Abstract. Modern design of urban forms is venturing towards performative, site-specific architecture that are formed according to the attributes of its urban context. Parametric modelling techniques offer designers the ability to embed generative mechanisms into the design process to allow performance based design. This paper focuses on the development of a synthesis model that generates an Urban Form schema using computational design principles. The design system illustrates a rule-based systematic approach to urban form generation and is a precursor to the automatic exploration of urban forms based on design analytics and evaluation of urban metrics. The role of the architect begins to shift from the designer of objects to the designer of processes with urban planning following a trajectory of data-generated and contextual specific design.

Keywords. Parametric Modelling; Urban Modelling; Scripting; Urban Analysis.

1. Introduction

The design of modern urban forms is venturing towards performative, site-specific architecture that are formed according to the attributes of the urban context. A data-driven method of design is emerging where information regarding behavioural mannerisms and the urban context is embedded into modelling procedures and processes. Models are able to “reflect the complexity and dynamism of the systems with which they engage” (Barett et al. 2007). This evolution of urban type is directly associated with developments in Parametric tools as they permit the collection, storing and processing of vast amounts of data.

Parametric modelling provides the opportunity to automate the design process and quickly produce thousands of design forms that vary in spatial character. With scripting, designers have the ability to generate and select the most architecturally fit design outcome out of an extensive range of data-embedded, digitally generated alternates. Within this context, it is possible to pursue an evolutionary approach to urban design founded on the optimisation of design characteristics. An informal
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urbanisation (Verebes 2014, pp. 17) is proposed where urban planning and the creation of urban space is developed according to “population thinking as opposed to typological thinking” (Verebes 2014, pp. 17). The result, is customised, site-specific architecture where the design embeds, and is a reaction to, the attributes of its surrounding urban context.

This paper presents the construction of a conceptual model that generates an abstraction of Urban Form using computational design principles. The model consists of a series of interrelated components that represent urban features including the Site, Transportation Network, Blocks, Plots, Buildings and Public Spaces. Each integrated component is reliant on the data gathered from its connected modules, with each module being a direct outcome of its linked predecessors.

2. Design System

Parametric modelling techniques offer designers the ability to embed generative mechanisms into the design process which result in a multitude of solutions that need to be assessed. Alfaris (2009) presents a framework for a multidisciplinary design system that describes how to decompose, formulate, model, integrate and explore designs computationally. A major aspect of this framework lies in the modelling phase which can be broken down into Synthesis, Analysis, Evaluation and Optimisation models. To produce a performative design system, a designer must be able to produce a synthesis model that outputs solutions. These solutions must be analysed, evaluated and optimised. Whilst each of these models are critical in the system, this paper focuses on the development of a synthesis model for generating urban forms, as the latter models are reliant on the initial synthesis model. A synthesis model abstracts design intentions into a collection of design parameters, rules or algorithms and can be constructed by parametric or algorithmic descriptions. This paper presents a synthesis model based on a design schema (Frazer 2001) that describes an urban form as a related network of design elements, namely Precincts, Road Network, Blocks, Plots and Buildings. The following section describes each element in more detail.

3. Urban Form System

The synthesis model described below demonstrates the generation of an Urban Form founded on a specific set of input data. The model is illustrated through a prototype tool that has been scripted in Python and visualised in Rhinoceros 3D to graphically illustrate an instance of a generated urban city block. The following components form the system.

3.1. PRECINCT

The precinct is the initial input driver for the system and defines the boundary of the urban site. It is represented by a 2D polygon and the initial shape and dimensions of the precinct have design implications for the next components. As part of the precinct definition, the designer can also specify global parameters about the design, including the number of road divisions, ratio of built environment to
parkland and range of building heights. The precinct is stored in the system and made available as an input to the Road Network module.

3.2. ROAD NETWORK

The Road Network is generated by firstly choosing an initial starting point along the Site Boundary. A line is drawn in the Normal direction from the original point and extended to the boundary line on the opposing side. An iterative process continues whereas each generated line is subdivided at a random point, with new perpendicular lines generated and extended until an obstacle is hit. This process is repeated until the number of iterations specified by the Precinct is complete (figure 1). The length of each projected line is maximised by the distance required to reach the closest obstacle. At each iteration, the linework is categorized as Primary, Secondary and Tertiary Road Segments. The result, is a network system that contains road segments of varying types.

Extending this notion further, an Offset tool is implemented where each road segment is offset by a specified amount according to the type of road. This offset amount can be varied manually by the user and results in Primary, Secondary and Tertiary Road networks with progressively smaller road widths (figure 2).

