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Parametric-based Approach in Architectural Design Procedures

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Abstract

The growth of computer-aided tools used to illustrate or represent the results of architectural projects has been outstanding during the past several years. The establishment of technologies is meant to help designers produce architectural shapes swiftly and interactively. During the earliest design stages, architects may build highly complicated geometric forms and make numerous creative choices due to recent advances in computer technology for parametric design.

New ideas and theories could be needed to investigate architectural parametric design alternatives within the theoretical framework. The relevance of parametric design in space design exploration in contemporary architecture is theoretically covered in this study.

The topic will then be strengthened by looking at a structure that incorporates parametric design, namely the Abu Dhabi Louvre Museum in the United Arab Emirates in order to assess the efficiency of parametric modeling and design ideation.

Keywords

Computation; Design Procedures; Parametric Design; Space Exploration

1. Introduction

The practice of architectural design is radically changing to a different paradigm as a result of computational technologies. Architectural designers have used the parametric paradigm to help with the design of complicated building envelopes, patterns, and structures that adapt to their surroundings, climatic conditions, and contextual elements. Additionally, these recent and ongoing advancements have started to have considerable effects on the architectural profession (Schumacher, 2009) (Woodbury, 2010). The theoretical basis for developing such tools is offered as an evolutionary paradigm that investigates existing design processes and design thinking. Firstly, it is demonstrated that the only effective design system that might serve as the foundation for this new generation of design tools is the evolutionary paradigm. Furthermore, it is argued that characterizing design as a search problem is a critical misconception. Rather, it is suggested that evolutionary design systems ought to be seen as generative processes with the ability to assess their own results. Thirdly, a general framework is introduced for systems

using generative evolutionary design. Fourth, the framework created might be an alternative approach where parametric design is employed as a tool to address the multiple aspects of the design process and design thinking. The research primarily combines knowledge management as tools, design processes as frameworks, and decision-making as design activities. The created model may be used and put to the test by designers, architects, institutions teaching architecture, and educators. The topic will then be strengthened by looking at a structure that incorporates parametric design, namely the Abu Dhabi Louvre Museum in the United Arab Emirates in order to assess the efficiency of parametric modeling and design ideation.

2. Methodology

The methodological approach intended to be adopted in this context is qualitative based on an inductive approach. The study begins with a brief review of the current developments in parametric thinking, models and techniques as well as their relations to the architectural design process. In addition, the results obtained from this review are used to propose a conceptual framework that supports space design exploration and the customization of the desired output. The proposed framework is the result of collecting and criticizing existing models of the design process in order to derive a model that works for parametric architectural design by examining and abstracting the existing trials.

3. Parametric Design Thinking

The debate on the subject of architecture covers a range of topics, from environmental concerns to building codes. Many of these jobs and laws are quite complicated, and a multi-disciplinary, compound approach is required to manage their complexity (Lawson, 1998).

Parametric Design thinking was initially proposed as a type of solution-based thinking. Particularly, it takes place in and around the computer aided design (CAD) medium. The goal and challenge of parametric design thinking (PDT) is to formulate and clarify the key ideas in the area and their theoretical and practical relationships (Dorst & Cross, 2001).

On the one hand, Parametric Design thinking works especially effective in situations known as complex challenges, in which the problem is poorly defined and/or has a highly nonlinear connection with the solution. On the other hand, it can be summarized as a type of solution-oriented thinking that results from the convergence of a cognitive model of the activity Figure 1. The overall view of what is supposed to be done, information processing models, and design processes or procedures (Oxman, 2017).

4. Model-based Parametric Design

This section presents a holistic view of the role of parametric-based approach in architectural design. To fully understand this role, this section is going to deal with an important aspect; presenting the conceptual framework of different parametric models throughout the architectural design process. The general characteristics of the parametric design process have been described in previous studies, as well as, their influence on the final architectural product.

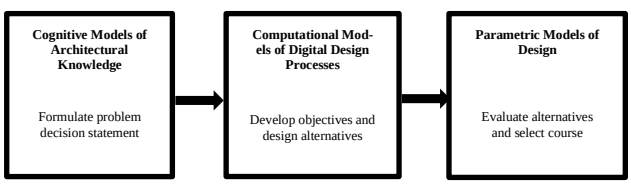

Figure 1. Diagram of intersecting fields of research in PDT.

