpose. Measurements are carried out on predefined morphological specificities of these entities.
Dealing with conservation in architecture, photogrammetry, computer science, MOMA meets the stakes of a multidisciplinarity research. Moreover, The heterogeneous technical systems and tools met in the scope of these disciplines clearly call for a platform-independent tool giving access to the patrimonial information gathered. Web interfacing is an answer to this problem, its implementation in our research puts a strong focus on VRML visualisation as a central entry point in the system.

MOTS CLÉS : ARCHITECTURE, MODELISATION, VISUALISATION, REPRESENTATION DES CONNAISSANCES , PROGRAMMATION ORIENTÉE OBJET, ROME ANTIQUE, HYPOTHESES DE RESTITUTION ARCHEOLOGIQUE, VRML, WEB,

RÉSUMÉ :
MOMA interroge les domaines liés aux techniques du relevé architectural (outil photogrammétrique, modélisation des connaissances...) et les domaines liés à l'analyse et la représentation du patrimoine bâti (étude de pathologies, simulation d'hypothèses,.).
La stratégie développée dans MOMA s'appuie sur l'apport des langages informatiques orientés objet en matière de formalisation des domaines de connaissance complexes. Les disciplines abordées à chaque étape du processus de traitement de la mesure comme en gestion de données seront analysées en fonction du postulat d'un raisonnement par classification rendu possible par cette technologie. La multidisciplinarité du domaine abordé et l'hétérogénéité des données manipulées conduisent naturellement vers un outil de travail indépendant des plate formes matérielles. L'interface Web du processus MOMA répond à cette exigence et se sert des représentations tridimensionnelles VRML comme d'un noyau central fédérant les données assemblées sur l'objet architectural.

1. FOREWORD

The MOMA research programme (**M**odels and **O**ptical **M**easurements in **A**rchitecture) , developed at the GAMSAU CNRS laboratory, formalises and implements representations of the architectural patrimony summarising three features of the domain : information, representation, conservation. Taking advantage of the consistency of object-oriented programming with complex knowledge, the project can be described through three phases :

Formalisation, measurement processing, and information of the architectural model.

Representation and implementation of archaeological hypothesis.

Platform-independent web interfacing of the research outputs.

MOMA therefore focuses on the field of architectural surveying (photogrammetry, knowledge representation) as well as on the field of the architectural heritage (identification of pathologies , simulation of hypothesis). We consequently develop a knowledge tool using the architectural model as the core of an interdisciplinary representation. Handling the exchange of experiences and skills covering the wide scope of the architectural conservation discipline requires the use of models able to represent diverse points of view and practices. Relevance of this interdisciplinary approach therefore relies on the ability of a computer-based system to convey within the simulation process the information detained.

High development prospective in web technologies naturally lead us to promote this network approach as the major exchange modus to favour. It opens our research to didactic approaches of patrimonial studies, taking advantage of our computer developments.

2. THE RESEARCH FIELD

2.1 Object technology and Architectural patrimony

The scope of the architectural conservation field extends to more and more buildings.

From Nîmes Maison Carrée to the silos of Marseilles port, from the antiquity to our XXth century, the number of buildings considered in terms of patrimonial objects increases year after year. This architectural heritage is described in the MOMA research according to two major principles :

Splitting of the building into elementary , univocal objects, that we call architectural entities, organised with the help of relations stemming from the architectural vocabulary

(perpendicularities, relations to an axis, topological behaviours, ...)

Building restitution methods that allow, given a single set of entities, the representation of diverse hypothesis concerning the manner with which they were organised, composed.

Architecture, and therefore these entities, is considered as a non-ambiguous mean to federate information both on morphological aspects (issued for instance of a survey

