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INTERACTIVE PARAMETRIC MODELLING.

POG a tool the cultural heritage monument 3D reconstruction.

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Abstract. Historic monument and archaeological site 3D reconstruction is nowadays often required for many applications (scientific and architectural studies, virtual visits for a better understanding of the monument, etc). This task is very time-consuming. Automating the modelling of the most common components could ease this 3D work and produce accurate, consistent and re-usable models. Based upon compound rules of architectural elements but also upon various other data sources such as photographs and 3D laser scans, we have conceived and developed an interactive tool for virtual 3D reconstruction of heritage monuments. It allows a quick modelling and accurate adjustments to the measured data. This tool could be a great help for architects and archaeologists. Research first has began with the study of classical architecture, and has gone on with other architectural styles. Architectural elements are described with parametric data, then generated by our tool. Our main application context was the town of Nancy in France where there are lots of classical architecture buildings which allow us to test our tool. It will be further extended to be applied to other architectural styles and will be combined with photogrammetry methods.

Keywords. parametric modelling, cultural heritage, 3D model.

1. Introduction

Historic monument and archaeological site 3D reconstruction is nowadays often required for many applications (scientific and architectural studies, virtual visits for a better understanding of the monument, etc). This is a great part of our laboratory work and also the work of many companies. This is very time-consuming and the same architectural components have to be remodelled. Automating the modelling of the most common components could ease this 3D work and produce accurate, consistent and re-usable models.

Based upon compound rules of architectural elements but also upon various other data sources such as photographs and 3D laser scans, we have

conceived and developed an interactive tool (called **POG** Parametric Object Generation) for virtual 3D reconstruction of heritage monuments. POG allows a quick 3D modelling and accurate adjustments to the measured data. This tool could be a great help for architects and archaeologists. The usefulness of POG is various: it goes from the 3D quick modelling for movie or game scenery to accurate modelling for archaeological aims or to the creation of a 3D as-built model (for instance for monument lighting simulation).

After an introduction, we present a state of the art for 3D reconstruction in architecture (part 2). In part 3, we look into classic geometry. We then explain the principles and advantages of our method in the fourth part. The composition of complex scenes from basic elements is then described in the fifth part. Results and examples are presented in part 6 and finally we conclude in part 7.

2. State of the Art

Various ways exist to model architectural buildings in 3D: 2D architectural plans with a CAD user modelling is the most time-consuming method. Chassagnoux et al. (1998) developed a tool to automatically create a gothic vault from its 2D representation in order to study its movement in time. Not all particularities can be created because 2D plans do not contain all characteristics. Image based (for example photomodeler) and photogrammetry (Debevec et al., 1996) methods are also widespread but are able to model the general shape of the building but not its details. Texturing makes the model realistic. 3D meshes from laser point clouds (Remondino, 2003) produce data with high precision, however the modelling step is tedious because only simple geometrical objects are recognized (no architectural libraries are available). Modelling from architectural rules (Fuchs 2007, De Luca 2007) and parametric design (Schnabel, 2007) are a promising investigation field because architectural objects can be created in real time with default dimensions (taken from architectural treaties for example). Then object shapes can be adjusted to create the desired shape. De Luca *et al.* studied ancient styles. They also use point clouds and photographs to help the 3D reconstruction, but their work is only based on moulding profiles. They generate surfaces by revolution or extrusion of moulding and do not handle more complex and compound shapes (fluting column, door, window, pediment...) for an automatic generation. Furthermore they hierarchically organize the 3D components of the scene *a posteriori* but don't use a hierarchical description to build the 3D representation of a compound scene. Finally, techniques appear that combine several methods (photogrammetry for global shape, laser scanning for accurate model of complex shapes such as sculptures) with interactive and automatic parts (El Hakim et al. 2002, De Luca 2007).

3. Studies of the Architectural Styles

Architectural components (vault, door, window, column,...) are first theoretically studied for various styles (ancient, classic, gothic, Asian styles...) from bibliography and also from building practices. Lots of

architects, from Vitruve (1996) to XVIIIth century architects (Palladio, 1965) have described ancient and classic styles. Lines are straight, symmetry and geometry are widely used. These styles are principally based on mouldings, each moulding having a shape (cavetto, circle...). Dimensions are given proportionally to a module (Figure 1). A module is subdivided into minutes (12 for Tuscan and Doric styles and 16 for Ionic, Corinthian and composite styles). When the value of the module is chosen, all the dimensions of the object are known. The basic parameters for a moulding are simple: shape and height. The shape requires from one to several parameters (type, radius, offset center...). Complex mouldings, like cyma, echinus or break are composed of several basic mouldings. The mouldings are then revolved to form columns (radius and sweep angles) or extruded to create entablatures (direction and length). Supplementary parameters are required to model specific characteristics (hood moulding, fluting...).

