Action Based Approach to Archaeological Reconstruction Projects: Case of the Karnak Temple in Egypt

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Abstract. *The proposed paper deals with a numerical approach that could better assist the archaeologist in the archaeological reconstruction projects. The goal of our research is to explore and study the use of computerized tools in archaeological reconstruction projects of monumental architecture in order to propose new ways in which such technology can be used.*
Keywords. *Architectural heritage; archaeological reconstruction; action-based modeling; architecture and complexity.*

INTRODUCTION

The definition and development of new modeling methods is the objective of a research project in progress at the CAD research group (GRCAO) of Université de Montréal. These methods aim for a better integration of the varying types of knowledge implicated in the reconstitution of ancient architectural structures, as well as greater flexibility in the manipulation and utilization of this knowledge. To reach this objective, technology will not suffice. It is necessary to integrate methods, knowledge and goals of a collection of scientific disciplines that are not used to working together (without forgetting the inherent incoherencies): to social sciences as with archeology (in the classical and not the anthropological sense of the term), history, art history, epigraphy and chronology, architecture, geometry, optics, and information technology must be joined. This requires that each discipline define itself in terms of what it can bring to the reconstitution of physical objects in an environment, and thus, the reconstitution of architectural heritage.

The case study: Karnak Temple

To do this, our project uses as laboratory the Karnak temples in Egypt: certain information is already available in the form of plans, surveys, elevations and sections of existing monuments (with or without proposed restitutions), and excavation reports, while other information is still to be surveyed on site, or catalogued. Beyond the technical aspects that allow for the precise encoding of the basic components of constructions and structures, the method allows for the elaboration of a reconstitution that notes the different proposed reconstitutions of parts that are either currently missing or have been modified several times over a millennium of history. Also the method takes into account the degree of probability of the proposed reconstitutions.

To experiment our general approach of restitution, we choose the case study of the VIIth pylon in the Karnak Temple. The choice of this case study follows directly from the data availability. Indeed, the seventh pylon was a pretext for testing survey func-

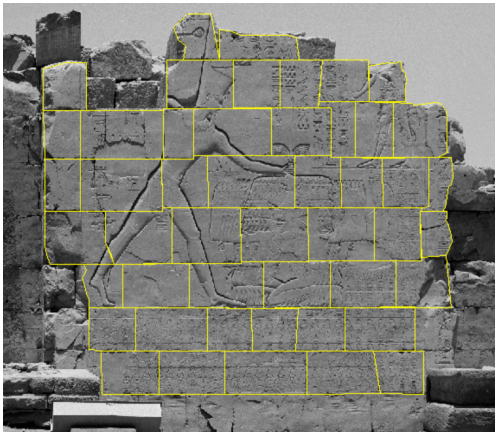

Figure 1
The VIIth pylon divided into as many blocks as it contains.

tions in the project "Karnak-1" in GRCAO. We made a division of the complete structure of our case study (the VIIth pylon in the Karnak Temple) in as many blocks as it contains (Figure 1). Our goal is to assign to each of the blocks from corpus, its place in the general scheme of the studied structure. It is a set of epigraphied blocks with variable dimension.

When the corpus of blocks to be processed is very important, it is necessary to find the necessary resources to divide the whole into "manipulable" units through a multitude of actions which identify the blocks that have one or more common characteristics. The data can be used to identify the relative position of a unit with respect to another. Based on the geometric attributes, iconographic or other, the goal is to identify, manipulate and / or to connect and recreate these attributes in order to find indices that will help us to argue one or more assumptions about the hypothetic position of a block in relation to the adjacent ones, respecting of course the overall assembling of the general unit.

The survey and description of blocks

Carrying out epigraphic surveys is a very important task in archaeology, particularly in Egyptology because all the monuments contain numerous texts and scenes engraved on their architectural elements. It is a matter of urgency to do such surveys, because the inscriptions are deteriorating at great speed and there is a real risk of losing completely some impotents scenes.

The main problem at the present time is that the traditional methods carried out to survey the inscriptions are very time-consuming. For example the most common of these methods consists in making facsimiles of the wall to be surveyed, with photographs as background or simply with transparent sheets placed against the surface of the wall. This method involves numerous checks during the drawing process and is therefore rather tedious, because it requires the collaboration between different drawers.

