Knowledge-based Virtual Reconstruction of Museum Artifacts

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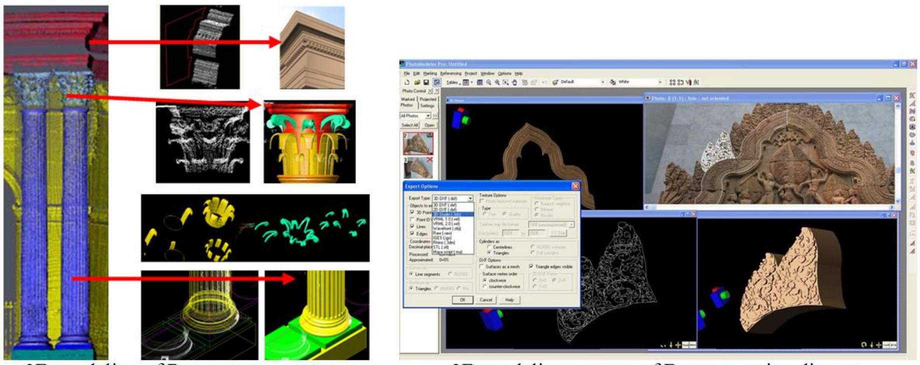
Abstract. Within the framework of heritage preservation, 3D scanning and modeling for heritage documentation has increased significantly in recent years, mainly due to the evolution of laser and image-based techniques, modeling software, powerful computers and virtual reality. 3D laser acquisition constitutes a real development opportunity for 3D modeling based previously on theoretical data. The representation of the object information rely on the knowledge of its historic and theoretical frame to reconstitute a posteriori its previous states.

This project proposes an approach dealing with data extraction based on architectural knowledge and Laser statement informing measurements, the whole leading to 3D reconstruction. The experimented Khmer objects are exposed at Guimet museum in Paris. The purpose of this digital modeling meets the need of exploitable models for simulation projects, prototyping, exhibitions, promoting cultural tourism and particularly for archiving against any likely disaster and as an aided tool for the formulation of virtual museum concept.

Keywords: Heritage Preservation, Digital Reconstruction, Laser Scanning, Data Extraction/Processing.

Thematic overview

Architects and archaeologists for years focused on 3D acquisition tools instead of operating the measured data. Because of complex geometry of architectural elements, the modeling task is still tedious and time consuming whatever the method employed. In lasergrammetry, we introduce the primitives that would adapt best to the cloud of points, when photogrammetry calls upon the user's manipulation. 3D objects libraries in commercial modeling software seemed not adapted to architectural objects and not confronted to real measurement.



3D modeling of Peyrou water tower — 3D modeling process of Banteay srei pediment

Fig. 1. Lasergrammetry [5] and Photogrammetry [6]-based modeling

Our aim is the automation of 3D modeling requiring the organization of architectural knowledge that lead to structuring the points cloud.

1 Theoretical Study, the Khmer Architecture

The Khmer civilization was developed from the 7th century, also called pre-Angkorian period, to the middle of the 13th century in a geographical area currently occupied by Kampuchea. The main monuments, built out of stone many centuries ago, still exist: they therefore became the object of archaeological and architectural study. The Khmer architectural language is governed by a set of correspondences and spiritual representations that have a specific vocabulary and syntax. “The concepts of symmetry, axiality and repetition constitute the major morphological characteristic of this architecture.”[7] They are to be found as well on the outline level of the monuments as on minute architectural details, what interests us more particularly in this study.

1.1 Exploratory Study of the Colonnettes: Classification, Synthesis, Prioritization:

From a morphological point of view, the colonnettes show the same characteristics as a column. However, “their role consists of supporting the decorative lintel of the openings, and contributing to update the stylistic development of the Khmer architecture” [7].

The study of various descriptive texts and available graphic elements allowed us to establish a preliminary classification of the colonnettes. The synthesis of Henri Marchal and Henri Parmentier’s work published by Jean Boisselier [1] was used as a reference for this classification.

Fig. 2. Various colonnettes of Khmer buildings (pictures: O.Cunin)

The photographs carried out by Olivier Cunin [3] during his archaeological studies of various sites completed the information available. The next step was to establish a prioritization of the preliminary classification made on the basis of the elevations and characteristics of the colonnette's sections.