Lots of compound elements of the ancient and classic styles are also based on moulding (doors, windows, pediments...). From the study of each of these elements, a set of parameters and moulding profiles enable them to be described. For instance, a pediment can have various shapes (triangular, circular, with one or several arches, open, broken or scrolled pediment...)(Figure 2). The bottom profile can go further than the top profile. A head profile can be added, etc. The pediment will thus be specified by its global dimensions, specific parameters, various profiles and by the presence or not of its sub-elements (entablure, head, oculus...).

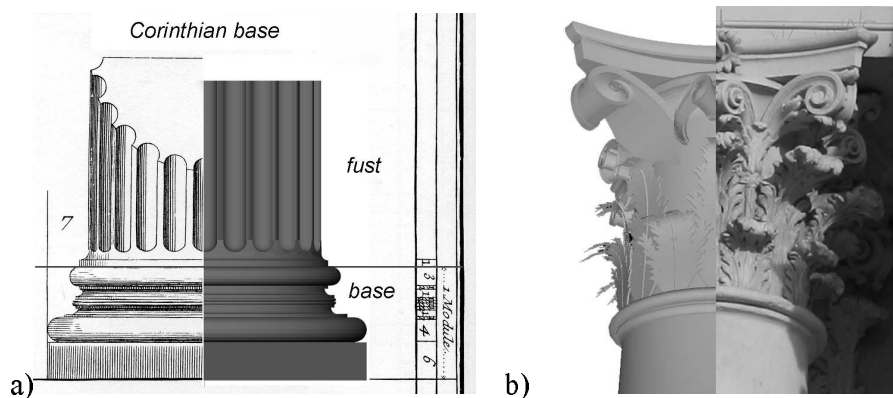


Figure 1: Elements of the Corinthian column: a) left part is architectural drawing and right part is 3D automatic modelling creation. b) Left part is the adjusted 3D model and right part is a picture of the Corinthian capital of the “Porte Héré” in Nancy.

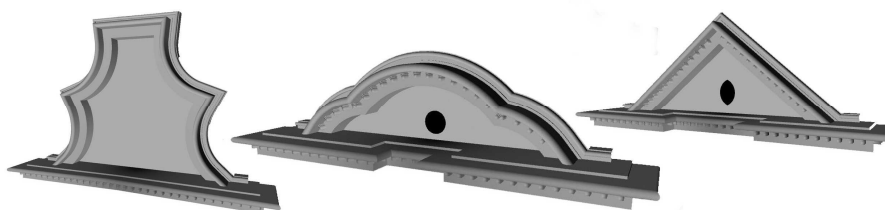


Figure 2: 3D automatic modelling of various pediments.

The aim of this study is to describe an architectural component by a minimal set of parameters allowing its construction by a specified method. The

element can then be developed in **POG** and various practical or theoretical examples of this element can be instantiated in a library by identifying the values of each parameter. The following part explains the main principles of **POG**.

4. Principle of the Method

Architectural components (moulding, vault, door, window...and also sculptured elements) are described by their own parameters in a file library. As an example, a Doric column and a Corinthian one are both described with the help of the moulding object, only the parameters are different. They are both described in a file. Several files can be used for describing the same Doric column for different theorists (between Vitruve, Vignole or Diderot one can find several little differences in the theoretical descriptions).

When the user chooses an object predefined in this library (by means of a menu in the user interface), it is created by **POG** in real time with the parameter values read in the file. It can then be adjusted by modifying the parameters to adapt the shape to the various practical situations. Parameter adjustments let us obtain a 3D model close to the real object. Surfaces of the 3D rebuilt scene or the architectural objects and their parameters can be saved in a file. In the second case, the file can be added to the library.

The software development has been performed in the Maya environment in MEL and C++ language. Maya allows the adding of some plugins and menus to the graphical user interface. A Maya object is described by a set of attributes that appear in a window (the attribute editor) when the corresponding graphical 3D object is selected in the scene. When an attribute is modified, the "compute" method is called and the object can be generated again with the new values of the parameters. To each of our architectural components corresponds a Maya object, to each parameter corresponds a Maya attribute. Furthermore Maya allows the use of all the modeller functions and possibilities for the sculpture creations, specific adjustments and deformations in the shape (erosion, breaking, non perfect shapes). Finally Maya is not only a modeller but also a computer graphic image generator that can be used for various uses: archaeological presentation as it was in the past, 3D scenery for movies and much more.

