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Strategies for Parametric Design in Architecture

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Abstract: *A new specialist design role is emerging in the construction industry. The primary task related to this role is focused on the control, development and sharing of geometric information with members of the design team in order to develop a design solution. Individuals engaged in this role can be described as a parametric designers. Parametric design involves the exploration of multiple solutions to architectural design problems using parametric models. In the past these models have been defined by computer programs, now commercially available parametric software provides a simpler means of creating these models. It is anticipated that the emergence of parametric designers will spread and a deeper understanding of the role is required. This thesis is aimed at establishing a detailed understanding of the tasks related to this new specialism and to develop a set of considerations that should be made when undertaking these tasks. The position of the parametric designer in architectural practice presents new opportunities in the design process this thesis also aims to capture these. Developments in this field of design are driven by practice. It is proposed that a generalised understanding of applied parametric design is primarily developed through the study of practical experience. Two bodies of work inform this study. First, a detailed analytical review of published work that focuses on the application of parametric technology and originates from practice. This material concentrates on the documentation of case studies from a limited number of practices. Second, a series of case studies involving the author as participant and observer in the context of contemporary practice. This primary research of applied use of parametric tools is documented in detail and generalised findings are extracted. Analysis of the literature from practice and generalisations based on case studies is contrasted with a review of relevant design theory. Based on this, a series of strategies for the parametric designer are identified and discussed.*

Keywords: Parametric Design

I. INTRODUCTION

In order to gain an understanding of what parametric design means it is helpful to look briefly at definitions of ”parametric” and ”design” independently. “Parametric” is a derivative of “parameter” which itself originates from the greek para, meaning a subsidiary or beside and metron, as in to measure (OED, 2002). In mathematics a parameter is defined as ‘a quantity constant in the case considered but varying in different cases’In architecture, design involves a response to a problem, often the nature of the problem is not clear and therefore the design process also involves developing an understanding of the problem. Lawson (2006) recognises architectural design as “a matter of finding and solving problems”. Subsequently many alternative solutions may exist and design, or finding a solution, becomes a process of selecting amongst them. For Simon (1996) this should be a rational choice, but in architecture choices based on aesthetics may seem irrational to some. Gero describes the design process as one that “involves exploration, exploring what variables might be appropriate” (Gero, 1990). In summary “design” in this thesis is a task that involves defining a description of a problem, then generating and searching amongst alternatives to find a solution that satisfies the problem. “Parameter” has been defined as any measurable factor that defines a system or determines its limits. “Parametric design” is understood as a process where a description of a problem is created using variables. By changing these variables a range of alternative solutions can be created, then based on some criteria a final solution selected. On this basis it could be said all design is parametric. For the purposes of this thesis this definition needs expanding to include the context of contemporary architectural practice. Contemporary design practice is dependant on the use of computers. The computer supports parametric design by providing a means of defining a model1 which represents the design problem. Such a model defines the relationships and parameters in the design problem and by adjusting these

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parameters alternative designs can be configured. A parametric model can be defined by programming or writing code using a specific programming language. Alternatively many computer aided design (CAD) applications can be extended to provide parametric functionality by using their application programming interface (API). More recently CAD applications have become available that have parametric functionality that the user can control through a graphical user interface (GUI). This kindof application is described as parametric software, typically these applications provide the option to use a scripting3 language to further customise the parametric functionality. Parametric software offers users the means of creating relationships and associations between geometric objects and objects that are definitions of variables or functions. For this reason parametric design is sometimes referred to as associative design. Parametric design is therefore understood in this thesis to be the process of developing a computer model or description of a design problem. This representation is based on relationships between objects controlled by variables. Making changes to the variables results in alternative models. Selection of a solution is then based on some criteria which may be related to performance, ease of construction, budget requirements, user needs, aesthetics or a combination of these.

