ACHIEVING COMPUTER AIDED DESIGN 3D MODELS FROM VIRTUAL TO REAL IN ARCHITECTURE LEARNING

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Abstract. The existing gap between the 3D physical models done by architecture students and their digitized 3D virtual models in architecture design is truly spectacular. The increasingly efficient and more specialized digital applications allow the designers a whole range of facilities providing drawing commands and changes very easy to use, which puts 3D physical model in a less priority or being useless. This paper studies how to minimize This gap by teaching students that 3D physical models are not only the outer physical result of the design but it could be also the way to learn the architectural relationships and values in architectural design, where 3D physical models techniques now had been updated and related in a way to the digital 3D models and CAD applications.

1. Introduction

In Architectural Design and Education, it is common to refer to prior design cases. This is apparent in a teaching context, where students don't only study existing projects, but also in a professional context, where reflection on existing design examples can inform the architectural student about possible solutions or as historic reference.

This Paper discusses results from the reconstruction 3D physical model for a well-known building projects then projecting it digitally using measuring techniques and relative scales. These examples illustrate the added value 3D models enable, compared to traditional drawings or photographs. Even the structure and presentation of recent design projects can be improved using diagrams and overlays, capitalizing on the results of the 3D modeling efforts. The combination of these diverse techniques enables an increased accessibility of the inherent design information, which would not be established using each technique as such.

The practical study in this paper illustrates the added value taken from 3D models, compared to traditional drawings. Even the structure and presentation of design projects can be improved using diagrams and overlays, capitalizing on the results of the 3D modeling efforts. The combination of these diverse techniques enables an increased accessibility of the inherent design information, which would not be established using each technique as such.

2. Shifting Modeling Approaches

Modeling allows architects to explore an idea in a three-dimensional form whether it was physical or virtual one, models communicate an architectural idea in an accessible way, immediately showing aspects of scale, form and material. A model can be produced as a full-size prototype of an element (such as a door or window) at the scale of a room, or at the scale of a city (in the form of an urban model). Physical models allow an idea to be explored in greater depth, as certain elements of the scheme or their scale may not be understood until they are seen in the context of a model form. The physical model is the most accessible form of architectural communication. Students use finished models for presentations, others also embrace sketch models as quick, economic and flexible generative tools. CAD visualizations offer impressively realistic models that can allow the viewer to choose how they move through a building. CAD models can be used to develop complex forms in the design process, allowing shapes to evolve and explore a range of forms. (Farrelly, Lorraine2008). It is only with the rise of the virtual that the advantages and disadvantages of more traditional models can be fully evaluated. (Mark Morris 2006).

In Architectural learning, wide techniques specified for representing Building design practice are introduced, which is normally done under the guidance of Technology and Science subjects. Traditionally, Architects communicated their design intentions using specific representations originally these mainly two dimensional drawings are in the form of Computer Aided Design and Drafting (CADD) or ubiquitously simply CAD. While CAD has significant productivity and accuracy advantages over the earlier manual method, it still only produces specific representations of the design. (Schueremans and Van Genechten, 2007). With the increased usage of 3D techniques in visualization, simulation and Building Information Modeling, architects nowadays produce more and more designs as 3D models. This is also the approach taken in most traditional university courses and mirrors the reality of the situation in the building design. A successor to CAD, in the form of 3D Modeling, is presently evolving in the Architecture learning and Design stage. CAD is mostly a technical tool that conforms to existing Design practices. 3DModeling on the other hand is revolutionary both as a technical tool and as a design practice. Rather than producing representations of design intent, Modeling produces an exact Virtual Prototype of any building that in an ideal situation is centrally stored and freely exchanged between the project team. Essentially, Modeling builds any building twice: once in the virtual world, where any faults are resolved, and finally, in the real world.

Virtual models provide new means to visualize and interrogate the design, much of this potential is left unused, as the models are seldom shared to exchange design information. The Architecture design use widely differing techniques, from regular 3Dmodelling using CAD and visualization software, to physical Model for the Design.

