PARAMETRIC DESIGNING IN ARCHITECTURE

A parametric design studio

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Abstract. Parametric design techniques offer obvious advantages for engineering and manufacturing processes, now architects emerge to apply these methods in their creation of design suggesting solutions at an earlier stage of the process. Through the coupling of architectural design with parametric modelling methods, the paper presents novel techniques that enhance architects' contribution to building processes based on parametric design creation. This allows a deeper comprehension of the design objectives and aids designers in their decisions to find solutions.

1. Parameters in Design Studios

Architectural design studios are an essential learning experience for architectural students. Their traditions and proceedings are well established. These studios are, additionally, informed and supplemented by courses and seminars, which can feed into their learning outcomes. Studios go beyond pure skill training and require reflection upon, and the creation of, knowledge. There can be, however, a gap between skills training and the application of knowledge within the studio context. At the final presentation of the work, students may not be able to identify how they arrived to their solution and what were the individual contributors that inform about the design.

This tension is also apparent in digital media courses. These present the underlying concepts of architectural design using digital communication tools, but also have to provide training in software skills and other technical subjects (Kvan 2004a). The integration of digital media courses into design studio curricula often fails, because the compound acquisition of skills prevents a deep exploration of design and the theoretical aspects involved. Participants can employ digital media tools within a studio context only long after they have learned subject matters and acquired proficiency in their
skills. By then, however, the studio may consider these skills no longer valid.

A dilemma of semester-based teaching is that students reach their highest level of skills and experience at the end of a term, after which they leave for their break and are therefore unable to apply their knowledge immediately. At the beginning of the next following term, however, the knowledge and skills they had gained earlier are likely to be either inactive or not employed, and learning foci may have shifted to other aims.

The architectural design studio presented here addressed these issues by integrating the learning experience from the beginning by focusing on parameters that create or inform about the design. The objective of this ‘parametric designing’ was to allow participants to understand the impact each step and variable has on the design and follow the impact it has onto the project. Participants developed and communicated their understanding of architectural design parameters by utilising their skills training within the design-studio environment. Because of this, students began to think about design problems in different ways.

The studio explored design by basing it on parameters. In order to build up a philosophy around parametric dependencies and relationships, the participants used digital tools that allowed them to create and express their designs. With these tools, users can develop expertise to engage creatively in design. Typically, architects employ such tools only for visualisations, or after the designs are completed, in order to feed them into the construction and manufacturing processes.

Parametric applications have inherited two crucial elements. These are that all entities start with a point in space and allow the study of architectural conditions in a three-dimensional environment, rather than the commonly used two-dimensional or layering techniques. And that the underlying concept of parametric modelling is based on data, variables, and their relationship to other entities, which can then respond to variations of input data.

Participants were able to employ digital media skills early in the studio experience and expand on their understanding and communication of design issues from there. The studio built upon design studios where participants explored design methods and tools beyond their original definitions and perceived limits (Schnabel et al. 2004).

2. Parameters in Architecture

The exploration of the relationship between human beings and the natural world, and the subsequent implications of interactions between them, has deep roots in our social and cultural understanding of society. Cities, therefore, are direct reflections of their inhabitants, as their architectural
expressions directly influence the living conditions of their people. In recent practice, architects have designed and described buildings through the means of master plans, or descriptions of picture-perfect, complete cities in which change was not part of the picture. A few, however, have tried different approaches to communicate architecture.

In their design for Beijing’s Soho Shang-Du buildings, LAB Architecture Studio translated planning codes into series of parametric design rules (Figure 1). As a result, the outcome both complies with and confounds the rigid regulations (Davidson, 2006). In other words the architects did not prescribe a fixed gestalt, but on a set of rules and instructions that inform about and can generate the desired outcome. This allows a reaction on a variety of site-specific variables that can be modified according to the need.

A design studio project at the Technical University of Eindhoven employed a similar methodology. Students responded to functionalism and economic cost-effectiveness of production processes in Sao Paulo’s favela neighbourhoods by creating parameters from building blocks as well as architectural and urban contexts (Vanderfeesten and de Vries, 2005). This resulted in design a set of design proposals that can react to changing condition of the favela without loosing the influence of the architects design guidelines.

In the 1960s and early 1970s, Archigram already presented a similar idea. Reacting against the permanence of houses in what it called the “Plug-in City” (Figure 2), it proposed ever-changing units adaptable to different
social and economic conditions (Karakiewicz 2004A). Despite that this design proposal did not develop any further than its conceptual stage, it contrasts the common design practice that Le Corbusier describes as non-intelligent building machines. These machines cannot think, and are therefore unable to adapt to change.

