

Space syntax. Mathematical analysis of traditional Chinese private gardens planning structures

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Abstract. The article is devoted to the analysis and comparison of spatial structures of traditional Chinese private gardens with the use of spatial syntax tools. The history of garden development and park complexes of China is considered. A historical analysis of private gardens has been carried out: the main stages of development, the principles of formation, the basic elements, as well as geographic reference have been revealed. The article gives the history of development and the main provisions of the spatial syntax theory. The types of analyses and basic spatial quantities are considered. In the Garden of the Blue Wave, as well as in the Garden of the current time, historical periods of formation were revealed, an analysis of the territory and spatial structure was carried out. The results are spatial quantities that show the nature and regularities of space.

1. Introduction

Private garden-park complexes in China, along with imperial ensembles, are some of the most famous and exemplary representatives of East Asian culture Park. Traditional Chinese roots go deep into the garden for a few millennia. It absorbed all the ethical, philosophical and religious worldviews of Chinese culture: Taoism, Buddhism, Feng Shui, philosophy, poetry, painting, and calligraphy. By the early 20th century stable typology of gardens has developed, which include national parks and reserves, the Palace and park ensembles of the Imperial (inside and outside the city), the Imperial parks necropolises, monastery gardens and some personal gardens (the gardens of the pundits or the gardens of literature, other private gardens of townspeople, gardens and penjing gardens natural landscapes) [1, 2].

The historic private gardens are attracting a lot of attention today. Relatively small areas of the private garden clogged almost all of the type of functionality. Personal garden and park complexes were located in capitals, towns or areas with booming economies and appropriate natural and climatic conditions. The Southeastern region of Jiangnan was the most suitable for it. Most of famous parks, preserved up to the present time, are now here, in the cities of Suzhou, Hangzhou, Yangzhou and Shanghai [1, 3].



2. Chinese private garden

The first personal parks appeared during the Qin Dynasty (221-206 BC), but their flourishing, formation of an ideological concept and a spatial organization came in the time of the Sui Dynasty (581-618), Tang (618-907) and Song (960-1279), when the most famous historical private parks were created. paintings, calligraphy and literature had a great influence on the private garden-parks. At that time, general principles of the planning structure and a set of basic garden elements were laid out.

As opposed to the rigid hierarchical and regularity of the Chinese house, the Chinese garden is dominated by a picturesque composition allows to plan the energy flow (QI), the creation of a scenic image, panoramic, open, closed or miniature views, the application of the principles of diversity and spatial depth, etc. [4, 5].

During the entire period of development, the private garden acquired a special type of landscape in the territory, partly characterized by its spatial location [2].

3. Space syntax

The space syntax is a theory and a set of methods that have grown out of the work of Hiller and Hanson about the social structure of space (social logic of space). One of the space syntax strengths analysis is how to understand architectural and urban spatial configurations by translating their properties into topological graphs (diagrams), which can then be converted mathematically [6, 7, 8, 9].

The syntax, as part of the architectural semiotics, combines the body of knowledge about the spatial qualities of architecture, the structure of a large architectural elements combination (buildings, ensembles, gardens, their components and other architectural and urban formations) and the rules of their formation and transformation. In addition, their possible social effects, as well as the methodology of their analysis. There are several tools available for parsing space: Axman, WebMap and Depthmap [6, 7, 10].

4. Space syntax analysis

The aim of the research is to identify and compare spatial data of traditional private gardens in China. Two different garden complexes were chosen for the analysis. The Blue wave garden and the Linger in garden differ in construction time, area, number of elements, etc., but the most important difference, in the context of this research, is the different principles of the space formations. Using the space syntax analysis tools, it is possible to understand how different or similar the two gardens are [1].

Using syntax theory, space can be presented in a variety of forms, but the most effective way to explore landscape features is to use axial map and convex map.

Axial map. It is a set of straight lines that are both direction and visual axes. This scheme is built by hand, based on the understanding of the space and the experience of the researcher. The axis scheme is one of the most and widespread space maps in the syntax theory [8].

Convex map. The whole area is divided into cells with closed contours, formed by the features of the terrain, individual architectural elements or buildings. Plots are formed in such a way that any two points within a single cell could be connected by a straight line, which means their mutual visibility [8].

Both types of spatial schemes are based on graph theory, in which edges are pedestrian ways, nodes are intersections of these routes, and the weight of the lines are different spatial values.

The data obtained from the syntax analysis is expressed in the following values: connectivity, entropy, control, but the most important are: integration, choice and depth. Integration and selection are calculated using Dijkstra's algorithm and are some of the main indicators. Related to the concept of the shortest path, they are able to show how centralized the whole system is. The values are calculated to study the characteristics of each functional space types in a large plan network [8, 9].