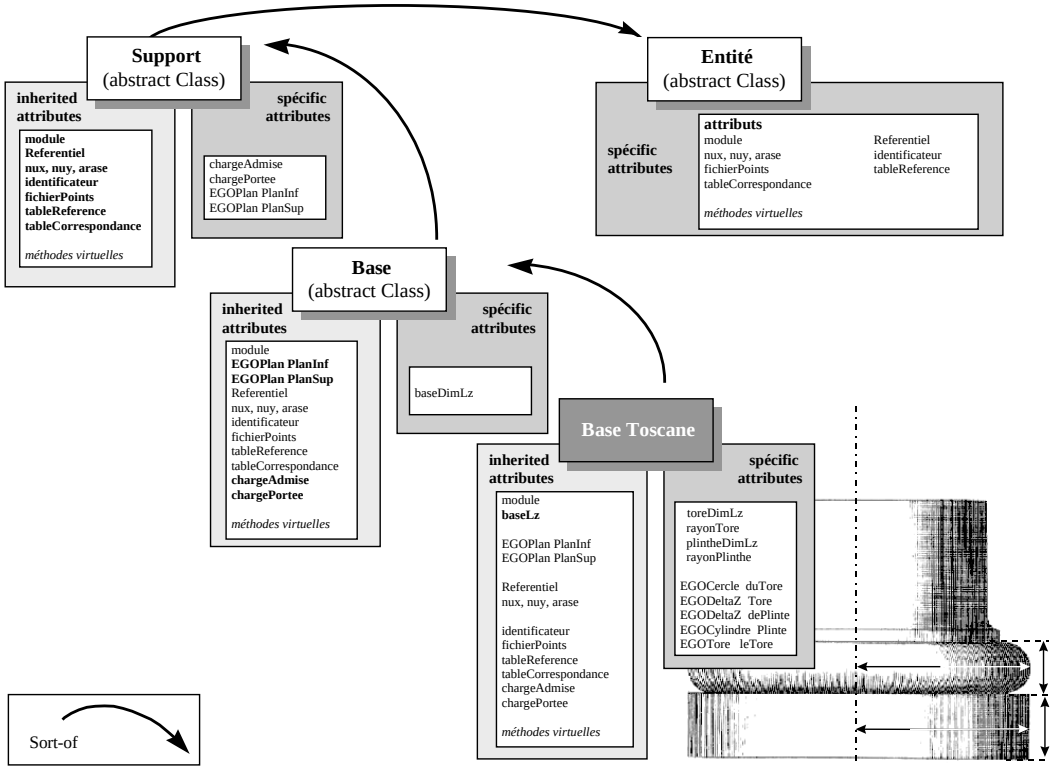


Figure 1. Inheritance example : the tuscan base.

campaign) and more specific aspects of the patrimonial field.

2.1.1 Definition of the architectural model

Elements of a building will be described as "entities" (elementary elements) providing that they meet two requirements :

An entity is a unique " object " identified by a single element of the architectural vocabulary.

An entity has an obvious and permanent role in the physical structure of the building.

A typical example of this approach can be found in the description of the roman column : its base, shaft and capital are entities (one word, one role, indivisible) ; the column itself isn't (one word, several objects, divisible).

Entities are then physical individuals to which we attach various elements of knowledge such as non measurable data (historical information and so forth); and geometrical information (dimensions, orientation) which we use to organise topological relations between the entities.

Besides, the MOMA data model describes relations between entities and predefined groups of entities (called "reseau"). Typical examples of arrays are each column of the roman or Greek architectural orders : predefined groups of generally three entities aligned according to each order's rules. The "reseau libre" will then be groups of entities that do not fit a predefined scheme but are necessary to meet a specific need : they are freely composed sets of entities and relations.

2.1.2 Structure of the architectural model

The object-oriented programming approach lets us gather generic entities into hierarchies of elements sharing properties or common behaviours or attributes, each property added giving birth to a new, more specialised (lower in the hierarchy), generic element .

Architectural entities, structured by the inheritance of class mechanism, are analysed from the viewpoint of intension ,thus isolating object categories for which similarities of structure or behaviour can be observed.

Once the architectural entity's proprieties are described (both nature and behaviour), relations between entities are formalised in order to organise the building.

2.2 Measurements and survey process

2.2.1 Dimensioning the model

The survey process we present in this research makes use of photogrammetrical survey techniques to propose a method that integrates a pre-defined knowledge of the elements to be measured.

The process first gives dimensions to the independent elementary entities, using canonical definitions of the models involved, then makes use of one or more hypothesis on their combinations so as to link them to one another. The background of this research, and consequently the outputs to figure, is therefore a dimensioning process in which architectural models are informed by a photogrammetrical survey.

