AN ALGORITHMIC METHODOLOGY TO PREDICT URBAN FORM

An Instrument for Urban Design

SHUVA CHOWDHURY[1] and MARC AUREL SCHNABEL[2]
[1,2] *Victoria University of Wellington*
[1,2] *{shuva.chowdhury|MarcAurel.Schnabel}@vuw.ac.nz*

Abstract. We question the recent practices of conventional and participatory urban design approaches and offer a middle approach by exploring computational design tools in the design system. On the one hand, the top-down urban planning approaches investigate urban form as a holistic matter which only can be calibrated by urban professionals. These approaches are not able to offer enough information to the end users to predict the urban form. On the other hand, the bottom-up urban design approaches cannot visualise predicted urban scenarios, and most often the design decisions stay as general assumptions. We developed and tested a parametric design platform combines both approaches where all the stakeholders can participate and visualise multiple urban scenarios in real-time feedback. Parametric design along with CIM modelling system has influenced urban designers for a new endeavour in urban design. This paper presents a methodology to generate and visualise urban form. We present a novel decision-making platform that combines city level and local neighbourhood data to aid participatory urban design decisions. The platform allows for stakeholder collaboration and engagement in complex urban design processes.

Keywords. Knowledge-based system; algorithmic methodology; design decision tool; urban form; .

1. Introduction

Computation tools in urban design methods have brought a shift from idealistic design approach to systematic procedural design approach. Shifting from top-down modelling to more generative and bottom-up systems has influenced urban designers to address morphogenetic changes in urban design (Ayaroğlu, 2007; J. Beirão & Duarte, 2005; J. N. Beirão, Nourian Ghadi Kolaee, & Mashhoodi, 2011; Verebes, 2013). Such design systems can perform as creative design assistants during the initial stages of concept development. The traditional urban design and planning approaches have limited ability to address multiple urban complex rules and are not able to provide necessary information to predict the urban forms. Computer-Aided Architectural Design (CAAD) has already

T. Fukuda, W. Huang, P. Janssen, K. Crolla, S. Alhadidi (eds.), *Learning, Adapting and Prototyping, Proceedings of the 23rd International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2018*, Volume 2, 401-410.

proved rich possibilities to create design tools that can address urban complexity. However, the current developments of these tools are in design production rather than instruments for design decision-making process (Schnabel, 2007). Therefore, the study creates an algorithmic methodology as an instrument to generate multiple urban scenarios and can engage stakeholders in design decision-making process.

2. A Middle Approach

Bottom-up design approach encourages the process of local participation in every aspect of development. It involves local participants either through design consultation or by collaboration. The communitive theory has brought the idea of the bottom-up approach in the participatory design process. Healey (1997) indicates the demands of public participation in decision-making for more accountability on the parts of stakeholders. It brings the shift from a top-down to bottom-up strategies in urban planning practices (Murray, Greer, Houston, McKay, & Murtagh, 2009). Design discussion in bottom-up approach is time-consuming, and most often the design ideas stay in assumption. Moreover, because of lack of visual information, the stakeholders aren't able to compare multiple urban scenarios.

Traditional top-down urban design and planning approaches provide limited information for lay people to understand the process of idea generation. These methods have communicative established symbols which only can be calibrated by professionals. They have lack of communication channels for stakeholders to participate in the design discussion process. Also, the final rendered outputs are not flexible enough to visualise multiple design ideas at a time.

There are always differences exist in thinking and communicating language between professionals and laypersons (Forester, 1988; Friedman, 1973). The lack of engaging ways eventually pushes researchers to rethink for a new form of design-decision making platform where non-designers can fully understand the spatial implications of design decisions. A computational virtual platform can overcome such communicative gap between practitioners and laypersons. Previous collaboration methods have a stance on developing concepts in early design phase which can't demonstrate engagement with the details of physicality. Relatively detailed architectural models either physical or virtual can provide further collaboration between the professionals and the non-designer professionals or non-professional stakeholders (Steino, Bas Yildirum, & Özkar, 2013). Therefore, we are creating a platform which would provide real-time visual information on two different scales to bridge the gap between top-down and bottom-up approach with the help of virtual instrument.

3. Computer Codes on Urban Codes

The term "code" has a long history in the designing and realisation in architectural theory despite the fact that it has surfaced recently in the field of architectural theory. Urban Design Ontology (UDO) defines the set of investigation rules in the realm of the computational design approach. In general, ontology describes the concepts of a domain and defines the relations among them. Such domain comprises the specification for representing entities, classes, functions and relationships among components, which constitutes a knowledge-based boundary condition (Gennari et al., 2003). The production of ontologies provides a vocabulary for researchers to share information in the defined domain (Noy et al., 2001). Similarly, UDO concedes the idea of defining a domain of urban components (i.e. networks, blocks, zones & landmarks) and the relationship between them (Montenegro & Duarte, 2009). The essential characteristic of the ontological design system is the sharing of information. Montenegro and Duarte call this sharing the "shared knowledge" which promotes the integration of different urban rules as a recursive procedure under the same body of inquiry (Montenegro & Duarte, 2009). Such process reduces the ambiguities between different results. Our work addresses the term "ontology" as "investigation rules". Our research adopts the concept of urban design ontology to develop the investigation rules which are relevant to the attributes of urban forms.

