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DIAGRAMMING IN A DIGITAL ENVIRONMENT

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Abstract. Research into digital design environments has explored modelling, generating and testing design propositions. When considering the broader design literature, however, we notice that a significant contribution to design is absent, that of diagramming. In the realm of architectural theory discourse in the past few years, diagramming has been much discussed with many interpretations of the activity. This paper will demonstrate that the development of digital techniques can change dramatically our ability to conceptualise and produce generative diagrams as previously not possible. The paper will follow the work done at the in the Melbourne School of Design. We will demonstrate how students are introduced to diagramming techniques and shown how to formulate a concept, then a program generator and to test a final proposal. The paper will also demonstrate how digital techniques can dramatically change the way we conceptualise and approach design problems. In this repeated teaching technique, we illustrate how digital systems contribute to conceptual diagrams and this contributes to the larger theoretical debate on diagramming techniques by introducing digital perspectives. The paper will therefore contribute to discussion on the ways in which digital systems can be engaged in substantive architectural teaching beyond the rote application of proprietary software and representative approaches.

Keywords. Diagramming; parametric; design; urbanism; abstraction.

1. Diagrams and the design process

Although the fundamental importance of diagrams and representations has been examined and understood across disciplines (for example, Latour 1986), our exploration of the potential and contribution of diagrams in architectural design (Herr and Karakiewicz 2007, Karakiewicz and Kvan 2010) has recently been reinvigorated (Garcia 2010). In this edited collection, for example, Spuy-

broek (2010) writes that diagramming is one of the most important innovations in architecture during the past 15 years.

The current understanding of diagrams in design can be observed to emerge through the past half century; in 1966, Christopher Alexander described diagrams as "any pattern, which by being abstracted from real situation conveys the physical influence of certain demands or forces" (Alexander 1966). Scholars, such as Lawson concluded his research on the design process by stating that architects and designers "finding it hard to think without a pencil in their hand" (Lawson 1994, p. 141).

Fraser and Henmi (1994) describe diagrams as a self-conscious reductive process, pointing out that diagrams have an important feature to exclude a lot of irrelevant information. The examples given are abstractions of movement, noise, shadows that maybe symbolised in order to represent intangible information and to focus on their relevance to the design context. Although almost all chapters in Garcia (2010) limit themselves to description and representation, the potential is far greater. For example, Schön (1992) wrote persuasively about architects using sketching and diagramming to enable conversations with the object that is being designed.

Designers use diagrams to test and develop their intentions and concepts or to convey complex information. Design ideas that we explore in our cognitive capacities need to be externalised and tested in order that substantive progress can be made through structural reinterpretation (Verstijnen et al. 1998); in this, diagrams play an affordance role as condensers of our visions. Diagrams not only influence how we think about design processes but also how we communicate them to ourselves and others, thus influencing profoundly what we understand of our own conceptual ideas (Kraut et al. 2003, Heiser et al. 2004).

We sketch and diagram when we want to involve others with our design processes (Tovey et al. 2003). Diagramming amplifies our capacities through communication to bring others into the design process, engaging a collective capacity to design. Typically, we use diagrams in the initial stages of design: in the restaurant when we draw on napkins, on the train, on the back of envelope (Lawson 1980, Robbins 1994). In these discussions, diagrams and other non-scalar representations are abstractions that play significant roles because they allow for reinterpretation that open up the conversation to emergence and discovery (Goel 1995, Schön and Wiggins 1992). It is the qualities of abstraction and non-representational imagery of diagrams that enables this kind of engagement.

And if we were to describe the process of design as of making the new, at the design stage "the new" is only the projection, or an extension of what

is already there, and therefore not that new at all. However by abstraction of essence, or meaning, of what we are trying to achieve, we are often able to get rid of our preconception and be able to perceive "the new" (Boden 1992).

