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► **To cite this version:**

Emmanuel Alby, Pierre Grussenmeyer, Jean-Pierre Perrin. Analogy between the architectural design process and the documentation of architectural works. XXth CIPA International Symposium, 2005, Italy. pp.923-928. halshs-00264540

**HAL Id: halshs-00264540**

**<https://shs.hal.science/halshs-00264540>**

Submitted on 21 May 2008

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# ANALOGY BETWEEN ARCHITECTURAL DESIGN PROCESS AND THE DOCUMENTATION OF ARCHITECTURAL WORKS

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Working Group II

**KEY WORDS: Acquisition, Architectural, Design, Documentation, Management**

## ABSTRACT

Our primary goal is to establish a 3D acquisition methodology for the documentation of architectural works. To reach our objective, it is essential to take account of the diversity of the information sources related to the built objects. Dimensional data cannot load exhaustive geometrical model. Furthermore, architectural modelling cannot be summed up by acquisition of the object geometry alone. However, combining acquisition with organization and management of different kinds of data has a high potential for producing built work documentation. To approach efficient management of different data sources, we focus on the architectural know-how. Thus, we study the integration of data according to increasing levels of detail. At the beginning of the building design process, few elements are fixed, but the layout of the building and its general shape is already defined. We have a global representation but not very detailed. The complexity increases in the successive stages. During documentation, the quantity of information rises according to a similar principle: from global understanding through detailed analyses of elements to acquisition of details. Structuring information related to a built work according to increasing levels of detail offers several advantages. The division of data integration into identified stages can induce an acquisition methodology. Furthermore, the combination of 3D data with other type of information in a single interface allows a rationalization of the building modelling stage. The modelling approach by simple model enrichment gives the possibility to efficiently manage the complementation related to the increasing levels of detail. Our proposal is thus based on comparing the building design principles with the building modelling methods, to obtain a model as complete as possible and still consistent with the construction process.

## RESUME

Notre objectif initial est d'établir une méthodologie d'acquisition 3D pour la documentation d'ouvrages architecturaux. Pour atteindre notre but, il est essentiel de tenir compte de la diversité des sources d'informations relatives aux bâtiments. Les données dimensionnelles ne permettent pas la construction de modèle géométrique complet. En outre, la modélisation architecturale ne peut pas se résumer à la géométrie. Cependant, la combinaison de l'acquisition avec la gestion de différents types de données a un potentiel élevé pour produire la documentation d'ouvrage bâtis. Pour envisager la gestion efficace de différentes sources de données, nous nous concentrons sur le savoir-faire architectural. Ainsi, nous étudions l'intégration des données en fonction de niveaux de détail croissants. Au début du processus de conception architecturale, peu d'éléments sont fixées, mais la disposition du bâtiment et de sa forme générale est déjà définie. Nous avons une représentation globale mais pas très détaillée. La complexité du projet augmente d'étapes en étape. Pendant le processus de documentation, la quantité d'information augmente selon un principe semblable : de la compréhension globale jusqu'à l'acquisition des détails en passant par l'analyse détaillée des éléments. La structuration de l'information liée à un ouvrage bâti en fonction de niveaux croissants de détail offre plusieurs avantages. La division de l'intégration de données en étapes identifiées peut induire une méthodologie d'acquisition. En outre, la combinaison des données 3D avec d'autre type d'information dans une interface simple permet une rationalisation de l'étape de modélisation du bâtiment. L'approche de la modélisation par enrichissement d'un modèle simple donne la possibilité de contrôler efficacement la complémentation liée aux niveaux croissants de détail. Notre proposition est ainsi basée sur la comparaison des principes de conception architecturale avec la méthode de modélisation de bâtiment, pour obtenir un modèle aussi complet que possible mais aussi conforme au procédé de construction.