The parametric-based paradigm is a process based on algorithmic thinking that enables the expression of parameters and rules that define, encode and clarify the relationship between design intent and design response (Woodbury, 2010).

This key aspect can be defined by the secondary vocabularies of the role of parametric modelling in the design process, the time of model creation, the type of design approach that employs parametric modeling, the stages of the parametric design process, and the progress of work

between the stages of the parametric design process (Hudson, 2010) (Wortmann & Tunc¸er, 2017). This framework divides the models of design process into two main approaches. The first approach concerns set-based design and the second approach refers to knowledge-based design. Generally, these approaches that support the variation in parametric design obtain the most important, necessary, and obligatory meaning, and attempt to simplify the language of the design process. This abstraction will become mature in contemporary context. The components of the framework are summarized below:

4.1. Set-based Design

Architectural design can be described as transforming a set of functional specifications and requirements into a complete description of a product or system (in design space) that meets those specifications and requirements (in performance space) (Nahm & Ishikawa, 2006).

Set-based Design (SBD) considers a broader range of design possibilities from the outset by dividing the solution space into relatively equal volumes Figure 2.

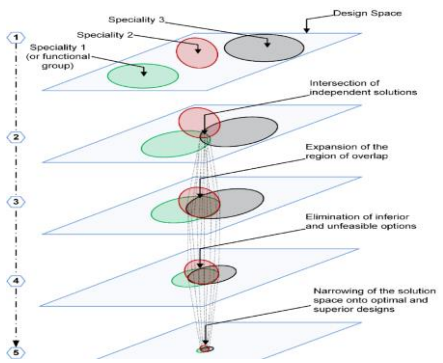

Figure 2. Diagram of Set-based Design.

In order to cope with several sources of variations and ensure design robustness, we need to explore a large design space to get feasible sets of design possibilities, by a set-to-set mapping from design space to performance space. There are many different parametric models available in this context, there is a broad range of parametric models, varying from simple to complex, which aid designers (Nahm & Ishikawa, 2006) (Toche, Pellerin, & Fortin, 2020).

These models include formation, generation and performance, which can be applied to architectural design tasks and content starting in the early conceptual phase, development phase, detailing phase and fabrication phase (Hudson, 2010).

4.2. Knowledge-based design

A knowledge base is required for designing the desired components. The parametric modeling technique is useful because it can be used where geometrical model changes frequently during the design process. The design process must be carefully developed to generate the most suitable design recommendation. With the help of evolution of the Knowledge-based Systems (KBS), the designing time is further reduced. Moreover, KBS has become the practical method for visualizing and analyzing the design process with the help of simulation tools Figure 3 (Jayakiran Reddy, Sridha, & Pandu Rangadu, 2015).

5. Parametric Design Framework

Numerous research initiatives have been made to investigate parametric design thinking in order to categorize it as both a philosophical and theoretical idea in contemporary architecture as well as a brand-new architectural style with specific traits.

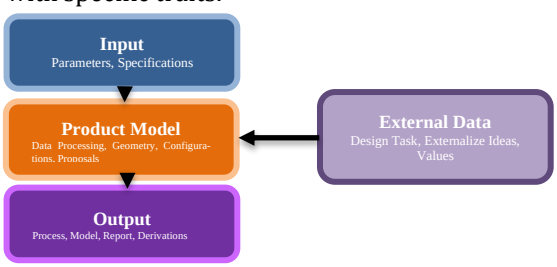

Figure 3. Diagram of Knowledge-based Design.

Furthermore, the new paradigm is based on the Systems Thinking school of thought, it has given rise to a wide variety of assumptions in the design fields (Al-Azzawi & Al-Majidi, 2021).

One of the most important features of parametric modeling is that it supports the incorporation of technical knowledge and the outset during the design process. Following the outline of parametric models and their conceptual framework that support design exploration and

optimization in the whole architectural design process. Parametric Design Framework can develop the fundamental knowledge about the product that in turn leads to easy preservation.