4. Existing Decision Support Tools

Parametric Design along with BIM modelling system has already pushed architects to go for a new endeavour in building design. Such design method offers distinct advantages for engineering and manufacturing processes (Schnabel, 2007). BIM comprises an integrated system that aims to incorporate all aspects of design from geographical information, to building geometry, to the relationships between components and, to the quantities and detail properties of building components (Guarino, 1998; Montenegro & Duarte, 2009). CIM allows a holistic approach to deal urban design on a large scale scenario. However, commercial software instruments in city modelling (*Autodesk*, *McNeel*, *ESRI*, etc.) still not intuitive enough in switching scenarios to be performed well in a design charrette (Kunze, Dyllong, Halatsch, Waddell, & Schmitt, 2012).

Virtual, Augmented, Mixed (VAM) environment modelling allows novel ways to merge real-life situations with the virtual information in the field of Architecture, Engineering, and Construction (AEC) Industries. It has offered a variety of instruments to bridge the gap between the idea of a design and its way of representation, communication and realisation (Schnabel, 2009). VAM comprises a variety of realms from reality to virtuality which has already explored by design professions as useful interaction instruments (Milgram & Colquhoun, 1999). Recently researchers are trying to integrate simulation in virtual and augmented reality for architecture and urban design (Shimizu, Takei, Sato, Yabuki, & Motamedi, 2017). Moreover, an application like *CityViewAR* has already added a new dimension to visualising historical buildings through mobile devices (Lee, Dünser, Kim, & Billinghurst, 2012). As an example, Chen and Schnabel (2011) have explored collaborative urban design studio by using tangible interface as means for collaboration within Augmented Reality (AR) where participants can actively participate in the design process and can load library models into their scene.

5. The Methodology

The methodology indicates a linear approach of five steps to generate algorithmic urban codes for neighbourhood design (Figure 1). The steps are i) defining urban codes, ii) developing investigation rules, iii) mathematical algorithmic modelling, iv) developing a platform- an interface and v) evaluation. The output of every step feeds into the next step. The first step defines the contents of urban codes for a particular site (this study considers low-density suburb Karori, New Zeland and high-density suburb Tsim Sha Tsui (TST), Hong Kong). The second step configures algorithmic relationships between different urban elements which are to translate into the computation system. This step develops the investigation rules between different urban parameters (Schnabel, 2006). Our study adapts density rules as Floor Space Index (FSI), ground coverage in relation to building height and building width.The third step develops a mathematical-algorithmic integrated modelling platform as programming scripts on the sets of density rules to generate multiple urban scenarios. The fourth step produces an interface to visualise the iterative outcome. Finally, the fifth step validates the output by engaging stakeholders in a web-based application. During the design process, reflections and iterations define the design itself (Chen & Schnabel, 2011) and computation and engaging people can enhance the process. Therefore, our methodology gets internal feedback from the output of the computational simulation and external feedback from stakeholders.

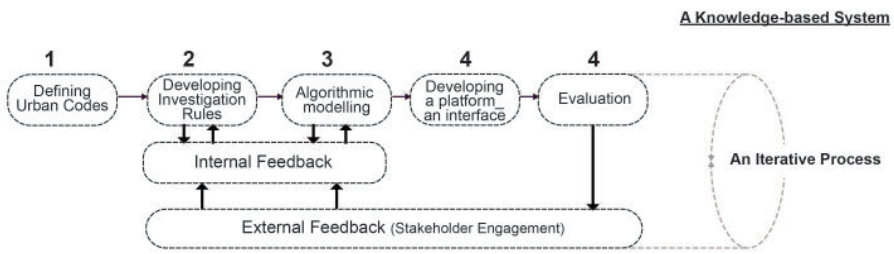

Figure 1. Research Framework .

5.1. STEP 1: DEFINING THE CONTENT OF URBAN CODES

This step defines different urban parameters. Urban components are associated with urban coding. The urban parameters posit an intricate lattice within themselves. At this moment, we consider the content of urban elements which are related to density criteria. This step can also consider other parameters like construction cost, energy, etc. The elements are listed from slowest rate of change to quickest rate of change. So far, our considered urban elements are:

- Open Spaces
- Subdivision of Lands in Blocks
- Plots/sections
- Subdivision of Plots

- Ground coverage
- Buildings height

The research addresses these content of codes to set the boundary of urban investigation rules.