Interestingly, Pieter Bruegel painted in the sixteenth century a representation of the Tower of Babel as building that is constantly redefining its needs, as it grows larger and more complex (Figure 3). The painting depicts a tower piercing the clouds, showing all the problems then associated with cities, buildings and life within and the constant change and reaction to new situations during the process of building.
These samples illustrate the constant need for architecture to adapt and react to a variety of parameters that are driven by its use and context.

The gap between the architectural design conceptions and the translation of these designs into the real built environment can be addressed differently by an intersection of process and outcome. Parametric design techniques suggest controllable and adaptable solutions at an earlier stage of the process that react to the given situations and the outcomes.

3. Parametric Architectural Design Studio

A building or architecture in general can be expressed and specified in a variety of ways. Commonly, drawings describe geometric properties that can explain, depict, and guide the construction of buildings or streets. Alternatively, performance specifications can describe observed behaviours. It is also possible to describe properties as relationships between entities. Spreadsheets, for instance, specify the value of each cell as the result of calculations involving other cell entries.

These calculations or descriptions do not have to be explicit. Responsive materials change their properties in reaction to the conditions around them. A thermostat senses air temperature and controls the flow of electric current, and hence the temperature of the air supplied. Using such techniques, artists have created reactive sculptures and architects have made sentient spaces that react to their occupants or other relevant factors. Streetlights turn on if light levels fall below a threshold; traffic flow can be regulated according to need; walls can move as users change location.

Links to a variety of data can be established and subsequently serve as the bases to generate geometric forms using parametric design tools. When designing spaces, it is usual to collect some data of the type of architectural qualities desired. These are then, for example, translated into master plans, which are themselves specific spatial descriptions. Performance requirements for spaces can then be written, linking the description of the architecture to experiential, financial, environmental, or other factors (Picon 1997).

Design studios mimic the typical working processes of the architectural profession and are the essential learning experience for architects. However, little or no research exists that examines or validates the claim that the framing of design creation using parametric methods enhances the process (Schnabel et al. 2004). This studio, therefore, couples parametric methodologies within the creation of architectural design, ultimately re-framing the question and proposing new answers and methods of design thinking.

Participants in this study solved a typical architectural design problem using applications that focused on the parametric dependencies of spatial
perception, fabrication, and form finding. Their creation and exchange of ideas followed the rules of a design studio within a cyclical design-exploration paradigm (Schnabel and Kvan 2002). This design-cycle had the framing of the design question at its centre (Gao and Kvan 2004), while taking full advantage of available building information modelling technologies to explore it. This approach tested the limitations set by conventional, design-only methods. The cognitive aspects of the design creation and its relationship to parametric design methods operated as an influential factor for understanding the perception, framing, and creation of spatial knowledge within architectural design.

The studio then explored the design processes by using sets of variables and series of relations to question, create, and define the form and function of the resulting designs. Thus, it examined interaction techniques between the design intent, its framing of the design problem, and its subsequent creation, while at the same time establishing a connection to building information models. Participants engaged in a collaborative architectural design studio involving the creation and fabrication of architectural spaces. This formed the basis for a transfer of knowledge to the larger context of the profession and building industries (Riese and Simmons 2004).

The studio took a distinctive neighbourhood within the urban context of Sydney as its base of exploration. Within this suburb, a mix of residential, public and commercial buildings can be found: a medium dense area offering a variety of architectural languages.

Driven by a fast growing population, an architectural strategy that steers further development was sought. Sydney's scale, its growth through immigration and the need for new housing have an impact on its inhabitants’ sense of place and sense of community. Earlier urban planning did not anticipate the changes that arose over years of population growth. A new strategy for development could address these issues, creating a new identity for the place and the city itself (Forrest et al. 2002).

The design studio examined a site with typical characteristics and architectural requirements. Located at the upper riverbanks of the Parramatta River, next to parkland, cultural, office and residential buildings, the site offered a great challenge for an architectural proposal. River, city, work and living had to be addressed and responded to.

4. Parameters of the Design Studio

To allow the students both to acquire skills and training within their studio and to apply this knowledge to their design, the studio had an integrated digital media component that addressed parametric modelling in architectural design. The studio was one of the required design studios of the postgraduate architectural programme at the University of Sydney.
Two groups of each fifteen students elected to join this studio, which was supervised by two design teachers and one architectural consultant in digital media. The studio was structured into four phases that related to and built upon each other. The aim was to acquire and integrate parametric design knowledge and to use it as the base of the design creation of their architectural proposal. This resulted that the final design could be modified and manipulated based on the parameters and their dependencies. This allowed a deeper understanding of the design process and outcome as well as the reaction of the proposal with the various influences of the environment.