For the convex map analysis, each garden has been divided into functional spaces, and the center of each space is an architectural element. Therefore, regardless of the exact shape of the space, if it has one function, it is treated as a single node. However, garden space does not have strict functional boundaries, each piece is effectively serves as a place of passage, contemplation or involved in public

activity. Ten different spatial types have been identified for this study: the hall, the pavilion, the gallery, the entrance, the kiosk, the tower, the Garden of stones, the orchard, the veranda and the lodge. Each plot inside the garden is focused around the architectural construction or landscape object. Using Voronoi diagrams we are breaking down the area into functional zones. Each park has its own unique set of elements, the number of architectural volumes depends on the complexity and depth of space.

5. Blue wave garden

It is one of the oldest private gardens in the city of Suzhou. The name of the garden was given by the eponymous poem in the book "Songs of the South". In 1044, Su Zi May (1008-1048), a famous poet of the North Song Dynasty, built the Blue Wave Pavilion and broke the garden near the canal, where the imperial flower existed from the year of 960. During the period of the Yuan Dynasty (1271-1368) and Min (1368-1644) The residence of the monks and the Buddhist monastery were located in the territory. Garden was restored by the governor of Jiangsu-soon Lo Province in 1696. Governor Zhang Shushjen became the owner of the garden and it was restored again in 1873. Most of the surviving structures were built during this period [2]. In 1955, the garden was opened for visiting, and in 2000 was added to UNESCO's World cultural heritage monuments.

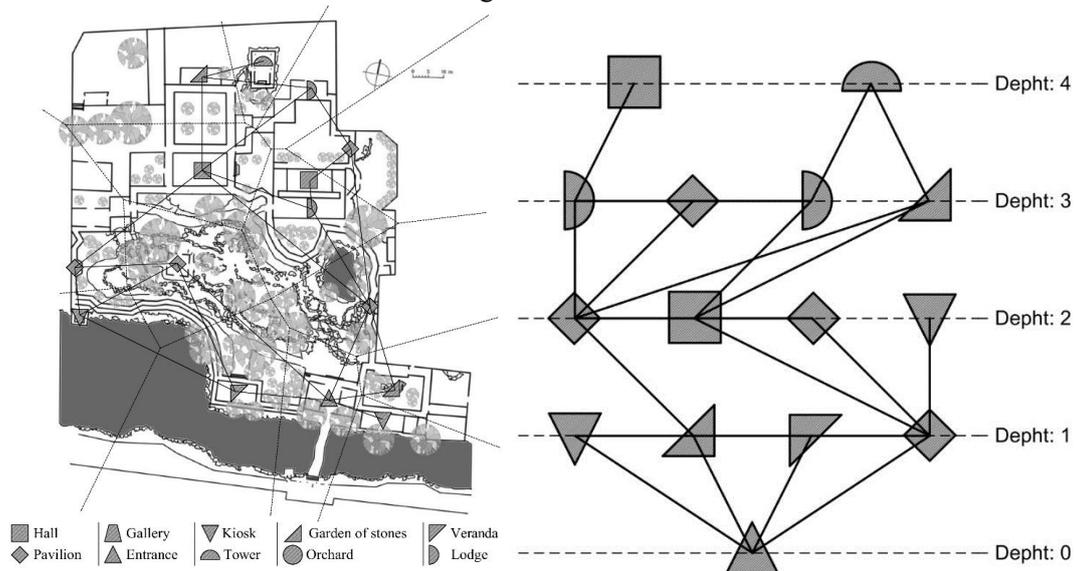


Figure 1. Plan of the Blue wave garden. **Figure 2.** J-graph of the Blue wave garden.

The garden occupies a territory of 1,6 hectares and it is divided into two main parts. The garden was built on the principles of Feng Shui and has 108 scenic Windows. A clear separation between the structures and the garden area is read in the layout. On the North it borders the canal, which is the natural border of the plot. A stone bridge with a curved shape is built through the canal, with which you can get into the garden. The garden area is located in the northern part. The main building is the Blue wave pavilion, towering over other buildings on the artificial mountain. In the initial design of the garden, the pavilion was on the bank of the canal, and in 1696 it was moved from the edge of the water to the top of the artificial mountain, its main purpose was admiring water and fish. A covered gallery is located along the perimeter of this area. A dual gallery is located on the Canal bank. The slope of the artificial pond was made by yellow stone. The western part of the garden is a artificial reservoir. In the southern part many buildings are located, both residential and recreational, diluted with small green spaces [1, 3].

The territory of the garden is a 15 parts (fig. 1). Due to the small number of objects on the site of 1.6 hectares and the openness and accessibility of the facilities, the space has 5 depth levels (fig. 2).