## 1. INTRODUCTION

Among several documentation projects we can observe a tight relation between 3D acquisition and its figuration. But it is required to remind that figuration and representation are simplifications of a three-dimensional model. Throughout our research we have to consider architectural documentation in a larger way to include as much as possible the variety of

documentation projects and the diversity of provided techniques. Acquisition tools suppliers often propose visualisation module to represent acquired data. Since we intend to manage several kinds of documentation project, it is hazardous to follow this way; consequently we suggest a process to build a model instead of direct representation tool. Three-dimensional model is a reduction of existing architectural work. Considering an architectural documentation project, the

geometry is deduced from the dataset. But acquisition techniques, even when they are combined; don't allow the user to model the entire knowledge of the building. Consequently, we propose another approach for architectural documentation: an analogy between architectural design process and architectural modelling. The geometry is defined first and then qualified by three dimensional data.

## 2. ARCHITECTURAL DOCUMENTATION

### 2.1. Architectural documentation targets

There are several reasons to manage an architectural documentation project.

**2.1.1. Conservation:** An International authority or organization, declare that a build work belongs to universal cultural heritage. Its physical conditions has to be managed properly so that it can be preserved and prove its cultural specificity. Building restoration provoke the modification of initial state. The documentation of an architectural work in such a condition implies its complete understanding (how it had been build, its original occupation, for example). In a case like this, there is a need for precise dimensional dataset and appropriate management of it.

**2.1.2. Promotion:** cultural heritage is a part of the urban identity and the community can thus promote itself by emphasizing it (Figure 1). In such a case the documentation is focussed on representation and communication.



Figure 1. Water Tower (VRML and Photograph)

### 2.2. Three-dimensional data acquisition techniques

In the field of 3D data acquisition we can find two kinds of techniques: Scanning and Photogrammetry. They represent two opposite approaches: active and passive mesure. We can associate this antagonism with the difference between the automation ability provided by scanning techniques and the difficulty to obtain architectural data without human intervention considering Photogrammetry (more and more reduced but still significant).

**2.2.1. Scanning:** on one hand lay LASER scanners and their vast application field (Fuchs, 2004). On the other hand another technology is being developed, a technique based on structured light theories, which promises lot's of advantageous uses in architectural detail survey. This method has the property to be reachable with cheap tools (Batlle, 1998). Those automatically produce point clouds. Post-processing steps are necessary to integrate this kind of data in an architectural modelling process.

**2.2.2. Photogrammetry:** 3D acquisition remote techniques originate from this discipline. There are many different

approaches to handle architectural survey with Photogrammetry (Grussenmeyer, 2002; Saint-aubin, 1992). A great advantage of using photographs as measurement source is the fact that they allow to carry out photo-interpretations, which are helpful in the modelling process. At the end of restitution step, we can obtain 2D plan or 3D vectors. Thanks to correlation, it is possible to get point cloud automatically but only when the project has already been oriented.

### 2.3. Encountered problems

Even if dimensional data are numerous and very precise, we always miss a part of the build work, primarily due to the mask phenomenon. Masks are hiding a part of the object to be surveyed and create a "hole" in the collected dataset (Alby, 2004 & Figure 2). Missing part of build work can also provoke such a deficiency of data. As the buildings are the result of architectural design, there are parts which have been repeated. Consequently the acquired data contains duplication of the same observable fact. There is therefore a discussion to manage about the significance of the architectural model we want to carry out based on such dataset and the knowledge to bring during the modelling process.

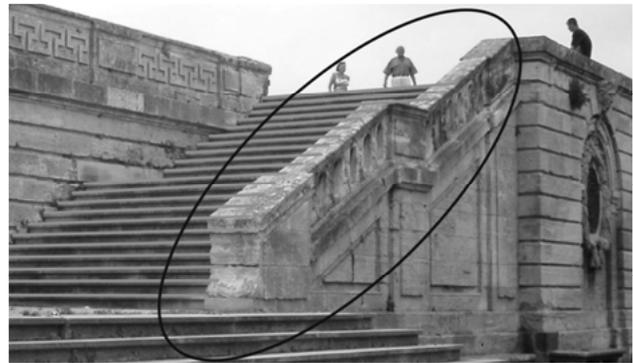


Figure 2. Mask due to projection and building itself

## 3. GEOMETRICAL MODEL AND DATA

### 3.1. Geometry

In this part, the differentiation between 3D data and geometry will be highlighted.