5.2. STEP 2: DEVELOPING INVESTIGATION RULES

Step 2 tries to establish the operable relation between different urban elements. At this moment, we are adapting density rules and cost. So the rules are developed on the parameters related to density and construction cost per sqm. The density indicators like building height, floor area ratio, ground coverage, building width, etc are related to each other, changing one parameter will change the other. Parallel, these are related to construction cost, so for every single different input in density indicator will generate different urban forms along with construction cost for per sqm floor area.

5.3. STEP 3 : ALGORITHMIC MODELLING

This step translates the relationship of urban parameters in a computational platform as programming scripts to generate urban forms. The method is Object Oriented Parametric Modelling (OOPM). The script has written in a programming language like Grasshopper. The script has linked to the test sites by GIS or Open Street Map (OSM) generated vector maps. As we are examining Karori, NZ and TST, Hong Kong, so we have linked our scripts with the vector map of desired locations of Karori. The script also accommodates the information of the topography. The map is available in online and has sufficient information to meet the requirement for this investigation.

5.4. STEP 4 : DEVELOPING A PLATFORM- AN INTERFACE

Since beginning, the study is developing communicative Graphical User Interface (GUI). This interface offers a platform to operate and visualise multiple options of urban scenarios which are generated by various inputs. We are using Grasshopper for *Rhino* to generate real-time urban forms.

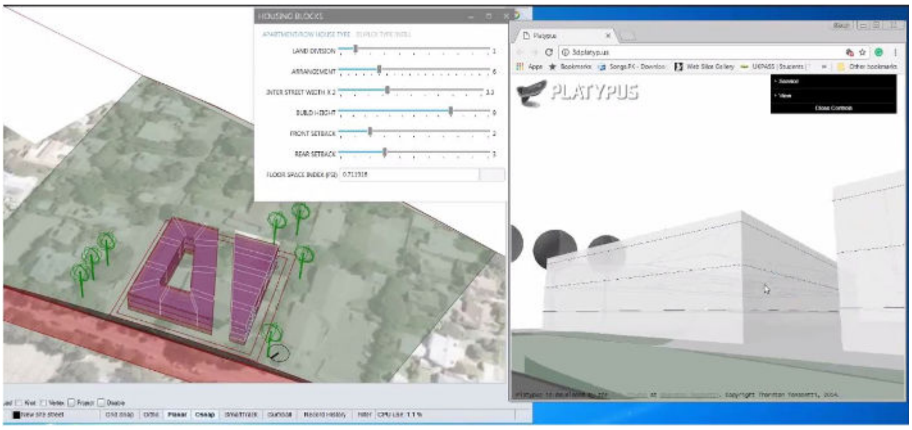

Figure 2. A GUI interface to generate housing types for Karori and visualise in online to get real-time feedback.

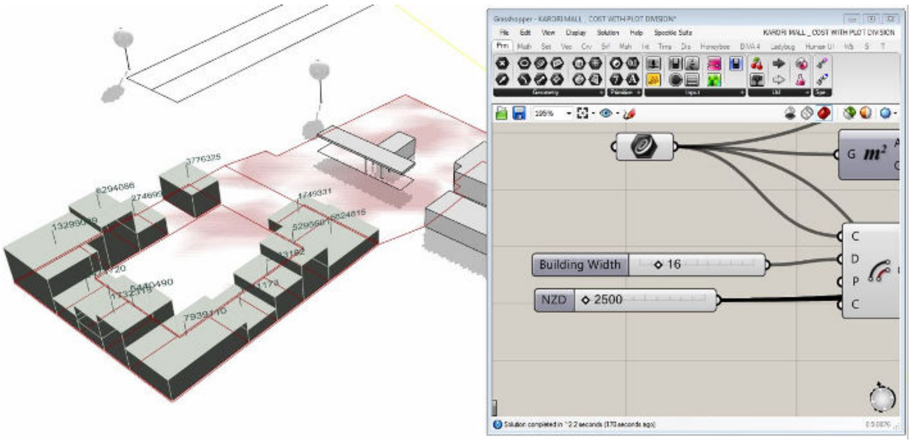

Figure 3. Visualizing Karori Mall with construction cost per square meter by changing the building width and height. The cost per unit also can be changeable as per as the requirement of the stakeholders.

We have developed several interfaces to visualise urban forms in online platforms. Figures 2 & 3 illustrate design platforms for Karori where a change in urban parameters in the interface provides a real-time output in online. Such online platform encourages distant collaboration between stakeholders. The parameters in the interface indicate the density values. The script has designed in such a way that the density indicators regarding plot ratio can generate new urban scenario for every single input in the sliders. The information on density helps stakeholders to decide which kind of urban forms they want to have for their neighbourhood. Recently we have developed another script to visualise urban forms with the information of construction cost and building energy for Karori

Mall (Figure 3). This platform offers to envision multiple urban forms for Kaori Mall precinct through online collaboration. Similarly, Figure 4 illustrates another platform for TST where the interface provides the information of multiple urban forms regarding plot ratio.