2. Digital diagrams

The work of Bill Mitchell traces the transition of our approaches to computer aided design from a computationally driven prescription through to a means to understand design outcomes. As Mitchell (2001) notes in *Vitruvius Redux* he made a fundamental shift in his thinking since writing *Vitruvius Computatus* (Mitchell 1975), a transition from a generative approach to computational design through to a renunciation of this in recognition that the potential of the computational lies in an interpretive. In the latter, the logical and procedural are opportunities for reconceptualising the theories of architecture by removing representational and semantic constraints of design processes. Thus, computer aided architectural design moves from prescription to potential.

The computer has not replaced the pencil as means of exploration although the end was declared (Mitchell 1989). It has long been recognised that computer-aided design systems, whether for architectural applications or otherwise, fail to support conceptual exploration through their focus on literal representation by means of geometrically specific data (Lonsway 2002, Meniru et al. 2003).

In addressing this shortcoming, a variety of approaches have been taken. For example, Gross (1996) sought to allow sketching to facilitate references to precedents as part of the exploration of possible form, a matter of graphical search rather than conceptual development. The failure of CAAD to simulate design processes similar to that involving the back of the envelope, or napkin lies not only in the representational form of the computer images which look too perfect, unlike the ill formed and evocative bleeding pen lines on absorbent napkin which invite contribution. Nor is the failure the result of technical accessibility to such digital environments – with current tablets and sketch apps, only a blunt figure is needed and, as the increasing number of iPad-based exhibitions of art and imagery testify, creative graphical images can be achieved (Hockney 2011).

As with many such apps, such systems are context bounded in their applications. For example, the Dynamic Engine (Autodesk Maya) is equipped with a solver to address complex networks of both forces acting on objects and objects interacting that diagrams complex outcomes in relatively simple form. Constrained to a particular realm of data types and output forms, the system facilitates certain conversations.

While these sketches are trapped in their system constraints, there are side benefits of sketching in the digital environment. We are able to share and develop our designs intents in even more extensive ways today by posting our diagrams on line and asking for contribution by others. Time and explorative capacity are expanded as diagrams travel around the world (Hirschberg et al. 1999).

Fundamentally problematic, these 'tools' are not exploratory devices. "Computer-aided design representations have for the most part ignored this progression from abstract and low-commitment diagrams to detailed, specific and higher-commitment drawings." (Gross 1996). It is still difficult to have the same conversation on-screen that we can have over the napkin in the restaurant, or on the back of an envelope. Our proposition is not that the systems are inappropriate to this conversation but that we could engage with them in a different manner. To do so, however, we need to consider how we might use the opportunities particular to such an environment.

While diagrams and sketches are often thought of in a graphical manner, it is clear that such conceptual explorations occur in other representational modes and that the transfer of concept from one mode to another plays a powerful role (Kvan et al. 2003). In this aspect too, apps and task specific tools fail in their support of this conceptual activity.

In recent years, though, a palette of choices have emerged that offer a context for developing diagrams for design. In parametric systems, we have identified an opportunity to reconsider the way in which we create diagrams through representations in graphical, data and analogue representations, thus extending diagrams to encompass cognitive activity beyond the pencil and napkin.

Parametric diagrams can manipulate more variables that we can visualise in our heads. Interactive diagrams of sun and shadows can test our proposal and inform us of the implications of our data decision and even suggest what we need to change. Parametric diagrams powerfully engage complex data arrays and permit a range of manipulations of such data outside system assumptions that allow us to *diagram* without lineation. In doing so, however, we contend that it is important to retain the potential of diagrams and how they can be employed. In the following sections, we will describe our engagements in a teaching context with parametric diagrams.

3. Teaching parametric diagramming techniques

For the past 15 years we have been using diagram in our studios at the University of Hong Kong (1995–2008) and at the University of Melbourne (2008–2012). The non-representational quality of the diagram was the main interest

in these early studios, reinforced by an engagement in data and algorithm as a means of manipulation.