**3.1.1. Model:** Scientifically, modelling is a reconstruction process of the studied object in order to manipulate it. In architectural documentation, 3D data are often directly translated into representation, due to the fact that surveyor and architects (or archaeologist) are distinct person. But it would be interesting, for two reasons, that providers and users focus on the model: firstly the increasing use of computerised data induces the user to need other complex information instead of representation; secondly, during representation step, a provider has to make hypothesis which does not necessarily belong to his attribution. The model is a geometrical model. In this case geometry is good enough to describe architectural works for restitution of shapes and dimensional query.

**3.1.2. Acquisition:** Data collected during an acquisition operation has to be related directly with the real object. But this is just a mean to construct its 3D model. Based on the preceding paragraph, the 3D data can be seen as a relation between the model and the reality but not the only source of definition of

geometry. Topology is another method for the preliminary definition of the model. It is very important to consider 3D data as one tool among others in a first approach. Even if it could have a central position in the provider point of view. It is necessary to separate, intellectually, the field of acquisition from architectural documentation, to reconnect it later but differently.

**3.1.3. Representation:** Theoretically the representation comes after the model, when it exists. A model can not automatically be shown; that is why representation is an essential step. It may be a projection (elevation, section for example), a render with specific lights with particular layer. Representation can be seen as a reduction of the model elements we want to show. This is an excerpt. Three-dimensional data, if we try to represent it can only offer a reduced number of representations and unsuitable, so it is necessary to use a geometrical model to provide appropriate representation of architectural documentation.

### 3.2. Point cloud

In chapter 2.2, we presented the actual three-dimensional acquisition techniques. It is rational to deal with point cloud as a common product of 3D automated acquisition. During this preliminary study we admit that the data collected, regardless of the technique used, is synthesised in a point cloud. The 3D points collected give information about the position of the external surface of the building. This is only a part of information we need to complete the definition of the geometrical object that will be used to model the building at this specific stage.

## 4. ARCHITECTURAL KNOWLEDGE

In the previous part, we introduced the fact that three dimensional data are not sufficient (if exclusively used) to entirely define an architectural model. The complement of data is definitely architectural knowledge (Alby, 2004). Architectural knowledge can be divided into two parts.

### 4.1. Theoretical background

Theoretical background means the knowledge that exists before the erection of the building.

**4.1.1. Historical information:** This is the information we still have nowadays on the existing knowledge there was during the period when a building had been erected. The historical information gives the possibility to understand the evolution of the principle that was used for the construction. Globally it deals with the notable facts that happened in the past of the building and enabled to make it as it has been constructed. It allows the architect creating the model to recover the technological background of the period of erection and give the opportunity to know whether such a discovery was made or not, for example.

**4.1.2. Know-how:** there is tight relation between historical information and know-how linked to a specific building. The typical difference is that the building is the principal source of know-how knowledge. The way the construction supplies are disposed indicate the ability of the worker to do so at that time. Information about the tools can orient hypothesis about construction too. The building is the aid of the rediscovery of know-how knowledge.

**4.1.3. Doctrinal position:** The architect, with his experience in construction, can establish rules that define a variety of buildings. Consequently buildings can be classified through specific doctrine. This is a principle that can evaluate to a style. The doctrine is deduced, formalized and rationalized. This is a logical reasoning of the design of a type of building. The doctrine can so let trace on architectural works and allow hypothesis of similarity with the others to help the comprehension and restitution.

### 4.2. Analysis

We now consider the knowledge that can be formulated thanks to the information the building provides.

