Using Historical Know-how to Model Design References

A Digital Method for Enhancing Architectural Design Teaching

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Abstract: The main purpose of this paper is to demonstrate that new computer and communication technology has the potential to change architectural education in a positive way, based on previous experiences and learning from the past. This research is based on two historical aspects that we bring together in order to propose a new didactic method and material for architectural education: the first one consists in finding obsolete architectural training practices and reconsidering them from a modern point of view; the second one proposes using precedents in a new constructive way in situation of teaching architectural conception in studio. This historical approach, combined with architectural design studio observations, has lead to an outline of a prototype of a digital assistant for teaching architectural design. Some aspects of its functioning are here discussed.

1 INTRODUCTION

New tools are proven by history to be able to bring radical novelty to architecture and its communication. This paper supports the idea that new computer and communication technology has the potential to change architectural education in a positive way, even when they are inspired by previous experiences and learning from the past. This research brings together two historical aspects with the purpose of proposing a new didactic method and material for architectural education: the first one, finding out discontinued good practices of architectural training from the past and reconsidering them from a modern point of view; and the second one, using precedents in a new constructive way in situation of teaching architectural conception in the studio. This paper is structured in the following parts: a historical background reviews the methodological foundations of this research and reveals the role of precedents in architectural education and design, so as to highlight problems often encountered in the pedagogy of architecture. Computer approaches addressing this issue are then given. Afterwards, we propose a new method of precedents description that can be used by students in architectural studio. At the end, we discuss some preliminary results and draw directions for future research.

2 BACKGROUND

New computer approaches are usually seen as being the result of pure invention, as is a newly designed building, for example. However, most of the *new* creations are based on past experience, personal or not. That is why we started by looking at the *origins*.

2.1 Historical Study

The goal of this section is to extract historically relevant data that can shed some light on the way ancient architectural methods may be of use for modern design education. In other words, what can we gain from the way architects were educated before the first school of architecture (in the modern sense), the *Académie Royale d'Architecture*, was founded in 1671? Back in Antiquity, architectural orders were created, synthesizing building know-how and aesthetics. In the Middle Ages, building cathedrals was learned directly by working on the construction site, what Schön (1988) would define as 'learning by doing'. Architectural conception and construction were indeed not dissociated until the invention of perspective and the plan-section-elevation representation of buildings during the Italian Renaissance. Thus, architectural and building know-how was passed down directly form masters to "apprentice-architects". Emphasis was put on architectural process rather than only on its final result (Tidafi 1996). Discontinuing this medieval tradition of secret transfer of architectural knowledge, the first architectural schools revived the classical orders, although they had become obsolete in terms of scientific and technical development. This way, the teaching methods focused on the final appearance of the projected building, more-or-less forgetting along the way the process of its making. Thus, *in the modern way of teaching architecture, transfer of know-how has been replaced by learning how to represent a final result of the project; and learning on the site has been substituted by a representation of the final result, that is completely detached from the construction process.* We use these conclusions in the method of modeling of precedents later in this research.

2.2 On the Role of References

Art and architectural precedents are omnipresent in today's architectural education. While in specialized courses they are well analyzed and interpreted by students, this is rarely the case with their use in architectural studio projects. So, we asked the question: "Are precedents important for learning architectural design?"

2.2.1 According to Literature

Bibliographical research on the role of precedents has shown their important role in learning architectural conception. Although this study is not object of the present paper, here are some of the insights we got from it: a person best perceives and understands new things based on analogies with past experiences (Léglise 2000);

references and cases offer holistic knowledge and provide a shortcut to a solution of a complex problem (Kalay 2004); the 'Design World' of architects consists of references and "things to think with", that embody implicitly architectural know-how (Schön 1988); and learning is especially effective when using know-how in a constructionist way (to create something new with it) (Piaget 1970; Schön 1988). The new method of precedents description that we propose is conceived to bring these characteristics to students in architectural design studio.

