MODELS IN THE DESIGN CONVERSATION: ARCHITECTURAL VS. ENGINEERING

Thomas Kvan + Ruffina Thilakaratne
The University of Hong Kong

Keywords:
Representations, Drawings and Models, Designing

Abstract: Models are used in architectural design for several purposes. Early in a design cycle, sketch or study models will be created to examine particular aspects of a design idea. Such models are often assembled rapidly and crudely for it is the immediacy of the feedback that is sought. At later stages in a design cycle, more carefully assembled detailed models may be created to present ideas to colleagues, clients or decision-making bodies. Extending Schön's observation that drawing is a process of conversation, we observe that models also participate in conversations. The introduction of digital media changes the nature of the conversation. This research revisits the role of models in the design conversation. It has been noted that models can be classified in two roles: 'models of' and 'models for'. In architecture, we extend this by adding 'models with' as we employ three and two dimensional representations in the conversations of design. This paper presents experiences with students in the use of Rapid Prototyping technologies and manually made physical models in design tasks.

REPRESENTATIONS

The act of designing requires the designer to engage representations of the designed object. Representations thus play a significant role in the design process: as a mode of conversation, communication or documentation. Representations embed ideas, knowledge and reasoning (decisions) through sketches, drawings, physical models, digital models, or mathematical models. Representations function as virtual worlds, which help designers to experiment at relatively low risk and cost.[1] In architectural design, the range of representations employed at any time may vary. As new technologies appear, so many new modes of representation be developed and a different palette of representational media established as those favoured.

For many years digital forms have remained confined pixilated and vectorized, denied easy translation into physical form. With the introduction of lower cost and faster rapid prototyping machines, however, the premise is that we have broken through this barrier and can at last reconnect the tangible with digitally ethereal. Some have gone further and claimed a reinvigoration of the craft traditions as a result of the connection in digital technologies from design to manufacture, postulating the realization of the 'digital craftsman'.[2]

For the same reason of time and money, RP machines are finding their place in schools of architecture. Clearly, the contribution in learning is not simply the possibility to make tangible the forms previously intangible. Although we are beginning to develop a pedagogical framework for digital design[3], this has not engaged these newer modes of output and it is timely to examine the role of RP in the design process.

WHAT IS A MODEL

What is a model? A helpful definition can be found in the Dictionary of Weather:

> Model: Any theoretical representation of a process or system, including conceptual, as well as numerical, models. In general, for practical reasons, a number of simplifying assumptions must be made, which limit the extent to which a model truly represents actual conditions, the time period over which any conclusions are valid, and the application for which that model may be employed.[4]

In this definition, we see that a model is described with conditions of simplifying assumptions, with these simplifications limiting the use of any model. Models are used in architectural and engineering design for several purposes[5]: including exploration, experimental, presentation purposes. Models vary in terms of their scales, accuracy, and material, depending on the purpose for which it is made. Models are abstract representations, not replications of realities. Therefore architectural models do not represent properties of materials, true colours, textures etc. just as weather models do not represent the precise properties of the atmosphere.

Architects, and architecture students, employ models for a variety of reasons. Early in a design cycle, sketch or study models will be created to examine particular aspects of a design idea. Such models are often assembled rapidly and crudely for it is the immediacy of the feedback sought. According to data these rough models assist students in their design thinking process in many ways shaping their decisions: help them perceive their 3D imagery easily and clearly, explore different forms and understand relative scales within the existing context (Fig. 1). Janke[6] and Ratensky[7] indicate the use of models to develop spatial thinking and explore certain aspects of design, often massing. We see this in the work of professionals as well.[8] Constant created his examination of New Babylon by making models, models that he considered not as disposable tools but as manifestation of polemical positions. Indeed, Constant did not design by drawing but made models first and then drew his models.[9]

Fig. 1: Exploring various forms and understanding relative spatial scales

Models are often highly articulated as they strive for verisimilitude, apparently departing from the simplifying assumptions of early design models. It is easy to forget that simplifying assumptions continue to be embodied in these representations and the claim to accuracy is a fallacy. “The reality of the model is a fiction, it’s not real, it’s only a tool for the final building”.[10]

MODELS IN STUDIOS

A research was carried out to examine the role of models in the design conversation. This research was carried out over six months following and observing year three engineering design sessions that are conducted once a week and architectural design studios that are conducted twice a week. We considered four different design projects carried out by four groups of engineering students and a range of studio projects carried out by architecture students.

