ASSOCIATIVE PARAMETRIC URBANISM:

A Computational Approach to Parameterization of Conceptual Design Phase

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Abstract. Urban planning projects usually comprise a complex set of objectives that needs to be addressed by developing a number of proposals. This requires a lot of repetitive steps resulting in fewer and slowly-developed design alternatives. To address the limitations of the existing system, this research introduces the merge of associative parametric design tools with the conceptual design phase of urban planning process to propose a Parameterized Conceptual Design Phase. The developed Associative Algorithm within the proposed phase represents a computational approach that translates a site's settings into local attractors to define urban fabric, and provide the designer with variations for optimal solutions. The Informal Settlement of Ezbet El Matar, Alexandria, is selected as the case study of this approach.

1. Introduction

Urban planning lays the foundation for the new buildings and public spaces that shape our lives. Traditionally, urban planning process consists of a sequence of phases that may vary or overlap to suit the project nature. During the conceptual design phase, a complex set of objectives and requirements are addressed regarding certain factors such as land use, site considerations, circulation, and environmental issues. To respond to these complexities, a number of design alternatives is needed to be developed and assessed against certain criteria. However, designers normally develop only few alternatives that may not be able to give the optimum design solution, as they are considered static tools. Moreover, the amount of time spent in generating and evaluating alternatives using traditional design models and tools, such as CAD systems, forces many designers to use these methods only for validating a selected alternative rather than exploring multiple scenarios (Shea *et al*., 2005: pp. 253-264). Urban planning now finds itself at the mid-point of an ongoing cycle of adaptation to comply with the demand for an increased level of complexities. To address the limitations of the existing system, it is essential to consider new methodologies of design techniques at a higher level of understanding. Among new ones is the Parametric approach, which is a novel trend that utilizes the computational technologies to model geometries based on multiple parameters, and can offer explorations during the conceptual phase of design process.

In response to the above-mentioned challenges, this research will aim at merging parametric approach with urban planning process for developing urban planning projects and their alternatives during the conceptual design phase. The research methodological objectives are realized through two main steps. The first step is to define the parametric approach in design, and to delineate the parametric urbanism and review its current approaches, in addition to merging the parametric approach with urban planning process. Secondly, the Parameterized Conceptual Design Phase will be developed, with the application of a case study, to support this computational approach.

2. Parametric Approach in Design: Parametric Urbanism

Given the digital nature of the contemporary design, parametric approach is becoming an essential tool for architecture, and urban planning. It has its roots in the digital techniques since the mid-1990s, though it only fully emerged over the last fifteen years with the development of computational tools (Schumacher, 2009: pp. 14-23; Stavric & Marina, 2011). It has become clear that parametric tools could bring similar benefits to architectural design projects, having even effectiveness in higher scale of urban planning (Nagy, 2009: p.14; Leach, 2009: p.19). The design is controlled by fixed or variable relations, either numerical or geometrical (Kilian, 2006: pp. 54-55). New forms and ideas can emerge when the designer converts all his concepts and design guidelines into a parametric environment (Hernandez, 2006: p.38). Parametric approach also allows setting rules and relations to the design to minimize the time consumed in modifications during the design process (Araya, 2006: p.11). In short, parametric approach is the process of modeling and designing with geometrical sets that hold fixed and variable attributes, in a computational environment where variations are effortless (Ayoub, 2012: p.86).

Many researchers developed new urban planning techniques to enable a more flexible and faster design developments parametrically (Batty, 2013; Beirão *et al*., 2011; Stavric & Marina, 2011; Oxman, 2008; Saleh, 2012).

Parametric Urbanism is a new trend in urban planning that uses advanced computational technologies to plan geometrical urban spaces, and by variating their parameters values, different geometrical configurations could be generated (Canuto & Amorim, 2012; Schneider *et al*., 2011; Schumacher, 2009: pp.14-23). It is defined as the ways in which associative design systems can control dynamic information and design components to affect and adjust design process by embedding intelligence into the formation, organization, and performance of urban spaces, uses, and activities (Stavric & Marina, 2011).

