A Study on Block-Type Commercial Space Based on Space Syntax and Scripting

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Abstract — Taking a set of certain typical block-type commercial buildings as example, this paper integrates scripting and space syntax, and synthetically uses Depth map and Grasshopper 3D to analyze the spatial structure of those buildings by means of axis analysis and visual graph analysis. Finally realizing a space syntax analysis and real-time feedback design. The paper probes into the change from a subjective design to a model combing subjective and objective design in the block-type commercial spatial design, in order to enable scientifically the deduction of rationality of design and to predict the mode of using space.

Keywords - Space syntax; Scripting; Block-type commercial space

I. INTRODUCTION

Commercial space has a structural attribute. How much the attribute fits the events occurred in this space determines the quality of the space. As the grasping of spatial structure often relies on the subjective experiences and judgment of architect or expert, which may produce subjective and empirical restrictions, therefore, the rationality of various relevant parameters in spatial structure of commercial buildings needs to be judged objectively[1-2]. Integrating sociology with psychology, the space syntax theory can conduct quantitative analysis on spatial structure and its topological relations, so as to provide possibility for objectively and scientifically predicting the mode of using space[3]. In existing researches, some scholars have already utilized space syntax to accurately predict the distribution of commercial people streams in shopping center under different spatial organizing modes[4]; space syntax has also been applied to analyze multi-storey commercial spatial structure and predict its distribution of people streams[5]. The research demonstrates that the space syntax technology has prominent performance in quantitative analysis of spatial structure, however, it is insufficient in the real-time feedback design which based on the analysis results. To remedy this defect, the research integrates with scripting tools to write the space syntax variables into the design logic algorithm program as a design restriction condition[6], thus reaching the purpose of using space syntax to analyze and real-time feedback spatial structure design.

Figure 1.
Based on above analysis, the research chose a set of typical block-type commercial buildings, integrated space syntax technology with scripting tools, and accorded with two quantitative analysis ways of space syntax to implement a real-time syntax analysis on spatial structure and explore the possibilities of applying it in different design phases.

II. RESEARCH DESIGN

A. Research Sample

The research selected a set of one block-type commercial buildings in Chengdu as its research sample, because those buildings are typical in the building scale and the type of spatial structure which make them suitable for research. The buildings contain multiple commercial spaces. To facilitate follow-up space syntax research, firstly, we processed the space of buildings by type. Mirroring the method of classifying architectural spaces that was proposed by Prof. ZHUANG Weimin in his Architectural Programming Guide, the research classified this block-type commercial space into three types, namely, A+B space, C space and D space. Where, A+B space refers to the operating space of stores; C space is the space to link horizontal transportation space, vertical transportation space and transportation junction; and D space is the auxiliary space. C space functions as a “framework” to link A+B space with D space, which is the block-type commercial spatial structure. The building volume of the sample includes 2 or 3 storeys with corridor in some part of 2nd storey. The research mainly takes the plane commercial spatial structure on the 1st storey as the object of research, as shown in Fig. 1.

-B. Introduction of Space Syntax in Digital Platform

In order to integrate space syntax with scripting, Rhino and its plugin Grasshopper 3D software are selected. As a graphical algorithm editor, Grasshopper 3D is different from other programming software. It can set up all kinds of simple or complicated programs only through “component” and “ligature” containing logic programs, rather than requiring the designer to master complex programming language. Once some fundamental algorithms in Depthmap X are copied in “component” of Grasshoppe 3D, the designer will program the different space syntax analysis variables through basic “component” and express the analysis results by visual graphical “unit”[7].

Space syntax describes spatial structure on basis of the variables calculated by topology, in which, five basic variables are depth value, connectivity value (Cn), control value, integration value (Rn) and intelligibility. Rn gets rid of the effect of node number and topological structure, making different nodes of system to be comparable. The higher the value is, the stronger the centrality of node will be. Intelligibility is the relevancy between local variables and global variables, which measures whether a person can perceive the global spatial structure through local structural of the space or not, normally represented by Rn-Cn scatter diagram. In the calculation results, if R2 is larger than 0.5, the relevancy is thought to be good; if R2 is above 0.7, the relevancy is thought to be perfect and people is easily to set up a global spatial structural system by understanding the local space[8-9].