It allows interdisciplinary exchange of information, documentation and knowledge to establish collaborative design as the development associated with many activities in knowledge management phase. Moreover, the process of implementing is beneficial for identifying and standardizing the design decisions (Megahed, 2015) (Hernandez, 2006) (Oxman, 2006). Consequently, this framework, which attempts to close the theory-practice gap, records the interaction between conceptual systems and practical enablers (Chokhachian, 2014).

Table 1. Parametric Design Framework Measurment Indicators (Set-based Design).

Secondary Vocabulary	Variations	Values	Parametric-based Approach
parametric modelling in the design process	parametric modelling in the design process	Representation	**Set-based Design**
		Generative	
		Performative	
Time of Model Creation	Time of Model Creation	Conceptual	
		Development	
		Detailing	
		Fabrication	
Cognitive Parametric Model	Parametric Method	Explicit	
		Implicit	
		Top, down	
		Bottom, up	
	Cognitive Artifact	Parametric Schema	
		Spread Sheet	
		Geometrical Representation	
		Rules	
		Design Specifications	
		Scripting	

Table 2. Parametric Design Framework Measurement Indicators (Knowledge-based Design).

Secondary Vocabulary	Variations	Values	Parametric-based Approach
Parametric Modelling Activities	Data Collection	Assign initial values	Knowledge-based Design
	Externalize Ideas	Experience	
		Case Retrieval	
		Morphism	
		Prototype	
	Translation	Understanding Design Task	
		Assign Parameters	
	Rationalization	Pre-rational	
		Post-rational	
	Control	Design surface	
		Fragmentation	
Alternatives Exploration	Analysis	Find appropriate parameters	
		Assign Proposals	
	Testing	Testing	
	Critique	Critique	
	Sorting	Sorting	
	Presentation	Presentation	
Enhancing Alternatives	Development Method	Adjustment	
		Changing	
		Transformation	
	Development Target	Optimization	
		Adaptation	
Association	Standards	Functionality	
		Structural Performance	
		Environmental Performance	
		Aesthetics	

6. Space Design Exploration (SDE) Framework

After presenting the main vocabulary of the theoretical framework, in this part the proposed scenario's framework will be presented and analyzed Figure 4. In order to propose a system that can deal with complex problems not only in theoretical framework but also in practical discourses by implementing available tools, methodologies, and enablers, this framework tried to implement the maximum potentiality of architecture theory within the practice. The following section describes the framework in more details:

- Solution Space

The framework's first point of interaction is the solution space. The boundaries of a solution space define the range of possible solutions. A solution that complies with all specified limitations and is included inside the solution space is referred to as a feasible solution in this context. The purpose of the solution space is to reduce the number of potential solutions in order to give the explorer a meaningful set of workable alternatives.

- Generator and Solution Set

The generator—which offers the "generative" aspect—is at the center of the generative design methodology. The generator produces a collection of feasible alternatives that may be investigated. A series of inspired processes drive a genetic algorithm technique, where each solution is assessed by an optimization algorithm.

- Exploration Approach

The generated solution set has to be studied due to the generated solution set's potential breadth and in order to assist users in finding possibly unique solutions. This consists of two stages: presentation and preference management. This phase advances the idea that generative design methodologies should be considered as "collaborative partners".

- Evaluate Solutions

Each solution must be run through a series of evaluations in order to provide metrics for each one in order to ease user exploration of the alternatives. The evaluations are an essential part of providing input in the form of metrics and potential sources of visualization of each solution, as this is the information that will guide the generator methods and users' decisions.

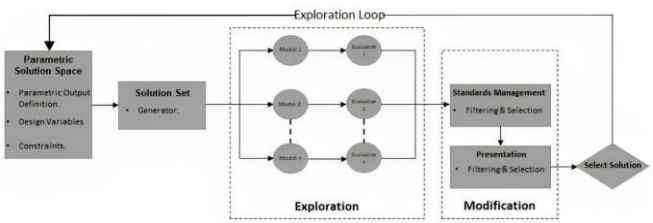

Figure 4. SDE Framework.