Initially we used abstraction as a form of diagramming that freed students of their preconceptions reinforced by traditional precedent focussed studio teaching and expanded potentiality. Commonly used as a teaching strategy, this encounters skill constraints immediately. When asked to create an abstract painting to develop concepts for the site or illustrate the essence of the site conditions, students were only as successful their artistic talents permitted.

We progressed to another form of diagram, that through metaphor. Metaphors are used to help students to express the difficult unknown through that which they know (Lakoff and Johnson 2003). The advantage of the metaphor was that it does not establish a relationship immediately; it permits reinterpretation and allows imagination to develop in more than one direction. Metaphors are also successful in multiple forms, whether graphical, linguistic or numeric. In this, they lend themselves to parametric interpretation. As Jencks (2010) observes of what he calls *semantic space*:

> …when meaning is concerned, it is the relationships that count. Why? Because the mind, language and reality operate in a hyperspace of multiple dimensions, of countless relationships, not just in a well-laid-out supermarket, with all the aisles clearly marked.

We started by using CATIA Digital Project software as part of the studio and diagramming techniques for Urban Design in 2004. Used at this time only for specific descriptive representation of building form as a BIM system, we were keen that students use Digital Project not to create a final alluring object but to use it as a device to represent a conceptual process; therefore, we were very specific that our students should only use Digital Project to develop *diagrams* that developed design intentions.

Importantly, this process required students to distance themselves from literal translations of digital diagrams into formal architectural propositions.

One student used Gamelan Music as a metaphor to create a program generator (Figure 1). The notation of gamelan music was adapted by replacing different instruments in the orchestra with urban functions. The notation of each instrument was analysed to make sure that the relationships between values are semantically correct. The musical script was then translated to a site specific context (Figure 2).

From the functional mix composed by the Gamelan generator, possible structural and formal responses were explored. Importantly, the translation is not literal – the functional mix is not a formal composition.

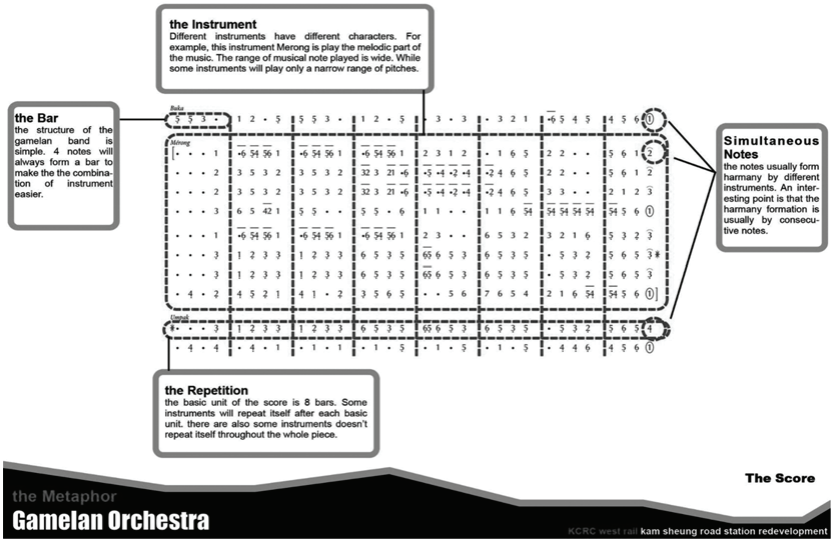

Figure 1. Gamelan Music as a metaphor for program generator.