2.3 The CAD file generation et numerical results

The dimensioning process provides the user with diverse types of results :

magnitudes (dimensions, position and orientation of the architectural entities involved)

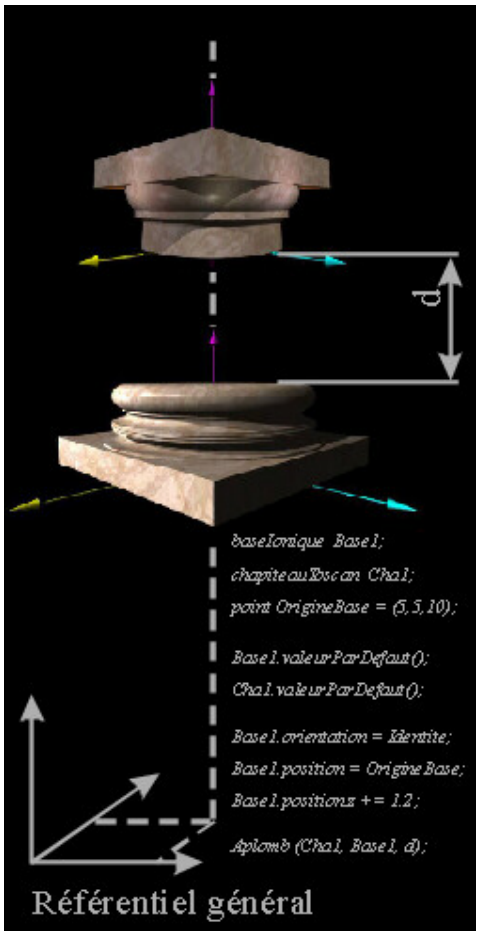
statistics figuring diverse information related to the process itself (remainders)

relevance of the models chosen (the statistics show the consistency of the model and of the measurement)

A good approach to enabling analysis of those results is providing a link between, on one hand, numerical and textual results, and, on the other hand, a CAD tool representing the model computed.

Moreover, our research is targeted at diverse users: researchers in both computer field and disciplines related to architecture (close-range photogrammetry, conservation, education), and PhD students. Web technologies (VRML, Java) and object oriented approach through C++ and an OODBMS are the choices made in order to open the outputs to platform-independency.

3. FORMALISING THE ARCHEOLOGICAL HYPOTHESIS



3.1 A manipulation language

The theoretical architectural model is described in a script that can be read and interpreted through a parser, member of the " réseau libre " class.
This parser, developed by alain Coëtmeur [Coëtmeur 1993] (Flex++ and Bison++), is an extension of the Flex / Bison pair, able to generate C++ classes. The solution adopted is to consider the scanner as a member of the parser after having derived the LaDemarcheLex and LaDemarcheSyntax classes of the original Flex++ & Bison++ classes [Donnelly, 1992].
The theoretical model is described by a formal grammar. The vocabulary used in this **script** corresponds to the architectural entities and their relative positions.
Regner (Chapiteau1, Chapiteau2) ;
Au Droit (Fut1, Fut2, y, 1.230) ;
Aplomb (Chapiteau1, Fut1) ;
Percer (Mur1, Baie1) ;
are four valid phrases of the grammar, where :

Regner *corresponds to a common altitude of the entities involved*

Au Droit *corresponds to a common axis of the entities involved in plan, with a parameter stating the distance between them.*

Aplomb *corresponds to a common vertical axis of the entities involved.*

Percer *corresponds to the performing of openings inside a wall entity.*

3.2 The building " as it might have been "

The model corresponds to a current state of the archaeological knowledge, meaning that it figures its certainties as well as its remaining elements of uncertainty. It therefore allows the representation, given a single sample of data, of several hypothesis. The flexibility of the model's description also permits the representation of the evolution of knowledge related to a building, or of the evolution of the building itself.
The use of CAD tools forbids any omission on the morphological model, to the image of an anastylosis, the whole of the dimensional data has to be informed, and the final model ensures a consistency of the entities nevermind what accuracy and complexity their definition takes. Given data on an urban fabric at one point, our approach gives way to an evolutionary model taking into account advances in the fields of archaeology, history, literature. A restitution of an urban fabric at different points is thereby possible, showing stages in its construction, growth. The final model has educational features that can be targeted at non-specialised publics.