3. Different Approaches to Model and Visualize Buildings

Architectural modeling is mostly described as a product in the architectural design, and has not been sufficiently analyzed as a process. Therefore, the paper sets out and analyzes a strategy to contribute architectural modeling in architecture learning. The primary motivation was the use of effective computational tools that would support modeling. The initial study consisted of observing architectural students which had just learned architecture projection, architecture conventions and they had performed early design activities that led to three-dimensional models. Data were collected that revealed specific mechanisms that were repeatedly and consistently used as an integral part of several widely recognized design strategies. These include management of masses relationships, scale, design hierarchy, topology–geometry relationships and the restructuring of problem parameters.

The next section will begin the discussion with a description of case study, followed by a review of regulating elements used as design strategies. We then discuss each strategy as described in the literature and manifested in the study tables. The conclusion is by describing concepts for computational support for modeling strategies and by discussing the implications of modeling strategies for architectural education.

The case studies have different characteristics and have utilized different techniques. Information retrieval is often the result of a literature research; the visualization outcome is also identified, ranging from 2D CAD drawings to rendered 3D models or even interactive scenes. The case studies include historic reconstructions, but also 20thcentury modern buildings. Students were free to choose any of the following buildings (figure 1):

- The Leaning Tower of Pisa, Italy.
- Big Ben-London, England.
- The Parthenon - Athenian Acropolis, Greece.
- Mesoamerican pyramids, Mexico.
- Bank of China Tower, China.
- The Arc de Triomphe de l'Étoile Paris, France.

Figure 2. the different 3D physical model done by students in the first stage for the case study buildings

4. Practical Observation

Recent studies on new computer methods for design education look ways of integrating precedents in the architectural studio in an intelligent and intuitive way. Consequently the set up a practical study for the purpose of gaining a deeper understanding of the strategies that guide modeling processes. Since modeling does not occur in isolation, a series of protocol observation were done during the sessions that capture modeling as well as early design activities that influence modeling decisions; for instance, mass proportion, Scale, or levels.

4.1. EXPERIMENTAL SET-UP

Protocol analysis has been widely used for studying human cognitive behavior within problem-solving contexts. (B Kirwan,1993). Protocol analysis was chosen because it captures comprehensively and simultaneously the students' graphical representation and their corresponding verbalization. These verbal expressions include the motivation and rationale that are not evident in graphical representations therefore, clarifying possible misty that are often present in the latter.

Our protocol experiment consisted of observing architectural students which had just learned architecture projection and architecture conventions as well while they designed a three-dimensional massing model. Each session lasted two hours on the average, but was not limited by time, in order to avoid putting participants under pressure. Each session was followed by a brief post-experiment questionnaire.

We considered all participants as fresh architectural students which had just learned architecture projection and architecture conventions as well. All participants were CAD users with a minimum of one year experience. The task consisted of two stages the first stage is building up a physical model for a well-known architecture building and then learning its architecture vocabularies projection planes and levels its dimension and in what scale it was constructed in their physical model the second stage was to draw its projected elevations in CAD system.

Sessions were completed in the computing medium (CAD system). This allowed capturing strategies that transcend representational media. In the computing sessions, different industry-standard CAD systems were used (AutoCAD, Revit) so that results would not be influenced by the limitations of a single system. The participants were also allowed to use paper whenever they needed in order to reveal the modeling design activities that would be difficult to achieve on the computer directly. Furthermore, the switch between the media is considered to be significant data for analysis.

4.2. ANALYSIS

We refer to participants as P1 to P20 and the corresponding protocol sessions as S1 to S6. In the first two session (S1 to S2), participants used the AutoCAD software then they used Revit in the remaining sessions. Models generated by each participant are referred to as Ai ‘i’ corresponds to the participant ID.

