A Workflow of Data Integrating and Parametric Modelling in Urban Design Regulation

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Abstract: This paper presents a computer-aided workflow that supports data integration and parametric modelling in urban design regulation. The recent urban regulations are criticised regards the inefficient data exchange, ungearing across two-dimensional provisions and three-dimensional constructions, as well as unpredictable development results. Although various attempts have been made to utilise parametric design instruments in urban scale, most of them are only for modelling fast. This paper proposes a parametric methodology on algorithm platforms to offer a rational workflow for urban design regulating. The workflow includes three phases: (1) data integrating, (2) form-based regulation modelling, and (3) object-oriented regulation modelling. Rhinoceros 3D™, Grasshopper 3D™, and related plug-ins are employed as modelling and data analysing instruments. The proposed workflow is examined and evaluated through experimenting with real-world contexts. This paper further demonstrates that parametric methodologies provide a high-quality contribution to decision-making and urban regulating in next 50 years.

Keywords: Data integrating; parametric modelling; workflow; urban design regulation.

1. Introduction

An urban design regulation is to create design standards, codes or guidelines to specific districts for ensuring urban space quality and site development. Various types of urban regulations have been created upon particular concern with various strategies, but zoning has played a significant role in shaping the built environment (Kim, 2014). Among numerous zoning types, the representative and distinctive zoning approaches are Euclidean, Performance, Incentive, and Form-Based (Barnett, 2011). Euclidean and Form-Based zoning are broadly utilised in contemporary urban planning and design.

Critiques on zoning and urban design regulations are broad. One is the inefficient data exchange from designing process perspective. The regulating plan is one of the essential files in both Euclidean and Form-Based zoning. For formatting the regulating plan, the planning team consists of urban planners and architects creates zoning maps with the spatial and geography data from Geographic Information System (GIS); the regulating team provides text-based regulations; the construction companies and engineers require CAD files. Data exchange has become a problem because of the various requirements and
extended the working process. Another critique is ungearing across two-dimensional provisions and three-dimensional constructions from practising perspective. The urban design regulations are described commonly by using words, tables, and two-dimensional figures. It is queried that the paper files simplified the urban morphology control and hardly regulate the construction of the whole urban site. Besides, the current urban regulations cannot offer directly visualised outcomes which easily lead to unpredictable development results. The benefit to visualise urban regulation is supplementing the word-based codes and reducing misunderstanding.

This paper hypothesises that parametric methodologies and algorithm platforms can provide a high-quality contribution to urban design regulation. Computer-based urban modelling enables urban design stakeholders to describe existing urban future developments, in large part replacing the conventional use of drawing and physical models (Brail, 2008). The capabilities of computer-aided tools have been applied broadly in architecture, engineering, and construction (AEC) industry, while, their application of urban regulation is still in infancy. This paper explores the workflow of data integrating and parametric modelling in urban-scale regulation.

The workflow consists of three phases. The first is data integrating. Spatial and attribute data are the essential materials. Elk, a plug-in of Grasshopper, works as the tool to integrate geography information by connecting with .osm format maps. It provides more accurate feature types than GIS like land use, building, transportation and subtypes like busway, walkways, etc. The second is form-based regulation modelling. A series of transect types and subtypes are addressed to generate the transect matrix of Form-Based Code. This research utilises Rhino and Grasshopper as modelling platform to visualise the form-based provisions in the urban scale. The third is object-oriented regulation modelling. We extend the urban design regulation into micro scale. Galapagos provides a generic tool to apply evolutionary algorithms for object-oriented modelling in microscale regulation.

We experiment Tsim Sha Tsui (TST) region of Hong Kong to examine the methodology and workflow. The motivations of choosing TST as the context are: (1) density should be highly considered in the urban regulation process; (2) mixed use of land-hungry metropolitan regions prompts the urban regulation transformation from figure-based to model-based. In Death and Life of Great American Cities, Jacobs identified the city as complex layers and proposed four generators of diversity including mixed uses; walkable block size; variety of building age and condition; and higher density (Jacobs, 1961). Hong Kong is a typical place to meet the diversity standards of Jacobs and well-placed for test the parametric planning methods. The experiment results are a workflow framework of parametric regulation of TST region and examples of provision model in different scales.

