PARAMETRIC URBAN DESIGN EXPLORATION
IN A GRADUATE DESIGN STUDIO

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Abstract. A city is a typical complex system that composed of billions of individual factors that interact with each other, and evolve dynamically. Parametric design method considers design conditions as the parameters of form generation, and introduces bottom-up emergent process in computers into architectural design. Because of such mechanism, it is supposed that parametric design can be applied in urban design problems, and brings rationality and creativity into urban design. In the year 2011, a joint design studio of Princeton university, Tokyo University and Tsinghua University is carried out. Graduate students from the three universities dive into the design of a micro-city that expands from Haneda airport in Tokyo bay area. The design studio in Tsinghua lasts for 16 weeks, and the students are asked to develop their ideas in a parametric way, and explore the potential of bottom-up generation of urban design using computer tools.

Keywords. Parametric urban design; Haneda airport; complex system; urban form generation.

1. Urban space as a complex system

Modern city is a combination of natural system and artificial system, and is a gray system in which the information is partially clear and partially unknown. An urban system is composed of biological system, infrastructural system, economical system, social system, etc., and each subsystem is composed of smaller subsystems, even basic elements. Some statistical results show that the amount of elements in a city accounts for the amount of at least 10^8. A city is a system with complex structure and diverse functions, it is located in a macro complex environment, and evolves dynamically in the continuous process of exchanges of materials, energy and information (Pei 1999). It could be
said that a city is a complex system which composed of numerous individual elements that interact with each other. The local interactivities finally result in a dynamic development of the whole system (Wu and Li 2010). During the evolving of a city, this kind of bottom-up self-organisational process is combined with the top-down urban planning process, and these two processes decides together the urban form and its development.

Parametric architectural design method is based on the contemporary development of computer technologies, and is greatly influenced by the theory of complex system and non-linear science (Xu 2009), this makes parametric design a method adaptive and of great potential in dealing with planning and design problems of the urban system.

Schumacher (2008) proposed the concept of parametric urbanism, and applied it in his research and teaching. The assumption is that the urban massing describes a swarm-formation of many buildings. These buildings form a continuously changing field, whereby lawful continuities cohere this manifold of buildings. Parametric urbanism implies that the systematic modulation of the buildings’ morphologies produces powerful urban effects and facilitates field orientation. Schumacher point out that modernism was founded on the concept of space. Parametricism differentiates fields. Within fields only the global and regional field qualities matter: biases, drifts, gradients, and perhaps even conspicuous singularities like radiating centres. Deformation does no longer spell the breakdown of order but the lawful inscription of information. Orientation in a complex, lawfully differentiated field affords navigation along vectors of transformation.

Leach (2009) considers that city is composed of a large number of smaller discrete elements, and displays a bottom-up collective intelligence that is more sophisticated than the behaviour of its parts. In short, the city operates through a form of ‘swarm intelligence’. He points out that the term itself does not necessarily refer to contemporary design issues. On the contrary, it could be argued that emergence could be viewed most clearly in traditional urban formations. Leach points out that the term ‘swarm urbanism’ has been used fairly extensively within design circles, and he explains the concept of swarm urbanism though introduction of the bottom-up multi-agent generative design of Kokkugia. In this paper, graduate students’ works in an urban design studio in Tsinghua University, which is part of an international joint design studio, is introduced. In this studio the concept of complex system is introduced to the students. And the students are encouraged to explore possibilities of bottom-up generative urban design method using computer tools. Three of the student works are selected here which show a variety of exploration of possible bottom-up urban design strategies.
2. The Haneda Micro-City urban design

In the spring of 2011, a joint design studio of Princeton University, Tokyo University and Tsinghua University is carried out. The theme of the studio, proposed by Princeton, is Haneda micro-city design, which intends to study the urban space form related to modern international terminals in the context of Tokyo bay area. Since the design objective is more an open research topic, studios of different universities are able to explore design strategies according to their own understanding and interests.

In the past 30 years, Narita Airport has been considered the central hub connecting East Asia. But Narita is far away from Tokyo, an obsolete facility that is expected to be replaced by a new hub. In response to these pressures a new international terminal was completed at Haneda which, benefits from its proximity to the metropolitan centre and access to high-speed rail. The federal and local governments however, recognise that the new terminal is only a partial solution to the problem. They are striving to create an attractor for international travellers as a way of re-centring Japan in the new Asia. Metropolitan planning initiatives have recognised the importance of developing a new urban centre in proximity to Haneda. The intension of the design studio is to discuss the possibility of such urban centre.

During the early stage of the studio, the students are required to study the ideal urban design theories, such as Garden City, Archigram, etc., also including the Tokyo bay project of Kenzo Tange. Tange’s urban planning project in Tokyo bay has a far-reaching influence on the development of this area, including multiple aspects related to urban planning. This kind of study becomes one of the important start points of the students’ designs.

On the other hand, the students are encouraged to explore possible bottom up generative design strategies using parametric design tools. It is expected that computer could be employed in the simulation of self-organisational development of basic urban elements, which can result in urban design that is adaptive to the functional requirement and the law of development of urban space. As mentioned above, parametric design method has great potential in dealing with large amount of urban elements that interacts with each other. In this design studio, it is also expect to explore possibilities of parametric design methods for urban design in this kind of research through design (Herr et al. 2011).

3. Student works

The design studio in Tsinghua lasts for 16 weeks, and 10 graduate students are divided into 5 groups. Parametric methods and computer tools are used extensively in most groups, and at the end, the design results display new
exploratory organisation and possible urban structure of future cities. Some of the students’ works are introduced below.