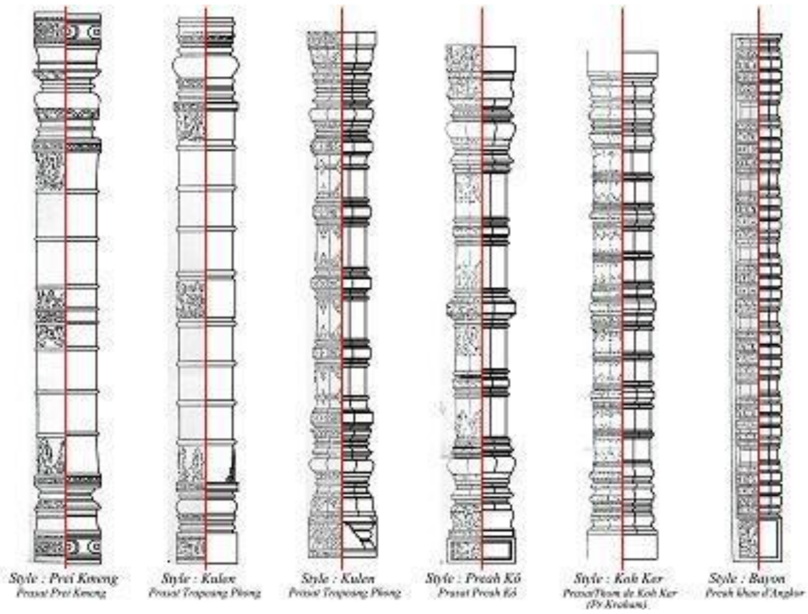


Fig. 3. Stylistic classification [1] and CAD models

A detailed decomposition of six defined colonnettes was then carried out in order to identify their morphological characteristics. The colonnettes we correspond to: the

Prei Kmeng style (636-656), the Kulen style (802-877), the Preah Ko style (877-889), the Koh Ker style (921-941) and finally the Bayon style [3](881-1219). In general, the pre angkorian period presents a cylindrical form, heritage of the Indian art, whereas the style of Angkor presents a barrel of polygonal section with carved base. On a strictly morphological point of view, it is noticeable that the oldest colonnettes (Prei Kmeng style) are all based on a horizontal symmetry, based on a central fillet. This fillet gradually evolved and became the more complex shape of central ring supplemented by secondary rings in later styles. Starting from this original axiality, the decoration of the colonnettes' barrels resembles a composition and repetition of those rings. This orthogonal form -initially cylindrical- is based on number 4, synonym of perfection in Indian cosmology [7].

1.2 Development of the Architectural Model:

The following step consists in working out an architectural model of the colonnette itself. This operation consists in a breakdown of the architectural object by a search for repetitive elements. As soon as the components of the colonnette are identified, they are broken up into several sub-elements.

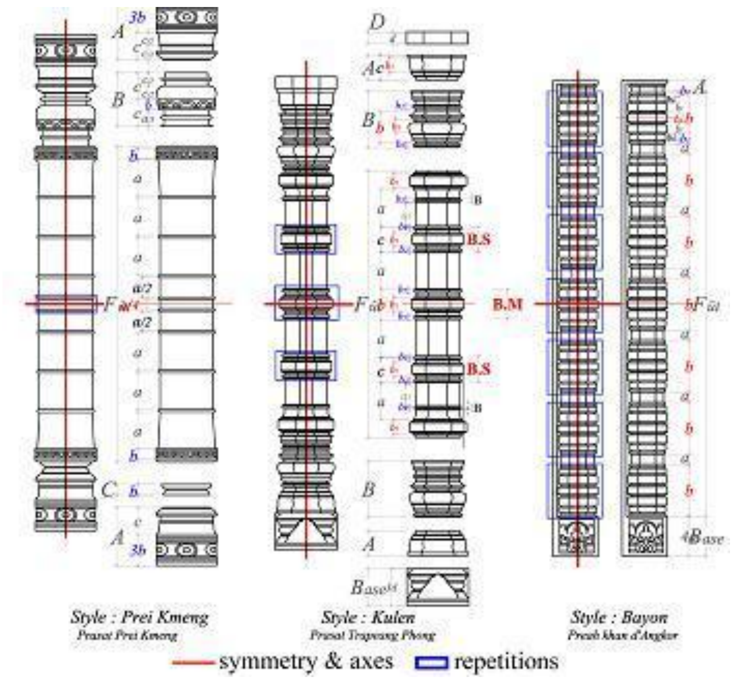


Fig. 4. Hierarchisation and colonnette analysis

The detailed morphological analysis of those elements reveals a constant logic of symmetry and proportion. It is important to underline one of the rings' characteristic: identical elements are indeed to be found between various styles of colonnettes, but their drawings and proportions are variable. On the other hand, the study reveals a noticeable variation on the ring scale factor in the same colonnette. Each sub-element is then analyzed in order to specify its geometrical primitives as well as their parameters. Analysis of components of the column was used to extract the most basic architectural unity: the molding.

The work consequently consists in identifying each molding type and to carry out its breakdown in geometrical primitives.