2.1. APPROACHES OF PARAMETRIC URBANISM

The computational processes of form transformations are referred to computational architectures. Using these technologies in design has established new approaches. Kolarevic stated a number of architectural subcategories that emerged from studies with different computational techniques: topological space, isomorphic surfaces, motion dynamics, parametric design, and genetic algorithms (Kolarevic, 2005: p.251; Stavric & Marina, 2011; Saleh, 2012: p.8). On the other hand, Oxman proposed that the computational approach provides a medium for the structure of design models according to various relationships of the designer, his concept, the design processes, and the design object itself. She identified the approaches of computational design: CAD models, formation models, generative models, performance models, and integrated compound models (Oxman, 2006; Saleh, 2012: p.8). However, not all of these approaches can be related to the urban planning domain. Some of them have made a notable impact on the development of urban planning methods and techniques, moving from the traditional methodology to a more dynamic one. The correlation between these approaches and the urban planning has led to the emergence of four parametric urbanism approaches [FIGURE 1]:

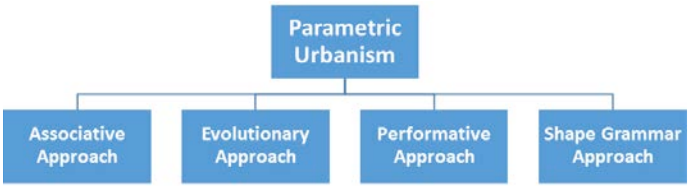

Figure 1. Approaches of Parametric Urbanism

2.2. PHASES OF PARAMETRIC APPROACH

Parametric design process integrates new way of thinking into the design process through the ability to control variables, and to adapt the designs, which allows the formulation of more precise, and even complex solutions

(Gane, 2004: p.14). The idea is that the designer first establishes rules and relations by which design components are connected to minimize the time and effort consumed in modifications, and to provide multiple solutions that could not be reachable by traditional methods. The parametric approach has been studied and analyzed by numerous academics and designers (Araya, 2006: pp.11-12; Gane, 2004: p.54; Hudson, 2008: pp.18-19; Llabres & Rico, 2016). Most of them coincide describing it as a series of phases, which increase in the level of detail and precision, as they involve from preliminary concept to construction. Herein, the parametric design process starts with *Design Exploration*, in which background data and design problems are determined, including the design objectives, variables, and constraints. The second phase, *Design Development*, includes possible solutions for design problems and manipulations of design instances. Generation of alternative solutions are reviewed and evaluated in the *Simulation / Evaluation* phase, to satisfy project goals, and previously built constraints. After these explorations, a development is considered one single direction in the *Manufacturing / Construction* phase (Araya, 2006: p.12; Gane, 2004: p.54).

3. Parameterization of Conceptual Design Phase, Case Study: An Informal Settlement in Alexandria (Ezbet El Matar)

The proposed Parameterized Conceptual Design Phase (PCD) comprises the merge of the parametric approach with the conceptual design phase of the urban planning process. It can help the designer by embedding intelligent computational tools in terms of using the parametric approach in urban planning. It conceives site qualities that represent unique character and scale of a project in a way that would eventually shape its character. Relations and dependencies of the design components are developed and linked together by suitable rules and definitions. Grasshopper (a visual programming language developed by David Rutten at Robert McNeel & Associates) will be the modeling platform used in this research, in which, geometric models will be integrated with these rules to generate project variations parametrically. The following application will focus on the proposed process of PCD, which consists of three main stages [FIGURE 2]:

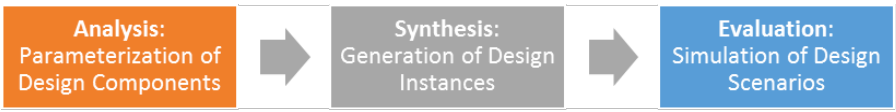

Figure 2. Parameterized Conceptual Design Phase (PCD) Process

Regarding the case study, Smouha Area is one of the most diverse parts of the City of Alexandria, Egypt’s second largest city and main port.