Research carried out by the GRCAO leads to present method of computerized epigraphic survey that can be used for drawing and recording the hieroglyphic signs for all planar, but also conical and cylindrical, architectural elements of Egyptian temples. This method is user-friendly for archaeologists and epigraphists alike, thanks to the very detailed menus created in the AutoCAD© software. Numerous choices are constantly available during the surveying process, and every operation can be undone if necessary. Each surveyed sign is recorded in a database, in the form of a text file, which can later be used for other research purposes: studies on the shapes of hieroglyphs, automatic translation of the texts, search for missing elements, etc. This method considers the needs of the epigraphists and offers them the possibility of controlling various operations during the computerized survey process. Particular emphasis has been put on the fact that the decoration of a monument is indissociable from its architectural support. The drawings must be recorded with all the information necessary to understand their real meaning (i.e. the architectural and archaeological context). The recording format has been normalized so as to be exploitable for research purposes (statistics, restoration of structures, etc.) (Figure 2).

Moreover, various exploitations (reconstitution, paleography, etc.) are possible, thanks to the fact that all the signs drawn are recorded in a universal format. The publication of the texts can still be made

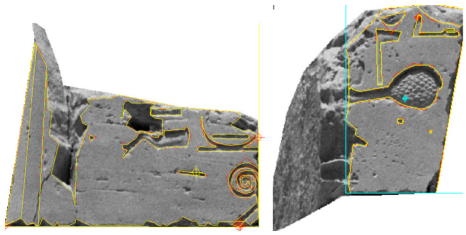

Figure 2
Survey of the blocks in the VIIth pylon using the GRCAO method.

in paper form, but can now be in numerical form too, which in turn leads to other possibilities such as data exchange. This approach is of course adaptable to the survey of other types of temples (Greek for example).

DEVELOPMENT AND VALIDATION OF OUR ARCHAEOLOGICAL RECONSTITUTION MODEL

This part presents an exploratory prototype developed to assist (but not to control) the reasoning and decision-making in the formulation and computer simulation of architectural reconstruction hypotheses. This "assistance" will be taking advantage of the knowledge and data available or extrapolated by the production of computer models as well as alphanumeric documents resulting from targeted questions of the databases.

The Use of ICT in archaeological reconstruction projects

In our quest to answer this question, we begin with a study of the different restitution approaches used in various phases of archaeological reconstruction projects. This involves understanding how the different methods of approach have evolved (epistemologically), how those involved in such projects have put information and communication technologies (ICT) to use in the field of built heritage. This study has identified two main avenues: one whose aim is the "representation" of project results and another whose aim is to model this process in order to assist the archaeologist through various phases of a project. It is the second approach that can better respond to our goals and that can guarantee to the archaeologists an effective utilization of the possibilities offered by computer-assisted tools. This study allowed us to demonstrate the complex and systemic nature of using ICT in the field of archaeological reconstruction. The multiple actors, conditions, means and goals considered in archaeological reconstruction projects have led us to explore a new approach that reflects this complexity.

Study of the publications in the archaeological projects

In order to achieve the goal of our research, it was necessary to further study the nature of the archaeological process. This involved understanding the links and interrelations between the various components that defines the archaeological approach and the various thought processes involved in archaeological reconstruction projects.

In summary, archaeologists perceive and describe their approaches through filters determined by their use of these descriptions. Any scientific description is both the result of past constructions, and the source of present and future constructs to enrich them or replace them. These filters can, in many cases, push the archaeologists to become very attached to their hypothesis and persist in not recognizing their weaknesses.

From this perspective, archaeological publications all look the same slightly "*there can not describe a monument without referring implicitly to the state of knowledge and research objectives that determine proper method the substance and form of the description, so that a catalog, especially when the terms "rational" is a theoretical construct in the same way if not to the same extent that any historical essay* " (Gardin, 1979). This study showed a direct relationship between the subjective nature of the process and the diversity of approaches and thought processes which can be implemented.

This exploratory and propositional research reinforces the systemic and complex nature of our approach and prompts us to explore, in practice and through published literature, the elements of known reality. The study of archaeological reason-

ing through academic publications has allowed us to propose an initial typology of arguments studied. Each of these typologies reflects a methodological approach based on organized actions that can be recorded in a set of reasoning modules. The classification of the various arguments by type of reasoning in order to determine the configuration of a building has enabled us to establish a model of the various components of the archaeological process as well as validation rules that have been used by archaeologist in real reconstruction projects.