4.1. CREATION OF PARAMETERS

The project’s first component included the collection and understanding of data that arrived from the site. In order not to overcomplicate the issues, the tutors asked the students during this first stage to limit themselves to investigating of two parameters. This allowed focusing on the selection of the hierarchical parameters that the students believed would influence their building proposal or their site’s perception the most.

The parameters they chose informed them about the variables of their guiding design rules and provided them a description based on dependencies and interconnected relationships of relevant information. The chosen parameters helped the students to understand their design what impact certain variables may have on a design strategy. This component concluded after two weeks with presentations of data, parameters, and individual interpretations of the site.

4.2. LEARNING OF PARAMETERS

The programme’s second component focused on the understanding and creation of parametric concepts and the acquisition of design-application skills that allow rule-based three-dimensional design. Participants were trained intensively during studio time in the use of Digital Project™ (2004). This software allows users not only to create three-dimensional models, but also to establish rules, create parameters and their dependencies on a variety of entities.

Parametric functions require a different understanding of the conceptual approaches to design. Creating rules and dependencies, which then create the design, involved the students in a higher level of problem framing and definition of the concept of design. It allowed the visualisation and modelling of highly complex forms that may result from non-traditional design data, such as noise data or spatial requirements.

The students used their own parametric and rule-based design analyses from the first component and subsequently studied the use and operation of the software, the creation of rules, and parametric and generative design.
During this phase, they used the time allocated to the design studio to establish a basic understanding of the software in its relationship to the design intent developed during the first phase. After three weeks of interactive digital media training, the students reached an advanced level of skills that enabled them to use the parametric software as a tool for the creation of their own designs.

4.3. DESIGNING OF PARAMETERS

The programme’s third component, scheduled for seven weeks, concentrated on design creation, reflection, and the communication of architectural design proposals. Using the data of the first component and the skills of the second, the students then started to establish and visualise their designs in three-dimensional forms that created spatial expressions of their findings and explorations.

Due to the emphasis onto parameters, the studio was in particular interested in describing a building form by creating dependencies of parameters that defined the relationship of data to architectural expressions. With the use of a parametric modeller, it was easy to create geometric entities, relate these solids and voids. This method made it obvious to learn about the design and explore alternatives by manipulating the parameters, variables and rules.

4.4. MERGING OF PARAMETERS

The programme’s concluding component brought together the various aspects and results of the earlier three modules. Within two weeks, the students merged their individual designs into larger cluster files. This synthesis created compound descriptions and dependencies that were highly complex and interrelated, yet both the content as well as the tool allowed seamless communication to a larger audience by using describing the rules and parameters. This phase created a design with shared authorship of all participants and allowed the students to study and understand the complexity and the interrelationships of architectural designing that they normally would have been unable to perceive immediately. The change of a single variable modified the whole design. Participants understood therefore the complex dependencies that one variable has in a large building and the impact in can have on the design.

5. Parametric Design Solutions

The students had already acquired the highest level of skills in using a specific tool within the first half of the semester. This enabled them to employ the tool as an amplifier to generate their design. Subsequently, they
were not limited by their knowledge or level of skills in order to be able to create their designs.

The students produced a variety of individual design proposals as well as one large design-cluster. They created rules and parameters that allowed complex and interrelating designs to emerge. These representations, however, could not be communicated using traditional architectural design methods or tools.

For example, one proposal related street lighting, neon-signs and display-windows with human activity around the building site (Figure 4). These parameters provided the engaging surface for the building mass. Subsequently they controlled the use, orientation and appearance of the building. The author took references to Japanese inner cities, where innovative ways of spaces are created by the means of lights, advertising and projections. Void, volume and density is controlled and created by the rhythm and intensity of lights. The student transferred this concept into parameters, which redefined the spatial understanding of the site and used these variables to create an architectural proposal.

![Figure 4. Prudence Ho: Landscapes](image)

Another solution explored biological growth models based on Lindenmayer’s system fields (Figure 5). It explores the possibilities that a topological approach to designing with a parametric tool will yield an emergent architecture that is governed by a bottom-up hierarchy. Topological forms created a variety of physical and programmatic
 instantiations. The author had however, difficulties to translate the theoretical aspects of his parametric design studies into a buildable and inhabitable form. He acknowledged that he would require more time to become fluent with this novel approach to design. Therefore, he presented his work in two stages, the theoretical and the practical. Figure 5 illustrates the process of analysis and theory on the left side and the translation into a workable build form on the right.

