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Research on Automatic Generation Method of Urban Spatial Form Based on Parameter Translation——Taking the Planning of Suijiang New Town in Guangning County as an example

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Abstract. With the development and innovation of computer technology such as artificial intelligence, traditional urban design has an opportunity to reform and innovate. This paper proposes a set of automatic urban spatial form generation design proceses based on the parameter translation, taking the design of the Suijiang New Town Project in Guangning County, Guangdong province as an example. For different parameter types, three design methods, which are morphological control of key factors, rule formulation of multi-agent, and iterative optimization of design mode are summarized and compared. The three design methods are applied in process of "data investigation, parameter translation, stepwise generation, and iterative optimization" based on the single static parameter, multiple static parameters, and multiple dynamic parameters respectively, and established a generation system for different design objects and design stage. Research provides a solution for the practical application of parametric design and lays a foundation for the future development of the parametric urban design.

Keywords:parameter translation; morphological control; multi-agent; iterative optimization; automatic generation

1. Introduction

With the continuous development of artificial intelligence, the application of computer in the field of design is no longer a simple drawing tool. Big data, artificial intelligence and other technologies have made breakthroughs in urban scale computational design. The intelligence and computational performance of parametric chemical can effectively help planners reduce and optimize the various processes of urban design. It is generally believed that the essence of parametric design lies in the formulation of parametric design logic. As a cluster state of buildings, the city has a large number of complex and regularly changing parameters in the continuous change area [1] formed by it, which is an important design reference for planners.

In China, scholars have done a lot of research on various indicators and parameters of cities. 18 li lh by applying GIS to study the building density parameters, found that Beijing has the "single center" model to "multi-center" development model [2], xiao-dong xu by integrated application of biological climate factor, natural factor and human factor, formed a set to adapt to different scales and different conditions of ecological urban design strategies and methods [3]. Sun Cheng proposed the intelligent optimization design theory of building green performance [4], and also introduced the neural style transfer technology to construct BST-CNN to control the generation of building form, providing an idea for the combination of weak artificial intelligence era and architectural design [5]. Xiong Lu made use of shape grammar theory and parameterization technology to propose a generation method suitable for the urban form of historic blocks [6]. Liu Yubo's team conducted quantitative research on innovation space in European and American countries based on space syntax [7].

The urban density in developed countries is low and the degree of urbanization is high, so the selection of parameters in academia is more focused on the quality of cities (building clusters). MIT Senseable City Laboratory (MIT Senseable City Laboratory) uses the form of visual data to show the City intelligently and digitally, focusing on the influence of multiple parameters, such as sound

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and taxi driving path, on the urban form, function and overall quality [8]. Liu Yuezhong from Nanyang Technological University used the software platform of TensorFlow artificial intelligence system to output recommended urban design parameters in multiple iterations, providing requirements and guidance for subsequent design [9]. Kpfui, a collaboration between KPF and Google Sidewalks, allows the public to generate thousands of urban designs by entering various parameters such as street grid type, population, building height, and the number and distribution of green Spaces, The platform also assesses various performance criteria for outdoor comfort, energy efficiency, landscape, sunshine and pedestrian experience [10].

Although the academic circles have conducted in-depth studies on the relationship between parameters and cities, there are still the following problems in using various parameters to control urban form :(1) it is difficult to uniformly parameterize different types of data. (2) It is difficult to control the design ideas at different levels dynamically in real time. At the present stage, many parameterization methods tend to focus on a single level, such as Ge Dandong's parameterization design of rural road form [11], Chen Qiuxiao's research on parameterization modeling of urban road network [12], Liu Kai's research on generation of parameterization layout scheme of slab housing [13], and Chi Zhiwei's research on application of parameterization in landscape [14]. (3) It is difficult for various frontier theories to play a role in design practice. Xu Weiguo explored the combination of parameterization and internal geometric relations of organisms in his book Digital Illustration of Biological Morphology [15], and Zaha automatically generated new city roads through wool algorithm and other methods in the design of Istanbul New City in 2010 [16]. But these achievements are difficult to apply to practice.

2. Design idea of urban form generation based on parameter translation

According to the top-down design logic, this paper puts forward the design process of urban form generation based on the practical application of parameter translation, including data survey, parameter translation, step by step generation, and iterative optimization.

(1) Data survey: data collation from the designer and the design target. Mainly collect data for upper planning, design concept, regional characteristics, climate characteristics, etc.