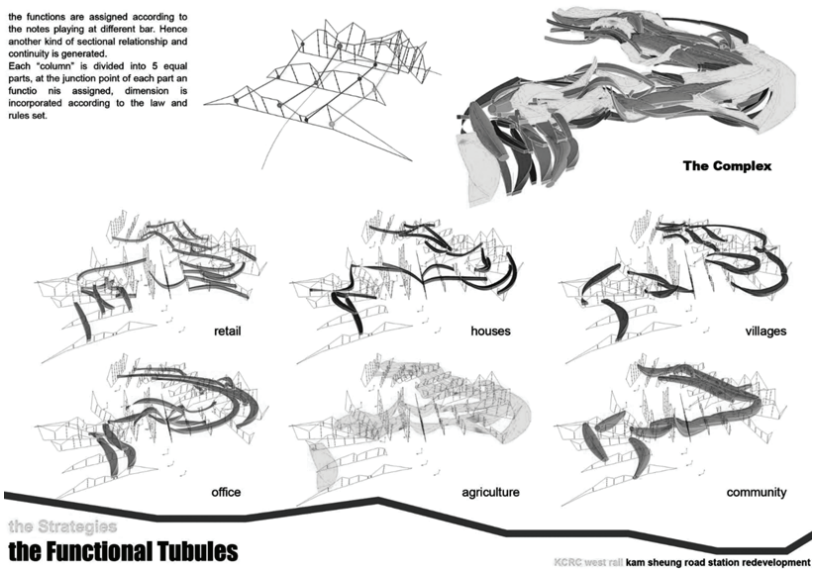

Figure 2. Output from the Gamelan Music program generator.

In another example (Figure 3), the diagram explored the permissible plot ratio and possible functional mix based on parametric modelling of required sun

hours for different functions within the plot ratio boundaries. In this instance, the models for sun penetration in winter, summer and spring engaged with assigning the floor plates to functions which could be accommodated based on the sun hours delivered during winter time.

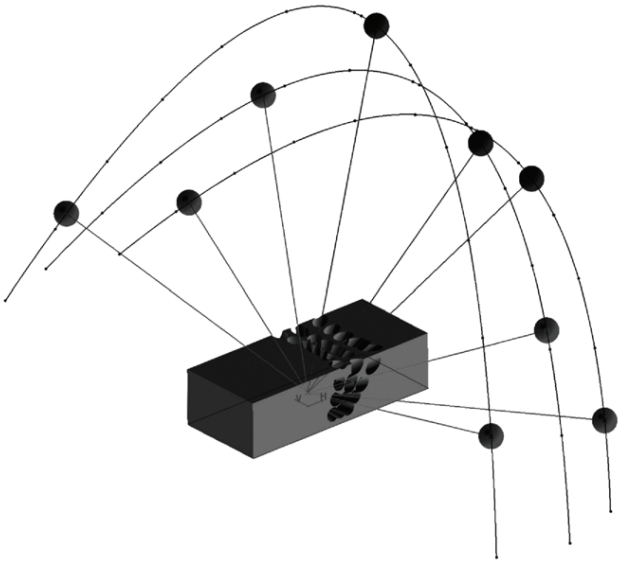

Figure 3. Sun path diagram, executed as a subtractive exploration of form.

3.1. DIAGRAMMING EMOTIONS

In 2010, another series of diagrams started to appear in our studio. Those based on emotions, exploring how emotional sensitivity might play a role in our perception of our environment. In this, the students explored the significant role of emotional reaction to the way in which we experience our environment.

Students recorded smells, noises and textures. Smell was particularly interesting since it related to desire to encounter a pleasant smelling object and the reactions it provokes, such as consumption. The weeks spent on collecting data, resulted in series of stimulating diagrams; students used Rhino to visualise data reflecting the emotional reactions on site as reported by sample populations taken across demographic groups that included participants from different backgrounds, cultures, age groups and sexes. Students used the same diagramming techniques to represent all the different senses and these diagrams became the starting point for designing interventions within the city structure.

3.2. TRANSLATING DIAGRAMS

Diagrams can be useful in representing complex, intangible data that cannot be easily visualised. Because these diagrams are often seductive, however, they can be very easily understood as a final product of form even if they are specifically called diagrams. Students find it difficult to move past literal translations of the diagram to form to understanding that diagramming techniques could be used as program generators or starting points of the design processes where intentions or relationships are first established. In this, the studio that involved diagramming emotions was particularly interesting. Emotional diagrams cannot be easily mistaken for built form but translating these type of diagrams is even more difficult that translating diagrams of wind or sun movement.