In examining the use of models by engineering students, we observe that they construct and use models differently to architecture students. Engineering designs are often limited to smaller artefacts. Since their objects are often small, often the model is larger than the object in reality, an inversion of the architectural relationship. Engineers appear to make models for experimentation more than for exploration of design ideas. Figures 2, 3 and 4 represent three series of experiments conducted by engineering students using physical models. For these purposes they not only construct physical models, but also mathematical or digital models. These models may be intended to experiment with particular properties and to investigate the behaviour of features and elements. Large objects are often represented by detailed typical sections instead of constructing the entire object (Fig. 4).

Fig. 2: A series of tests to experiment with the desired rotation and the impact of buoyancy of an upward moving balloon

Fig. 3: An installation to test gas leakages (pressure drop) in the pipelines buried inside concrete

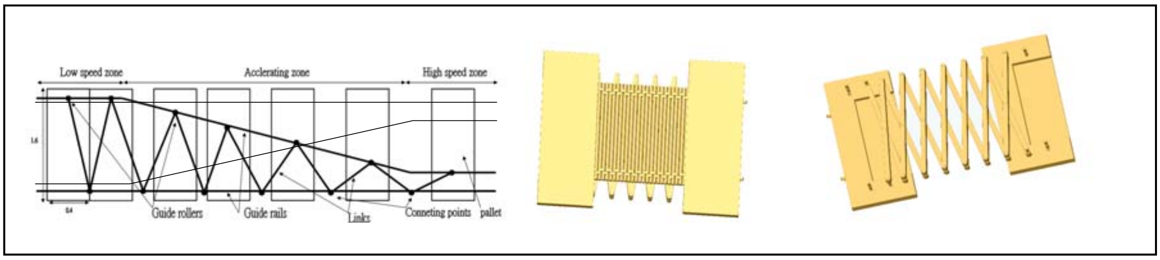

Fig. 4: Representing large object designs by detailed typical sections

DRAWINGS AND MODELS

Paper-based drawings freed the architect from working on site at a scale of 1:1.[11] The development of paper in the late 16th century led to the development of the tradition of drawing as the act of designing. Through this development, design moved itself from the production of solid objects to become an intellectual discipline engaged in the plane of paper.[12] The medium is convenient for conveying ideas rapidly and facilitates the exploration of alternatives by means of easy editing. In recent years, the introduction of digital tools has raised concerns that the relationship of the designer to the design is changing[13]. The tangibility of paper and its manipulability constitute significant properties that support work in ways not found in the digital desktop. It is also suggested that paper-based drawing affords collaborative design activities[14] and further observed that working on paper supports collaborative activities better than digital modes of working.[15]

Drawings and models both can be used to represent the three-dimensionality of structures from different angles. Unlike physical models, however, drawings control the observer in the angle or focus of attention, directing these to significant elements. It is necessary that a viewer be trained to comprehend certain drawings, such as the standard geometric projections of plan, section and elevation, while other drawings may only be comprehensible to their creator.[16] No matter how elegant, drawings have their limits. “No three-dimensional drawing, however accurate or sophisticated is a substitute for three-dimensional physical models”.[17]

Models offer benefits of approachability, tangibility, manipulability and collaborative engagement. For these purposes, models are used at all scales, ranging from town planning to explanation of particular building sub-components. In particular, complex mass-void relationships or spatial sequences are said to be more easily communicated in models. Digital models have evolved to become sophisticated virtual environments able to be understood by tyros and the untrained eye, capable of communicating invented spaces and forms.

ROLES OF MODELS

From this we can see that models play a role as communication tools. In addition to representing form, models can be used to examine processes as well. Models can be used to assist in testing constructability such as in the integration of services into complex or tight structural spaces. Engineering models are particularly constructed to examine processes or to test constructability, compared to architectural models (Fig. 2-4).

Models also can be disassembled to reveal the components of a building or the spaces within, or they can be abstractions that reveal to the viewer particular properties not hidden when the real object or complete model is viewed.[18] Models also can be used as a means of prediction of certain behaviours and are sought as cost effective means of experimenting with possible and alternative solutions. For pedagogical purposes models also can be used to understand theoretical explanations of certain material properties and structural behaviours.[19] Certain geometries can be examined in model form more easily than other means. By assembling and disassembling forms and by representing ideas conceived but not imagined, models help the designer to understand the spatial implications of their drawn two-dimensional decisions.