Value Rn can be obtained by the following formula:

\[
R_n = \frac{D_n(n-2)(n-1)}{2(T_d-n+1)} \tag{1}
\]

\[
D_n = \frac{2(n\log_2(n/2-1)+1)}{(n-1)(n+1)} \tag{2}
\]

Where, n refers to the number of nodes; Rn is integration value; Td is total depth of node; Dn is the standardized parameter.

In the study, we used axial illustration and visual illustration to segment the space[10], and then set up axis analysis scripting program and visual illustration analysis scripting program respectively through programming on digital platform, and finally made analysis on spatial structural variables of the sample. The axis analysis actually aims to simplify the spatial structure, which meets the rapid real-time feedback required in the prime of scheme. The visual illustration functions as an accurate real-time feedback in deepening design phase. The scripting can complete space syntax analysis, besides, in the design...
process, it can also form logic circuit and utilize real-time space syntax to analyze and optimize the design. (see Fig.2).

III. AXIAL LINE ANALYSIS ON DIGITAL PLATFORM

A. Axis Analysis Programming

The space syntax utilizes axis to segment the space, which is mainly decided by the visual perception and motion state of people. To proceed along an axial direction is the most economic and convenient mode of motion within the scope of human vision. The least and longest axis is used to cover the whole C space, in which the point of intersection represents the connectivity relation of space. Next, each axis is taken as a node so that an illustration of spatial structural relation is obtained, as shown in Fig.3.
After the relation illustration of axis model that was completed on digital platform generated, according to the calculation formula of depth, connectivity, control and integration values in space syntax, the data processing “component” of digital platform is used to link and form corresponding calculation script, so as to realize the translation of space syntax analysis. Then the display “component” of digital platform is utilized to visually express these calculation results with cold and warm colours in axis model. On the digital platform, data automatically transfer and analytic data is automatically saved. The statistic software interface “unit” is used to export the calculated results into SPSS in order to analyse the relevancy between Rn and Cn and finally acquire the value of R2.

B. Axis Analysis

(a). It can be known from Fig.4 that, in Rn-Cn scatter diagram of the sample, R2 is 0.8733, which means the space has a high intelligibility value. That’s to say, not until a customer goes through the whole commercial block, he/she can perceive the spatial structure of the block and generate a good map in the mind. Intelligibility value reflects the relevancy between the globe and local parts of the space. In the following, it is necessary to analyze the global and local variables.

(b). In Fig. 5 and Table 1, the four major east-west streets(axis 1, 2, 3 & 4) and seven south-north streets(axis 5, 6, 7, 8, 10, 11 & 15) interweave into a mesh structure. In this structure, axis 10 has the highest integration value 3.2575, followed by those of axis 1, 3, 4, 7 and 15, namely, 2.8955, 2.9613, 3.0302, 2.4129 and 3.0302. Axis 1 has an integration value of 2.8955, relatively low centrality, the highest control value of 4.1206 and connectivity value of 14, which is linked to subway entrance square S1, perfectly guiding population flow of S1 square into the sample block and let them scattering to each neighbouring street space.

TABLE 1. QUANTIZATION TABLE FOR PARTIAL AXES OF THE SAMPLE

<table>
<thead>
<tr>
<th>Axis</th>
<th>Cn</th>
<th>Md</th>
<th>Cv</th>
<th>Rn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>2.0465</td>
<td>4.1206</td>
<td>2.8955</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>2.5581</td>
<td>1.3429</td>
<td>1.9448</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>2.0233</td>
<td>4.0690</td>
<td>2.9613</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>2.0000</td>
<td>2.7040</td>
<td>3.0302</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>2.7907</td>
<td>1.5909</td>
<td>1.6922</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>2.5116</td>
<td>0.5238</td>
<td>2.0046</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>2.5558</td>
<td>0.8647</td>
<td>2.4129</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>2.5349</td>
<td>0.5310</td>
<td>1.9742</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>2.7442</td>
<td>1.7576</td>
<td>1.7373</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>1.9302</td>
<td>3.2385</td>
<td>3.2575</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>2.3721</td>
<td>0.8810</td>
<td>2.2084</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>2.5814</td>
<td>0.2381</td>
<td>1.9162</td>
</tr>
<tr>
<td>13</td>
<td>3</td>
<td>2.5814</td>
<td>0.2381</td>
<td>1.9162</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>2.4186</td>
<td>2.5373</td>
<td>2.1360</td>
</tr>
<tr>
<td>15</td>
<td>9</td>
<td>2.0000</td>
<td>2.3219</td>
<td>3.0302</td>
</tr>
<tr>
<td>S1</td>
<td>4</td>
<td>2.4884</td>
<td>0.5325</td>
<td>2.0359</td>
</tr>
<tr>
<td>S2</td>
<td>4</td>
<td>2.4419</td>
<td>0.4433</td>
<td>2.1016</td>
</tr>
<tr>
<td>S3</td>
<td>4</td>
<td>2.2558</td>
<td>0.4076</td>
<td>2.4129</td>
</tr>
<tr>
<td>S4</td>
<td>4</td>
<td>2.4419</td>
<td>0.4643</td>
<td>2.1016</td>
</tr>
<tr>
<td>S5</td>
<td>3</td>
<td>2.6512</td>
<td>0.6444</td>
<td>1.8352</td>
</tr>
</tbody>
</table>