4. INTERNET AND VRML : A PLATFORM-INDEPENDANT INTERFACE

The MOMA platform interface monitors:

- The model

Entity dimensions references (tables)

Script edition, in which instantiation and definition of the entities involved and of their relations to one another are enabled

- The remote process interpreting the script
- A set of reports including textual data and graphical representation.

The reconstructional hypothesis formalisation method proposed in our research requires an iterative interface.
The development presented implements this feature (iterative action on script and tables editing, on process execution and visualisation of reports) on a distant collaborative interface, a relevant approach in the highly multidisciplinary field of conservation and archaeological researches.

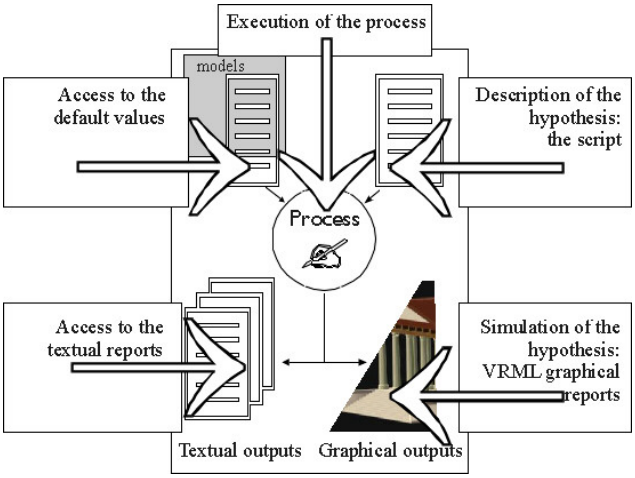


Figure 2: Inputs / Outputs of the process

We have chosen a now standard communications architecture, using an HTTP server and web clients connected via HTTP or IP (java sockets) protocols. The HTTP server distributes the GUI in the server-client direction, and allows the execution of programs.
The textual description of the model in the client server direction is enabled through a socket connection.

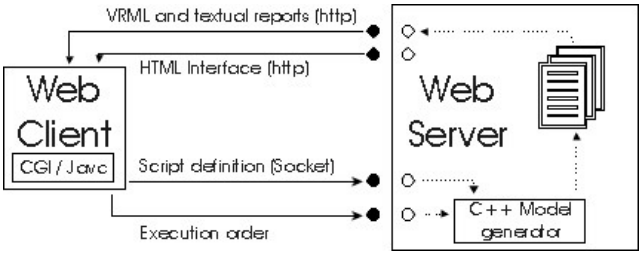


Figure 3: architecture of connexions

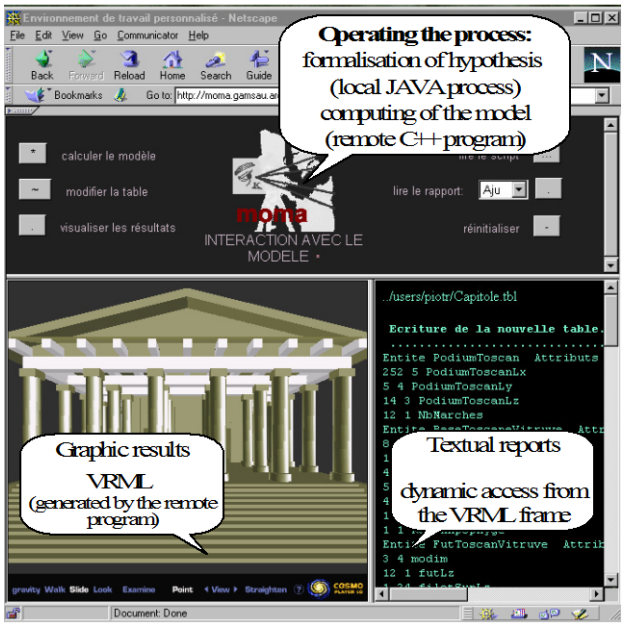


Figure 4 Web graphic interface of the MOMA process.

