Research on Spatial Morphology and Protection of Traditional Rural Settlements Based on Space Syntax: Taking Xiazhuang Village and Shijia Village in Huzhou as Example

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Abstract—Space syntax, a paradigm of the urban research, which manifests people's intuitive and abstract perception of a material space with a solid mathematical way, explores how space represents its social characteristics. Taking Xiazhuang village and Shijia Village in Huzhou as an example and focusing on inward structure and street space, this article recognizes the connotative significance of the settlement with the aid of space syntax theory and quantitative analysis method from the perspective of spatial configuration to present relevant suggestions for its future planning and provides references for traditional rural settlement protection.

Keywords—Shijia village, space configuration, space syntax, traditional rural settlement, Xiazhuang village.

I. INTRODUCTION

THE settlements come from the gathering of human beings, and its formation and development are the result of the interaction between human beings and the environment. Settlements can be divided into two categories: the rural settlement and the urban settlement. The rural settlement is a small settlement based on agricultural activities and agricultural population. Due to its comparatively closure, the rural settlements have carried on the renovated mode of construction and the simple environment concept to form typical spatial nodes such as water-gap space, street space and ancestral temple space during almost a thousand years. In the respect of traditional settlement of spatial composition, the current research relies more on qualitative methods to study the spatial characteristics of partial nodes and location selection which lacks cognitions of the whole settlement space.

At the same time, in the stage of rapid development of the city, the natural evolution mode of traditional settlements called "bottom-up" has been influenced by a series of external factors and transformed from the simple settlement constituted by single-production model to an aggregation structure which combines a more diverse mode of production and life and a more complicated social industrial structure, in the form of morphological and substantial changes. As for the traditional settlements, the contradiction between protection and development has been highlighted. Many protection and development plans which can guide the rational

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transformation and development of traditional settlements are not as successful as the designers envisioned.

Applying the method of space syntax theory, this article takes Xiazhuang Village and Shijia Village as an example to analyze the internal visual isovist model and the axis model of the street space to establish a quantitative description of the settlement space, providing a new perspective for the study of cognitive space of traditional settlements and a reference for the subsequent development of protection.

II. OVERVIEW OF SPACE SYNTAX

A. Background

The space syntax theory was first proposed and used by Professor Bill Hiller and his researching group in the late 1970s in UCL. Space syntax is a quantitative description of human residential structure, including buildings, settlements, and even city landscape, as the theories and methods to study the relationship between spatial organization and human society [1]. Configuration is the core concept of spatial syntax. It is defined as a series of interdependent relations, each of which is determined by itself and all other relationships.

B. Method

The difference between spatial syntax and other spatial theories lies in that it regards spatial morphology as a self-organizing system, dividing the space into a relational graph based on the viewpoints of graph theory, while describing the spatial structure and morphological characteristics intuitively through relational graph and analyzing a series of basic variables based on topology [2]. Connectivity is connected to the space permeability. The higher the connectivity is, the better permeability space has. The integration describes the degree of the relationship between a certain space and the entire space system. The higher the integration is, the more accessible and controllable the space is. The depth describes the reachability of the whole system in terms of topology. The larger the depth is, the lower accessible space is [3]. The synergy is measured by understanding the local spatial structure in space, whether it helps to establish the image of the entire space and guides the invisible overall space, and whether the local space and the overall space are related and unified.

III. VILLAGE OVERVIEW

A. Xiazhuang Village

Xiazhuang Village (Fig. 1) is located in southern Changxing County, Huzhou City, Zhejiang Province, and 19 km from Heping Town. Heping Town is adjacent to Anji County and near Tianmu mountains. Xiazhuang village is built along the lake, the village area is around 4.84 hm^2, and the ancient building area is around 18748 m^2. Due to being far away from urban roads and small settlement area, the village space is relatively intact, which belongs to the traditional Jiangnan water village settlement.

Shijia Village is located in the northeast of Anji County of Zhejiang Province, Huzhou City, and 17 km. The northwest side of Shijia Village is 306 provincial road, the village area is around 2.42 hm^2 and the building area is around 12865 m^2. Due to its proximity to major urban thoroughfares and close proximity to Xilong downtown, Shijia Village belongs to a village with a better development level and a higher degree of openness.