3.3. BLOCKS

The next module, Blocks, is derived directly from the Road Network. The Road Network segments are used to split the Site Boundary area into a series of street Blocks. As the road widths are automatically generated using the offset function described earlier, the blocks are created taking into account the physical space of the road network (figure 3). The Block sizes are determined and limited to the space remaining between each road segment. The size of each block can be determined by the initial user-defined percentage input into the system as the user is able to define the number of road divisions and ratio of built environment to parkland and can ultimately gain control over the range of block typologies. The individual blocks provide information on the size of each block, their location, surrounding road network, proximity to one another and so on. The benefit of this is that this data can be used to determine the function and use of each block. For example, blocks that are long and thin could be split to create smaller roads between the two longer edges.
3.4. PLOTS

With the blocks now constructed, they can be subdivided into a series of plots. The strategy for subdivision is determined by the type of block, the dimensions and available area. The blocks are split into three categories: Parks, Residential and Commercial. Based on the type of block, it is subdivided into a series of smaller plots to host a variety of building forms. The designer is able to define a specific percentage of blocks they wish to be residential and commercial as well as the maximum and minimum heights they require for each building. This is achieved by firstly assessing the width and depth dimensions of each block. If deep enough within the constraints of the block type, the block can be split using a centre line through the mid-point of the smaller side of the block. This centre line is then divided into equal spacing and lines are drawn from each divided point in the direction of the normal to the opposing boundary line to form plots. Variations in the block subdivisions can be seen in figure 4. Variations in the park to building form can also be seen in figure 5.
Figure 3. Splitting of Blocks using Road Network.

Figure 4. Plot Subdivision.
3.5. BUILDINGS

The system now contains individual plots, an area-driven offset tool, and a parameter to determine the minimum and maximum height of each building. These parameters are able to be varied by adjusting a number in the Python script. By changing the number range of the parameters, the user is easily able to manipulate the size, shape and overall form of each design variation outputted from the system. In this design system, the buildings are represented as simple extruded masses to give an indication of the urban character (figure 6). As this is an independent module in the system, it can be refined and enhanced to produce more detailed generated building forms in future research. At a later stage, a Grasshopper component could be implemented into the system to improve the accessibility of the project parameters for the user. Rather than manipulating the parameters through a Python script, they can be represented as a plugin in Rhinoceros in a manner that visualises the variables simply.
4. Implications for Urban Design

The design system illustrates a method for generating complex urban networks through a parametric approach based on a series of rules and parameters. It proposes a “clear rule-based systematic approach to form generation” (Knapp 2014, pp. 42) and therefore possesses the ability to automate the design process by quickly generating forms founded on urban design schema and user input. Each element of the Urban Design system is separated as an individual component and therefore begins to break down the current perception of urban form. As a result, users have the option to accurately design each aspect of the Urban Form system separately. Each component relies on its predecessor for information and input data and therefore the overall form is founded on the combined data of each individual component. The role of the architect begins to shift from the “designer of objects to the designer of processes” (Knapp 2014, pp. 42) with urban planning following a trajectory of data-generated and contextual specific design. Each element of the design system is modularised and is open to development and variation in design logic. The result of the Urban Generator system is evident as even within a single design schema, a multitude of design options can be generated by modifying the input parameters (figure 7).

It becomes evident that computational design techniques offer new methods to “reflect the complexity and dynamism of the systems with which they engage” (Barnett et al. 2007). These revised methods permit the profession to extend their design capabilities by offering a new medium to present building information that is “characterised by dynamic change” (Belesky et al. 2015, pp 196). With the development of this synthesis model and the flexibility it offers in designing the conditions required to generate urban form, it becomes possible to review and manipulate concept designs at an early stage of production. The parametric model permits the simulation of a range of dynamic building forms that emulate a variety of urban design scenarios. The benefit, is that it reduces the amount of time taken to form, document and analyse each concept design. Using this system, the design process can be improved as it allows the assessment of a greater set of design options in a short amount of time. Improvements to design concepts are palpable as generated forms are now created off user and contextual-based data using this parametric system. Urban design data that has previously been difficult to obtain and implement into a design is now available and easily integrated into concept designs, giving designers the ability to test, assess and generate numerous contextually-relevant forms.

In addition to this, further urban design forms can now be generated using analysis, evaluation, and optimisation modelling. Architects and designers gain access to rigorously test urban design options without the burden of having to represent and manually model each individual design. The use of automation is therefore favoured as it “significantly accelerates the design process by front-loading key design decisions about composition and performance, while also significantly reducing the effort required to represent the resulting decisions” (Belesky et al. 2015, pp 199).
5. Future Work

Further research would involve exploring and developing related urban design models and using the associated data to enhance and complete the performance design system. Creating analytical models would allow data and associated metrics to be extracted and stored in a database that can be assessed in a larger context. The type of data metrics available would include common metrics such as FSR, Building Heights, Population, Density, Size and Public Space areas amongst others. This would then allow for evaluation and optimisation models to be constructed, facilitating an iterative, performative process that results in an array of urban forms. The design space gains flexibility and is easily manipulated. Following this, designers are able to pursue an alternative role in the architectural field. Rather than focusing their time and efforts on manually testing design iterations, the automated process associated with parametric design allows them to focus on design optimization and performance.
6. Conclusion

It becomes evident that data driven methods of design are shifting the field of architecture from that of repetitive building techniques to performance-driven design where data is able to be extracted from digital models and implemented both as an analytical tool and as a method for evaluating architectural designs. Digital design becomes a form-finding process where evaluative criteria drives the design process itself. The benefit of this, is that each simulation is able to be tailored to its surrounding urban parameters such as existing plots, road layouts, streets and so on. The design system demonstrated in this paper is an example of how urban form can be generated with its data extracted and used further to create performative architecture. Having the ability to generate vast amounts of urban forms through computational design techniques offers an advantage to the architectural field as designers are able to focus on assessing and evaluating their designs rather than performing monotonous modelling tasks.

References