7. Applying SDE Framework

Space Design Exploration (SDE) is a dynamic strategy to help designers during the decision-making process to generate a more responsive design morphology. SDE is an assessment model in which the designer can enter rules to associate changes in the physical fabric with achieving certain qualities. The purpose of this system is to bring the potential of design research under a complete system and not just to produce designs using computational tools, but also to interact with the actual world using computers.

To implement the SDE strategy on real-world challenges, a case study will be introduced to develop the parametric design techniques in the communities. In order to direct the building techniques to interact more responsively with the consequences associated with each design scenario Figure 5 a methodology that allows the designer to associate any changes in the geometrical parameters of the final morphology will be as follows:

- The parameters will be specified, the constants and variables defined, with the variations set that could be individually controlled between certain boundaries that respect the current case and the building rules and set the boundaries for the solution space in the parametric design approach through the product definition.
- Generating the solutions sets, applying a random sampling technique as the generator, where each combination represented a potential solution.
- Facilitate a user exploration of solutions, each solution needs to be passed a set of evaluations through selection and filtering that are used to derive metrics for each solution based on the design problem and its objectives.
- The solution sets then be brought forward to be further developed into the final phase of the parametric design process.
- The final generated alterations acquired after going through all the parametric aspects that can be associated with the final optimum solution.

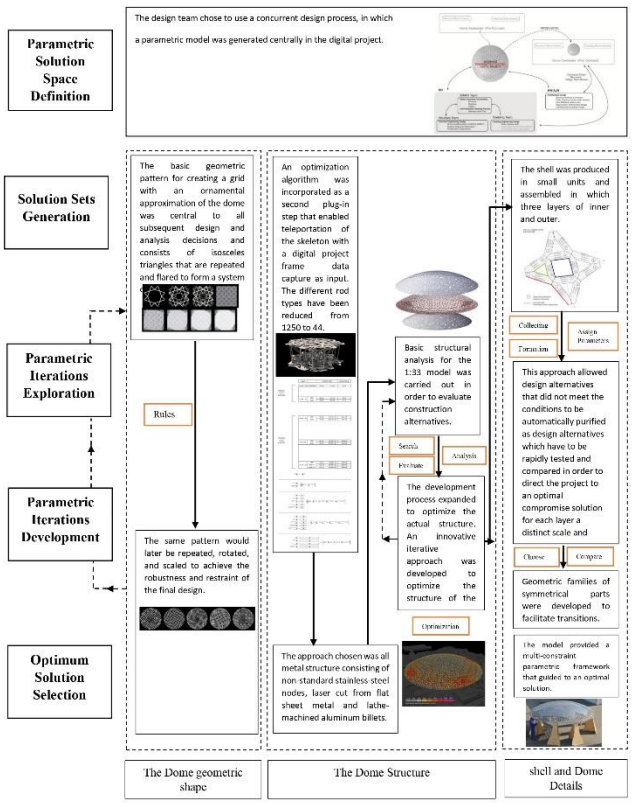

Figure 5. SDE Framework for LAD.

8. Results and Discussion

Parametric design in practice is flexible in dealing with the rational and intuitive aspects of architectural design. It represents an iterative process of generating and testing according to the principle of " trial & error" to solve the ill-defined architectural design problems by adopting both standards, objectivity and subjectivity. The activities of generation, formation, selection, identification a diversification of parameter values in the design production stage, and the effectiveness of analysis in the design solutions exploration stage are basic activities within the parametric design process, in addition to the rest of the activities that are used in assigned proportions according to the need.

Thus, this paper has addressed a radical discussion of parametric tools and their potential influence on the architectural design process by encouraging designers to reveal the significant opportunities offered by this new paradigm of thinking. Therefore, creating a parametric model to be used in the decision-making stage. The model was able to generate various design alternatives by changing the inputs in every alternative.

The SDE framework is abstract in both practice and theory to avoid any impractical contemplation, as a result of a study into continuous design activity among architects as well as theorists. The proposed framework might be examined through its subsystems and revised later in light of newer practicalities. Collaboration across many disciplines preserved through a systematic approach might improve the quality of architectural design and the use of modern tools, not merely in theory but primarily in practice by embedding their effectiveness into the main body of the design process.

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