Fig. 1 Current situation of Xiazhuang Village

Fig. 2 Current situation of Shijia Village

IV. APPLICATION OF SPATIAL SYNTAX QUANTIFICATION ALGORITHM IN VILLAGES

A. Graphical Analysis Based on the Visual Model

The so-called "field of view", usually refers to the scope of a person's vision, an ability attached to subject, while being limited. In architecture, simply speaking, the field of view is a region that can be seen from a point in space in three-dimensional concept. In space syntax, we regard the view as the visible range of the view point on its horizontal plane [4].

In the structure analysis of the space in the space syntax theory, the two-dimensional space system should be transformed into a node and a relationship diagram of connection between each other. It is mainly through the form of motion that the cognition of the actual space is established through the visual experience [5]. Therefore, we divide the plane figure into several grids with certain density on the plane that we want to analyze. Every grid is not only a small-scale space, but also a view point itself. In the visual model of Xiazhuang Village and Shijia Village, the grid is set to 1000, which is close to the width of narrow alley in traditional settlements and more suitable for the size of those settlements.

According to Jan Gail's *Life Between Buildings*, within a distance from 0.5 to 1 km, people can be roughly distinguished from each other based on the factors such as background, light, especially the observed movement of people. In the distance of 100 m, the silhouette seen at greater distances becomes a certain individual and that range which can be called as a social horizon [6]. Therefore, in this calculation of the visual model, the restricted visible distance is set to 100 m.

Connection refers to the number of nodes directly connected to one node in the system. In certain space system, the higher the connection is, the closer the node is to the surrounding space which has the stronger influence to surrounding place and the better permeability of the space.

In space syntax, the distance between two adjacent nodes is defined as one step, and the depth represents the shortest topological distance between any two nodes. The depth expresses the topological reachability between nodes rather than the actual distance, which is the convenience of a node in the entire space system. The Mean depth refers to the sum of the average depth values of each node. Generally, the smaller the mean depth is, the more convenient the space is in the entire system. Otherwise, the space is more profound and difficult to reach.

The visual integration is the most important variable in the space syntax analysis, reflecting the closeness of a certain point with other nodes in the space system, which can be divided into integration [HH] and partial integration. Partial Integration refers to the degree of closeness between a node and another node in a certain topology distance which is usually calculated as three topological units called Integration R3. The higher the integration[HH] is, the more likely to seize the attention.
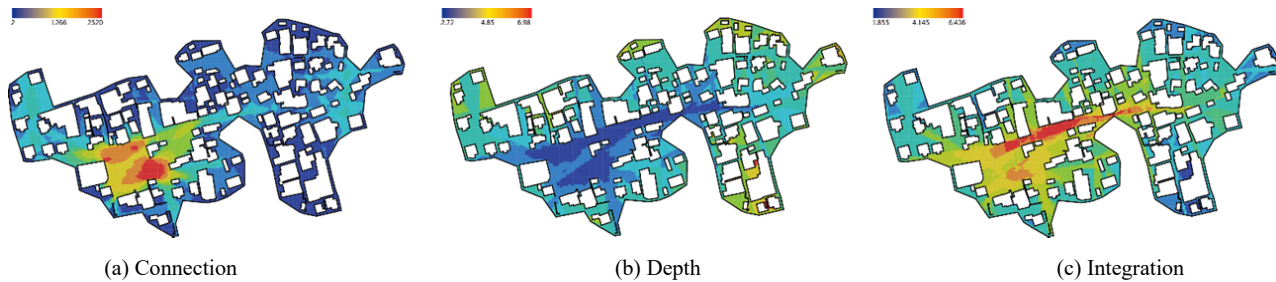

| (a) Connection | (b) Depth | (c) Integration |

Fig. 3 Visual model of Xiazhuang Village

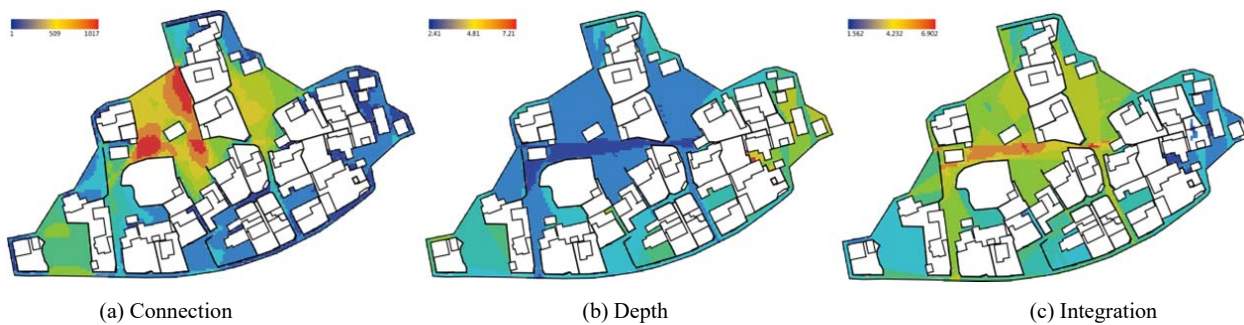| (a) Connection | (b) Depth | (c) Integration |