(c). Among the south-north streets (axis 5, 9 and 10) along both sides of the northern district, axis 10 with the highest integration becomes the central passage of this district to connect the southern commercial district; while axis 5 and 9 with lower integration have commercial interface along a single side, where commercial atmosphere is low and thus it’s easy to form a rest space. Among the south-north streets along the southern commercial region, axis 7 with the highest integration of 2.4129 becomes an important commercial streamline to guide people coming from south into S2 square; however, other south-north...
streets (axis 6, 8 and 11) with circuitous path into the block and a low integration become the secondary important commercial streamline.

C. Optimization Analysis

In line with above analytic results, we adjust the local plane designs, analyze the scripts via space syntax on digital platform, implement real-time feedback of the quantitative results of spatial structure in design scheme, and finally adjust the optimization effect.

Optimization 1: Conduct block reduction on two buildings by the right side of northern district, enabling axis 5 to more directly connect to S5 square. From Fig. 6, there is no significant change in global structure, however, the integration value of axis 5 is increased to some extent, with enhanced accessibility and more convenient commercial streamline. Optimization 2: Extend axis 3 in southern district to reach axis 15 so that people can directly enter in axis 3 from the street interface. Due to originally high integration of axis 3 and 15, to connect these two axes will bring large impact on the global structure. The region with the strongest space centrality will convert to axis 3 from axis 10. Optimization 3: Carry out above two optimization designs at the same time. As is known from feedback results, the global commercial structure is stable, the merits of optimization 1 & 2 are inherited, and the integration value of axis 3 is greatly improved.

In case of modifying the district with low integration value, there will be no significant impact on the global spatial structure, but local part can be improved; in case of modifying the district with high integration value, the global spatial structure can be varied. Thus, it is essential to use space syntax to conduct real-time analysis on digital platform, in order to help designer to adjust the merits and weakness of each scheme quickly and optimize the design continuously until it conforms to the respected design goal.

IV. VISUAL ILLUSTRATION ANALYSIS ON DIGITAL PLATFORM

A. Visual Illustration Analysis and Programming

The visual illustration analysis method sets up a regular lattice in the space and segments the space exhaustively. Each point refers to one unit of space. The visual relation between points determines the connection relation between unit space. Finally, a space relation illustration is produced [11], as shown in Fig. 7.
B. Visual Illustration Analysis

Figure 7. Visual illustration

Figure 8. Ni scope.

Figure 9. Shortest path between nodes

Figure 10. Integration illustration.

Figure 11. Rn-Cn scatter diagram.

$y = 0.01x + 3.4178$

$R^2 = 0.6195$
The visual illustration contains main variables: global variables, mean shortest path length ($L_i$), visual integration ($R_n$); local variables, clustering coefficient ($C_i$), neighbourhood ($N_i$), as shown in Fig. 8. Compared to axis analysis, using mean path length to calculate the mean value of the shortest path between nodes will enable us to obtain a higher “resolution” and can reflect the motion mode of people in the space with more details. The number of directly visual nodes is the scope of $N_i$, similar to connectivity value. The clustering coefficient represents the strength of restriction of spatial boundaries on vision (4). The variable calculation formula is translated into the “unit” of digital platform, and then different calculations are used to connect the unit modules to complete programming. After the calculation is completed, the results can be visually expressed with cold and warm colours.

The exhaustive segmentation method in visual illustration can produce huge data results. Though it can directly display data discrepancies via colors, it is not able to make detailed and intuitive comparison. So it is a necessity to partition the data, and then we can comprehensively compare and analyze between and within each partitions. Integrated with visual expression, we can obtain an intuitive feedback results at last.

