ATLANTIS PRESS

Advances in Social Science, Education and Humanities Research, volume 324

International Conference on Architecture: Heritage, Traditions and Innovations (AHTI 2019)

Parametric Design Modelling in Urban Art: Approaches and Future Directions

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***Abstract*—Although the notion of parametric modelling could date back to the hanging chain model of Gaudi, the utilization of parametric model in architectural design has only become a phenomenon in recent years. Both practitioners and researchers have demonstrated the great potential of these design models when performing architectural design tasks. Meanwhile, there are also artists and architects who actively investigate the possibilities of using parametric models in landscape or urban art. Combining with 3D printing technology, efforts have been put into the creation of public art pieces by using parametric models. Although parametric models are still largely used to create sophisticate geometries or forms, artists are also exploring the feasibility of parametric modelling approaches other than merely geometric operations. As a result, the primary objective of this paper is to review different possibilities and approaches of parametric modelling adapted by artists and architects in the realm of urban art. This would also shield light on new possibilities and future directions of parametric modelling in both fields of architectural design and urban art.**

Keywords—parametric design model; digital design; parametric art; urban art

I. INTRODUCTION

There has been a trend to adapt parametric design in the fields of architecture and urban design recently. Indeed, parametric design in architecture can date back to the hanging chain model created by Gaudi [1]. Although parametric design can be done without the utilization of computer, it has been a norm for designers and architects to take advantages of computer and programming technologies when adapting parametric design.

As a matter of fact, parametric design has been a topic of interest for both practitioners and researchers. It has even been suggested that parametric design is fundamental to creativity, in a sense that design variations can be generated by altering values of different parameters [2]. Having design variations is also the key of creativity [3]. As rules such as "climate" and "structure" have to be explicitly considered when developing parametric design models, new ways of design thinking would be drawn to designers and architects [4].

To this end, tremendous efforts have been put on exploring the various possibilities of it. For example, the technique of parametric design was used to create the structure and cladding systems of the Hangzhou Tennis Center in China [5]. With the help of parametric modelling, the design of the arched roof of the train shed at Waterloo Station in Britain was created [6]. Architectural practices such as Frank Gehry Associates and Foster and Partners even set up specialist teams for parametric modelling [7]. In academe, a study was conducted to utilize parametric model to optimize site planning, massing, building form (by considering solar heat gain) and building structure [8]. Meanwhile, a parametric design process for the design and construction of modernized traditional Korean house was proposed [9]. In another study, the workflow for parametric modelling to design shading devices so as to optimize daylighting and block excessive sunlight for office buildings in hot and humid climate was also explored [10].

Apart from architectural design, parametric design has also been adapted in other related fields such as urban planning and design. Parametric urbanism has been the agenda of the Design Research Laboratory (DRL) in the Architectural Association (AA) [11]. With the notion of parametric urbanism, Zaha Hadid Architects also won a series of planning competitions including One-North Masterplan in Singapore and Soho City in Beijing, China [12]. It has also been suggested that parametric modelling could be used to generate urban design solutions in high-density cities such as Hong Kong [13]. In parallel, there are designers and artists who engage in parametric modelling when creating installation structures or urban art. However, documents and literatures about these installations or artistic works are relatively fragmented, rendering it difficult to understand the different parametric modelling strategies and approaches adapted by these designers and artists. As a consequence, this paper aims at reviewing the approaches of parametric modelling used by designers and artists while designing installations or urban art. This will also shed light on possible future directions for parametric design approaches.

II. PARAMETRIC DESIGN

Traditionally in architectural design, objects were declared by the forms of them. When it comes to parametric design, however, objects are declared by parameters instead [14]. This means that designs are created "by means of objects which are defined by a set of constituent parameters" [15]. In this case, a rectangle will not be declared directly as the form of a "rectangle". It will be declared by the height and width of it. By varying the values of height and width, different "versions" of rectangles can be created. When performing design tasks with parametric modelling, designers have to think "with abstraction", "mathematically" and "algorithmically" [16]. By considering parameters and using parametric models, designers can explore design ideas which are constrained by sketches [17].