The analysis of depth, integration, connectivity and entropy revealed that space is not uniform and

systematic in its structure. At each stage the elements of both low and high levels were marked, relative to the entire configuration (fig. 3). As a result of the analysis, the following values were obtained in total over the entire space: depth 7.2 – 14.4; integration 0.34 – 0.74; connectivity 1 – 7; entropy 3.5 – 4.2. On the picture we can see white circles. These are maximum and minimal volumes of different date.

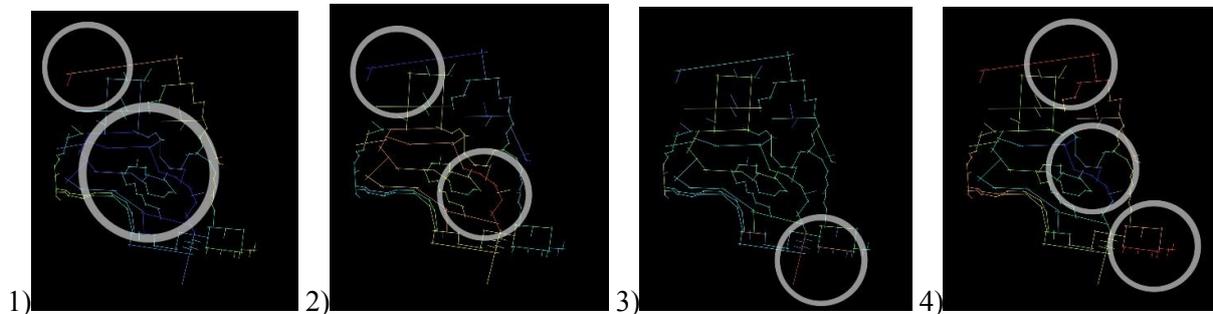


Figure 3. Syntactic analysis of the Blue wave garden. 1-depth analysis, 2-integration analysis, 3-connectivity analysis, 4-entropy analysis.

6. Linger in garden

The years of construction of the garden are 1522-1566 (age of the Ming Dynasty). The creator of the garden is a retired official, Xu Taishi. The layout of the garden includes 4 zones: Central-pond and the mountains, Eastern, which concentrated buildings North, reproducing a rustic Idyll and Western-trees, resembling wood. In the eastern part of the garden, a large stone with a height of more than 6 meters is located "Guanjunfjen", brought from Lake Taihu [1].

The planning structure is based on the principles of Taoist organization of space 一一 Feng Shui. The "Jie Jin" principle is used in the garden design: an incomplete landscape. The whole garden and its large parts are not visible at once. This is possible because artificial obstructions-pavilions, mountains, walls, were created. So the visitors can always see only the garden fragments. Exploring the grounds, the person sees all new and new pictures, sometimes through window frames or openings [4].

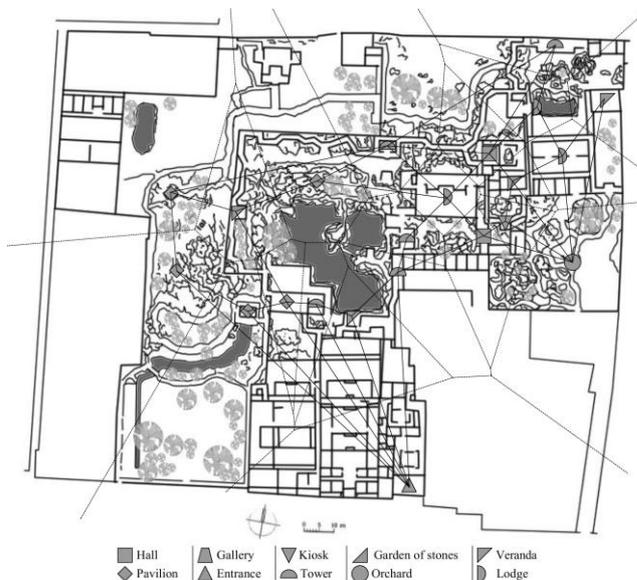


Figure 4. Plan of Linger in garden.

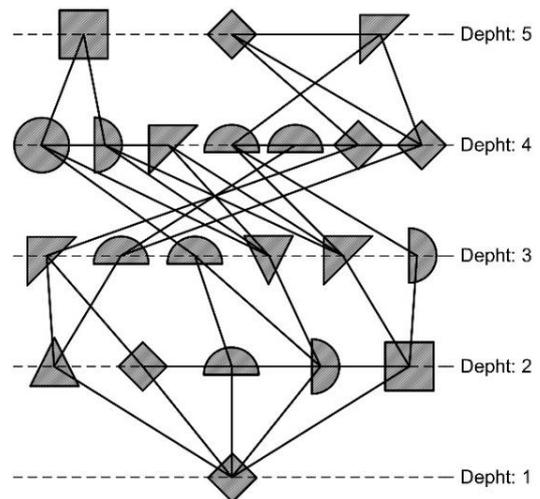


Figure 5. J-graph of Linger in garden.