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Figure 13. Contrast of visual integration in optimized schemes

From Fig.10 and Fig.11, the calculated integration values of both visual illustration and axis highly coincide with each other. While in visual illustration, space is segmented into smaller pieces, and tiny differences between space units can be expressed. (a) The whole block is covered by a net-like trunk which is formed by Street 1, 3, 4, 7, 10 and 15, and each street is varied due to the change of local space. The integration value of southern district is higher than that of northern district; the integration values of east-west streets are generally higher than those of south-north streets. (b) The visual integration values are divided into six intervals by gradient, i.e. R1–R6.

R1 contains the space located along east-west streets in southern district of the sample block, in which square S2 is the maximum value, followed by the start and ending points and intersection of the streets. Square S2 is located in the most central position of this commercial spatial structure. The transforming places of space are vital nodes in spatial structure, and the stores nearby possess the highest commercial value; R2 contains other main squares (S1, S3 and S4), street 1 and western street stores, which is linked to the nodes of space with higher integration value. S1 square is the turning point of street 1 and western street stores and is linked to subway entrance, which endows it with strong extroversion and guidance. S4 square is the turning point of street 1 and street 10, which is the close-up of street 1 and also leads commercial population flow to street 10 in northern district. Similarly, S3 square is the turning point of east-west main street (3 and 4) and south-north street 10; R3 contains the south-north street 7 in southern district, south-north street 10 in northern district and street commercial stores by the south of the block, which functions as the vertically key connection passage of R1 and R2. Street 10 directly inserts in southern district where the integration value of a detailed point increases with its location, and it effectively leads commercial population flow in southern district to the northern district; R4 contains other south-north streets (6 and 8) in southern district and narrow east-west street 2. As street 6 and 8 link the east-west streets by an irregular style, so their integration values are not high. Some interesting space may be produced here. Street 2 is taken as main logistic and evacuation path for stores at both sides, so there is few stores; R5 contains street hotels facing the east and city road in the north; R6, with minimum globally spatial structure, contains the streets with unilateral street stores at the east and west sides of northern district of the block, which is least connected with other street space.

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From axis analysis, primary strategy of design optimization can be acquired. While the visual illustration analysis can be adjusted on basis of specific design. This paper adopts above-mentioned three optimization strategies to make analysis.

Optimization 1: Control the plane size of two buildings mentioned in strategy 1 on digital platform. Through controlling the size of two planes, it is possible to real-time preview the change of space integration caused by optimized design. Finally, the southern and northern building volumes are cut down by 7m and 11.5m respectively, so as to optimize the local space. Optimization 2: Similarly, control the plane size and parameters on digital platform and obtain corresponding space syntax analytic results. In the optimized design, the integration value of street 3 is exactly and obviously enhanced, but there is no evident change in that of street 10 compared with axis analysis. The author considers that due to long length of street 10, the simplified processing of axis easily makes the local adjustment to significantly influence the space along axis, however there is little impact on street 10. Optimization 3: Combine the above two design adjustments. The analytic results reflect corresponding results of each adjustment, and there is subtle change in global spatial
structure. The visual illustration analytic method completes the deepen task after axis analysis, which enables the design to make delicate prediction of the space.

V. CONCLUSIONS

(1) As far as space syntax theory is concerned, the application of digital platform can not only realize spatial structural analysis, but also integrate the spatial structural design, analysis and optimization.

(2) As far as digital design is concerned, at present, its design results often show a strong sense of form and cause people to make formalism error judgement. But if integrated with space syntax theory, the digital design will get closer to the nature of space.

(3) In the course of sample analysis, it can be found that the axis analysis scripts are more suitable for spatial structural syntax analysis in the prime of scheme, while the visual illustration analysis scripts are more suitable for syntax analysis after the spatial form of design scheme is basically fixed. If using corresponding algorithm script in different stages on digital platform, the real-time syntax analysis of spatial structure can be realized.

(4) The integration of scripting and space syntax may help the architects to change from a subjective design to integrated subjective and objective commercial space design, in order to scientifically deduce design and reasonably predict the use mode of block-type commercial space.

ANNOTATION

(1) Illustration is a discipline which takes diagrams as the research object and uses them to express and analyze the idea of design in order to sum up the rules of spatial structure through graphic analytic mode.

(2) In China, parametric design is basically used to refer to all content of digital design. To distinguish with the formalism design trend, this paper takes scripting as presentation.

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