(2) Parameter translation: Multiple types of parameters for data research in translation. The screened data, including road network structure, land use nature, resource load, plot indicators, etc., are translated into one or more forms of reference from graphics, 3D models, figures, texts, etc.

(3) Step by step generation: use variable parameters to step by step generate urban form. Parametric data are used as restriction conditions or generation conditions to generate through the road network, plot, node, and building.

Iterative optimization: Iterative optimization for the generated model. The urban form can be optimized by selecting factors such as sunshine, plot ratio, and shortest path according to the prerequisite conditions, plot attributes, and resource conditions of different levels.

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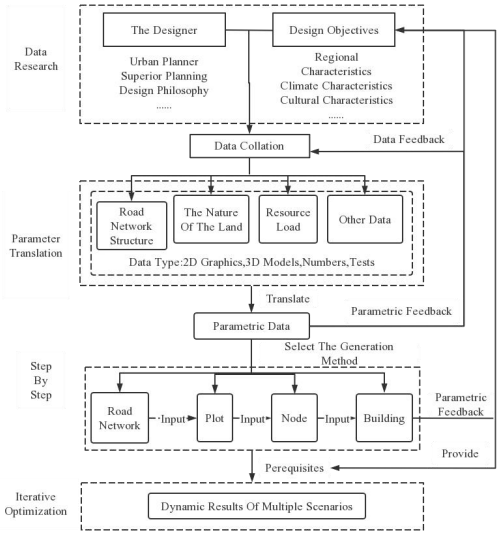

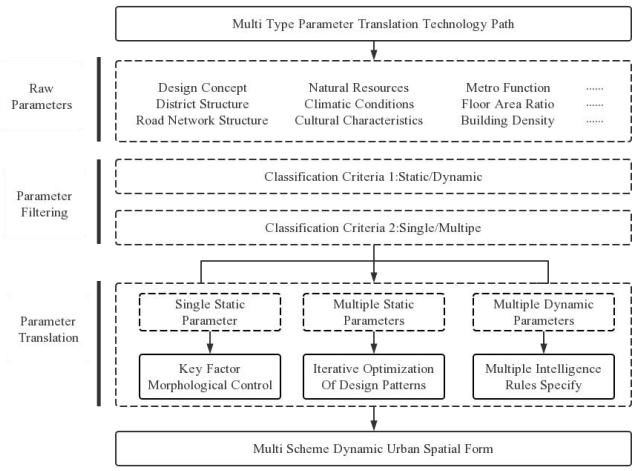

Figure 1. Design process of urban form generation based on parameter translation (left) (photo source: Zhang Kexin).

Figure 2. Path map of multi-type parameter translation technology (right) (photo source: Drawn by Zhang Kexin)

Based on the above, the design process, the research team for different proposes the corresponding design parameter types: the key factor to form control, multi-agent rules, design patterns, the iterative optimization, respectively for single type parameters inside, the connection between the multiple parameters of the same type, various types of dynamic contact parameters, to the actual land parcel to carry on the design practice. Three design methods three methods of the trinity, complement each other, from one-dimensional to multidimensional, from shallow to deep, from multiple levels of different types of data proposed design solutions, for the design of different stages of the parameter translation method has practical significance (see Figure 2).

3. Design practice of urban spatial form generation based on parameter translation of Guangning Ecological New Town

The site of this design practice is in Suijiang New Town, Guangning County, Guangdong Province, with a total planning area of 1961.45 hectares. The land in the area has various functions, including residential and commercial land, hotel land, new industrial land, etc. The area is rich in surrounding resources, with the Suijiang River to the south and the gentle slope of surrounding mountains, which is suitable for the targeted design. The area is rich in cultural deposits and is the "hometown of bamboo" and "Hometown of Martial arts" in China.

3.1 Morphological control of key factors

3.1.1 Design idea

The key factor to form the key factor of control refers to by choosing specific includes planning in all kinds of indicators such as volume rate, green area, building density, etc.), the design goal of all kinds of resources (such as natural resources, such as area terrain), representative of all kinds of ideas (such as space nodes, the line-of-sight propylaea, etc.), using the iterative optimization method to control form for the optimal solution of urban form.

In the design practice, researcher Lu Yunxuan determined landscape factors as the main control conditions. In the process of parameter translation, by analyzing water resources and mountain resources around the area, water catchment and sight corridor were selected as the main control factors, while building density, floor area ratio and development intensity were selected as the secondary control factors. Generate space for residential, commercial and office blocks (see Figure 3).