It has been noted that models can be classified in two roles: ‘models of’ and ‘models for’.[20] Here, models are distinguished between those that are representational and those that are developed as tools of investigation. A similar distinction has been drawn[21] between *semantic* and *illustrative* representations. Young suggests that “Semantic representations represent by being true…Illustrations are not the sort of thing that can be true” (p 26). A distinction is drawn here between those representations that can be correlated directly to behaviours of real objects in the world through the application of semantic rules of interpretation and those representations that cause us to reflect on an experience rather than factual condition. Thus, ‘models of’ might be considered to be illustrative representations, while ‘models for’ are semantic. Architectural models cannot be adequately explained by either of these categories.

ILLUSTRATIVE REPRESENTATIONS OF

Illustrative representations are not tied with semantic conventions. Instead they are tied with our experiences of real life objects. Illustrative representations do not depend on the compositionality; a part of an illustrative representation can still make us recognize what it ought to be. A snap shot, a painting, a diagram are examples of illustrative representations. Similarity of experience hence is a key feature in illustrative representations. Some models such as miniatures of structures are illustrative representations. Figure 5 represents illustrative models of the Sydney Opera House and the IBM Pavilion, constructed using the Rapid Prototyping technology.

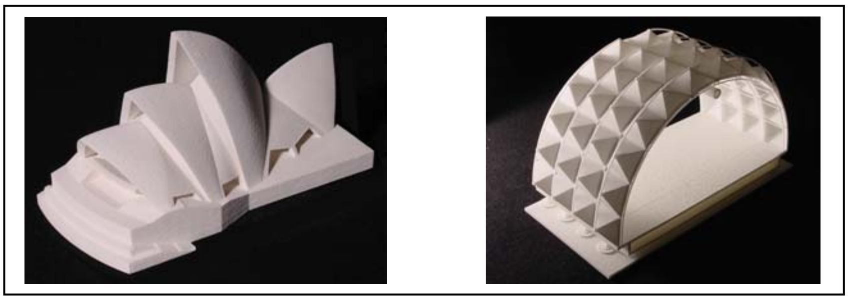

Fig. 5: Miniature models of the Sydney Opera House and the IBM Pavilion

SEMANTIC REPRESENTATIONS FOR

Semantic representations are true representations. They are conventional statements. Road signs, mathematical statements, charts and graphs are semantic representations as we adopt fixed conventions to read them. In architectural work construction drawings are semantic representations. Semantic representations are tied with semantic compositionality. A part of a representation will not be a semantic representation as it would be as a whole. From the models we consider for this study, engineering models are semantic representations. They are the representations that demonstrate true facts. Some examples from our research are, model installations to test the constructability of a wind power battery charger (Fig. 6), models of golf spikes and cleats that test their performance, and a model of a cervical stretcher that test human comfort and performance.

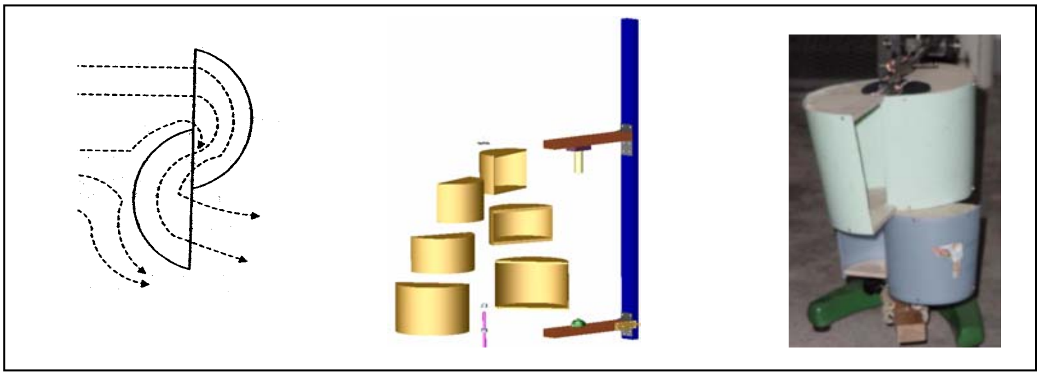

Fig. 6: An installation to test the constructability of the wind power battery charger

CONVERSING WITH MODELS

Semantic and illustrative representations do not adequately explain the representations by architectural models. Architectural representations inherit more than static semantics and experiences; in addition to representing form or an end product, they are used throughout the process for communication and self-reflection (conversation). Architectural models are important for their contribution in re-representation[22] facilitating analytical and creative thinking during the process of designing. The translation from digital to physical and the reverse becomes an immediate part of design process and hence in representation. When reviewing the use of models, therefore, these two conditions do not adequately encompass the realm of needs, leaving out one additional category, those representations by architecture, we extend the categorization of representations to include a third category by adding 'models with' – that is, models with which we converse, the models of design conversations.