However, the impact of settlements unplanned-process has become unmistakable towards the city's urban border. Ezbet El Matar is one of the informal settlements localized in Smouha Area near the El Nozha Airport. The 0.163 km^2 site stretches between the Alexandria Agriculture Road, and Airport Lake waterfront. It is surrounded by formal housing units and industrial warehouses from the north, Airport Lake waterfront from the south, agriculture land and German Company for Sewage System from the east, and El Nozha Airport from the west. The original development was planned to be an industrial and warehouses area near Alexandria's borders. However, informal housing units were sustained there, and became cohesive to the urban fabric as the city expanded decades ago. Ezbet El Matar is characterized by very narrow streets with varied widths, poor environmental conditions, and absence of open spaces and green areas.

3.1. ANALYSIS: PARAMETERIZATION OF DESIGN COMPONENTS

Parameterization of Design Components is the first stage of PCD process. It starts with *Exploration of Generators* step. A number of Grasshopper definitions is carried out during this research. These definitions focus on translating of the site's settings into local attractors with range domains as main drivers for geometric variations of a site's urban fabric within certain boundary. The current step begins with identifying all available generator nodes on the site (Alexandria Agriculture Road, Airport Lake, formal housing units, and El Nozha Airport), which vary in magnitude and response. Then, an exploratory point cloud is represented on the site with regard to generators that dominate the preliminary settings for point cloud population by manipulating their coordinates. The generator nodes act as local attractors for the propagation rules affecting surrounding points to generate a unique range domain for each one [FIGURE 3].

Figure 3. An Exploratory Point Cloud (Left), Preliminary Settings for Point Cloud Population (Middle), Point Cloud Population after Applying Propagation Rules (Right)

The second step is *Parameterization of Generators*, in which the designer assigns parametric attributes (dependent, independent, fixed, or variable) to the previously stated generators and point cloud to convert the static site model into a parametric one. Independent fixed attribute is applied to the generators, which are considered geometrical entities that control the behavior of other components. Dependent variable attribute is assigned to the point cloud, then, a set of transformations is applied on every point to be attracted towards the closest generator point. In order to create contextual urban subdivisions, a series of Voronoi tessellations is created, which divide the site into polygons based on the dependent variable locations (point cloud) after applying the propagation rules. A linkage correlation is then developed for the tessellations to establish contextual urban relationships between them (to be converted into triangulation subdivisions) [FIGURE 4]. It is noted that all the above mentioned parameterized design components are dictated by the input location of the generators in the parametric model.

Figure 4. Voronoi Tessellations (Left), Linkage Correlation Development for Establishing Contextual Urban Relationships (Right)

3.2. SYNTHESIS: GENERATION OF DESIGN INSTANCES

Synthesis: Generation of Design Instances is the second stage of PCD process. *Rules Setting* is its first step that is concerned with applying the rules and conditions in which the previously parameterized design components combine together. Within the developed linkage correlation, each triangulation subdivision varies depending on its polygonal area and the number of connections. Then, certain rules strategies can be derived from subdivision variations, which will define urban settings of open spaces as voids, and building masses as solids. Based on the subdivision variations of triangulation subdivisions, a set of geometrical responses, which correlate with the tessellations density change, is developed to define different urban settings of open spaces and building masses. External geometrical responses are applied to triangulation subdivisions for extruding building masses.

Other internal geometrical responses are set to these subdivisions to develop variable internal layouts. These variations are created to incorporate the linkage correlation with the site's urban fabric to produce a more coherent solid-void relationship [FIGURE 5]. The *Associative Algorithm* is the second step of this stage. It focuses on creating the Associative Algorithm and its computational definitions for different urban settings to acquire particular rules strategy of parametric urbanism, and eventually, provide the designer with explorations about the project to search for optimal design solutions. The implementation of this algorithm is developed using the associative approach in Grasshopper environment [FIGURE 6].