To illustrate the potential we will refer to a project that stood out, that by Shima Gafouri. Gafouri took water as an element, which could provoke all the emotions diagrammed previously. Reading and interpreting the messages hidden in emotional diagrams, she was able to construct a proposal where emotion could be amplified or suppressed, depending on time or by controlling points to enhance a location that previously had little to offer.

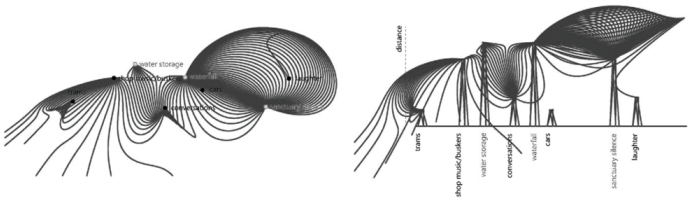

Figure 4: Water as an emotion (Shima Gafouri)

4. Discussion

We are in early stages of understanding the potentials of parametric diagrams and the many aspects of their creation and application have not yet been fully explored. As we have experienced with other representational forms, it will take time to engage sufficiently that we can move past a perception of these as limited to data manipulation. As it is with the mastery of drawing, music or dance, the immediate mechanical engagements initially overwhelm the interpretation of outcomes. It is apparent, however, from these teaching experiences that the potential is there in parametric representations to develop a language of diagramming.

What distinguishes this approach is that the design activity proceeds from a digital representation of a design idea – digital in that the idea is represented

directly by data i.e. numbers. This numeric description is then examined through graphical diagrams which may then be extended into an object representation. Manipulation of the data transforms the diagram and the object; design is therefore carried through an understanding the significance of the data themselves.

In this approach, the digital realm is employed to deconstruct our preconceptions of form as a design response. Initially, this is done by removing the design situation from its common frame of formal response. By disturbing the cognitive approach through a change of framing, we re-perceive the context of the design opportunity.

Typically, design perception privileges those aspects of a situation understood to be relevant, important or useful, but the measures by which we determine such attributes are grounded in our preconceptions or in precedents. We are therefore typically unaware of the frames in which we respond to a new situation. In studio teaching through a data-driven design response, we require new framing to be explored. Diagramming is central to this approach. As explained above (Jencks 2010), metaphorical diagramming allows the relationships of component parts to become the focus. Thus, as students diagram emotions, experiences or understanding, they can depict through data a new perception and review this in a diagram before progressing to a formal proposition. In studio discussions, the conversation moves back and forth between classes of data deployed, particulars of these data, the diagramming technique chosen and the knowledge revealed by these choices.

Studio critique then steps away from an immersion in form and object to the generators of these outcomes. Peer discussions are observed to be conducted in the language of particularities of a design opportunity and the generalisation of such specifics to architectural knowledge. The parametric is no longer then a stylisticism but a structure in which to reveal design strategy.

References

Alexander, C.: 1966, *Notes on the Synthesis of Form*, Harvard University Press, Cambridge.

Boden, M. A.: 1992, *The Creative Mind: Myths and Mechanisms*, George Weidenfeld and Nicolson, London.

Fraser, I. and Henmi, R.: 1994, *Envisioning Architecture: An Analysis of Drawing,* Van Nostrand Reinhold, New York.

Garcia, M. (ed.): 2010, *The Diagrams of Architecture*, Wiley, Chichester.

Goel, V.: 1995, *Sketches of Thought*, MIT Press, Cambridge.

Gross, M.D.: 1996, The electronic cocktail napkin: a computational environment for working with design diagrams, *Design Studies*, **17**(1), 53–69.

Heiser, J., Tversky, B. and Silverman, M.: 2004, Sketches for and from collaboration, *in* Gero, J. S., Tversky, B. and Knight, T. (eds.), *Visual and Spatial Reasoning in Design III*, Key Centre for Design Research, Sydney, 69–78.