This research has allowed us to highlight phenomena and observed processes, leading to a model representing interrelationships and interactions as well as the specific results of these complex interconnections. This pattern reflects a cyclical process of trial and error, in which the actors consecutively 'experience' (according to the project's goals and through reasoning modules), several answers to the questions exposed to him under the corpus definition, description, structure, interpretation and validation of the results until the latter would appear to meet the original targets. Three examples of reasoning modules have been developed and tested through a case study of the VIIth pylon of the Karnak temple in Egypt.

Geometric approach to restitution: Example of a module using the geometric reconstruction of 2D objects

Considering the large number of blocks that archaeologists handle in archaeological reconstruction project, it will be extremely difficult for them to visually identify formal and geometric complementarities among the studied blocks. The main goal of this module is to present a reasoning tool to search for possible complementarities among the geometric characteristics of the identified blocks. It can assist archaeologists to identify, among the huge mass of available data, a manipulable subsets based on their geometric characteristics (Figure 3). This reasoning module may bring, in this case, a considerable assistance.

Stone, the basic component of a wall, is made up of lines and surfaces defining the boundaries of those faces of points and defining the ends of these lines. These data are essential for encoding neighborly relations between blocks because they are the main reliable parameters of adjacencies. Each block is individually registered using the survey method adopted (GRCAO method), in two ways:

- The outline of the blocks: this corresponds to the detailed record of the actual boundaries of the block witch will be saved as control points.
- The min-max block: this corresponds to the polygon including the useful surface of the studied block. This contour is stored as control points coordinates.

Although this reasoning module is based on complex mathematical models, the user will not, in any case to manipulate them. All calculations will be back plans and the user will have to handle only 'objects', which he is used to deal with. We have demonstrated, through the explora-

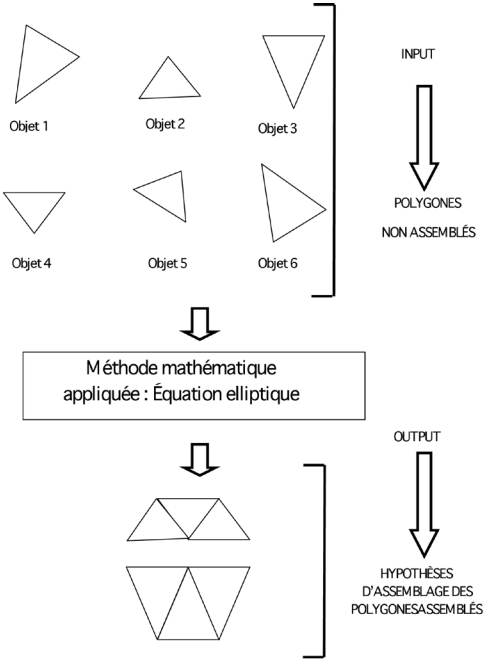

Figure 3
Operating principle to search for blocks assembly using the elliptical mathematical method.

tion of a 2D topological help reclaim the blocks, the relevance of such an approach and the relative facility on the computer translation of the actions that may include the reasoning module. This module, and meeting our original goals, open to the implementation of other actions (respecting the same logic). Depending on the initial objectives and methods that archaeologists adopt, a specialized team that will be responsible for translating actions that he wishes to undertake and thus to optimize the contribution that can bring computer tools in the success of the architectural reconstruction projects.

Iconographic approach to restitution

More than any other civilization, the ancient Egyptians have associated iconography and epigraphy to architecture. Indeed, the temple walls are covered with inscriptions and bas-reliefs whose theme, which meets to a large extent to known conventions, is the basis for the restitution of significant architectural parts of the temple.

Schwaller de Lubicz (1999) introduced a technique that allows the study of the key of reading scenes through the disposal of their constitutive iconographic elements. It is to identify the different modes of expression of what he defined as "an iconographic language", that when combined together, can give an early sense of the studied scenes. The three modes of expression used by this language are:

- Figurative language: it is a language that can cover all the iconographic elements that belong to different known elements and their associated scenes.
- The processes of arrangement: Addition and supervision of iconographic elements.
- Figures of style: It is to identify the language of the image through reading and decrypting formal and subtle arrangements that the Egyptians invented.

These complex arrangements are governed by mathematical principles that affect the structure of the scene. One approach will be to take advantage of these rules of composition through the implementation of the correspondent reasoning module. This will be our first approach.

Another very important consideration in the overall structure and composition of a scene element: the "continuity of the theme." Indeed, each of the blocks that make up the structure includes a portion of the overall scene. Our second approach will be to consider a scene as an assemblage of iconographic elements. These elements, taken together, could possibly give a meaning to the whole (register, wall, room, etc.). It is therefore to study the type of continuity and propose a reasoning module that can assist archaeologists in this type of work.