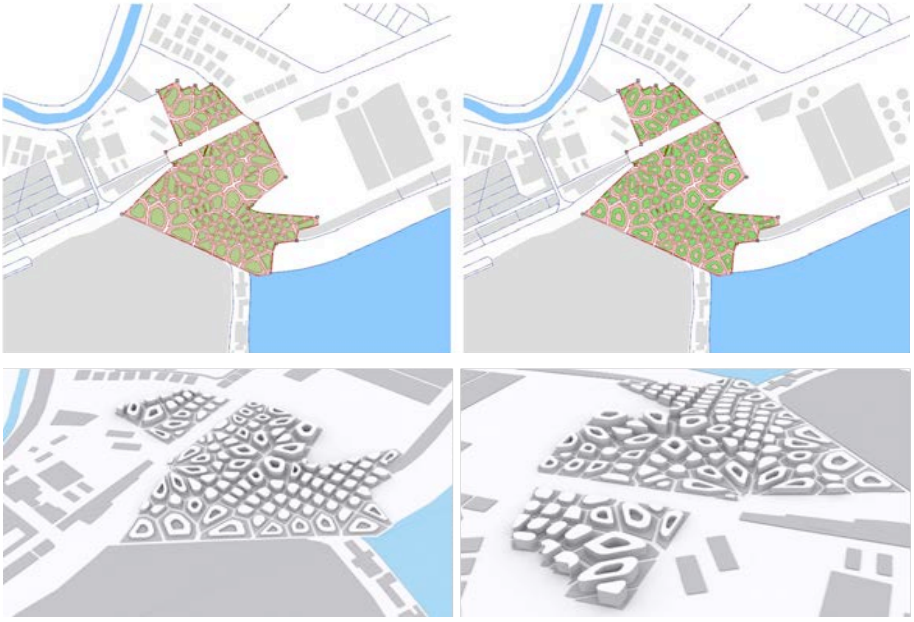

Figure 5. External Geometrical Setting to Voronoi Tessellations (Top Left), Creation of Internal Polygonal Spacing (Top Right), Proposal 3D External Shots (Down)

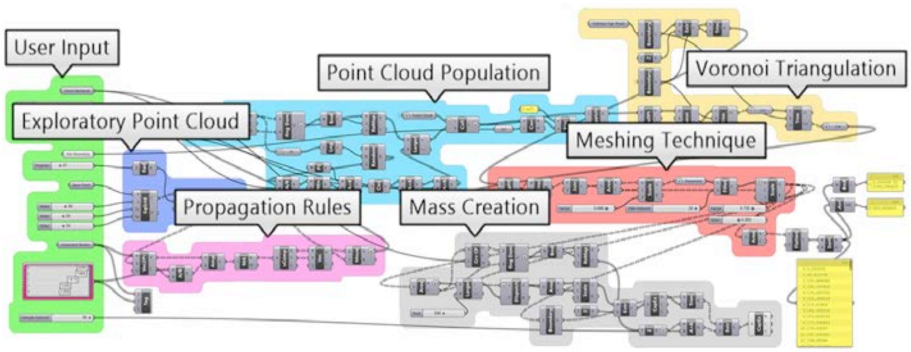

Figure 6. The Developed Associative Algorithm and its Computational Definitions

3.3. EVALUATION: SIMULATION OF DESIGN SCENARIOS

In the past, the only simulation method was to create, test, and evaluate physical prototypes. With the rapid growth of computational systems and numerical methods, recently, better simulation techniques can be achieved computationally. *Simulation of Design Scenarios* is the final stage of PCD phase, in which the generated design instances are evaluated and tested. Algorithms can be established for simulation purposes to make decisions about proposals against specific design criteria. However, this research will not emphasize on these issues due to the limitations of its scope.

Discussion

Recent decades witnessed a paradigm shift on how new techniques of parametric urbanism are utilized to facilitate viable developments, which are becoming an essential part of contemporary urban planning standards. This research aimed at merging parametric approach with the conceptual design phase of urban planning process to propose a PCD phase. The work within this research reveals the power of the parametric associative approach as a suitable tool to support and expand the development of urban planning projects. By applying the proposed PCD, designers can increase their understanding and creativity outcomes by assembling more dynamic components, exploring variable solid-void relationships, and guiding development through modular computational environment. This is valuable in high density cities like Alexandria, especially in informal settlements, to explore possible multidirectional solutions to design problems. Although the developed associative algorithm within the proposed PCD still in an early development stage, it has potentials to translate a given site's settings into design generators to define urban fabric and generate geometric variations for continuous urban development. Undoubtedly, there are more variables and considerations of conceptual design phase that could be considered, such as visual qualities, pedestrian services, land uses, etc. However, for a first experiment, this tool is sufficient. As for recommendations, PCD phase can be applied to parametric systems, which are widely used by designers.

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