2. Background: Parametric Urbanism and Smart City

Since the beginning of the first experiments of using parametric tools in architecture design process, it has become clear that these tools could bring similar benefits to urban design projects, having even effectiveness in higher scale urban cases (Nagy, 2009). With parametric urbanism, the design of solution is no longer conducted by axial forces or position of urban objects, but is guided by the distribution of densities of constructed urban fabric, by the sensitivity to deformations along the territory or by the development of compositional gradients, understanding space individualities that define the city (Pinto, et al., 2013).

Parametric Urbanism is of great interest for reasons that are both technical and theoretical (Ryan, 2013). One representative example of Parametric Urbanism is Thames Gateway Project by Zaha Hadid
and Patrik Schumacher. Digital design instruments worked in the project for presenting differentiated form patterns and exhibiting diverse scenarios. The parameterisation adopted in urbanism provides a novel method to create dynamic and interconnected built environment. Computer-based tools have been consistently produced to support the increasing parametric urban design ideas. For instance, SOM proposed Parametric Urban Design as a theoretical framework and created Blackbox Studio as a software prototype (Kim, 2014). Users can model buildings and blocks with the Blackbox Studio through the lens of parameters.

Parametric Urbanism contributes to making and remaking a Smart City. The concept of Smart City is often thought of as the utilisation of networked infrastructure to improve both economic and political efficiency and to enable social, cultural, and urban development (Hollands, 2008). Parameterization work as a methodology to integrate physical data and merge the data into Smart City information system. As Toppeta (2010) argues, a smart city is a place where information and communications technology (ICT) and Web 2.0 technology are combined with other administrative, design and planning efforts to speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, improving sustainability and livability.

In the aspect of place shaping, parametric urban design regulation is an alternative approach for Parametric Urbanism and Smart City generation. It is proposed that by building spatial databases of urban performance and analysing the patterns within these databases using simulation, it should be possible to provide service planners and government authorities with timely information to guide the planning process (Batty, 2012; Oliveria et al., 2015). Although many attempts have been conducted to apply parametric concepts into urban design, very limited research and projects are about regulation simulating. In this research, we aim to fill this gap and explore the interrelationships across parametric methodology and urban design regulation.

### 3. Methodology

In this section, we analyse the methodology. It consists of three phases, data integrating, form-based regulation modelling, and object-oriented regulation modelling (Figure 1). The result of data integration is a map of geography information on algorithm platform. Based on the information map of step one, step two is to generate a parametric regulation model in large scale. Step three is to model regulation in small scale.

![Figure 1: The research workflow and methodology framework.](image)
3.1. Data integrating

We utilise OSM data as the data resource and Elk the plug-in of Grasshopper as the data integrating platform. OSM and GIS are both common map data resources. GIS data has worked as the main database for tons of projects on the urban scale. In recent years, some scholars and designers doubt GIS’s capabilities in form-based urban planning and design. For instance, Kim and Clayton (2010) argue that many GIS data, such as parcel, road, and building footprint, may not be directly used in the urban design process due to the inaccuracy. The difficulty of regulation interpretation and the inaccuracy of GIS data converting process have been criticized (Kim and Clayton, 2010).

Compare with GIS, OSM data is more accurate in spatial forms of streets. Produced by UCL and Bytemark Co., OSM data can connect with Elk without exchanging data type in different regulation files. Elk organises and constructs collections of point and tag data so that people can begin creating curves and other Rhino/Grasshopper geometry (Logan, 2017).

3.2. Form-based regulation modelling

Form-based regulation, also called Form-Based Code (FBC), is used to substitute conventional land use-based regulations. As the main approach of New Urbanism, FBC has proven to prescribe the urban form, implement mixed-use development, and address place-based characteristics of sites (Ben-Joseph, 2005; Parolek et al., 2008; Kim and Clayton, 2010).

Algorithm methods work in parametric modelling for form-based regulation. The integration components of algorithm methods simplify the regulating process both in composition and review stages. By taking advantage of computer-aided instruments, urban codes become directly visualised models instead of paper-based text files. An efficient multiple-scenario review is possible through changing the parameter values. After retrieving the map data in the last phase, a form-based regulation model can be generated within Rhino and Grasshopper platforms. Two elements should be involved in this process. One is the transect matrix. FBC uses transect types and subtypes to hierarchize zones from natural to artificial. These transect types constitute the transect matrix of form-based regulation. The other is parameters. A series of parameters should be set to determine the urban and building forms in large-scale regulation modelling.