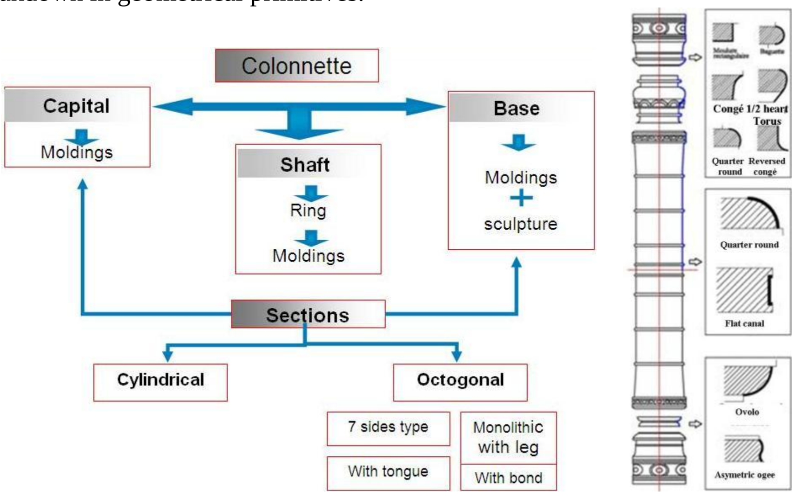


Fig. 5. Left: Colonnette components. Right: Breakdown of the Prei Kmeng colonnette

By combining these geometrical primitives between each other, the writing of algorithms then makes it possible to define architectural primitives, which can be considered as the "meta" level of the geometrical level. These algorithms corresponding to moldings (ogee, cavetto, quarter-round …) are programmed in LISP language, in order to be interpreted by the CAD software AutoCAD (AUTODESK). The tools aim to offer the possibility to adapt parameterized moldings to a points cloud. This may be possible thanks to anchor points.

Fig. 6. Specific objects library

Specific decorative elements are also incorporated in the previously defined library of architectural primitives. They are built from solid undergoing Boolean operations rather than profile extrusion. Automatic meshing is suitable.

2 Experimentation, 3D Data Acquisition in the Guimet Museum

2.1 Initiative and Work Context:

To experiment the tools set up in the theoretical study, our choice for the 3D survey has focused on two columns found at Guimet Museum in Paris.

The "National Museum of Asian Arts" gathers a great number of collections from various countries of South East Asia. Many elements relate to Khmer art and architecture including balusters, pilasters and columns.

2.2 The Historical Context:

In order to optimize the use of the tools we defined during our theoretical study, we chose two colonnettes with quite distinct morphological styles.

Fig. 7. Photographs and points clouds - left the Prei Kmeng style and right the Phnom Da style

The Prei Kmeng Temple Colonnette - Prei Kmeng Style (7th Century):

With a bare cylindrical barrel and interrupted fillets, it was developed under a vishnuite iconographic context, identified as the oldest phase of Kampuchean brahmanic art. Its capital and base consist of bulbs and florets [1].

The Phnom Da Temple Colonnette - Angkor Vat Style (12th Century):

This colonnette presents an octagonal barrel with central ring supplemented with secondary rings. The stylistic evolution led to the disappearance of the distinction between the base, the barrel and the capital by a continuous repetition of identical rings. This style can be identified thanks to the iconography located on the lower die corresponding to Indra deity.

2.3 Experimental Results, Tools Used in the Experience and Points Clouds Data:

The 3D Laser Acquisition:

The data acquisition lasted half a day for the installation of the measurement devices (Soisic sensor) [2] and to the launching of a first laser scanner measurement followed by the closing day of the museum. The scanning conditions were almost ideal: weak surrounding luminosity and few luminous variations. If we consider the symmetry logic of the colonnettes, a scanning of some specific parts would have been sufficient to obtain a complete model. However, it appeared interesting to scan the whole pieces in order to get data for complementary experimentations. The smoothness of the details enabled us a scanning precision close to the millimeter and a 900000 points density.

The Collected Data Processing:

For digitization process, the preliminary treatment of the laser scanning was performed using 3DIpsos software [2]. Consolidation, i.e. the fusion of all groups of 3D point's clouds in the same Cartesian reference mark, was accomplished semi automatically thanks to the installation of reference spheres during data acquisition. Various segmentations were then executed to facilitate the exploitation of the relatively dense data during the modeling. The point clouds were exported to CAD software (AutoCAD Autodesk) where implemented algorithms allow the modeling construction.

Geometric Modeling:

As shown on figure 8, the developed tools (moldings) adjusted on point clouds allow a precise modeling, close to the measured object.

The morphological variations between the two colonnettes lead to different procedures. For the Prei Kmeng colonnette, the reconstitution was carried out by the revolution of a total profile, with was built with moldings.