4.1 Data formalisation

The interface provides access to two levels of the chosen model's definition (ie. The Capitol : temple of jupiter in Rome, see §5.1) :

The script (see a brief manipulation language example in Figure 7) describes both the entities involved and the relations that link them to one another. It enables modifications on :

- Their dimensions, position and orientation
- The relations chosen to combine them
- The choice of a reference table in which ratios of proportions between the diverse attributes of each entity (defining its morphological features) and the module (basic unit of classical architecture) are stated. This knowledge is extracted from bibliographical resources and from the observation of remains.

The reference table:
the interface here gives access, for each entity, to the ratios of each one of its attributes.

4.2 Data analysis

4.2.1 Graphical data

Translation of the entities morphology, position and orientation to diverse CAD and synthesis images tools formats is provided by the MOMA process. The draughts, produced for three graphic modellers, correspond to three objectives :

Production of synthesis images : A description of the scene for the Pov -Ray Persistence Of Vision ray tracing software is generated.

Access to graphical expression and numerical data : The use of a CAD software enables the production of standard plans, sections, axonometry (...), and figures a thorough description of the entities' morphology. The Autocad software is used through automatically generated scripts, and allows access to the diverse Autodesk products (3D S MAX etc...)

Didactical approach : Interactive Visualisation and access to non graphical data is provided in a multi-site collaborative technical platform. The VRML formalism (Virtual Reality Modelling Language) has been chosen in this research in order to ensure interactivity and platform independency.

4.2.2 A link between graphical and textual data

The system's outputs include numerous textual reports. A linear analysis of those documents is not very convenient. Two possibilities of tackling this problem are given : statistical analysis of remainders ; and graphical access to the textual report through hyperlinks implementing relations from each entity available in the VRML representation to its own relevant elements of the textual reports.
The system generates hyperlinks anchors within the VRML file which are targeted at a frame of the browser-based interface, allowing contextual reading of the reports.

4.3 The VRML output

Figure 5. Demonstrative non-architectural composition : VRML visualisations of the script shown in Figure 7

VRML of course does not implement Boolean operations. In order to represent openings in a wall, the system generates a set of VRML blocks gathered in a single node. The recursive algorithm implemented can perform any likely arrangement of openings in a wall.
Access to information related to the wall and its openings is possible through a single link referencing the whole set of blocks that figure the wall. Access to the openings information is implemented by hyperlinks generated in the wall's report.
The system generates within the VRML file nodes corresponding to the 14 standard viewpoints relevant for each model (elevations, plans, axonometries, with perspective and orthographic camera). In a similar way, case-sensitive lights are positioned automatically.

5. THE BIGOT MODEL EXPERIMENT

5.1 Temple of the Capitol

The first temple built on mount Capitol, of tuscan order, was completed roughly around 509 BC, at the start of the republic. It totally burnt four centuries after its construction, in 83 BC. The temple was dedicated to three different divinities : Jupiter, Juno and Minerva.
The second temple was completed by Julius Caesar and destroyed by a fire in the year 70 AD, the third temple burnt ten years later under Titus' reign.
A fourth temple was completed with Domitien and has then been standing until the end of ancient Rome.
The Bigot model shows this fourth temple. The photogrammetrical survey of the model will only help us to locate, orient and dimension the buildings in the model's reference system since details cannot be exploited on a 1/400 scaled model.
Our experiment will focus on the first tuscan temple of the capitol, its position and orientation will be measured with the model's photogrammetrical survey.

Figure 6. Bigot model, general view of the river tibre.
Photograph : D. Lauvernier,
http://www.unicaen.fr/rome/rome.shtml

5.2 Survey process

We here use non-stereoscopic photogrammetry in which the orientations of the cameras are calculated by bundle adjustment. This approach costs less than stereoscopy and, in this case, is less accurate.
The pictures were taken with a semi-metric Rollei camera, 6x6 format. A gauged network of glass, integral with the camera and located in front of the film, draws on the image crosses which are determined in co-ordinates, and that will be used in order to model the film's distortion. The measurements are operated with a digitizer on photographic printouts.