1.1 Aims

The main goal of this thesis is to establish strategies for architectural parametric design. The need for strategy in architectural parametric design is driven by the popularity of parametric methods, and the observation of a new specialist role that deals with implementation of these methods. The potential benefits of parametric design have been acclaimed while simultaneously it is acknowledged that the complexity and time required for design tasks that incorporate parametric methods has increased (Aish& Woodbury, 2005; Woodbury & Marques, 2006). Strategies will assist future generations of architectural designers to overcome these added complexities and understand how to implement the technology to benefit from the opportunities offered. A strategy is adaptable and involves choice and selection from multiple options. Strategy is not repetition of a previously successful technique but assessment of circumstance and the development of a direction based on rational reaction. In architectural design the problems encountered are complex and vary greatly. The exact same approach is rarely suitable for new design scenarios. This thesis therefore aims to expose strategies and the basis on which they develop rather than specifying explicit methods.

1.2 Objectives

In order to develop an understanding of parametric design strategies, a deeper understanding of the choices available to the parametric designer is required. In this thesis it is proposed that a comprehensive understanding of the parametric designer can be gained by examining the tasks involved and considerations required in a parametric design process. Based on this approach, parametric design strategies will be identified. Comprehension of tasks and considerations form the key objectives for the thesis. These are developed through a combination of review, analysis and examination of theory and practice. The theoretical basis of this study originates in design methodology and extends to include theory that attempts to deal with parametric tasks. The practical basis is formed using published material from architectural and engineering firms and a series of case studies undertaken by the author. Throughout this document published material from practice is referred to as practical literature, and the case studies undertaken as part of this research are referred to as practical observations.

II. METHODOLOGY

The key objectives are to develop a comprehensive understanding of the tasks and considerations related to the role of parametric designer. Based on this, the aim is to identify strategies, the nature of a strategy is first defined. In this section, ways in which these objectives may be addressed are discussed. Three possible research approaches are described; the first is a review and use of literature originating from practice, the second is the use of case studies and thirdly the use of laboratory type experiments with designers. The first two of these approaches are used in this thesis and reasons that justify this choice are described. Issues relating to the chosen approaches are discussed, including reasoning in the choice and number of case studies undertaken. Research involving the use of case studies where the researcher is actively involved with the subject is recognised as participant-observer research. Key issues with this method are noted. Finally a set of precedents where architectural research has been conducted through case studies is presented. The next section then describes the specific means by which the thesis objectives will be achieved using this

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methodology. Published material from practice is the result of efforts by practitioners to encapsulate a process after it has been completed. These accounts sometimes reflect on multiple projects. Consequently they offer a concise way of assessing the processes taking place accross a series of contemporary practices. This type of assessment would otherwise be difficult to achieve due to the size of practice and the effort required to distill structured observations from large amounts of information. The size of practices mean that without a personal connection it would be difficult to access the relevant group or person within the practice. A personal visit to a practice is likely to result in documentation of anecdotal experience rather than the succinct information presented in the published accounts.