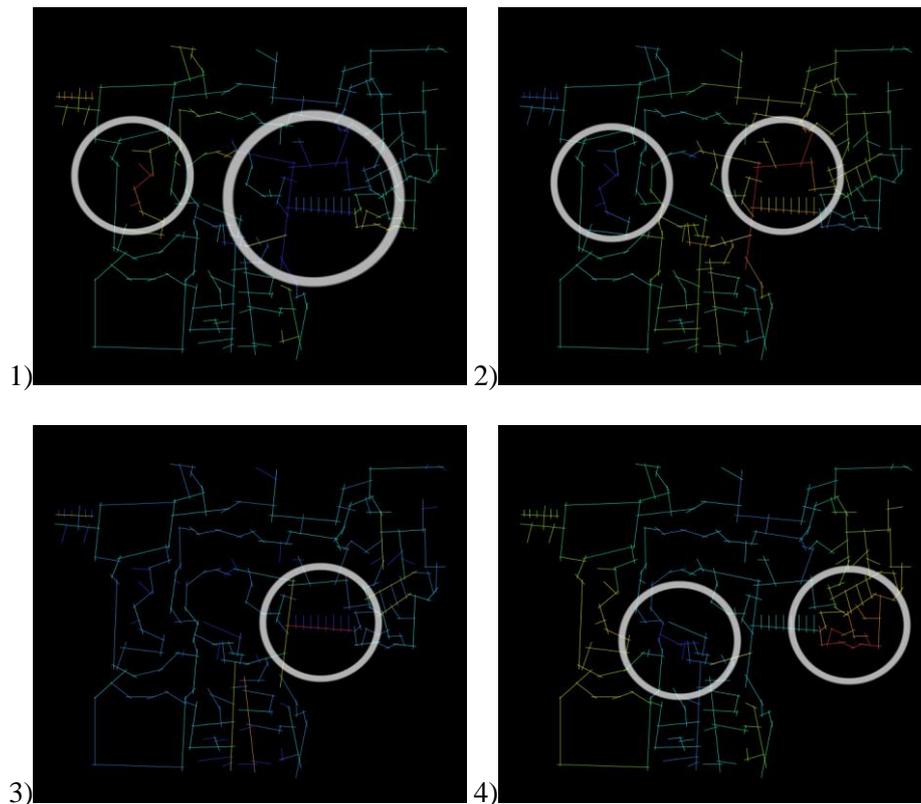


Figure 6. Syntactic analysis of the Linger in garden. 1-depth analysis, 2-integration analysis, 3-connectivity analysis, 4-entropy analysis.

Garden include 22 zones (fig.4). The most popular building in the garden is the pavilion. With the area of the 2.3 hectares park, the internal space has only 5 depth levels (fig. 5).

The analysis of depth, integration, connectivity and entropy revealed that space is not uniformly and systematically. The elements at each stage were marked by both low and high levels, relative to the entire configuration (fig. 6).

As a result of the analysis, the following values were obtained in total over the entire space: depth 8.2 – 18.4; integration 0.3 – 0.72; connectivity 1 – 9; entropy 3.8 – 4.6.

7. Conclusion

The results of the syntactic analysis of the two private gardens of China clearly show the diversity of the space of the studied garden complexes. Despite the fact that they all belong to the same type of parks – traditional Chinese private gardens, their design principles are different, but the spatial dimensions were largely similar. This is the General rules of construction of space in private gardens, despite the different eras, the design principles, the size of the territory, the number of architectural elements, etc.

The results of space syntax analysis of the 2 private gardens of China showed the whole diversity of the space data. Despite the fact that they all belong to the same type of parks-traditional Chinese private gardens, their inner filling of architectural structures, their dates and variety, as well as the depth of the space may vary significantly.

This study shows the relationship of architectural and landscape elements of Chinese private garden from a mathematical point of view. Creating a geometric scheme of the Park, studying its spatial dimensions and the relationship of the location of each element, a new view of the structure and perception of architecture and territory. Considering spatial arrangement as a fundamental aspect of

architecture that influences the social characteristics of buildings, syntactic analysis can become an integral part of the architectural design process.

The garden recreated using the output values will be the most appropriate to the original, as it is based on the normative rules that determine the architectural competence of the society. Thus, architecture is a natural part of the "culture transfer artefacts". Certain aspects of social knowledge characteristic of society are reproduced through special construction methods. The physical act of building through a system of well-defined tools becomes a means by which non-recursive models, which we call culture, are transferred to material and spatial forms.

8. References

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