**4.2.1. Break down:** this step is based on the work of J-M Peyrouse de Montclos (1993). It deals with the way to order buildings (Figure 3). Each part of it could be named clearly, as it had to be described to the workers. This way to proceed allows a description of the building in a very high level of detail. The break down stage can be done with geometrical primitive description too, but the architectural terminology is particularly elaborated; so it ensures the rationalisation of the analysis work. One element can be broken down into smaller parts until an entire description of the building.

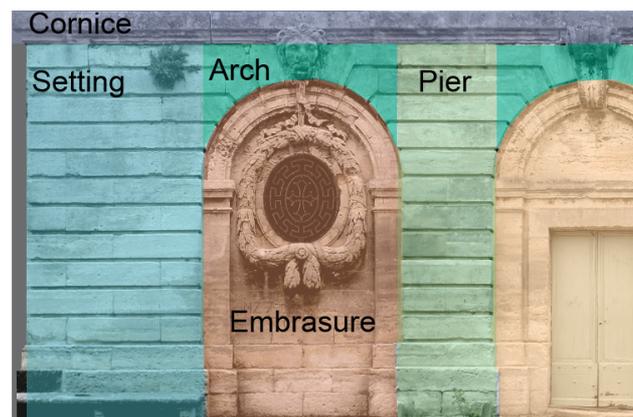


Figure 3. architectural break down

**4.2.2. Logical arrangement:** The analysis of architectural works can be carried out logically. Logical analysis tools are the symmetry, the copy, the proportional transformation and all geometrical relations. Several architectural styles offer the opportunity to be easy to rationalise, the classical style for example. Practically a building is the result of a logical reasoning. This logical arrangement has already been used during the building design. As a matter of fact, the description of an architectural work differs from one observer to another, depending on personal cultural background and drawing techniques, an observer will not describe an architectural work the same way as another would.

According to the fact that there are many ways to analyse an architectural work and that there are several acquisition techniques, we intend to set up a modelling tool to combine these criterias. Today technical solution exists to store, manipulate and manage an architectural model: computer. Architectural model is the meeting point of three-dimensional data and architectural knowledge. In the next part we will explain our modelling proposal.

## 5. COMBINATION

This part deals with the principal aim of the paper. Once having exposed the principal problematic that is architectural modelling with documentation approach, and discussed the different kinds of information we will have to manage and carry out, we now have the entire background to explain clearly our position and proposition.

### 5.1. Expert system

Our preoccupation lies in the intersection of two different and very specialized domains: architecture and 3D acquisition. According to the fact that we have to produce a way to manage the survey of architectural works and the latest acquisition technologies, it is obvious that users that can be architects as well as surveyors will miss about a half part of useful knowledge we intend to insert into our proposition. That is why we suggest an expert system like tool.

**5.1.1. Encapsulation of architectural knowledge in a modelling process:** the expert system aim is to put a specific knowledge at the disposal of someone that needs it and does not master it. Set up an expert system with architectural knowledge is a sort of encapsulation of it. The model obtained is the result of the combination of two domains by a specialist from only one domain. The encapsulation is a guaranty to reach a valuable result. With such a process we ensure the user to manage correctly the entire succession of steps and obtain a functional product.

**5.1.2. Method:** the combination of several domains in any level induces the discussion on the difference between a process that is the expert system and a method. We have an example of method linked to Photogrammetry which is the 3 x 3 rules (Waldhaeusl, Ogleby, 1994). It explains a good way to correctly carry out a photogrammetric survey on the field. It has been made in such a manner to be easy to remember and so ensure an efficient application. A method is strongly linked to a specific technique. So there is one method for each acquisition technique. Architectural modelling is not a technique but a process. Consequently there is not one good process but several ways to obtain an appropriate model. That is why we believe that an expert system with identified an easy to apprehend steps will respond correctly to the issue.

### 5.2. Hypothesis

The basis of our reasoning to set up the expert system is to take account, the best as it can be, of the architectural principles integrated in an architectural work.