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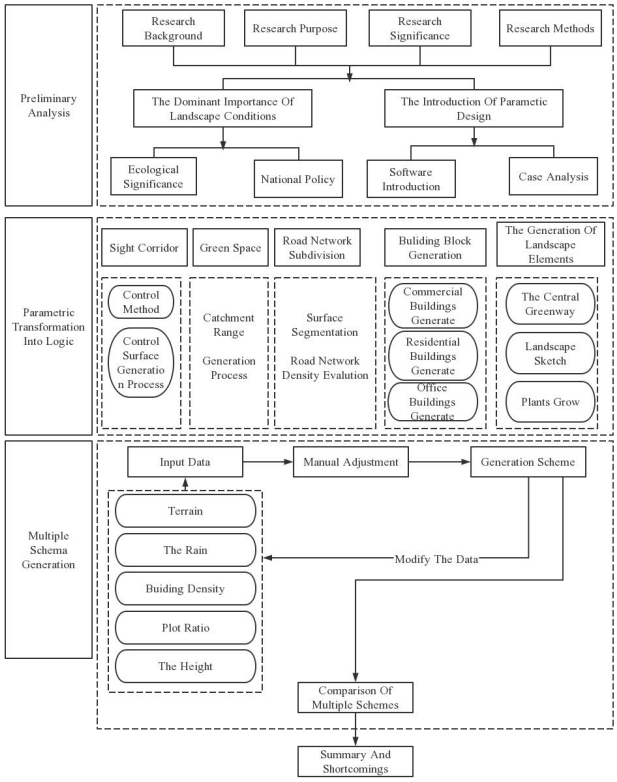

Figure 3. Design flow chart of urban spatial form generation under the control of landscape factors (picture source: Lu Yunxuan).

3.1.2 . Design Results

There are many tributaries of the water system around the area, so analysis of rainwater runoff and catchment measurement can be one of the important conditions of urban landscape space division. By simulating the trend of rainwater runoff, rainwater collection points are determined to generate landscape nodes, and axes and series of paths are generated around the landscape nodes.

To ensure that the view from the low point (the viewpoint of the high-speed railway station is selected as the view point), the west mountain landscape can appear in the range of vision, the study determined the following control factors: landmark building height should not be higher than the mountain; General building height should ensure that the mountain exposure is 20% or more; The height of buildings on both sides of the sight corridor formed by the high-speed railway station and the mountain ensures that the exposure of the mountain is at least two-thirds (see Figure 4).

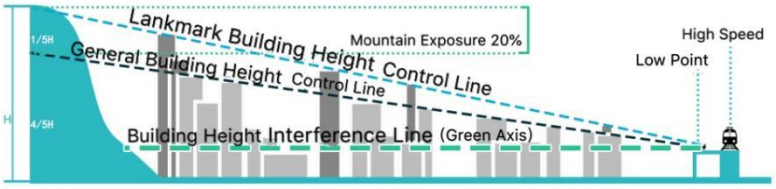

Figure 4. Urban spatial morphology based on sight corridor (picture source: Lu Yunxuan).

In grasshopper, the use of surface UV line of block division, in the plot area under the premise of meeting the specification, extraction, classification of UV line, and set different road grade and width, and get the block boundary and the property line, eventually make use of the building density, plot ratio as the main factor to interfere with the configuration, and generate multiple correlation plan (as shown in figure 5), Facilitate the designer to make the final decision.

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Figure 5. Comparison of multi-scheme urban design based on landscape factor generation (photo source: Lu Yunxuan.).

3.2 multi-agent rule making

3.2.1 Design Roadmap

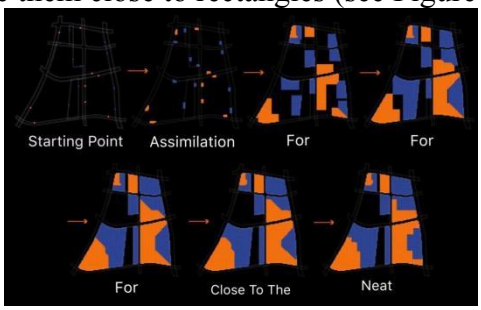
Multi-agent model is a model to simulate the macroscopic results of a complex system by defining the properties and behaviors of various objects in the system. Multi-agent rulemaking refers to the selection of appropriate objects, through the formulation of internal evolution rules between multiple parameters (such as cellular automata, BA model, etc.), to build specific rules of an urban complex system, and finally generate mixed urban spatial form. In the design practice, researcher Ziyi Wang selected cellular automata to construct an agent model and generate macroscopic results by evolving the attributes and behaviors of multiple plots.