III. USE OF CASE STUDIES

Observations of specific procedures, first hand, in the context of practice, using case studies, can provide an alternative view of practice not captured in the generalised descriptions published by practitioners. Case studies offer the opportunity to investigate aspects that in the literature may have been over-looked or commercially guarded. Practical observations from case studies can broadly avoid issues relating to protecting commercial interests of practices involved with the study. Practical literature is written after the event, descriptions will be generalised, rationalised and related to the finished process rather than the development of the process. Case studies will be able to report on events as they happen, capturing information on activities that moved the design forward and activities that led to a dead end of enquiry. Case studies allow the recording of both these valuable information sources that may be overlooked in the practical literature.While case studies offer a means of addressing areas beyond the scope of the practical literature there is also a need to realise the limitations. Observations are very specific to each practice and project and will not be completely replicable even on a similar project with the same practice. Documentation of new case studies will add to the published case studies and may cover aspects not previously dealt with. In order to gain some meaningful understanding, generalisations need to be made based on analytical reflection. Practices involved in case studies have been made aware that descriptions of those processes may form part of this thesis. Respect for the practices interests is required, any material considered sensitive has been discussed with the practice and addressed before inclusion in the thesis. Any particular practical observation that a practice feels is detrimental to their commercial position may still be referred to, but without attributing it to a specific project or practice. A single case study is unlikely to reveal enough aspects of great interest to provide enough material. Several case studies need to be undertaken in order to provide the opportunity to observe enough events of interest. Multiple case studies are also necessary to negotiate the unpredictable nature of architectural practice. At the start of a project it is not possible to know the time span, what precisely the project will involve or what is required. Working on multiple projects will also provide the opportunity to develop good working relationships with practices which will be necessary for successful projects. Good relationships with practices will increase the chances of opportunities to observe further projects. In order to maintain these working relationships it will be necessary to continue to work with the practice even when the work involved is no longer relevant to the thesis. Use of multiple case studies will generate large quantities of data, material that features in the main body of this thesis will only be included as a result of analysis of the literature from practice and theory. Inclusion of material is justified because it addresses one or more of the objectives described above

IV. CASE STUDY BASED RESEARCH IN ARCHITECTURE

Several precedents for the development of architectural theory based on some form of participant observation research exist. The participant-observation approach falls into a broader branch of research method called ethnography. Research into reusable patterns for parametric design undertaken by a group of researchers headed by Woodbury (2008) and published by Qian et al. (2007) is described as ethnographic. These studies are based around the observation of participants working individually at training events such as SmartGeometry workshops (SmartGeometry, 2008). The results of this study have been used to develop a reusable library of “patterns” or code for helping designers learn about parametric design. The study takes place outside the design office environment and is focused on individuals’ learning capacity while undertaking actual design tasks. The Royal Melbourne Institute of Technology (RMIT), Spatial Information Architecture Laboratory’s (SIAL), Embedded Research group aims to develop a better understanding of architecural practice using enthnographic methods in the work place SIAL (2006). Theprogram intends to capture research in practice that is lost because it is not documented. Based on this the aim is to advance knowledge and

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approaches to design. Here researchers are based in practice and their research is project-based. Broadly their goals are to develop new areas of research and development that will maintain the competitive position of Australian architectural and engineering design and its role in the construction industry in the world market. Two recent publications from the Embedded Research program are a thesis by Nicholas (2008) and a paper by Hyde (2007). In his thesis Nicholas explores the ways in which threedimensional digital environments facilitate closer links between architects and engineers. The basis of this thesis were eight case studies, which were primarily design investigations, undertaken during a two year working period with ARUP Australia. Hyde explored the way in which emerging technology can assist smaller practices to compete with larger architectural firms, this too was undertaken with a series of design studies. Several books have been developed as a result of research efforts where the focus has been the study of architectural practice. In ”Design Thinking”, Rowe (1987) examines the internal logic of decision making in architectural design processes through observation of a series of architectural projects and develops some theoretical considerations. In a similar way Lawson (1994, 2006) uses a series of observations of designers to study the psychology of the designer in order to gain insight into the process of design. In ”Architecture: The Story of Practice”, Cuff (1991) spent several years working with and observing individuals and architectural practices in the United States. The outcome of this study was an understanding of the social aspects of how design problems are explained and solved. A similar study by Krauss & Myer (1970) focused on a team of architects in Boston over an eighteen month period. This study followed a single project from concept to preparation of construction documentation. They documented the design stages and the decision making that took place. Akin (1986) describes how these empirical studies have proceeded first with observation and recording. Then a paradigm that can predict the observed is hypothesised. Next the validity of the hypothesis is tested with further empirical studies.

V. 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 whichto 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.

VI. CONCLUSION

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

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architectural expression, form finding, and communication, developing unconventional solutions. It coupled the studiolearning 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 predescribed purposes, and innovative design methods were deployed by interplaying digital media and design explorations.

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