Architectural design projects observed for this study clearly explain this third category ‘models with’ and the role of models in the design conversation. Architectural models are engaged more in design conversations than engineering models and, as a result, an architectural model can change completely from its initial form (Fig. 7 & 8). In architectural design, models and the design engage in a continuous conversation; models are used for design conversation between teacher and student or for collaboration. In engineering design, facts derived from the models such as functional attributes will be used for the design conversation than what can be seen from the model.

We found that the models used in architectural design develop more along the design process compared to engineering models (Fig. 8). Engineering models develop from one stage to the other without changing its design substantially (Fig. 2). Often the facts derived from mathematical or digital models lead to physical models in Engineering design, rather than the model conversing with the design. In engineering design, physical appearance of the model will only be an aid for 3D visualization and not as feedback for the design process.

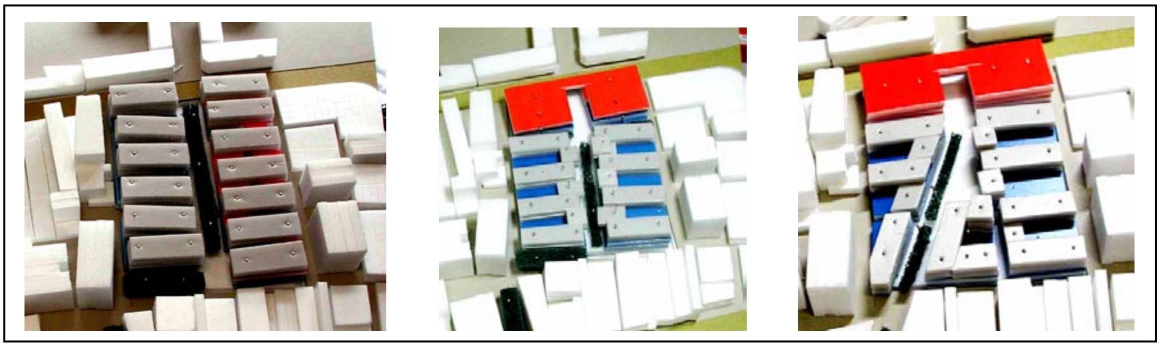

Fig. 7: Conversing through models in architectural design

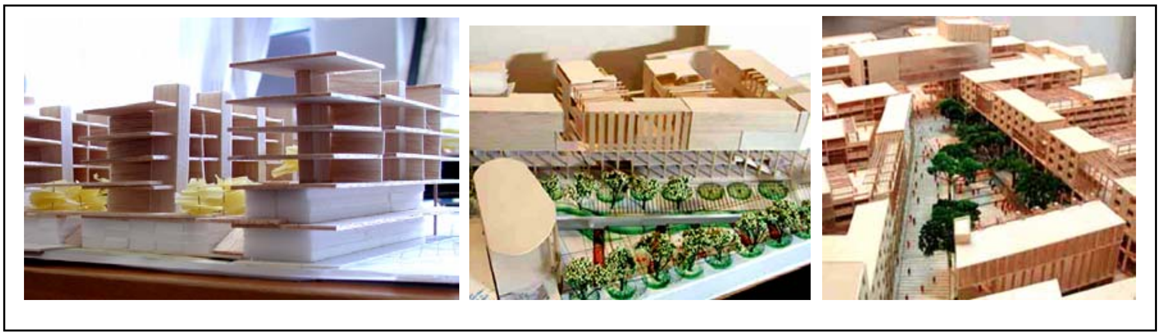

Fig. 8: Development from initial rough models to more refined models along the design process

Just as digital media have necessitated a change in the way we converse with drawings, so too have rapid prototyping models changed the way we converse by way of models. RP privileges 'models of' and facilitates 'models for', while debilitating the conversations with models. Cardboard models are assembled from discrete parts and lend themselves to being disassembled to different parts by tearing and gluing. Even though they are sold as devices for quick realisation of investigatory, disposable interim representations, RP models do not lend themselves to conversation as they are fixed in form and fragile in material. Thus, the conversation becomes stilted.

CONVERSING THROUGH RAPID PROTOTYPING

We have explored the potentials and limitations of drawings and models in representation and find distinctions between the role of models vs. drawings in representation and the role of models in architectural and engineering design conversation and noted limitations of drawings compared to physical models in assisting design thinking. Three-dimensional drawings are in part a substitution for physical models and not a replacement.