2.2.2 Based on Experiences in the Architectural Design Studio

Based on some practices in architectural studio and having in mind the visual over-consumption to which students are exposed, we wanted to find out what use do students make of precedents. In other words, beside getting inspiration from precedents, do they actually learn from them, and if yes what and how? Observations held with third year architectural students were quite informative in this regard. From the architectural studio experience, it was possible to come to the conclusion that there are at least two problems arising when students refer to precedents during their exercise-projects. The first one is that, if the reference is represented only by visual material, quite often it is not "understood". In other words, the essential characteristics of a precedent often remain hidden behind the image. For example, in our studio experience the specific form of the Building of the Greater London Authority (Architect Foster & Ass.) was not "understood" (at a 100%) as a product of ecological concerns and architectural know-how (fig. 1). This problem is, in some cases (65% of the students), resolved by the presence of keywords or textual information accompanying the visual support.

Figure 1 The GLA Building

The second problem is that sometimes students can "comprehend" the "essence" of the reference, but are not able to transfer the know-how into their own projects afterwards. A qualitative case study experience in the same third year design studio gave us key evidence on this issue. As shown on Figure 2, the student whose work is shown on the 2-c section of the Figure, has correctly identified the "essence" of the reference seen in Figure 2-a. But the fact that he could "name" it did not mean that he could immediately use it in a new design situation (that implies a new structural function of the form as well). Moreover, it took him much effort even to represent in 3D the hyperbolic paraboloid itself, because the usual CAD tools do not offer this element. In this particular case, a *description of the process generating the form*, or of the essential *chunk(s)* of knowledge used in it, could be of much help.

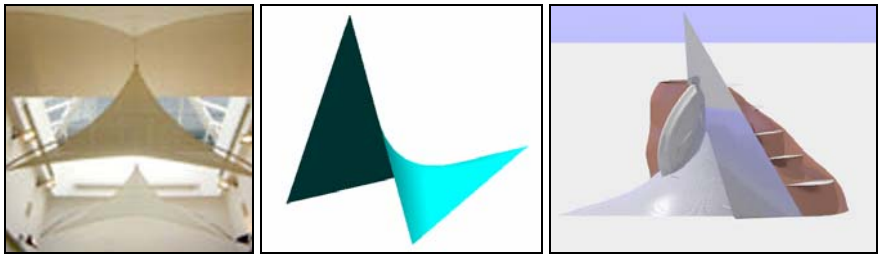

Figure 2 A structure based on a parabolic hyperboloid: (a) reference, (b) "comprehension", and (c) an effort to use it in a new design situation

We performed another design studio observation with the intent to determine what is the difference (if any) in the comprehension (guessing) of a concept, when represented (1) explicitly, by a geometric drawing, or (2) implicitly, by an expressionist image. Third year architectural students were asked to conceive a 3D model giving a spatial expression of such a concept. The experiment showed that the comprehension is sometimes surprisingly good, even from very "impressionist" visual material. Half of the students working from the "implicit" references could literally name the concept (which was in this case "dynamic equilibrium"). The fact that a geometrical drawing was shown to the group working from "explicit" references, did not considerably enhance their "comprehension" of the concept. However, it increased the precision of the models they designed, but on the other hand, decreased their artistic qualities. Another revelation was that even students who have "guessed" the concept could not "learn" from the references, even when mathematical formulae and geometric drawings were given. They were using previous knowledge for their designs, and this was not enough (in 80%) to give consistent results. *This leads us to the conclusion that knowledge should be implicit, hidden in expressive visual references, but extractable and re-usable.*

The design studio observations, together with the theoretical background from research on use of precedents in design pedagogy (1) shows that precedents are not used with their full potential in design studio projects, and (2) makes us believe that *reusable chunks* of design-process knowledge *extractable from visually represented precedents* could play an important role in teaching architectural design.

3 COMPUTER APPROACHES TO REFERENCES

Recent studies on new computer methods for design education look ways of integrating precedents in the architectural studio in an intelligent and intuitive way.