III. PARAMETRIC MODELLING APPROACHES

There are three basic components of a design process, and they are the input, design agent and output. These three basic components are valid for both traditional and parametric design. "Fig. 1" shows the flow of these components. Regardless it is architectural design, urban design, or installation / public art, the input is usually a combination of geometric and non-geometric data [18]. The design agent is the process of manipulating the input and generating the design output. The final output is usually a physical object. When the approaches of parametric modelling are in concern, it is about the parameterized input and how the design agent deals with these parameters (usually by means of mathematical formula) and generates the design output. Here, the parametric modelling strategies adapted by designers and artists to manipulate non-geometric and geometric data when creating installation structures or public art will be discussed by means of case studies.

Fig. 1. Basic components of a design task.

A. Geometrical Operation Approach

Geometrical Operation Approach is the most common approach when designers begin exploring the possibilities of parametric modelling. This is also one of the most used approaches for form finding. With this approach, purely geometrical operations will be performed. Usually, the design process will start with simple base geometries. With a pattern such as the Voronoi pattern [19], [20] to distribute these base geometries, 2-dimensional, or even 3-dimensional formal representations can be generated.

1) Case study: HIVE project: The HIVE project was a "parametrically designed interactive sound sculpture with embedded multi-channel digital audio which explores the intersection of sculptural form and musical instrument design" [21]. The basic premise of the project was that loudspeakers can be considered musical instruments [22] and they do not have to be hided. The sculpture itself was an array of horn shape multi-channel loudspeakers. These horn shape loudspeakers were arranged by using honeycomb patterns. Here, the horn shape acted as an "acoustical waveguide" while the use of honeycomb patterns could pack all these "horns" tightly.

"Fig. 2" shows the four stages of form finding. In the first stage, an arbitrary curvilinear surface composed by cells in hexagonal shape was defined. In the second step, cells which were not complete hexagons were excluded. Non-linear extrusions of the cells were performed to create a 3-dimensional solid shape in the third step. Finally, the mesh of the extruded form was smoothened, resulting in the final form of the sculpture. With this four-step algorithm of form finding, a honeycomb pattern packed with horn-like inner cells was created.

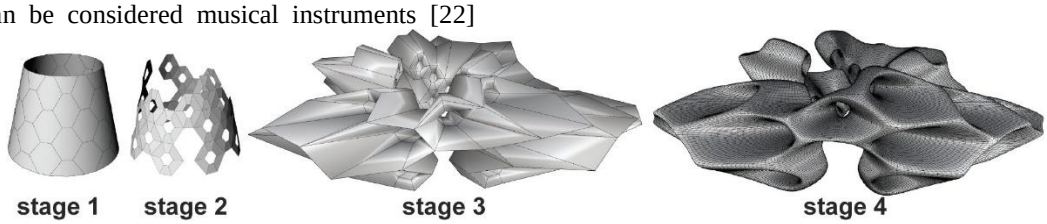

Fig. 2. Stages of form finding in HIVE Project [21].

It can be seen that, in terms of form finding, only geometrical operations were employed in the HIVE project. Due to the vision of the project, the basic geometry (horn shape) and patterns (honey patterns) were pre-defined. The geometrical operations evolved around these basic geometry and patterns to create the final 3-dimensional form of the sculpture. In the simplest terms, the geometrical operations involved were removal of cells that were not needed, extrusion of the cells and smoothening of the surfaces.

B. Data Driven Form Finding Approach

While geometrical operation approach searches for the formal representation by using purely geometrical operations, Data Driven Form Finding Approach is to search for the form by considering data instead of pure geometry. This idea can be illustrated by the design of a simple shading device for a window [23]. Usually, some basic geometry still has to be defined in the first step. In the case of shading device design, the shape of the window will be the basic geometries.

By assuming the sun direction as a vector from a point in the sky to the center of the window, the shape of the shading device would be generated. In this example, the azimuth and altitude angles of the sun were the data to drive the generation of formal representation of the shading device.

1) Case study: spatial polyphony of disparallel spaces: Disparallel Spaces was an architectural design exhibition hosted in Sydney in 2007. The main aim of the exhibition was to explore the "creative use of computer-aided architectural design tools, scripting, parametric design techniques" [24]. One of the aims of the exhibition was to reframe "the question of parametric methodologies". Of the different proposals and artworks in this exhibition, there was some employing the notion of Data Driven Form Finding Approach. Specifically, the proposal Spatial Polyphony [25] was to translate a music piece into an architectural design / installation ("Fig. 3"). For this particular artwork, the parameters were derived from the preludes and fugues of The Well-tempered Clavier composed by J.S. Bach. Variables such as pitch and tempo of the music piece were translated into parameters and eventually 48 forms were generated. The generation of formal representation was governed by an abstract form of music. The formal representation of this artwork "represented the relationship between music and architecture in the Western tradition" [24].