**5.2.1. Analogy reasoning:** the analogy admitted here is between geometrical model and build work.

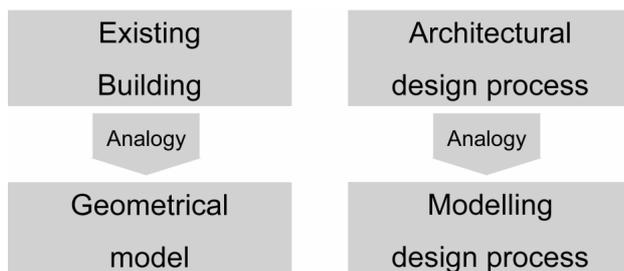


Figure 4. Differences between analogies

Because we are interested in the way to obtain the model, we will go further in the comparison; that is why we interest ourselves in the similitude linking architectural design process and modelling process (Figure 4). Build work is complex and there are numerous elements that constitute it. This complexity and multiplicity combined have to be dealt with, and the usual way to do this is to proceed by steps. The design is an appropriate reference to identify which step to establish.

**5.2.2. Translation between design and modelling:** In this part we will focus on the step by step definition of an architectural project. Five essential steps can be identified:

**Layout and shape:** first reflection about the volumes of the building in relationship with the city. Basic shape to measure the influence the building will have on the city.

**General principle of composition:** how many levels and parts the building will have to answer correctly to the initial project? This is the stage where global organisation is set up.

**Functional element organisation:** during this step, the functional elements like stairs and openings will be organised.

**Connexion between elements:** the complexity is growing and the elements have to be linked between each other logically and according to the first intentions.

**Details:** this step is not only an aesthetical step; detail is a concrete level of construction, two elements have to be linked together by a physical relation. Detail is deduced from the preceding step but it defines in which way the connection will be done.

Before translating these five steps, it is necessary to fix the limits of an analogical reasoning. This type of logical thinking gets value only if the translation is not complete. Architectural design has to organize the construction of the whole building. In our case we only have the external parts to model. Our proposition inherits from the architectural design principles but with simplifications.

**Topology (Step 1):** the shape has to be described as simple as possible such as each face of this large-scale model corresponds to one façade easy to identify (Figure 5).

**Horizontal and vertical dividing (Step 2):** due to the gravity, the most important force the building has to resist, the general shape of facades derives from the horizontal and vertical direction (Figure 5). Consequently the definition considering this direction helps us to reduce the complexity of the building.

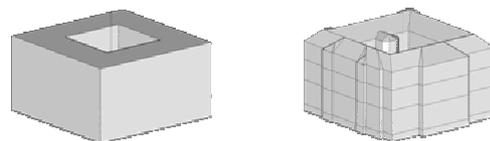


Figure 5. Two steps: Topology and divisions

**Opening insertion (Step 3):** facades are now divided; the openings can be placed easily according to the partitions and repeated if it is necessary (Figure 6).

**Boundaries qualification (Step 4):** each partition or opening has to be qualified in relation to the other elements (Figure 6).

This creates the boundaries that allow the identification of an element from another one.

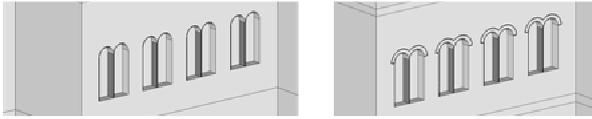


Figure 6. Two steps: Openings and boundaries

**Details (Step 5):** like the detail step listed before, this one gets the aspect of the boundaries: offset, extrusion or nothing (Figure 7). That gives the shapes of cornices, band or untreated transition.

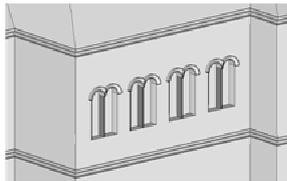


Figure 7. Last step: details

### 5.3. Semantic

In chapter 4.2.1 we introduce the particularity of the architectural knowledge that is to have one name for each element. The architectural semantic can help us as described in following sections.