3.1 Reference Data Bases

Research on reference-based computer-aided design or education (Oxman 2004, Léglise 2000, Heylighen, and Neuckermans 2003, Do and Gross 1996) propose

computer assistance based mainly on visual information on precedents (mainly pictures), combined with manipulation and association of concepts. The use of diagrams instead of keywords (as in *The Electronic Cocktail Napkin* developed by Do and Gross) facilitates the designer and leaves him the opportunity to work with modalities that he is used to: graphical expression and not words. Main concerns of these systems are sophisticated search systems, sharing of the information, and concepts association based on analogy or depending on the design context or situation. The advances in this direction are outstanding. However, comparing with the conclusions from the historical study briefly presented here, one can find an important didactic characteristic *lacking* in these assistants: *the communication of architectural know-how* (hidden behind the pictures and only named by keywords or concepts) *in a way, allowing for its constructive reuse in new designs*. In this way, the proposed research contributes mainly to the *content* of the reference-based assistant, adding a description of essential generating *process(es)* to the already present visual and textual data.

3.2 Case-based Reasoning (CBR) - Case-based Design

If we look at precedent knowledge from a different angle, we can see that there are already quite a few developments considering modeling of precedents for their future re-use in new design situations. This approach is known as Case-based design and is based on the belief that most of the design solutions are developed on the basis of similar, already existent references (Kalay 2004).

Systems based on precedent thinking require very large number of “cases” that are indexed in order to be retrieved during design. Once “found”, these cases are modified and adapted to the new design task. This process is often left to the architect, but several computer systems try to assist him/her in this process. Adaptation is possible if the case structure is modifiable. The success of this kind of methods depends on the adaptation of the precedent to the new situation, as well as on the fact if this adaptation will not modify (destruct) the essential characteristics “*that made the case worth emulating in the first place*” (Kalay 2004). This is a problem that our approach tries to resolve by encapsulating only these “essential characteristics” of a given reference in its digital model.

A possible way for solving this problem is the Issue-Concept-Form (ICF) formalism proposed by Rivka Oxman. The *chunking* memory organization is at the basis of her approach for reference representation (Oxman 2004). The information is subdivided into independent semantic fragments. Each « *chunk* » represents only one aspect of the whole case. Thus, a reference is represented by a multitude of *chunks*. Yet, these *chunks* are not “living models” and hence, not reusable in new design situations, a characteristic that we found useful in a learning environment, but missing from reference data bases.

3.3 Prototypes

Some research applications combine CBR with an automatic adaptation of prototypes (Gero 1990). Systems of a similar kind try to generate parametric and even topologic variations of the extracted cases, by combining them with the derived attributes of other similar cases, like in the CADSYN system (Maher, Gomez, and Garza 1996).

The affinity between the case-based reasoning and the design process is proven nowadays, but its potential is far from being realized. It is possible to notice that CBR and prototypes either lead to a rigid model, or the core knowledge is lost during adaptation to the new design situation. Oxman proposes two possible solutions, that we entirely share. The first one is seeing CBR as *only one* of the parts of the "complex hybrid reasoning processes in design". The second possible direction takes into consideration the visual reasoning as a fundamental attribute of design, and suggests that "combining these two research areas may provide significant results for the field" (Oxman 2000).

4 METHODOLOGY

From the study on the history of architectural education, we have concluded that in the modern way of teaching architecture, transfer of know-how was replaced by learning how to represent a final result of the project, and learning on the site was substituted by a representation of the final result, that was completely detached from the construction process. Moreover, design studio experiments proved our hypothesis that precedents hide a non-used potential for design education. On the other hand, computer applications commonly used in practice and in architectural digital studios do not offer possibilities for learning from past experience, nor for reuse of precedent know-how. *Focusing on the final result representation, they do not take into account the process of the object's construction or generation.*

Our general hypothesis is that a reference-based assistant, offering re-usable design knowledge and architectural know-how, could bring positive changes in digital design studio education. This assistant should be flexible and open for new references and modification of the already present ones; it should also provide non-invasive support to design learning and should leave entire creative liberty to the student architect. A specific hypothesis whose validation is an object of this study, is that such an assistant can be conceived and implemented on a computer.