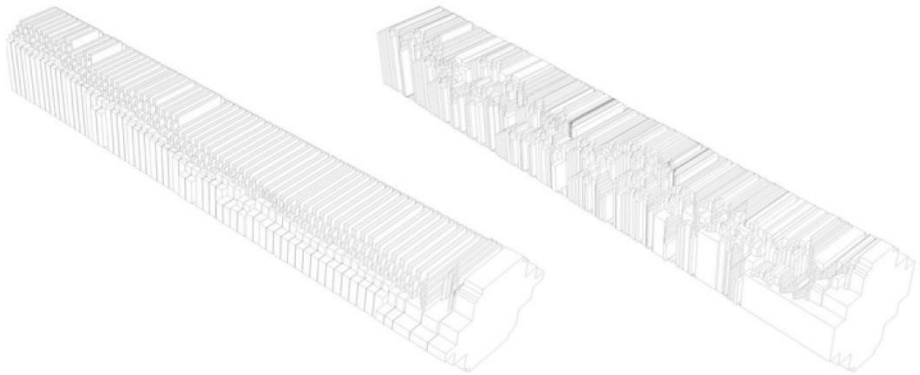

Fig. 3. Forms generated in the Spatial Polyphony Project [25].

For the artwork Spatial Polyphony, highly abstract external influences were used to guide the definition parameters and form finding procedure. Although the final formal representation will still be geometrical, the process of form finding does not have to be.

C. Hybrid Approach

The hybrid approach is considered a combination of the previous two approaches. Both geometrical operations and external influences will be considered in order to get to the final formal representation.

1) Case study: underwood pavilion project: The Underwood Pavilion [26] was a tensegrity structure ("Fig. 4"). The space in this pavilion could be inhabited by a group of 12 people. A tensegrity structure is essentially a structure which utilizes the concept of continuous tension. Within the structure, there are isolated compression members. Each compression member forms a node at each end of it. A continuous path of tension will then connect these nodes. Tensegrity structure has been employed in architectural designs such as the Warnow Tower in Rostock in Germany. Compared to other structural systems such as truss systems, tensegrity structures usually exhibit the qualities of being lighter and more cost efficient.

Fig. 4. The Underwood Pavilion [26].

A basic module was defined in order to generate the form of Underwood Pavilion. This module comprised two triangles, which were the upper and lower faces of the module. The sizes of these two faces and the length of the tensile members between two faces were variables that could be defined. Meanwhile, the distance and module rotation between the two faces were unknown and would be calculated by the parametric computer program. The geometrical operations included extrusion, scale and rotation so as to form different variations of the module. Individual modules would aggregate the whole structure. The strut and cable network forces would be considered for the aggregation.

The Underwood Pavilion project illustrates the notion of hybrid approach. In this project, geometrical operations were used to generate basic units (modules) of the design and external influences drove the aggregation of the final formal representation. It has to been noted the procedure employed in this project is not universal for the hybrid approach. Both geometrical operations and external influences can be used to generate the basic units, as well as the aggregation of the whole form of an installation structure. However, combining both geometrical operation and data will make the process of form finding more flexible.

IV. CONCLUSION

In this paper, three different approaches of parametric design adapted by designers and artists when creating installation structure or public artwork have been presented. Unlike the classifications of approaches suggested before [18, 27, 28], which were mainly derived from the programming point of view, the approaches discussed in this paper were about the input and the way to manipulate the input. Rather than programming, designers and artists usually focus more on how to actually use parametric models to generate designs. As a result, the approaches laid out in this paper will be in-line with the main interest of designers and artists when generating designs with parametric modelling techniques.

As illustrated in the case studies, the output of the parametric models is usually geometrical when installation structures or public art are in concern. It has been argued, however, that the output of a parametric model can also be data. The output of the model does not have to been geometrical. Instead, the output can be both non-geometrical and geometrical [18]. As a consequence, a direction of parametric modelling should be the generation of output combining both the physical object and data related to the quality or performance of it. It would also be of interest to explore the feasibility of treating the desired quality of the final object as data input to the model. In this case, the desired quality will become the driver to generate the design.

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