3.3. Object-oriented regulation modelling

In this phase, an object-oriented regulation model is assembled for microscale urban design. Conventional urban-scale regulation is insufficiently pitched at the small scales such as street-level open space, buildings’ façade, and front openings. Given the problem of discrepancy between urban design regulation files and street-level construction, we utilise evolutionary computing method to explore the parametric urban design regulation in microscale.

From the street-level perspective, the form of low buildings or accessory constructions of high buildings and pedestrian lanes/footprints are both essential design regulation points. The parameters of controlling buildings include height, width, ground floor ceiling, upper floors ceiling, and stories. These variables support parametric modelling on algorithm platforms. Galapagos of Grasshopper analyses the pedestrian lanes and footprints rationally. It provides a generic platform for the application of evolutionary algorithms to be used for regulating street buildings’ front opening and predicting people’s movement.
4. Experiment

We conduct an experiment in Hong Kong to indicate how to implement parametric urban design regulation in a working prototype of the algorithm platforms. TST area works as the research context for the empirical examination. This site located in the southern part of Kowloon Peninsula. Today TST is a major tourist hub and event venue of metropolitan Hong Kong (Zhang and Schnabel, 2016).

4.1. Phase 1: Data collection

The OSM map data source consists of a web-based user interface. We define the TST mapping area coordinates as N22.3078, S22.2925, W114.1641, and E114.1822 then receive a geography information database with manifold layers. The map data comprise four types: Standard, bicycle, transportation, and humanitarian. People can specify the data type as they want. In this research, we choose the standard map and import it into Elk and Grasshopper (Figure 2a).

The Location component of Elk pre-processes all node or point data from OSM file. Through connecting the Location to OSM Data component, there is a small menu to specify feature types (Figure 2b). It defaults to selecting Building, more types and subtypes like apartments, church, or commercial can be added or removed easily. The result of this phase is a geography information file of TST based on Grasshopper platform (Figure 2c).

4.2. Form-based model generation (urban-scale)

Before the generation of form-based models, two essential issues should be considered. One is the transect matrix; the other is the regulation parameter group. Naturalists use a concept called the “transect” to describe the characteristics of ecosystems and the transition from one ecosystem to another; Andres Duany has applied this concept to human settlements, and since about 2000 this idea
has permeated the thinking of new urbanists (Congress for the New Urbanism, 2016). A standard transect matrix of FBC consists of seven transect types including natural zone (T1), rural zone (T2), sub-urban zone (T3), general urban zone (T4), urban centre zone (T5), urban core zone (T6), and special districts (SD). As Zhang and Schnabel (2017) have pointed out, TST Hong Kong has only two transect types, natural zone (T1) and urban core zone (T6), because of the limited land and super high-density population. They extended the urban core zone (T6) with six sub-types from T6-1 to T6-6 to elaborate FBC in high-density performances.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table data</td>
<td>Depth 200’ max.</td>
</tr>
<tr>
<td></td>
<td>Width 150’ max.</td>
</tr>
<tr>
<td>Ground Floor Ceiling</td>
<td>17’ max.</td>
</tr>
<tr>
<td>Upper Floor(s) Ceiling</td>
<td>10’ max.</td>
</tr>
<tr>
<td>Storey</td>
<td>36 max.</td>
</tr>
<tr>
<td>Height to Eave/Parapet</td>
<td>367’ max.</td>
</tr>
</tbody>
</table>

A regulation parameter group is utilised to control the building units. The parameters are depth and width of building coverage, ground floor ceiling, upper floor(s) ceiling, building storeys, and height to eave or parapet (Figure 3a). The building coverage is defined in former phase. We get a base map of building coverage surfaces on Rhino platform by connecting the node data and adjusting the inaccurate points. This research uses T6-3 as a modelling sample (Table 1). We generate a group of building models and colour them for differentiating them with other transect subtypes (Figure 3bc). Urban design regulations become directly visualised to approach and gain insights about a predictable morphology simulation.

4.3. Phase 3: Object-oriented model generation (street-scale)

The elements influencing on street-scale urban design regulation are manifold, but there is a consensus among urban scholars that walkability is increasingly valued at street canyon and neighbourhood scale. As Southworth (2005) has presented, not only does pedestrian transportation reduce congestion and have
low environmental impact, it has social and recreational value. He argues that six criteria for the design of a successful pedestrian network: connectivity; linkage with other modes; fine-grained land use patterns; safety; quality of path; and path context (Southworth, 2005). In this phase, we explore an evolutionary process towards regulating walkable street atmosphere in TST.