The protocol sessions were first transcribed into a series of moves, which included verbal expressions, drawing actions or their combination. Then these moves were categorized and color-coded according to the activity to which they contributed (measuring, scaling, and drawing) and their type (analysis, decision, and evaluation). Moves are referred to as

Mi_n.n.n, where ‘i’ is the participant ID and n.n.n is the move number. The vocabularies of modeling elements are identified in the transcriptions. Tables illustrating substantial modeling strategies were further analyzed.

4.3. SUMMARY OF RESULTS

The principal mechanism utilized in modeling perception activities was the use of regulating elements. These include tools such as Scale, levels, alignment, mass proportion, openings, and bounding lines. All participants maintained geometric order in their designs using such mechanisms. Although they freely manipulated (added and removed) modeling elements, through the use of regulating elements they were able to preserve their underlying structures and even emphasize them. Analysis of the data showed that students used these regulating elements, among other things, to achieve the overall projection process.

4.4. REGULATING ELEMENTS

In each modeling configuration, there is an underlying structure. (A Chimacoff 1992) It is common practice in architecture to express the relational structure of modeling elements through regulating lines. As a matter of fact, in the past, prominent architects have actively promoted the use of regulating lines. In an effort to systemize the architectural design process, JNL Durand introduced a “method to follow in the composition of any project”, which relies on establishing the structure through regulating lines as a primary design step.(LMadrazo 1994) Both Le Corbusier’s and Durand’s prescriptive approaches highlight the role that regulating lines have played in the development of architectural theory. The research extend the concept of a regulating line to a regulating ‘element’ to scale, mass proportion, levels, alignment, solids and voids which, in combination, express the entire structure of the architectural configurations in three dimensions. Our concern in this study is not whether or not designers use or should use regulating elements, but rather ‘how’ they strategically use them in the creation of architectural form and the development of a design.

4.4.1. Scale

Models can appear in different roles along the process of creating architecture. As designs unfold, models tends to progressively increase in scale and detail, each successive model taking us ever closer to the design resolution (Porter,Tom2000). During the first stage sessions studied, participants were observed using regulating elements of modeling to organize their work. Scale appeared in their perception of the building and how big or small the building really is. An explicit use of a regulating element (scale) is illustrated in S1, where the participant repeatedly measures the main axis and heights of the building on every trace over the physical model then compares it to the real measurement of the building he had chosen. This is substantiated at several points in their work protocol, one of which is illustrated in table1, below. The axis is clearly the organizing element for the center of the model, the two sides of the building, and the main podium. These parts are used to create the whole (the entire building) by scale the perception of the building was generated in their mind and the scale factor was understood.

4.4.2 Mass Proportion

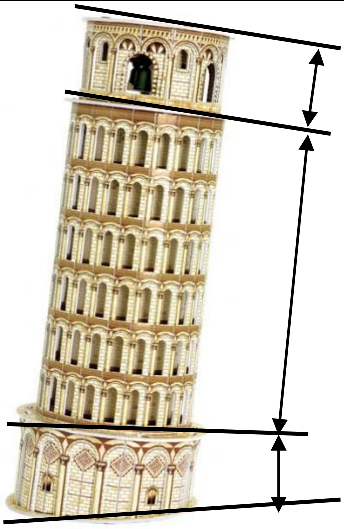
One of the most straightforward ways of perceiving the building form is to break it into more and more specialized parts. Massing with regulating elements seems to achieve this as well.

In this case, the decomposition of the building form is graphically driven. Participants appear to create local sub-masses by adding sub-division lines into the building massing representation. For example, P2 uses sub-divisions lines to develop the sub-masses of the building. table2. He then uses these as guides in the recessing parts of the mass.