Borrowing the classifications of 'models of' and 'models for', we have noted that the former are used for purposes of presentation while latter are employed for experimental purposes. As we have seen, architectural models are not limited to these two categories. More than any other discipline, models are used in architectural design for exploration of form and scales and for design conversation in iterative processes. The role and nature of models in design conversation differs between architectural and engineering processes. Engineering students often construct mathematical and computer models compared to physical models for experimentation. According to our data, three-dimensional drawings play a larger role in engineering design; in architecture, models have a greater prominence. Design conversations appear to be more wide ranging in architecture.

Rapid prototyping systems are designed for engineering processes. The systems appear to privilege illustrative and semantic models, thus disrupting the design conversation. The changes that are needed are changes in materials; for example, materials that produce models, which can be broken and reconstituted manually once prototyped. We suggest that RP, therefore, is not at the level of craft, material and process changes need to be made to establish the connectedness and facilitate conversations of design.

Acknowledgements

This paper is based on work supported by a Teaching Development Grant provided by the University of Hong Kong and also the considerable efforts of students at this university to master and explore the capabilities of digital technologies including RP machines. A special thank to Veanna Chan, Benny Lee, Tony Leung, Helen Ho, and final year (2003) mechanical engineering students of the Hong Kong University, for providing their projects for this research.

---

1 D. A. Schön, 'Designing: Rules, Types and Worlds', *Design Studies*, vol. 9, no. 3, July 1988, p. 182.

2 M. McCullough, *Abstracting Craft: The Practiced Digital Hand*, MIT Press, Cambridge, Mass., 1996.

3 T. Kvan, 'The Problems in Studio Teaching', in M. Tan [Ed.] *Architectural Education for the Asian Century- 1st ACAE Conference on Architectural Education*, Centre for Advanced Studies in Architecture, National University of Singapore, September 2001, pp. 157-166.

4 S. Dunlop, *A Dictionary of Weather,* Oxford University Press, Oxford, 2001.

5 A. Ratensky, *Drawing and Model Making,* Watson-Guptill Publications, New York, 1983.

6 R. Janke, *Architectural Models,* Academy Editions, London, 1978.

7 Ratensky, *Drawing and Model Making.*

8 C. V. Bruggen, *Frank O. Gehry: Guggenheim Museum in Bilbao,* Guggenheim Museum Publications, New York, 1999.

9 M. Wigley, *Constant's New Babylon: The Hyper-Architecture of Desire,* Witte de With Center of Contemporary Art: 010 Publishers, Rotterdam, 1998.

10 Bruggen, *Frank O. Gehry: Guggenheim Museum in Bilbao.*

11 E. Robbins, *Why Architects Draw,* MIT Press, Cambridge, Mass., 1994.

12 M. Wigley, Paper, Scissors, Blur, in: d. C. Zegher & M. Wigley [Ed.] *The Activist Drawing: Retracing Situationist, Architectures from Constant's New Babylon to Beyond*, MIT Press, Cambridge, Mass., 2001, pp. 27-56.

13 McCullough, *Abstracting Craft: The Practiced Digital Hand.*

14 McCullough, *Abstracting Craft: The Practiced Digital Hand.*

15 A. J. Sellen & R. Harper, *The Myth of the Paperless Office,* MIT Press, Cambridge, Mass., 2001.

16 G. Goldschmidt, The Dialectics of Sketching, *Creativity Research Journal*, 4, no. 2, 1991, pp. 123-43.

17 E. Robbins, reports an interview with Spencer de Grey in "Why Architects Draw", MIT Press, Cambridge, Mass. 1994, pp. 82.

18 S. Hohauser & H. Demchyshyn, *Architectural and Interior Models*, Second, Van Nostrand Renhold Company, Australia, 1984.

19 I. Gibson, et al, 'Rapid Prototyping for Architectural Models', *10th European Conference on Rapid Prototyping and Manufacturing*, Paris, 2001.

20 G. d. Zeeuw, 'Onderzoek in verandering', in *Rede Als Richtsnoer*, Mouton Uitgevers, The Hague, 1979, pp. 335-353.

21 J. O. Young, *Art and Knowledge,* Routledge, London, 2001.

22 T. Kvan et al, 'Rapid Prototyping for Architectural Models', in *Product and Process Modeling in Building and Construction*, ECPPM2000, Lisbon, Portugal, Balkema Publishers, Lisbon, 2000, pp. 351-359.