Herr, C. M. and Karakiewicz, J.: 2007, ALGOGRAM: automated diagrams for an architectural design studio, *in* Dong, A. et al. (eds.), *Proc. 12th CAAD Futures Conference*, Sydney, 167–180.
Hirschberg, U., Schmitt, G., Kurmann, D., Kolarevic, B., Johnson, B. and Donath, D.: 1999, The 24 hour design cycle, *in* Gu, J. W. and Wei, Z. J. (eds.), *Proc. 4th CAADRIA Conference*, Shanghai, 181–190.
Hockney, D.: 2011, *Me Draw on iPad*, Louisiana Museum of Modern Art, Louisiana.
Jencks, C.: 2010, Architectural evolution: the pulsations of time, *in* Garcia, M. (ed.), *The Diagrams of Architecture*, Wiley, Chichester, 288–309.
Karakiewicz, J. and Kvan, T.: 2010, Diagrams as parametric systems in urban design: parametric systems applied to conceptual design, *in* Dave, B. et al. (eds.), *Proc. 15th CAADRIA Conference*, Hong Kong, 337–346.
Kraut, R. E, Fussell, S. R. and Siegel, J.: 2003, Visual information as a conversational resource in collaborative physical tasks, *Human Computer Interaction*, **18**(1), 13–49.
Kvan, T, Wong, J. T. H. and Vera, A.: 2003, The contribution of structural activities to successful design, *International Journal of Computer Applications in Technology*, **16**(2/3), 122–126.
Lakoff, G. and Johnson, M.: 2003, *Metaphors We Live By*, University of Chicago Press, Chicago.
Latour, B.: 1986, Visualisation and cognition: thinking with eyes and hands, *Studies in the Sociology of Cultures Past and Present*, **6**, 1–40.
Lawson, B.: 1980, *How Designers Think*, Architectural Press, London.
Lawson, B.: 1994, *Design in Mind*, Butterworth, Oxford.
Lonsway, B.: 2002, The mistaken dimensionality of CAD, *Journal of Architectural Education*, **56**(2), 23–25.
Meniru, K., Rivard, H. and Bedard, C.: 2003, Specifications for computer-aided conceptual building design, *Design Studies*, **24**(1), 51–71.
Mitchell, W. J.: 1975, Vitruvius computatus, *in* Hawkes, D. (ed.), *Models and Systems in Architecture and Building*, The Construction Press, Hornby, 53–59.
Mitchell, W. J.: 1989, The death of drawing, *UCLA Architecture Journal*, **2**, 64–69.
Mitchell, W. J.: 1990, *The Logic of Architecture: Design, Computation, and Cognition*, MIT Press, Cambridge.
Mitchell, W. J.: 2001, Vitruvius redux, *in* Antonsson, E. K. and Cagan, J. (eds.), *Formal Engineering Design Synthesis*, Cambridge University Press, Cambridge, 1–19.
Robbins, E.: 1994, *Why Architects Draw*, Cambridge, MIT Press.
Schnabel, M. A. and Karakiewicz, J.: 2007, Rethinking parameters in urban design, *International Journal of Architectural Computing*, **5**(1), 84–89.
Schön, D.A.: 1992, Designing as reflective conversation with materials of design, *Knowledge Based Systems*, **5**(1), 3–14.
Schön, D. A. and Wiggins, G.: 1992, Kinds of seeing and their functions in designing, *Design Studies*, **13**(2), 135–156.
Spuybroek, L.: 2010, NOX diagrams, *in* Garcia, M. (ed.), *The Diagrams of Architecture*, Wiley, Chichester, 270–281.
Tovey, M., Porter, S. and Newman, R.: 2003, Sketching, concept development and automotive design, *Design Studies*, **24**(2), 135–153.
Verstijnen, I. M., van Leeuwen, C., Goldschmidt, G., Hamel, R. and Hennessey J. M.: 1998, Creative discovery in imagery and perception: combining is relatively easy, restructuring takes a sketch, *ActaPsychologica*, **99**(2), 177–200.