3.1. FLOATING AGGREGATION – JELLYFISH CITY

A lot of historical cities grow up in a bottom-up way without planning, but finally resulted in a good city form. The design here uses the method of diffuse limited aggregation (DLA) to simulate such an evolutionary process in which a small village grows into a huge urban complexity. DLA is the process whereby particles undergoing a random walk due to Brownian motion cluster together to form aggregates of such particles (“Diffusion-limited aggregation” 2011). It is supposed that a village in the sea can be initiated by random aggregation of small boat houses. When the village expends, and as the density of its centre area gets higher, permanent multi-floor buildings emerge (Figure 1). In the final design, an aggregation of high rise buildings was located in the centre area of the city, and a branching road system extends to the periphery area, where floating boat houses dock and become part of the city (Figure 2).

![Figure 1. The city form generation using DLA.](image1.png)

![Figure 2. Bird view of Jellyfish City design.](image2.png)
Since this kind of aggregation mechanism is developed based on understanding of bottom-up growth of historical cities, the result turns out to be organic and dynamic. On the other hand, the DLA has generated a road network which is too complex, and not so efficient for a modern city. Future research may discuss how to develop DLA into a method that can generate better form of a modern city.

On the other hand, through study of jellyfish, a self-sufficient living model is found. By reaching out its tentacles, jellyfish obtains energy from the sea that support its metabolism. The city is also considered as a living organism that obtains energy such as tidal energy, temperature-difference energy, salinity gradient energy, wind energy, etc., from its environment. Hair system in Autodesk Maya is used to generate a road and utility tunnel system that reaches out into the sea (Figure 3).

![Figure 3. The road and utility tunnel system generated by hair system of Maya.](image)

3.2. FUJI MOUNTAIN IN THE SEA

The discussion of ideal city could not only refer to the future. One can also go to the history, and get idea from traditional images.

Through study of the painting Fugaku Sanjūroku-kei by Katsushika Hokusai, it is found that the scenery of Fuji mountain is of great importance for the area of Tokyo bay. Because of this, the form of fuji mountain is selected as the prototype, and a scattered distribution of this prototype is used in the urban design, in order to rethink the contemporary land reclamation activities.

Computer simulation is used to generate an optimised scattered distribution of units. Three basic megastructure units of different scale are considered: scale of living block (diameter 200 m), scale of a business zone (diameter 400 m), and scale of urban complex (diameter 800 m). Possible distribution of these three types of units with hierarchical relationships are generated using com-
puter programs, and the ones adapt to sailing route are selected (Figure 4). On the other hand, illuminated by the wool thread experiment of Frei Otto, a rhino script program is written to simulate the evolving process of deformation of wool thread, and generate organic road network for the design (Figure 5).

![Figure 4. Generation of distribution of 3 types of megastructure units.](image)

In order to introduce natural light and open space to the megastructures, a minimum surface system is used to split each megastructure into functional space and void space (Figure 6), which gives the megastructure a more complex and organic form that contains multiple functions.

In this design, the parametric design methods can be used not only to organise urban functional spaces in an emergent way, but also used to generate beauty with regularities, such as the water wave like forms in this design. This kind of design concept is not a generated in a bottom-up way, but rather constructed in the student’s mind. This project demonstrates that the aesthetics of a parametric design can be decided by the architects based on their understanding of generation and aggregation logics of algorithm.

![Figure 5. The road network generation (left) and layers of the urban design (right).](image)
3.3. BRIDGE CITY

In order to solve the problem of severe damage on environment and ecosystem caused by land reclamation, and deal with the confliction of city and nature, a new model of city and nature is designed, which is, to hang the city above nature. The idea of the design is to build towers with the height of hundreds of meters, which hold up gigantic cable network in the sky, and hang buildings beneath it to form urban clusters above nature (Figure 7).

An urban development axis is selected which is the same as the Kenzo Tange Tokyo bay project, and the city grows along the axis from west to east. A Voronoi grid is used to generate the urban blocks. The grid is denser in the middle area and more spacious on the sides because the vertical density in the city centre is higher, which is heavier for the cable network, and heavier in traffic, so the grid is made denser to deal with this problem (Figure 8).
In the final design, forest and sea level are preserved as the original state. On the top of the bridge city, a green public space is formed. The great holes allow sun light to get to the city, and the nature beneath it.
Since the function distribution in each block is different, which gives different load distributions to the above cable networks, physical structural experiment of cable network is carried out as a way of form finding for urban blocks based on gravity (Figure 9). A traffic system is placed at the bottom of the hanging buildings, which provides tension forces, and makes the whole system stable (Figure 11).

4. Conclusion

The exploration of application of parametric design method in urban design is still at its early age. In the three postgraduate students’ works shown in this paper, different computational or physical methods are used to organise urban elements in a bottom-up way. Since the students have constructed their logic based on rational understanding of urban design problems, urban forms generated through these self-organisational methods are more organic, dynamic, and more rational in certain aspects. At the same time, although the tutors emphasised only bottom-up design strategies in this studio, the students all choose certain top-down strategy to control the general form. This may because that the graduate students have a better mastery of design techniques, and would employ such techniques in the design process in a very natural way. The top-down strategy plays an important role in controlling and selecting the bottom-up generation results, and in the development of the aesthetic performance of the design. In the end, the top-down and bottom-up design strategies become complementary in the designs.

It is expected in the studio the self-organisational generation in computer could lead to good city forms that are similar to the historical cities with very attractive urban spaces. But it is hard to say that the designs of this studio are efficient according to the requirement of a modern city. Further researches may explore the possibility of solving both the problem of space quality and efficiency at the same time by the method of self-organisational generation.

Notes

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