**5.3.1. Convergence tool:** The 3D data we gather are in the form of point cloud. It is necessary to segment this large amount of data to get signification from it. To distinguish the different parts, a name is allocated to each of them.

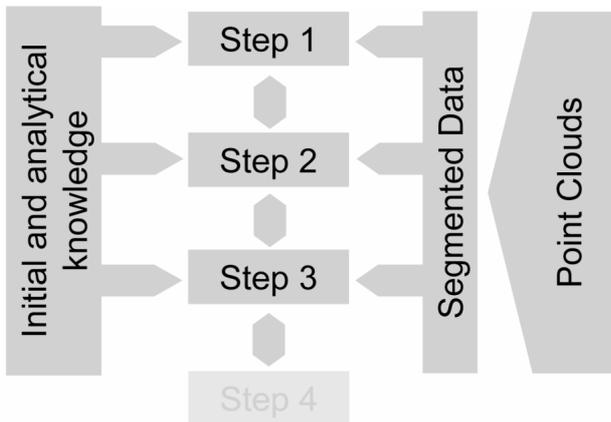


Figure 8. Combination between information in modelling process

This name comes from the architectural knowledge used to analyse the building. The semantic is here the convergence tool to assemble data and knowledge (Figure 8).

**5.3.2. Validation operation:** The semantic takes part into the modelling process in the nomenclature of the geometrical faces. It represents a validation operation; it allows the control of the ability for a face to exist: if there is no word, in the architectural knowledge, to qualify it, there is a chance to

identify a problem with the shape of the model (Figure 9). To sum up the use of semantic, there is first architectural knowledge, then geometry, and at last the 3D data integrated to the process thanks to the architectural semantic.

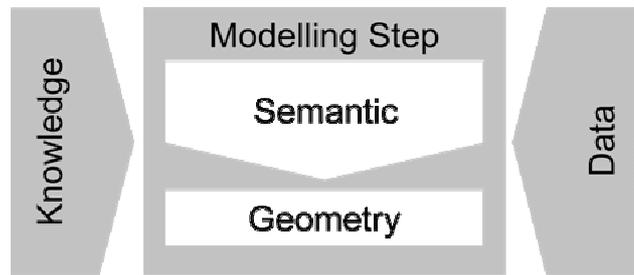


Figure 9. Semantic as a validation tool

### 5.4. Implementation

**5.4.1. Software and programming language:** In our work it is fundamental to be able to handle geometry and to develop in the same environment. There are many programs that manipulate geometry and have software development kit: MAYA, 3DStudio, AutoCAD for example. Maya and 3DStudio are essentially made for modelling and rendering; AutoCAD is polyvalent, and have two principal languages connected: lisp and Visual Basic for Application. We choose AutoCAD and VBA because geometry is used there as an autonomous tool and for the reason that VBA provides the opportunity to handle other application like MS Access and in an easy way.

**5.4.2. Topology, position and geometry:** The geometrical model gives the possibility to ordinate the topology and the position. The relative position of objects is the topology. It gives the shape of the model independently of the dimensions. The position is absolute place where object stays/is situated in a referential. The topology can be defined before the exact position of the object. The topology identifies the object when the position places it. The purpose of the definition of the topology before the position of the object is to solve the problem of masks and holes in dataset (Figure 10). At first create the model like the building is and then get the necessary data to dimension it.



Figure 10. Evolution of the geometrical model from topology to dimensions

**5.4.3. Architecture and geometry:** The geometry has been used to define architecture during design stage. In former period there were only few tools to do so, but there is a difference between architectural and geometric primitives. In the steps of model definition it is necessary to implement architectural tools to create appropriate geometry. In the third step we described in chapter 5.2.2, there are openings to add on the façade faces. Topologically an opening is a hole; but a window, for example, creates sub entities in the wall. A wall becomes a five parts entity after the insertion of a window (Figure 11).