To help the user in the creation and in the adjustment of a component, **POG** includes the possibility of using various data: pictures (selection of pixels), 3D laser scanning (selection of cloud points). These selections allow the positioning of the architectural element in the 3D scene. Another way to position elements in the scene is the use of a hierarchical description and relative positioning.

5. Composition of Complex Scenes: Hierarchical Description and Relative Positioning

Several architectural elements have to be generated to create a compound element. A column is composed of a stacking of mouldings, a monument is composed of several columns, cornices and so on. Each element has to be positioned beside the others: the door has to be at the right of another one, the

capital has to be above the column fust, etc. The location of components is done as simply as possible in a relative way with respect to each other. In order to help this description two methods are used: hierarchical description of a large scene and description of relative positioning between objects.

5.1. HIERARCHICAL DESCRIPTION

A monument is composed of various architectural elements. Each of these elements can be split in several parts again, so that we finally identify simple elements. Let's take the case of a column (Figure 1): this is composed of its pedestal, and of the column itself. The former is composed of a scamillus, a die and a cornice. The latter is formed with a base, a fust and a capital. Each of these elements is itself composed of several mouldings. Thus the entire column can be represented in a hierarchical manner and the same hierarchy is used to describe the column in the file library. In the same way, a building is an organisation of columns, cornices, doors, windows, pediments, sculptures, etc that can be described hierarchically and with notion of relative positioning (part 5.2).

In Maya, Objects can be hierarchically organized. However neither the ascii file format nor the MEL (Maya Embedded Language) are simple and easily readable. They are mostly composed of command lines and it is not easy to describe the creation of nodes or a hierarchical scene. That's why we choose another description language, the Open Inventor file format (i.e. VRML 1), in order to describe the hierarchy and the parameters of architectural elements. The representation of the component hierarchy is really simple. The values affected to each parameter are clearly visible.

A special node allows grouping elements and the other nodes of the hierarchy are architectural elements (vault, door...). Complex shapes, like pediments, have their own parameters (shape, dimensions, oculus...) and have also some child nodes to describe the moulding profiles. A window has the following child nodes: a balcony node, a pediment node. Grouping nodes have parameters common to all nodes (global dimensions and positioning parameters). These parameters can be set for the grouping nodes and they will be transmitted to the child nodes by a propagation mechanism. Every modification of one of these parameters is also transmitted to the child nodes and the corresponding 3D objects are recomputed. These parameters are for instance the value of the module, the number of minutes per module, revolution or extrusion parameters, duplication parameters. Every moulding of a column is a revolution shape, so this parameter is only once specified in the grouping parent node. Each object (leaf or grouping node) can be linear or circular instanciated to form a set. The volutes of the Corinthian capital form a four instance circular set. The dentils of the pediment form a polyline set with the required number of instances (automatically computed) to cover the path. One set can be inserted in another set: a Corinthian column with its four volutes can be globally instanciated to create a column set.

Architectural elements are built in 3D in a local coordinate system from their parameters and then are positioned in the scene according to their neighbours. They have to be correctly laid out to form the monument. This positioning is also indicated in the parameters of the nodes. The next section explains how we tackled this aspect.

5.2. RELATIVE POSITIONING

Positioning of components is done as simply as possible in a relative way with respect to the other components. No computation has to be performed by the user. Four kinds of positioning can be used: the stacking (mouldings are stacked to form a column) (§ 5.2.1), the anchoring to a component point (a sculptured key is positioned in a vault) (§ 5.2.2), the relative positioning to the bounding box of another component (a door at the right of another door) (§ 5.2.3) and the relative positioning to the bounding polygon (the second edge of one element is close to the fourth edge of another one) (§ 5.2.4). A positioning parameter modification of an element leads not only to the rebuilding of the 3D position of this element, but also of all the elements depending on this object if they are affected by the modification (i.e. if it modifies their location or orientation). For all kinds of positioning, attached components can be simple architectural elements or grouping nodes.

5.2.1. Case 1: Stacking

Column mouldings are stacked on top of each other according to their height. It is the same for every element that has a specified height (3D representation and not only a grouping node). The first floor is over the ground floor. Modification of the height of one of the elements affects the followings components. By the mechanism of propagation the following elements are automatically repositioned.

5.2.2. Case 2: Anchoring to a Component Point

A component C2 can be attached to another component C1. During the creation of C1, special points are automatically specified as potential anchoring points for other components. For example, an anchoring point is defined at the vault keys (Figure 3a), or at the door key (the horse sculpture in Figure 3b). A parameter in C2 indicates that it is anchoring to C1.