Figure 5. Daniel Wong: Western Sydney Virtual Offices

Other results used parameters that related to the relationships between people and attraction to spaces with responsive structures. Students created self-opening canopies that reacted to people activities, ferry schedules, weather conditions and the possibilities to collect rainwater to provide a comfortable environment in all conditions.

In the studio’s fourth component, the students presented in-depth clusters of multifaceted architectural design proposals for the site. They demonstrated a high level of thinking processes resulting in the generation of compound rules and dependencies that finally create the architectural design schemes. Each student contributed simultaneously to create a variety of design proposals. The participants gained a high level of expertise with digital parametric tools as part of their development at the studio, and used this knowledge to design parametrically. The outcome clearly showed that
thinking, learning and creating within parametric designing requires a novel and deeper understanding of the overall design goal and its anticipated outcome. This differs from design that deals with one problem at a time, regardless of its dependencies. The studio allowed participants to learn about designing and problem framing. They were able to theorise and reflect on design creation for this and other design tasks.

6. Discussion

With the development of various digital tools, designing in layers became popular, allowing architects to deal with problems that are more complex, with each different layer playing an equally important role. It allowed dealing with problems one at a time. Problems that are more complex were divided into separate issues and dealt with one by one. Parametric design opens up a novel set of opportunities. It enables architects to study causes of problems and their relationships to, and dependencies on, other elements directly.

This shift of design thinking and creation allows for spaces that accommodate change, diversity, and varied human activities without specifying particular functions. Additionally, such designs can provide for unpredictable events in connection with an overall architectural framework. Architecture can respond to unplanned changes and their resulting consequences. The outcomes of this design studio show that parametric dependencies allow still for a level of ambiguity that is required in creative processes.

One objective of the studio was to frame an intellectual research question that created links to data to generate form. The more interesting outcomes result from the ability to redefine and reframe the problems themselves by stepping out of preconceptions based on experience and exploring sets of unpredictable answers.

Preconceptions based on experience influenced previous methods of architectural design. Diagramming is an attempt by architects to allow for the reinterpretation of defined problems. In a certain way, parametric design tools do similar things, yet they act at a higher level of the problem framing. The establishment of meta-rules has instituted a form of problem framing that demands the reference of one problem or parameter with other ones.

The examples of the parametric design studio illustrate how non-linear design processes and the re-representation of ideas can lead to architectural expressions that differ from conventional approaches to design due to their different nature of design creation. The exploration of the gestalt can enhance the understanding of spatial issues and lead to meaningful and responsive architectural descriptions. Despite three-dimensional representations of an architectural space being only a medium through which
to aid in the understanding and communication of spatial arrangements, the designers’ comprehension of complex spatial qualities was enhanced by the re-representation by a parametric medium. The novel aspect of this studio work was the engagement of the process of translation itself as a creative act.

7. Conclusions

The parametric design studio presented in this paper addressed computational concepts of architectural designing that influence the recent development of architectural production. This studio exercise explored innovative methods of architectural expression, form finding, and communication, developing unconventional solutions. It coupled the studio-learning environment with an in-depth digital media assignment in order to close the gap between acquisition of skills and the reflection of knowledge, as well as to explore new avenues of framing and integrating compound design issues.

The use of digital parametric tools allowed the participants to design within an environment based on rules and generative descriptions. This amplified their design understanding and learning outcomes. The students connected their knowledge with their ambition to create their own design proposals.

The synthesis of all individual projects removed the students from individual ownership of their designs, but allowed them to reflect on both their own and their colleagues’ designs as a complete cluster of contributions (Kvan 2004b). This related to earlier research into design studios based on the same principle, in which media were applied outside their normal pre-described purposes, and innovative design methods were deployed by interplaying digital media and design explorations (Schnabel et al. 2004).

With the employment of parametric software that allowed students to experience the dependencies and rules of the various individual contributions spatially, as well as the overall common proposals, the design could be communicated using physical and digital models and representations. The generated design data could then be linked in a variety of ways to extract or generate new geometric forms and understandings. These descriptions could then be used directly in the manufacture of objects by means of, for example, digitally controlled devices (Seichter and Schnabel, 2005).

Each of the components was an essential part of the design creation. They addressed and expressed certain aspects of the process. A holistic discussion about design, form, function, and development was established, which is significant not only within architectural education, but also in all other dialogues involving spatial representations. Following the tradition of artists
and designers, participants have pushed creativity to new definitions of both their designs themselves and of their cultural contexts.

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References