Fig. 4 Visual model of Shijia Village

According to Fig. 3 (a), it is known that the highest connection in the inner space is the water area in the west side of the Xiazhuang Village. The water area is surrounded by some internal buildings and there is a small square which is formed by the combination of constructions. The road from west to east along the village, which connection drops from around 1500 to 700 immediately so that a huge visual difference is created between those space without any obvious transition. In Xiazhuang Village, the space connection which is below the average of 613.589 accounts for 71.77% of the total space. The village is in an inwardly closed state as a whole and these parts have poor permeability. The Connection reflected by the Shijia village's visual model are shown in Fig. 4 (a). The highest Connection is located in the north of Shijia Village, with large green fields and farmland and little visual barriers. Most of the Connection in Shijia Village are uniformly distributed in the interval of [407.4, 915.4], and the overall space is relatively evenly distributed. Compared with the Connection of Xiazhuang Village, the transition of inward and open space is more natural.

As can be seen from Fig. 3 (b), the minimum Depth of Xiazhuang Village is 2.72 and the maximum is 6.98. Most of the depth are basically distributed within the interval of [3.15, 4.42], which is basically showed as a linear from west to east in a graphic analysis, corresponding to the main road beneath the village. The area has higher depth is mainly located in the east and south of the village which is far away from the center and hard to approach. Fig. 4 (b) reflects the status of the Depth in Shijia village. The minimum depth is 2.41, while the maximum is 7.21 and 78.1% of the depth is within the interval of [2.88, 4.32]. The space with depth greater than 5.76 occupies only the 0.9% of whole space. The partial spaces have close relationships with each other, creating a strong integral feeling.

As can be seen from Fig. 3 (c), the integration of Xiazhuang Village's internal space is within [1.855, 6.436]. From the view of plan, the village houses or can form roughly their own group modes. Within these respective groups, the integration [HH] of some public space is basically in the interval of [3.229, 3.687], which also forms a series of group controllable

nodes. according to the analysis of connection, it can be seen that Xiazhuang Village forms a relatively complete grouping mode and has relatively abundance space experience among the groups although its local spatial connection is not tight enough. As can be seen from Fig. 4 (c), it can be showed that the integration [HH] of Shijia Village is similar to the Depth

condition. The integration [HH] of the two roads into the village are around 4.66 and the interior space relations are simpler than the Xiazhuang Village. The internal group distinction is not obvious. Besides the green area on the north, there is less space for public activity between dwellings, mainly lanes and alleys
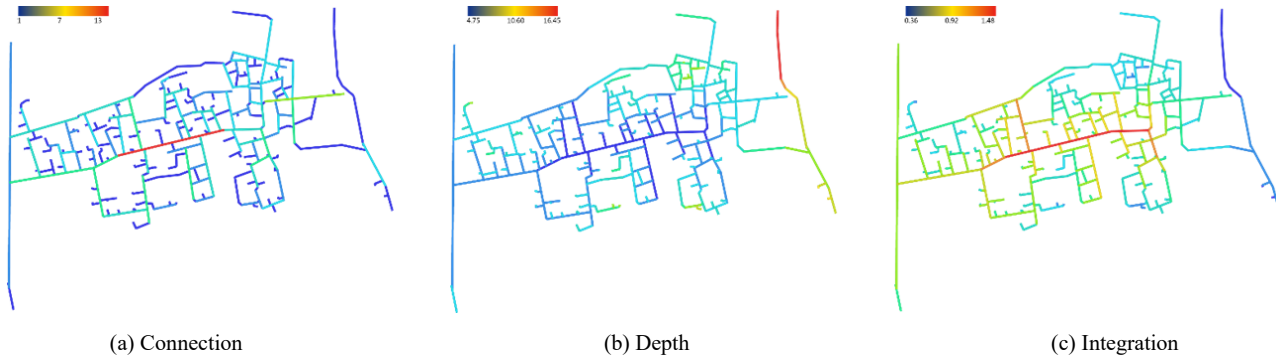