5.2.3. Case 3: Relative Positioning to the Bounding box

A component C2 can be in front of, behind, to the left of or to the right of another component C1. Above and below correspond to the stacking (case 1). The bounding box of each component is automatically computed during the creation of the 3D object and does not necessarily correspond to the real 3D bounding box. For instance, the key-door sculpture comes in front of the main part of the door and is not pertinent for the relative positioning. It can even alter the result if we want to attach another door, the main surfaces have to be at the same level. However, if needed, the component C2 can be translated with a parameter if its position has to be adjusted. As in the previous case, a parameter in the C2 element indicates that it is attached to C1, and a second parameter specifies the relative position (front, behind, left, right).

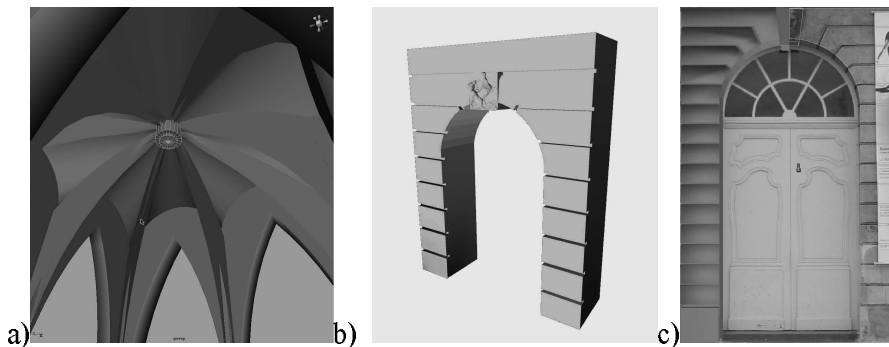


Figure 3: a) Key anchoring to the vault. b) Horse sculpture anchoring to the door. During the vault or door creation, an anchoring point has been specified. c) The model of a door of the “Place Stanislas” overlaid on the corresponding picture.

5.2.3. Case 3: Relative Positioning to the Bounding polygon

A C1 component side can be attached to a C2 component side. As in the previous case, the bounding polygon is computed during the creation of the 3D object and does not necessarily correspond to the real bounding polygon. We are just interested in the 2D horizontal polygon. Polygon edges are numbered from the lowest left point. A parameter in component C2 specifies which edge of C2 is attached to which edge of C1. C2 has to be rotated so that its chosen edge is in the same direction as the C1 chosen edge.

6. Results and examples

Examples and results obtained with our method are now described. Our application context is the town of Nancy in France, where there are lots of classical architecture buildings that allow us to test our tool. The results are promising and enable us to model various monuments. In Figure 1b, you can see the results for a Corinthian capital of the “Porte Héré”. In a first step, the theoretical Corinthian model was generated and compared to the existing one. We had noted some differences. Thus parameters of the mouldings and also of the volutes and sheets had to be adjusted to fit the existing shapes and dimensions. If necessary, moulding (or any component) can be suppressed or added. Further details for adjustments to measured data (pictures or point cloud) will be discussed in another paper (Chevrier and Perrin, 2008). Another example is given in Figure 3c where a door of a Place Stanislas building is overlaid on the corresponding picture. Figure 4 shows the 3D column for each ancient and classic style. All of these columns are described with the moulding object, only the parameters have different values. Figure 2 shows various kinds of 3D pediments for a same architectural parametric object. Finally, in Figure 5, you can see the facade of an auditorium in Nancy created only with parametric objects and relative positioning. Studies on the gothic style have just begun concentrating on the vault (Figure 3a) with all its various shapes. This style is complex to classify because there are almost as many variants as important gothic monuments. It is very rich in decorations, profiles, keys, and other elements.

7. Conclusion and future work

Our tests have brought out that there are lots of variants for a same architectural object (gothic vault, classic pediments...). We are currently working on this large variety to enrich our component library. In the future, we plan to go on with the study of classical and gothic styles, but also of other architectural styles. We have tested our tool on Khmer columns which can be described with mouldings.

When models of existing monuments are required, the use of measures is of great help for 3D reconstruction. We plan to use photogrammetry combined with point cloud techniques, to acquire some specific points for the positioning and the global dimensions of the objects to be built.



Figure 4: 3D models of ancient and classic columns.

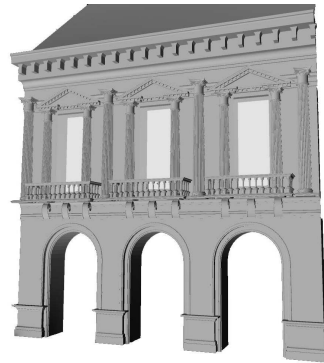


Figure 5: The facade of an auditorium in Nancy (France).

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