4.1 Modeling the Generating Actions

The didactic method proposed in this work is based on digital three dimensional modeling of valuable (from a didactic point of view) architectural know-how of precedents. The actions modeling approach developed by Tidafi (1996) and inspired by the apprenticeship practice before the Renaissance, allows processes that generate

an object or space to be represented. It enables a systemic approach to modeling both precedents and their organization in the assistant device. This method was successfully implemented by De Paoli and Bogdan (1999) for description of semantic operators that can be geometrically formulated.

4.2 Models of References

The core components of the design assistant are the references. They are either architectural precedents, metaphors, or any other analogue objects that can serve as inspiration and as a source of design knowledge. Together with their three dimensional nature and shape, they offer the know-how used for their creation.

We propose a method for modeling the most meaningful characteristics of the processes that have as result the "objects", that will be manipulated and transformed in the digital "Design World" of the student. The method is inspired by the object-types theory of Schön (1988) explaining the role of references during different phases of design. As problems associated with object libraries are due to the enormous number of precedent cases referred to by architects, we have adopted a non-causal approach based on complex-systems modeling. It enables transformations in space and time, which is the main characteristic of a dynamically organized model.

The models do not simply represent petrified precedent cases, but emphasize their generation processes, expressed by modifiable actions. In this way the final results can be of a great variety and the complexity of the architectural object-types is kept in their models. We join visual representation with a description of the most important characteristics: structural organization, production process, functional organization, spatial composition, etc. These can be either described or modeled by the original author, or interpreted by the precedent's user. Basic components of our model are actions that generate the object-types: formal, functional, structural or normative. These actions are translated into computer language as functions. They can be applied to various kinds of objects, according to the metaphors evoked by the designer. Creativity may result from variations in the variables of the generating function or from a different organization of object-types. The functional method of describing actions allows for object-type determination by explicit characteristics and by derived ones as well. In this way, emergent object-types could be captured.

This approach to object-type modeling is consistent with the paradigm of "situated design". The *chunks* of knowledge (representing object-types' meaningful features) can be combined and structured differently, according to the external conditions (design task or environment); or depending on the designer's experience or inspiration. These higher-order organizations and action definitions (object-types of more complex nature) are stored in memory as well, for future references and use. At least three types of information are recorded: (1) the semantics of the designer's intention, (2) the *chunks* of knowledge entering into a higher-order object-type, together with their organization, and (3) visual representations of these object-types. Functional programming together with a real time 3D visualization is used for the computer implementation of the method.

4.3 Structure of the Design Pedagogy Assistant

The *digital design-pedagogy assistant* enriches one of the dimensions of the "Design World" of the future architect. It is compatible with the creative work environment and contributes to teaching the design process. The structure of an assistant of this kind should be easy to use and give enough freedom to the teacher and to the student. So it is conceived not as a system taking care of all the process of design, but, on the contrary, as scattered fragments of references in a larger design-learning environment.

Essential is the fact that the design knowledge (the computer program's functional structure) that has generated a given architectural precedent case or "object to think with", is linked to its visual representation. Thus, the visual stimulus of a precedent can be joined with functional characteristics, production procedures and/or semantic meaning of the object. The functional nature of the programming language used for the computer prototype, enables modeling of complex structures, thus simulating real architectural and learning processes. A schematic structure of the assistant is given in Figure 3.