| (a) Connection | (b) Depth | (c) Integration |

Fig. 5 Axial model of Xiazhuang Village
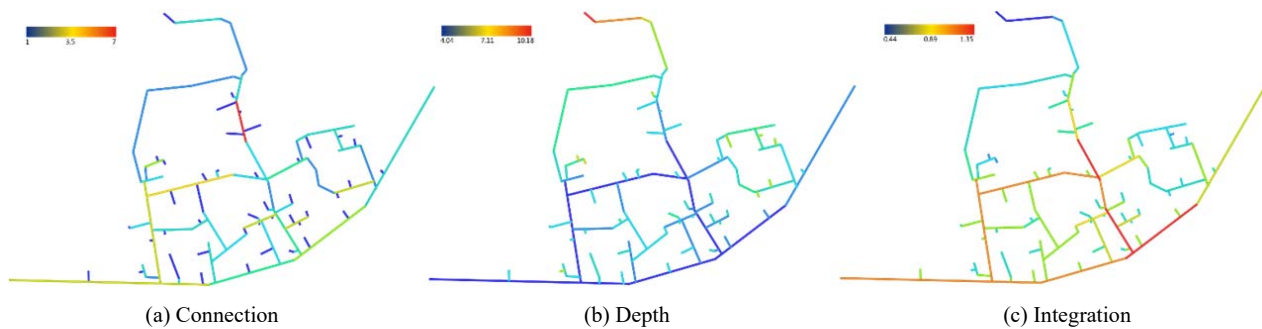

| (a) Connection | (b) Depth | (c) Integration |

Fig. 6 Axial model of Shijia Village

B. Axial Analysis Based on the Axis Model

The visual model describes the analysis of the vision seen by humans at a single point under static condition and further establishes the relationship between the partial space and the overall space [7]. The axis model is based on the interior convex street of the settlements, where each axis represents a space. Axis model is a description of the dynamic movement of the space and the concentration of the crowd.

Fig. 5 (a) shows the analysis of the connection of the Xiazhuang Village's axis model that the axis with the highest connection is a road with a horizontal position at the central position of the village and the value is 13. In addition, the street space with large connection in Xiazhuang Village leads east to west. Therefore, it is obviously found that the development trend of the village is from east to west. This is in line with the development of Xiazhuang Village in Google Maps during the past decade. Through the deep analysis of the axis of the highest connection, it is shown that this axis locates besides internal pond of the village, as well as the external water resource, which indicates that the road layout accords with people's habits of daily life, easily gathering civil and forming a typical Jiangnan life scene. As can be seen from Fig. 6 (a), the axis with the largest connection of Shijia Village is

located in the south, which is an urban development road and the maximum value is only 7. The whole village is more open with a white tea market on the west of the village, which has a closer relationship with the outside world.

As shown in Fig. 5 (b), most of the depth of the village streets and lanes are basically in the interval of [5.62, 8.12]. The closer to the center of the village, the lower the depth is, which creates a great gradation with winding streets and lanes leading to secluded places. As shown in Fig. 6 (b), most of the lanes in Shijia Village are in the interval of [4.65, 5.88], with no obvious gradation. Most of the streets and lanes of the village can be perceived after 4 to 6 turns, identical with the characteristics of its openness.

As can be seen from Fig. 5 (c), we can see that the axis with largest integration [HH] of Xiazhuang Village is leading from west to east, which is similar to the analysis of Connection. The street connects the entrance in the west side and branches to three lanes on the east side. The outside space approaches the inner space of the village through this axis which is also the center of space development with the highest commercial potential. Nearly 79% of integration [HH] is in the interval of [0.58, 1.03], well-distributed.

The intelligibility is used to measure the relationship

between the part and the whole. Linear regression analysis is conducted by using integration [R3] and integration [HH], and a linear equation is established to obtain R^2 to analyze the correlation between the horizontal axis and the vertical axis [8]. As can be drawn from Fig. 7, R^2 is equal to 0.461, which belongs to a low level of Intelligibility. The streets and lanes of Xiazhuang Village are more complex with lower identification degree, which belongs to an introverted village.