TABLE 4 Explicit expression of regulating scale (M5_1.1.1)

1.1.1	P5 places the three axis lines on the model at each corner.	
1.1.2	He placed another axis to measure the lower height	
1.2	He began to compare the measured lines with the known dimension of the building	
1.2.1	"its really a sky scraper we are so tiny"	
1.2.2	He calculated the model scale	
1.2.3	"Now I really understood what is meant by scale and scale factor for models	

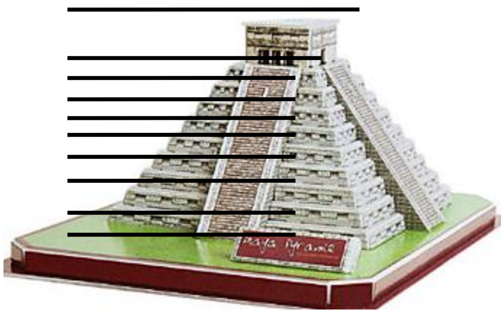
TABLE 5 expression of regulating scale (M2_4.1.1)

4.1.1	P2 places the three main masses dividing his building on the physical model.	
4.1.2	He began to divide it into three cylinders with different inclination axis of mass	
4.2.2	He began to calculate the inclination of each mass and its proportion to the others.	

4.4.3 Levels and Spatial Hierarchies

The part–whole relationship naturally leads to the notion of hierarchy. Parts are subsumed by higher entities, which in turn define other yet higher instances of building elements. It is not a surprise that architectural conventions include many examples of hierarchical decomposition: the building, its wings, their floors, suites found on floors, the individual rooms inside them, and so on. (Akin, 1998). This peculiar combination of breadth-and-depth strategy is responsible for creating and navigating levels and hierarchies in a building. First, there is the decomposition of the problem into sub-parts.

TABLE 6. Expression of regulating hierarchies (M6_6.1.1)

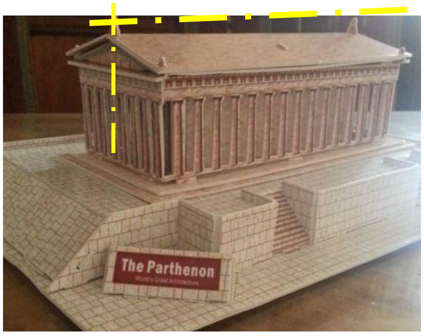
6.1.1	P6 started to identify the building levels and any related hierarchies	
6.1.2	He began to differentiate between stair level and the pyramid main steps.	
6.2	This building is full of levels that appear simple	

The evidence was gathered here suggests that modeling, in fact, relies on these universally known strategies of hierarchies. The massing strategies defined here, which use regulating elements to create geometric order, establish a two-tier hierarchy between the regulator (super-node) and the regulated (sub-node). Nested regulating elements of massing can then create indefinitely deep hierarchies (Table3).

4.4.4 Alignments and Projection.

A popular regulating element is the symmetry or alignment line that aligns individual design elements (whether they are rooms, windows, columns or stairs) with respect to it. Aside from the compositional order that results from such use, symmetry or alignment axes represent meta-elements that control the spatial organization of other, lower level elements. The relationship between the latter to the former is one of part-to-whole. P11 draws a massing element and then derives its central axis as the major axis of the configuration. Following the order specified by that axis, she draws the remaining massing elements. Rivka Oxman(2002) described semantic emergence as the emergence of the underlying structure or design organization. In the following example, P11 has recognized the emergence of the central organizing axis, in the middle of the process of creating massing elements. This is significant because it shows that emergent features, such as implicit axes, are just as likely to become scaffolds as explicit ones (Table 4).

TABLE 7.Expression of regulating hierarchies (M11_2.1.1)

2.1.1	P11 then derives the building central axis as the major axis	
2.1.2	She draws the remaining massing elements.	
2.2	The implicit axes, are just as likely to become columns as explicit ones	

4.4.5 Solids and Voids (openings)

Solid-void theory is the three-dimensional counterpart to figure-ground theory. It holds that the volumetric spaces shaped or implied by the placement of solid objects are as important as, or more important than, the objects themselves. A three-dimensional space is considered a positive space if it has a defined shape and a sense of boundary or threshold between in and out. Positive spaces can be defined in an infinite number of ways by points, lines, planes, solid volumes, trees, building edges, columns, walls, sloped earth, and innumerable other elements.(Frederick, Matthew.2007). Participant P15, for example, sets out an axially negative mass represent the voids, symmetric building.