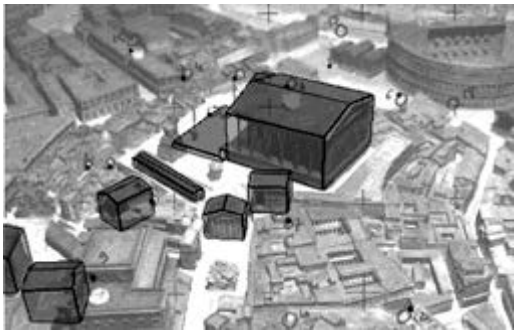


Figure 8: Including volumes of the measured buildings on a photogrammetric slide.

5.2.1 Numerical results

In this experiment, the result of photogrammetrical surveying is limited to simple volumes including the buildings, so as to position the theoretical models.
shows these volumes, represented via the Microstation CAD software. The perspective corresponds to the viewpoints of the cameras, as they were calculated by the photogrammetric process.
At this point, positioning and orienting the " reseau libre " describing the temple (entities + rules of composition) only requires the determination of the building's basement origin and its orientation matrix.

```
baieToscaneSousLinteau Baie1; baieToscaneSousLinteau Baie2;
baieToscaneSousLinteau Baie3; BaieToscaneSousLinteau Baie4;
murPignon MurP1;                                   // declaration of the entity MurP1 (gable wall)
MurP1.valeurParDefaut(); MurL1.valeurParDefaut(); // setting default values read in reference tableBaie1.valeurParDefaut();
Baie2.valeurParDefaut();
Baie3.valeurParDefaut(); Baie4.valeurParDefaut();MurP1.origine = (0.0, 0.0, 0.0);          // positionning the entity MurP1.lx
= 2.0; MurP1.ly = 35.0; MurP1.lz = 20.0;// dimensionning the entity
Baie1.lx = MurP1.lx; Baie2.lx = MurP1.lx; Baie3.lx = MurP1.lx;Baie4.lx = MurP1.lx;
Baie1.ly = 4.0; Baie2.ly = 3.5; Baie3.ly = 3.5; Baie4.ly = 10.0;
reel EntreAxeBaie = 2 * Baie1.ly;                  // declaration / initialisation of a local variable
Baie1.lz = Baie1.ly * 2; Baie2.lz = Baie2.ly * 2; Baie3.lz = Baie3.ly * 2;
Baie4.lz = 4.0;
Baie1.origine = MurP1.origine;
au droit (Baie1, Baie2, -y, 0.0, EntreAxeBaie );   //interdependancy of entities Baie1 Baie2au droit (Baie1, Baie3, y, 0.0, EntreAxeBaie );
aplomb(Baie1,Baie4,2.0); percer (MurP1, Baie1); percer (MurP1, Baie2) ;
percer (MurP1, Baie3); percer (MurP1, Baie4);
```

Figure 7. Brief benchmark script defining a gable wall with four openings.

5.3 Simulation of archeological hypothesis

The experiment deals with the first Capitol tuscan temple. Its position and orientation seem to have been preserved through time ands the diverse rebuilding it underwent ([Daremberg, Saglio, 1887] page 902).
Two hypothesis as how the temple was composed have been chosen :

Filippo Coarelli proposes an hexastyle tuscan temple

Frank Edward Brown, Emeline Hill Richardson propose a tetrasyle tuscan temple

The models corresponding to the two hypothesis are computed in real-time through our web interface, and figure the same architectural corpus. Three steps of the process are given access to :

- *The writing or re-writing of the script*
- *The computing of the model, and its outputs generation (graphical and textual)*
- *The VRML visualisation (giving contextual access to the textual reports)*