First approach: Metrological aspects in the Egyptian iconography

Our introduction to this metric aspects of Egyptian iconography is based primarily on the work of Robins et al. (1994), Donovan (1986) and Carlotti (1995). Egyptian architects built their monuments by following rules that respected the standards of proportion generally defined by type of building space, whether courses, pylons or columns (Carlotti, 1995). Restoring a monument according to length units commonly used in Pharaonic Egypt, using sometimes the digital measurement system (for architecture) uncial (the decor on the walls), proves a worthy track looking to be explored. Iconographic representations on the walls of temples do not escape this rule and follow a so-called "The Last Tile" technique based on the canons of proportions. Indeed, measurements of different parts of an Egyptian artwork, especially the wall decorations, were set one with respect to the other in a precise and rigorous way. This "Canon" was based on the proportions of the human body. Modern reconstruction of this canon of proportions is mainly based on the study of the guidelines partially preserved on the walls and statues. The data, the units of measurement as well as the rules of their use by Egyptian artists are still controversial.

For our case study, we have based our approach on the work of Carlotti (1995) to establish the proportion module used in the VIIth pylon at Karnak. Depending on the construction period, we may

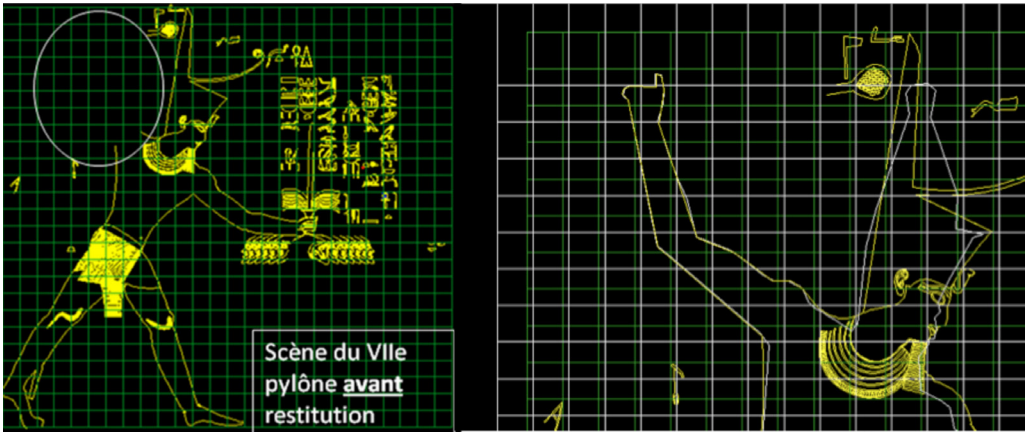

Figure 4
Restituation of the VIIth pylone scene using the iconographic module.

have an approximate value of the module used in the scene that appears on the "Medinet Habu" pylon. The iconographic analysis of the pylon reveals a traditional theme that represents the scene of the "massacre of the enemies". This scene was repeated in several Pharaonic structures. In an approach for a restitution by completion, and based on the complete scene on the temple pylon "Medinet Habu", our goal is to determine the missing elements, and so complete the scene studied (Figure 4). This treatment was made in four steps:

- Step 1: Determination of the modulus value proportion of the VIIth pylon at the Karnak temple,
- Step 2: survey of the representation of the Pharaon on "Medinet Habu temple" and on the VIIth pylon with the GRCAO method,
- Step 3: Making the superposition of the 2 surveys after practicing the technique of "tiles making",
- Step 4: Completing the missing part of the scene (Figure 5).

Second approach: Typology and iconographic connections

To study the iconographic continuity, we conducted an analysis of vicinity of each of the connections between the blocks that make up the VIIth pylon. Our goal is to study their type and their variants. Our analysis allowed us to identify eight types of continuities between the studied blocks :

- linear continuity
- Iconographic continuity: human body, hieroglyphic sign, other
- relief continuity: Level Difference, Surface Uncoupling
- Continuity of the type of engraving: texture continuity, etc,
- Text continuity
- Geometric continuity: same Min-max, etc.
- Theme continuity: Text, cartouche, human, etc
- Zone continuity: horizontal or vertical text, etc.