Figure 4: The process of evolutionary computing.

The research context is a commercial neighbourhood for pedestrians of T6-6, TST. We designate nodes as the surrounded buildings’ front doors. The node numbers can be adjusted in the Count Component. Through processing Galapagos component group (Figure 4 left) of Grasshopper, the pedestrian’s activity path has been simulated. Figure 4 right is a solvers window of Galapagos. The yellow part represents the tolerance degree; the thinner the closer to the optimum solution. In the underneath part, the point and

Figure 5: A sample of motion simulation.
line figures represent the measures of variability; the numbers represent the tolerance values. Use a simulated scenario as an example (Figure 5). Pedestrian’s movement track shows as the dotted lines. Designers can locate the front doors based on the calculated results and set urban furniture along the predicted tracks.

5. Results and discussion

The research results consist of two aspects. One is a workflow of urban design regulating taking advantage of computer-based data integrating and parametric modelling. The other is an examination of this workflow in the real-world context TST Hong Kong. The workflow contains three phases:

- **Data integrating.** Elk, the plugin of Grasshopper, works as the working platform with the support of OSM map data resource. In this way, a relative accurate database is prepared for the urban regulation modelling process.

- **Form-based regulation modelling.** A series of parameters regulate the building unit forms instead of using land use provisions regulate block functions. Urban regulation is reformed from text-based to visualised and model-based.

- **Object-oriented regulation modelling.** A simulation model of pedestrians’ movement is explored towards a walkable urban environment at the street canyon and neighbourhood scale.

The practice in TST Hong Kong experimentally examines the proposed workflow. The parametric methods are used towards an efficient urban design regulation process both in macro and micro scale. The experiment steps are data collection; form-based model generation; and object-oriented mode generation.

Applying the parametric concepts to the approach of envisaging urban regulation of future cities changes the way to analyse, perceive, and express. Conventional urban zoning and regulation is land-use-based which must be expressed in a two-dimensional method. People cannot predict what an urban atmosphere looks like simply through texts, tables, and imagination figures. Model simulation is increasingly valued to offer up predictable and controllable regulation outcomes. Data integrating and parametric modelling make it possible to visualise directly building forms, public space, street canyon, and rational analysis individuals’ movement tracks. The computer-aided approaches can provide a high-quality contribution to urban regulation especially for the high-density environment.

From the perspective of working efficiency, the proposed workflow is proved to be more efficient than the current urban regulation. In the data collecting step, the existing data exchange process is criticised because of the various file formats and redundant departments. In this research, we assemble the regulating process on a unified platform. All steps can be completed through Rhino and Grasshopper. A group of designers can conduct regulation workflow from data collection to provisions modelling.

The case study is used to describe how to merge the regulation workflow in high-density cities. By conceptualising the TST area as a dynamic system, two transect types and six subtypes intervene the zoning approach for change and reconfigure the whole morphology structure. For next 50 years, we argue that high-density will be one of the main urban development trends. The parametric modelling workflow provides an alternative way to regulate the future city towards walkability and sustainability.
6. Conclusion

In this research, we demonstrate that applying parametric methodology within algorithm platforms has the positive potential for digital urban design regulation of future cities. The concept of parametric analysis has been proven broadly in AEC industry. There are however rare considerations of using this novel approach in the field of urban design regulation. We use an experiment to examine the parametric workflow in the urban regulation of Hong Kong. The experiment results consist of an efficient data integration process; a visualised form-based regulation model in urban scale and a movement simulation in street canyon scale. Combing form-based regulation with parametric tools encourages people to analyse urban space as a dynamic system and urban regulation a continuous workflow.

For further research, we recognise that the workflow of data integrating and parametric modelling may introduce new problems. For example, the zoning regulations are manifold in different contexts. The way to combine parametric methods and local zoning process is still not clear. Besides, the presented regulation framework is simplified urban planning procedure. In reality, urban regulating is a complex system relating to different departments and inter-discipline experts. This research argues an architect-led urban design regulation. The feasibility of the workflow still needs deeper discuss.

References


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