3.2.2 Design Results

In general, the upper planning of the city only determines the general functional areas but does not divide the interior of the areas carefully. The selected area has mixed functions, including public, residential, idle, and other functions. The agent of "plot" and agent of "building" model is constructed. By griding the plot and simulating the process of different plots fighting for land, mixed urban land is generated.

The model includes three types of land use: public land, residential land, and idle land. The study divided each lot into minimum units of 12m by 12m to accommodate the general grid of roads, buildings, and land use. Each plot unit can be assigned a variety of attributes (that is, both administrative and public land).

By extracting the basic information about the surrounding environment, the model simulates the process of mutual coordination and competition between public land and residential land in the development process, to divide the land. The input ground map is divided into 90 *110 orthogonal grids of 12m*12m, which constitute the basic operation unit of cellular automata. The remaining idle land units will be assimilated into what kind of land according to the number of public and residential land units within the surrounding 8 grids. Under the condition that the proportion of public and residential land is guaranteed to be certain, the model revises the edges of all units to make them close to rectangles (see Figure 6).



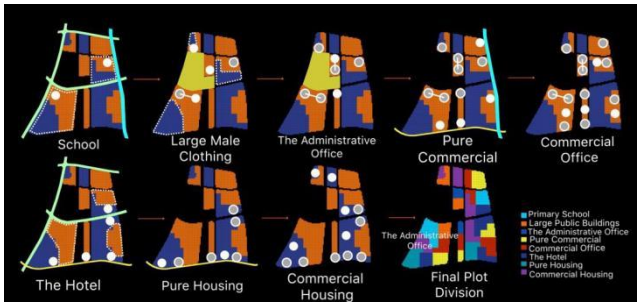


Figure 6. Steps of generating plot by agent model (left) (Image source: Yang Ziyi Drawing).
Figure 7.Final generation of plot results (right) (Photo source: Yang Ziyi drawing).

The plot unit changes the overall layout according to the state of other plot units in the neighborhood, and the form of the building is determined by the attributes of the plot unit it is located in. In addition to the mole the neighborhood and von Neumann neighborhood, which are common in cellular automata, the model also sets up many kinds of neighborhood to adapt to many

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changing rules. Compared with the original planning, regenerate after scheme, significantly increased the number of life centers, formed a purer commercial building around the school and life circle, broke the original layout depended, block greatly improve the function of the diversity, block mixed boundary proportion increased to 100%, almost every pair of internal boundaries into a mixed boundary, Increase opportunities for communication between blocks (Figure 7).

In this agent model, a reasonable program module is set up for the generation of the building block form of each functional block. Through the adjustment of two underlying logic, permutation and combination, set the input parameters such as the formation of 5 kinds of building blocks, corresponding to the eight different function block buildings generated by the rules, then through the public-private partition, the process variable plots for extract, using intelligent body model segmentation model of public-private plots, form different function block division, Finally, the road network is segmented and compromised (as shown in Figure 11) to generate the urban spatial form.

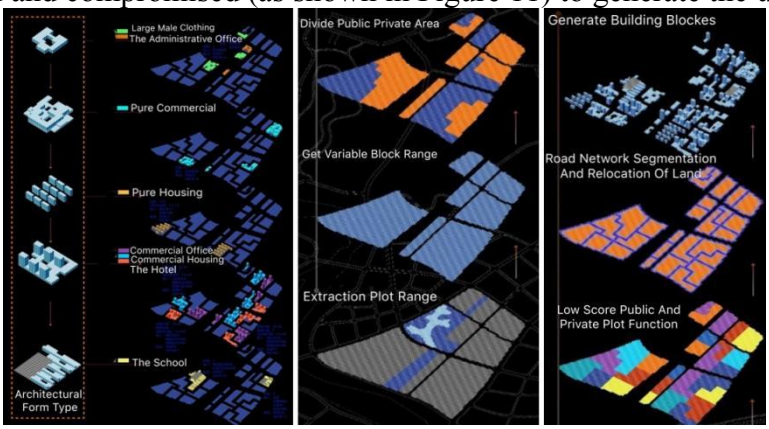

Figure 11. Building generation process of different functional blocks (photo source: Yang Ziyi painting).