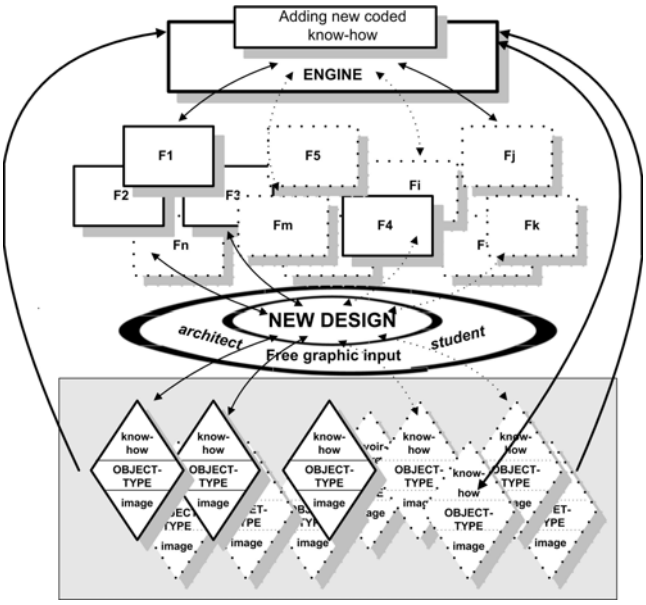

Figure 3 Schematic structure of the proposed Design-Pedagogy Assistant

There are three main parts: (1) The central part is entirely managed by the user and is occupied by the new-design conceived by a student-architect. He/she is free to use or not the references stored in the "surrounding" system. Upon request, a *chunk* of knowledge from one of the precedents can be evoked. It can either modify elements of the design solution already being conceived, or simply visualize a situation-dependent 3-dimensional instance of the coded know-how. (2) The upper part of the

diagram shows the computer functions which encode the architectural know-how and are able to visualize it. New functions can be added to this part of the assistant. Multiple functions of this type can refer to one or many references. Students themselves can be involved in the process of enriching the knowledge "pool" by coding *chunks* of functions. According to Yakeley (2000), programming gives a constructivist approach to learning and improves design method of students architects. (3) The lower part of the figure shows a data base of references (*object-types*). Each of them consists of: (a) visual information (images, drawings, sketches, 3D models, other media), (b) semantic and textual description, and (c) coded structure of the chunks of know-how used in the given reference, and reusable as a higher order model in new situations.

5 VALIDATION AND DISCUSSION

The approach to design education proposed in this paper needs a large platform including a reference data base, compatible with a CAD or modeling environment offering a powerful programming language. As the scripting possibilities offered by some of the commonly used software are ill suited for modeling the structure of the models and their organization in the assistant, experiments are made on a prototype of an assistant, not including all functions yet. The objective is to test the capacities and the flexibility of the modeling engine of the assistant, which is a prerequisite for its successful future use by students. The examples shown in Figure 4 represent: (a) an interactive exploration of the form and the visibility quality of a theatre. The colors above the seats show the level of "comfort" from the respective place; (b) a decorative pattern integrated as a floor mosaic in a Art Deco house. The specific actions of the builder, as found in the architect's instructions, generate the composition; (c) application of a sunlight/shadow and energy optimization *chunks* of knowledge on buildings with different forms of floors, and in different climatic conditions. These three examples are generated with SGDL-script technology, taking advantage of the Scheme programming language, and (d) a screen-shot of one of the folders containing the "visual" part of the design-pedagogy assistant.

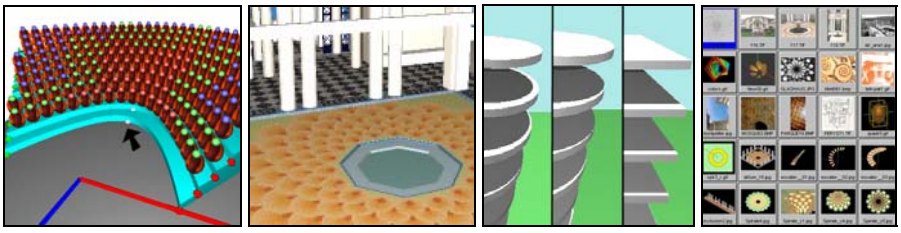

Figure 4 (a) theatre form quality exploration; (b) mosaic pattern generation; (c) taking sunlight into consideration; (d) visual" part of the assistant

We consider these results as a first and promising validation of the reference-based pedagogy assistant prototype. Its integration to a free modeling environment is

forthcoming and will be crucial for the acceptance of the assisting device in architectural design pedagogy practice. However, confident of the important role of precedents in architecture, and aware of their non-realized potential in design studio, we are able to foresee the possible advantages that students can take when referring to the assistant. Future architects will be able to get inspired by references and to learn from past experience, while developing their design approach constructively.

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