TABLE 8. Expression of solids and voids (M15_3.1.1)

3.1.1	P15 sets out an axially negative mass represent the voids.	
3.1.2	The building has 2 intersecting voids with different heights	

4.5 VIRTUAL MODELING

Regardless of the chosen applications, architects, designers or researchers are faced with work flow problems. Data has to be translated between very different systems, often requiring partial remodeling or restructuring of the passed geometry. Transferring more intelligent data, such as parametric assemblies or digital building models is even more problematic. The application of a format such as the Industry Foundation (IFC) is only supported with BIM applications and even then, information gets lost in the translation process. As described in (Mitchell et al, 2007), where the exchange between a design tool and energy analysis was investigated, the IFC model proved to be useful, but still incomplete, while at the same time being hindered by the modeling limitations of the BIM application. Figure2

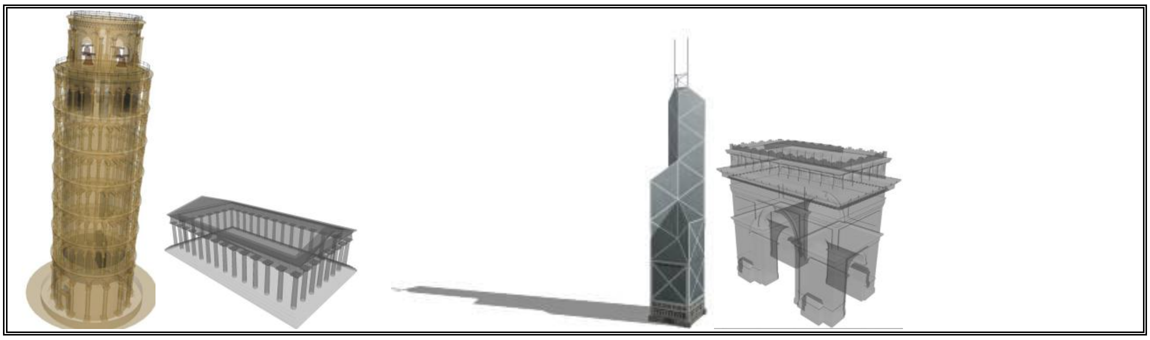


Figure 3. 3D virtual models for the same buildings which were chosen by participants.

In all cases, the translation process will also be unidirectional, where a model is translated, extended and then, possibly, translated into another tool. There is no way to synchronize these modifications between different applications. For a static reconstruction, this might seem less problematic than the modeling of a design-in-process, but nevertheless, new and updated information might and will become available during a reconstruction project and inserting it into the original model will start the translation process once again. The choice of a modeling system directly reflects the potential outcome. Participants started 2D drawings leaves no choice but to apply CAD or BIM applications. Auto CAD software can use the 2D drawing to generate a 3D model, but consequent changes in the drawing are not reflected to this model. The only method where the 2D drawings can be elaborated alongside the 3D model is the use of BIM software (Revit).

5. Discussion

The protocol results illustrated several situations where students handled the geometric structure of a modeling configuration in such a way that they seemed to be doing more than just reconstructing the buildings. These case studies have shown an added value for modeling Process. In parallel, it is possible to improve and increase information about the design, by adding additional metadata to the 3D model. The "enrichment" of the 3D models make better structured information available, which can in turn, facilitate the retrieval and recovery of such models, when searching or browsing for design information through online repositories.

5.1. COMPUTATIONAL SUPPORT FOR MODELING STRATEGIES

To combine interactive models with embedded architectural information requires the combination of different techniques, such as transferring models to open standards and the addition of metadata to facilitate online retrieval.

5.2. IMPLICATIONS FOR DESIGN EDUCATION

While the regulating elements discussed above are common practices in architectural modeling, they do not play an active role in architectural education. Students should use the regulating elements as explicit mechanisms for managing their model. It would takes trial and error out of the learning cycle and therefore reduces the amount of time required for students to develop their own model; explicit use of these strategies may increase their understanding of how well or poorly the model is.

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