3.3 Iterative optimization of design patterns

3.3.1 Design idea

The key factor to form control to solve the problem of single parameter control of the space form, simulation rules the result of the game between a variety of parameters, but the city as a complex system tends to have a one-to-many dependency between different parameters, the present abstract design pattern, the coupling between also known as the observer pattern. The observer mode effectively reduces the coupling relationship between the target and the observer, and the designer can select multiple parameters and use the observer mode to continuously iterate to generate the optimal spatial form of each parameter.

In the design practice, researcher Zhong Xiaoyang determined three indicators: plot ratio, relative building density, and relative publicity, which organically linked the plots and emphasized the dynamic connection between the plots, and finally obtained the maximum "relative plot ratio" of multiple plots.

3.3.2 Design Results

In general, the result of iterative optimization of multiple blocks is the largest set of the floor area ratio of each block, but the linkage between blocks is ignored. During the plot ratio iteration of each plot, other plots acted as observers. The researcher proposed a "relative plot ratio" (comprehensive consideration of plot ratio, building density, and publicity) to measure this dynamic model.

Among them, floor area ratio and building density are universal planning indexes. The public is defined as the public interface formed by the building block. As shown in Figure 13, when the base area (gray) of buildings in blocks A, B, and C are the same, the boundary lengths (solid yellow lines) of buildings and urban space are different by dividing the base. Theoretically, to achieve a higher boundary length, it is necessary to continuously slice the area of the base of the building. However,

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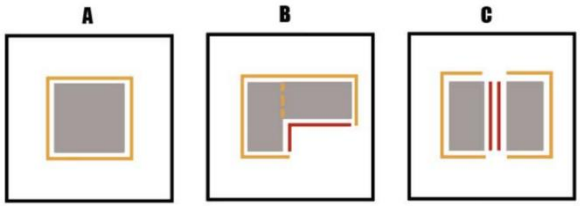
due to the limitations of fireproof spacing and building width, the segmentation value cannot be infinite. Therefore, the index of publicity is the segmentation ratio of the area of the base.

Research and design procedures to maximize the publicity of the site. When the publicity increases and the building base is too small (such as the area of a high-rise building is less than 600 square meters), or the building is significantly higher than that of other blocks (such as the tower is 40% higher than the average height of other observer towers), it means that there is no need to add this item again, and the program will double the result of this operation. And the excluded floor area is allocated to the observer block to eliminate the extreme value.

When the public Spaces of adjacent plots (inner streets, etc.) are directly connected to each other by the road, the two blocks will become observers of each other. A and B, B and C, C and D in Figure 14. D block iteration volume rate rises increase the total construction area of S, S is not a simple accumulation to D, but "notification" block other observers in advance according to certain proportion distribution, assigned to the area of the land and will notify all observers of this plot, so until all observers are assigned to a certain proportion of the area. The more closely connected the public space is, the more likely it is to maintain the dynamic balance of the relative plot ratio.



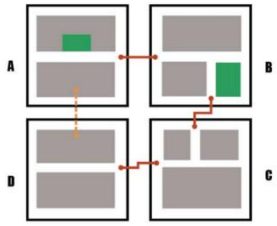


Figure 13. Different urban boundary lengths created by different base combination modes (left) (photo source: Painted by Zhong Xiaoyang).

Figure 14. Connection of observer mode (right) (photo source: Zhong Xiaoyang drawing).

As shown in Figure 15, the southern part of the area has better conditions (adjacent to the high-speed railway station), so it also undertakes more functions of public space. The eastern triangle is the square in front of the high-speed railway station. The north side is the supporting hotel catering. Across the main road is the entrance square, more public. To the west is the pedestrian commercial axis, leading pedestrians into it, which has the highest public character. In the north, near the high-speed rail line, are high-tech R & D, display, and office. The R & D Center is adjacent to the main commercial axis, connecting the industrial park with the commercial plot. A high-speed rail near the border is the logistics warehouse distribution center. According to the different functions of the plot, different initial conditions were set, and iterations were carried out. When the results were in line with the researchers' setting of the relative plot ratio, the overall urban form gradually increased from north to south, and the average plot ratio also reached a relatively high value (2.95) (See Figure 17).