The first hypothesis : an hexastyle temple

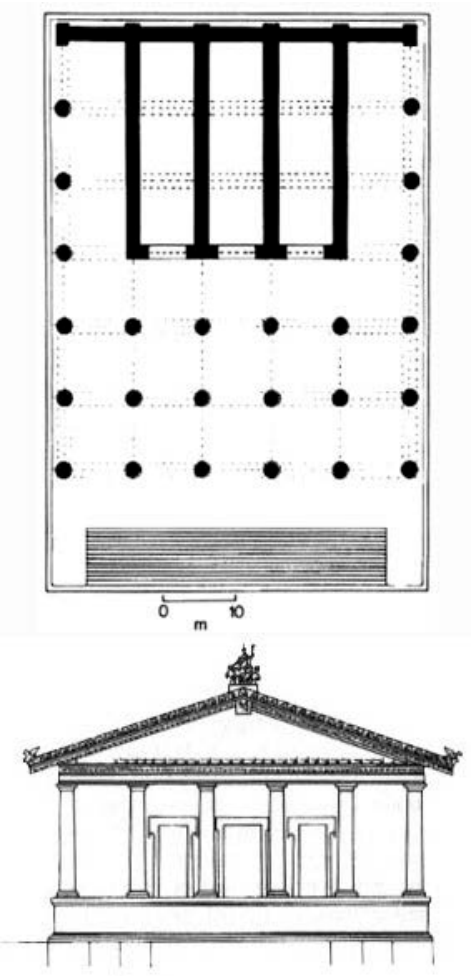


Figure 9. Reconstructional hypothesis of the Capitole's tuscan temple according to Filippo Coarelli. [Coarelli, 1994] page 30.

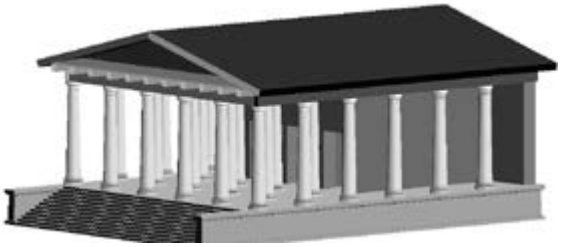


Figure 10. The reconstructional hypothesis of fhe temple of Jupiter Capitolin, according to Filippo Coarelli, generated by the MOMA process in Autocad.

The second hypothesis : a tetrastyle temple

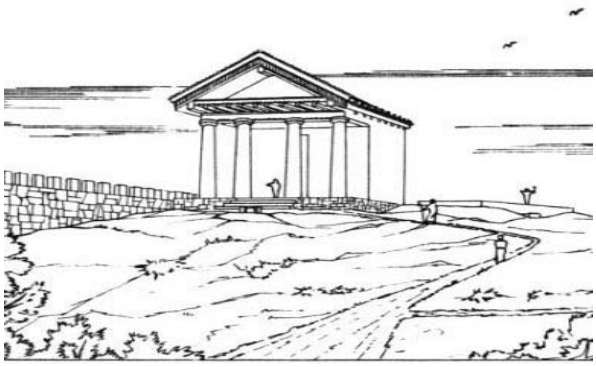


Figure 11. The reconstructional hypothesis of fhe temple of Jupiter Capitolin, according toFrank Edward. Brown, Emeline Hill Richardson, [Brown, Richardson, 1960]

Figure 12. The reconstructional hypothesis of fhe temple of Jupiter Capitolin, according toFrank Edward. Brown, Emeline Hill Richardson, VRML model generated by the MOMA process.

6. CONCLUSIONS & PERSPECTIVES.

Our purpose is to develop a new architectural survey tool linking a model of building (individual entities interacting one to others) and a remote sensing technique, photogrammetry.
Object oriented technologies will be used in order to formalise the heterogeneous data encountered in the architectural field. This approach of the architectural heritage opens up researches aiming at the definition of new building analysis tools :

- Development of a data management system dedicated to the architectural heritage : a tool helping to formalise and handle heterogeneous data. Information concerning diverse skills (history, archaeology, architecture, ..) are represented in a single model.
- Development of a tool for pathology analysis : either through model / measurement comparisons. (comparative reading in which diagnosis is based on the estimation of distances between the theoretical model and the result of the survey process) or through links of the theoretical model dimensioned by our survey process with calculation tools used by mechanical engineers. This approach will give an opportunity to simulate the behaviour of buildings or structures constructed in bonding.
- A multidisciplinary tool to represent archaeological hypothesis The development of a language describing the building's theoretical model gives an opportunity to represent diverse archaeological hypothesis based on a single set of data, therefore an opportunity to represent several possibilities on " how the building might have been ".
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The technical platforms corresponding to these problems are diverse (multiple operating systems and hardware) . We are consequently focusing on their web-interfacing, in order to provide a platform-independent access to the underlying models. Their graphical expression in VRML, through automatically generated anchors, stands as an interactive convenient entry point to the overall process.
Didactic access to patrimonial data should now be developed through a VRML-JAVA-OODBMS integrated system.

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