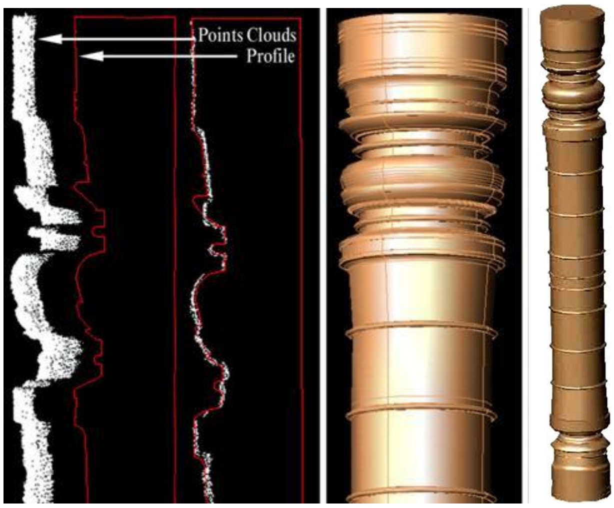


Fig. 8. Prei Kmeng colonnette; from left to right, points cloud, CAD profile and 3D model

On the other hand, the Phnom Da colonnette, with octagonal section, was executed by an extrusion of the rings profile, according to an octagonal way. These rings are then repeated on the barrel according to the superposition and repetition logic. The capital and the base modeling is made in a separate way.

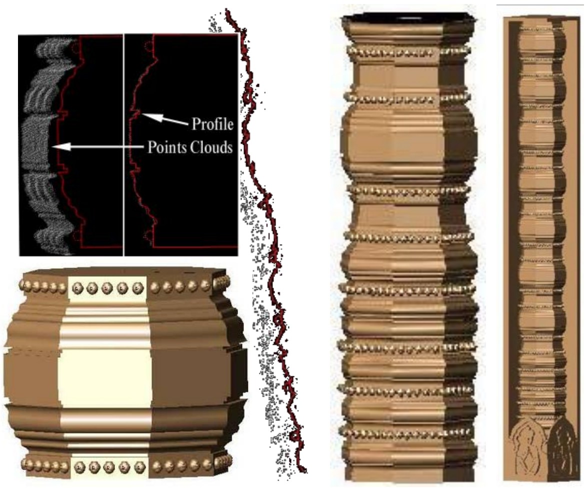


Fig. 9. Phnom Da colonnette, ring and barrel: points cloud, CAD profile and 3D model

Decorative elements such as the lotus buttons are added at the end of the modeling. When we leave the field of forms based on geometrical primitives, it is necessary to consider the solutions suggested by automatic triangulation, used for example in the case of the classical architecture.

We find it judicious to develop our research towards CAD software, but experimentations carried out with "Cabri Géomètre II Plus" reveal a more flexible use potential, as for handling moldings. The difficulty under AutoCAD lay in the ring (complex molding) adjustment at the many anchor points not easy to move without distorting the whole.

Not being a modeler, Cabri provides a range of features that allow free manipulation of simple geometric shape or infinitely complex, unfortunately its program is not compatible with the file formats of AutoCAD or such modeler.

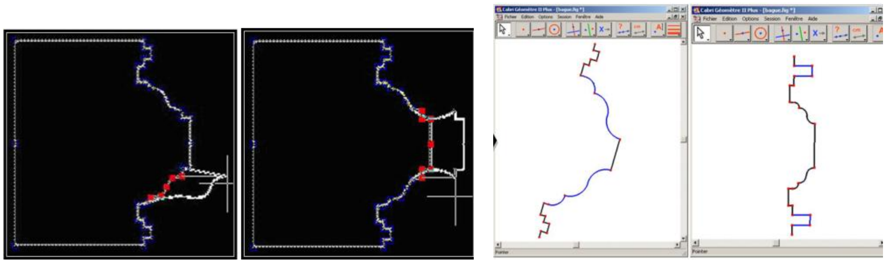


Fig. 10. Deformation moldings (Autocad) and Setting operations (Cabri Geomètre II Plus)

2.4 Extrapolation of the Method:

Our tool was then tested to model other Khmer architectural elements, as described by profiles based on the same moldings. Various concrete experimentations have lead to the validation of the digital measuring and modeling tools.

Fig. 11. Tests of the tools extended use: 3D models of balusters, a pilaster and a wall base.

Digitization executed in the form of point's clouds data acquisition constitutes a memory of the object condition at a given time: this can be extremely interesting as far as cultural heritage is concerned.

3 Conclusion

Architectural modeling facilitates the precise identification of what is needed from a digital tool. Thus, future work can consist in the development of additional and appropriate modeling tools to be implemented in professional modeling software, and their validation by concrete experimentation.

In addition, the methodology involved during this modeling process facilitates the acquisition of architectural knowledge. Indeed, if one considers architectural primitives (in our case, moldings) as the vocabulary of an architectural language, ‘the knowledge of the rules’ [4] that structure it, i.e. its grammar, cannot be carried out without some architectural and archaeological culture.

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