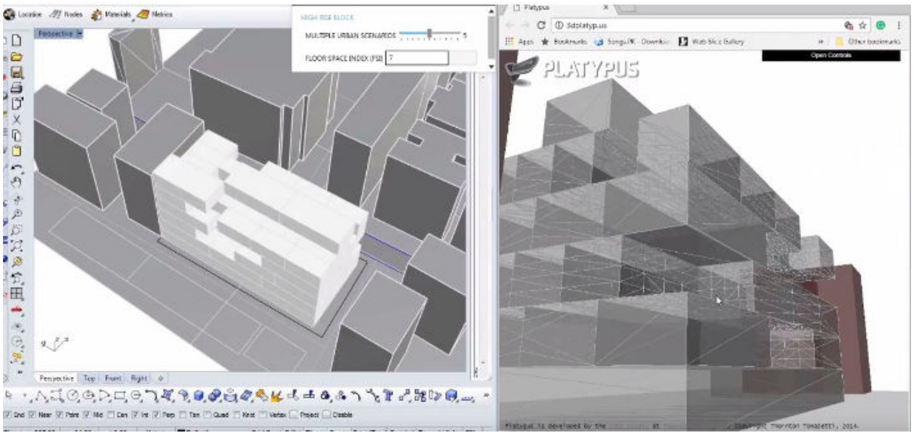

Figure 4. A GUI interface to generate building forms by manipulating Plot Ratio for TST and visualise in on-line to get real-time feedback.

5.5. STEP 5: EVALUATION

We already have developed a prototype for online collaboration by employing "Shapedriver" for *Grasshopper* (Figure 5). The whole interface has been exported from previously developed Grasshopper scripts to investigate density rules for Karori. The interface has options to get data logging by extracting certain generated output as "3DM" and also a screenshot.

Figure 5. An online collaboration platform to visualizing multiple scenarios of Karori Mall with construction cost per square meter.

The platform also ensures online collaboration through voice and message chat. Such collaborative real-time urban form generating platform enhance the level of design discussion. We are linking the system with *Unity 3D* to experience the urban iterations in an immersive VAM.

6. Discussion and Conclusion

Software like *CityEngine* deals with such procedural modelling but provides a limited interface for editing the regulation parameters without any analysis features (Bum Kim, Clayton, & Yan, 2011). Similarly, *CityCAD* does not offer programming interfaces that allow its extension (Gil, Almeida, & Duarte, 2011). In some extent, *ArcGIS* can work as a data editor and container of physical elements by using point, line, and polygon but demonstrate inaccuracy on the generated data. Compare to all of these tools; our proposed method shows more flexibility to cater multiple urban rules for urban professionals. However, further study requires validating the process in urban design charrettes.

The occupied challenges of digital technologies are as dialectic interfaces. Digital technologies are continually evolving to accommodate dialectic nature with reality which promotes innovative ways to interact with end users. A problematic issue for parametric design approach, in general, is that it never resolves all the parameters which are necessary for design. Urban professionals still need to elaborate most parts of the design in their mind. Another problem of parametric programs that they have been designed and attached with traditional workflow in alignment with process thinking not intuition. Hence, the operators of these systems have to anticipate the project directions beforehand to create geometry and to build the inter-relationships. According to Aish and Woodbury (2005), parametric modelling embraces unnecessary complexity with too much information on items. Additionally, the design decisions are usually made by an algorithmic process, not by the designer (Terzidis, 2006).

Urban planning and design always deal with complex issues of urban form. Throughout decades, urban professionals are working to engage end-users in their design process. But, most often all the participators aren't able to predict the urban form as they deal with such complex relation either a top-down process or a bottom-up process. This study bridges the scalability gap between these two design methods. The methodology embraces parametric design tools as well as online communication methods. We propose a robust computational urban design approach which can cater new design rules for different locations. That means, this platform offers urban professionals to create unique design rules between urban parameters and can produce and convey multiple design ideas to their clients. This study presents an interface where numerous urban parameters can be operated. So that, stakeholders can participate and select which kind of urban form they want to have for their neighbourhood. The value of the urban parameters defines the urban regulatory inputs where a change in one parameter affects the whole urban scenario. The generated outcome can visualise with relevant urban information to help the stakeholders to decide their desired urban form. Future steps would be to engage stakeholders in design decision-making charrettes with this instrument.

Acknowledgment

The research reported in this paper has been supported by grants from the New Zealand's National Science Challenge-Building Better Homes, Towns and Cities (BBHTC), Shaping Places: Future Neighbourhoods.

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