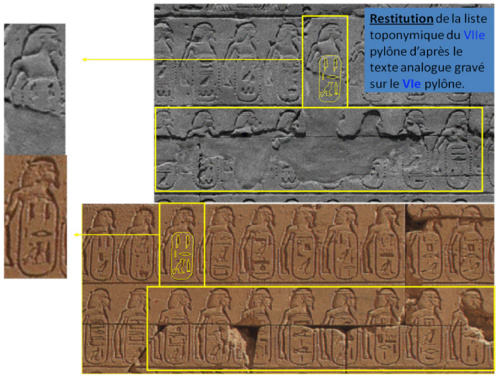

Figure 5
Restitution of the toponimic list of the VIIth pylon according to the similar text engraved on the VIth pylon.

Figure 6
Blocks assembled using the typology and iconographic connections.

Other elements of description can be added according to the competence of the actor and the degree of precision considered. Actors must not to describe the block as an overall unit, but exploded into as many constituent elements. That is to say, it must offer the user the opportunity to indicate areas of vertical text, horizontal text areas, friezes, human body, etc. A module based reasoning approach can provide the archaeologist additional tools to search, for example, all the text boxes with a width x or an additional sign truncated, etc.. This module is based on features to combine iconographic themes geometric aspects of signs and symbols. It is a tool to assist players in the field in studies of possible connections between the blocks to reconstruct.

The general topology of the block is defined in a data structure based on the control points where we can find the points that define the edges of the block which themselves define the surveyed surface. The direction of the view can also be defined (based on control points, too) in order to give meaning to the "left" expression, "right", "up" and "down" (eg the scene). All objects must be observed on the same side.

Attributes faces statements therefore represent qualitative information such as their orientation in the scene, exposure direction (smooth and treated when it is visible to spectators and untreated when it is not visible). It can also be determined by the inscriptions and it carries this on two levels: iconography (the figures, ornaments and inscriptions) and semantics (the interpretation and understanding of the iconographic elements) (Figure 6).

CONCLUSION

This experiment allowed us to confirm the overall appearance and total interdependence between the different components and activities of the archaeological approach in the archaeological restoration projects. On one hand, the procedure used to identify and describe the artifacts has a direct impact on the possibilities of data operations implemented. On the other hand, the goals of the actors and the nature of reasoning implemented determine the types of data to be recorded and the degree of interpretation to be made.

The results show that the reasoning modules offer an interesting solution to assist archaeologists in theses projects. The multiple action combinations offered by theses modules are an advantage to many approaches and thought processes which could be useful to such projects while maintaining the progressive nature of the overall system.

The type of goals of our project has greatly influenced the course of all operations related to the choice of corpus, to their description, to their structure, their interpretation and the validation of the results we had. Indeed, the survey methods and data structures have been chosen according to the nature of our corpus (pictures recovered) as well as "inputs" and "outputs" on the reasoning modules that we developed . The choice of data, the way to see them, how to classify them and how to comment them were determined with reference to the purpose of our construction: restoring the blocks of the VIIth pylon (Figure 7).

Our model expresses not the way has been built

construction, but its logical architecture, once completed. Indeed, the results presented, through our case study, have shown that the approach is often an iterative process that is constantly progressing (by trial and error) through the manipulation of data by actions encapsulated in various modules of reasoning (order of epigraphic (text and phonetic), constructive order, physical or geometric, etc..). In this progression, we have "experienced" various hypotheses through the application or implementation of new reasoning modules reasoning. The finding of inadequacy determined each iteration and pushed us back to the data and the means available to a new definition of corpus, description, structure or interpretation. It was mainly to combine several reasonings to reduce the number of available possibilities and progress until the results can meet the objectives of the study. The evolutionary aspect of the system allows us to add other modules of reasoning if the resources available cannot enable the objectives of the actors.

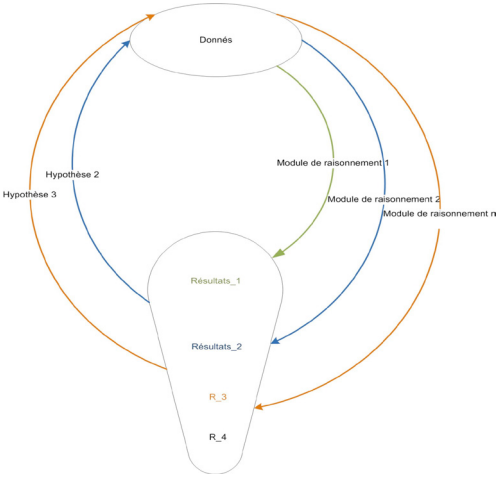

Figure 7
Model of archaeological reconstruction using the reasoning modules.

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