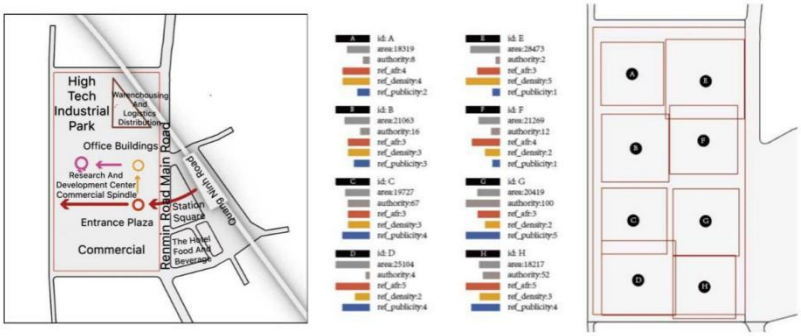


Figure 15. Design idea & initial setting of plot (photo source: Zhong Xiaoyang drawing).

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4. Summary and Suggestions

In conclusion, "the key factor to form control" in the design dimensions, emphasizes the study of a single static parameter on the formation of urban form, the method can be repeated use, and each step of the generated results can also be used as a primitive parameter into the further deepening of generation or iteration, the low required for software and design difficulty, finally can generate more scheme comparison of results. "Multi-agent rules" in the design dimensions, emphasizes the multiple dynamic parameters (which can be seen as multiple intelligent bodies) between each game simulation, these parameters are selected by human, and designers need to use the software to make the ruleset, higher requirements on technical difficulties, explore the parameters of multiple intelligence game to generate the optimal configuration. "Design pattern iterative optimization in the design dimensions, stressed and the use of" fuzzy "dynamic parameters, jump to the parameters of the traditional algorithms, will have a strong connection" observer "around, as also influence parameters into account, the unified into the parameter of the algorithm, the requirement for the technical difficulty is highest, the resulting dynamic result is more on behalf of the parties ' requirements. The three methods have certain practical significance for different design processes and design objects.

From design elements to the transformation of space form, parameter translation is only a method under the background of parameterization. In traditional design methods, designers can also complete the generation of space form through image selection, strong arrangement generation, and other methods. The two design methods have their own advantages and disadvantages. Compared with the traditional design methods, the design method of parameter translation is more intelligent, flexible, and adjustable, but it has higher technical requirements. In the 21st century, with the rapid development of computer technology, compound people with innovative thinking and smart city background are the urgent needs of future urban planning.

Table 1. Comparison of traditional design methods and parameter translation technology paths.

Technical path	Whether to generate adjustable schemes	Technical support	Transformation difficulty	Can you input the next design process
Traditional design method	No	Cad, Revit, and other software	simple	No
Key factor morphological control	Yes	Grasshopper and other parametric software	More difficult	Yes
Multi-agent rule making	Yes	Grasshopper and other parametric software, programming software	More difficult	Yes
Design pattern iterative optimization	Yes	Grasshopper and other parametric software, programming software	difficult	Yes

5. Conclusion and outlook

Parametric design interdisciplinary background determines the breadth and depth, its range of application in the parameters to translate, designers should pay attention to the design goal of all kinds of data, confirm the parameterized method in practice to participate in the design part and depth, the design of the path chosen, and a summary of existing resources further screening, integration to facilitate translation of design parameters, In order to reduce the difficulty and workload of parameter translation.

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Different from traditional design methods, the working logic of parametric design is very important, which is the primary cornerstone of whether the parametric workflow can be established. After selecting the design path and design parameters, designers should comb the design logic closely and compile a complete set of design procedures. At the same time of output of each step, they should always examine themselves and check whether the logic is self-consistent.

Increasingly along with the computer technology development, urban design more intelligent, automation tools, this study based on the top-down logic, this paper puts forward a set of parameters to translate the spatial form of the design of the automatic generation of process, focus on generating method and the combination of all kinds of parameters, to explore the methods of different kinds of parameters are translated into space form, A dynamic feedback model with different parameters is established and iterative optimization is carried out.

In this paper, the design process, as a kind of parameterized design of city space form generation, hoping to broaden the parametric design on the basis of existing research train of thought, because of various conditions is limited, the only selected the Suijiang new town as a practical case, the future should explore more practical possibility, at the same time, on the research object, The single area should also be extended to the form of multi-scale urban elements combination; In the generative logic, it extends the separated process design to the overall urban design. In the generation algorithm, deep learning, complex system and other interdisciplinary theories and methods are applied to the program design. In terms of design interaction, the final output results are compared with the original design concept in real time to strengthen the connection and feedback between the two.

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