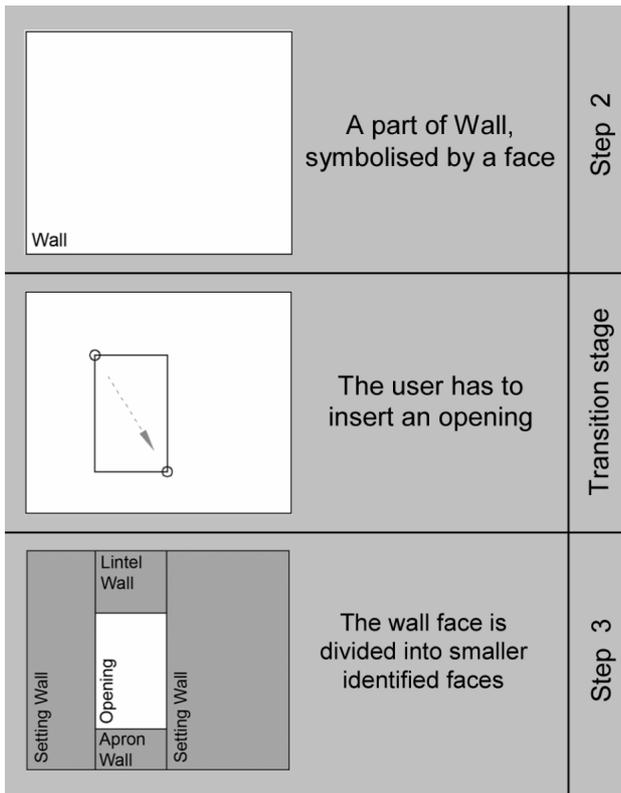


Figure 11. Insertion of architectural knowledge into modelling process

**5.4.4. Hierarchical organisation:** We have five distinct steps: topology, horizontal and vertical dividing, opening insertion, boundaries qualification and details.

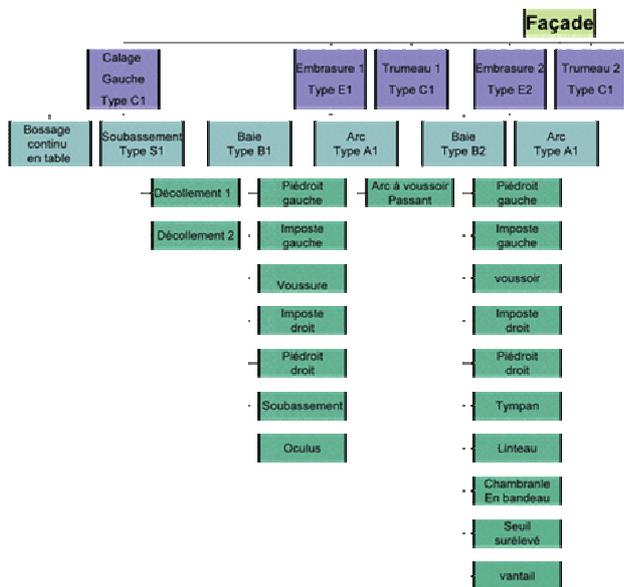


Figure 12. One part of Hierarchical organisation of modelling steps

The model is enriched all along this steps. We already mentioned that the semantic is a validation tool, but these five steps have to be linked between them. That is why we introduce a hierarchical management of the modelling process. Each object of one level is the parent of the object constructed from

its shape and properties (Figure 12). The hierarchy is helpful to select objects during copy stage for example.

## 6. CONCLUSION AND PERSPECTIVES

In this paper, we discussed the reasons not to put 3D acquisition in a central position during architectural modelling processes. A new way to manage and combine several types of information concerning the architectural works for the establishment of there geometrical model has also been described. The principle is based on the use of architectural knowledge in an attempt to build a geometric model without dimension. The modelling process is divided into identified steps to allow the progressive integration of 3D data. To ensure our reasoning, we used two fundamental constituents: architectural semantic and analogy with architectural design. These principles are currently being implemented into AutoCAD and VBA, and a prototype will be soon available.

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