As can be seen from Fig. 6 (c), we can see that the axis with the maximum degree of Integration[HH] is the main road on the south, and the integration of the surrounding is relatively close and lies within the range of [0.63, 0.99]. Internal and external space connects tightly with each other, meeting the daily needs of local civil.
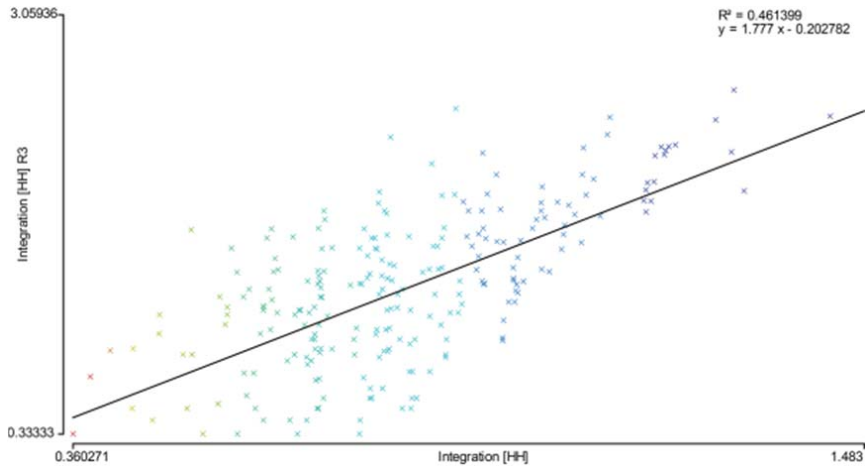

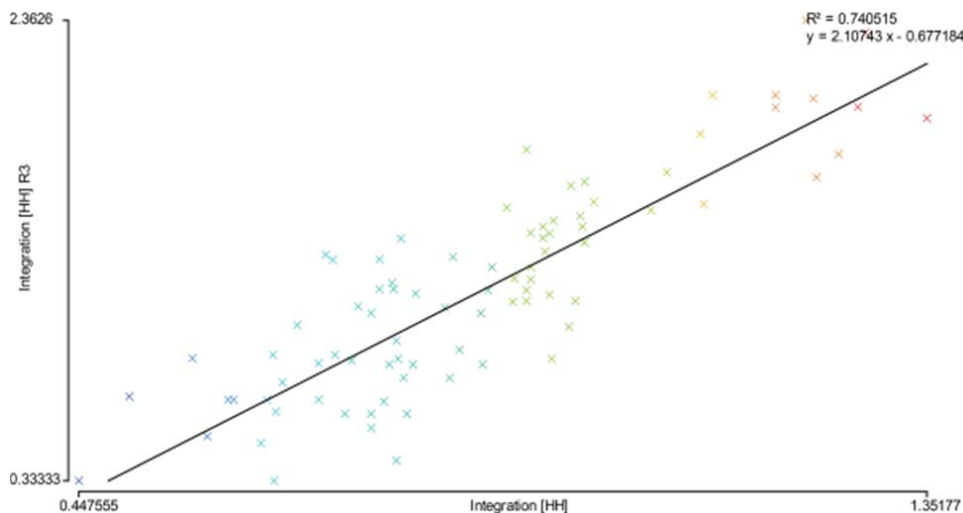
Fig. 7 Intelligibility of Xiazhuang Village

Fig. 8 Intelligibility of Shijia Village

It can be seen from Fig. 7 that R^2 is equal to 0.740, which belongs to a high level of Intelligibility. This indicates that human perception of the partial space helps to establish the feeling of the whole space. Through the analysis of the plan of Shijia Village, it is obvious that the space structure is clear with high level of recognition, which belongs to a non-coverup expression, similar to the analysis of the Depth of the visual model.

V. SUMMARY AND CONCLUSION

The composition of the space form of villages is diverse, and it has been difficult to conduct qualitative research in an accurate way. Spatial syntax provides a good method of quantification. Through the analysis of data expression, it reveals the intrinsic characteristics of village space.

It is easily accessible for civil to approach the internal space of Xiazhuang Village due to the tight connection between the village and outside environment. At the same time, the interior and exterior of the village are obstructed by buildings, and the space variation is extremely huge, creating a strong visual stimulus and making visitors feel lost. It belongs to the traditional introverted Jiangnan Water Village. The village environment of Shijia Village is an intuitive process of demonstration. People can easily perceive the entire space

environment through understanding the local spatial structure. The village belongs to a typical open-type village which is transformed by human-beings by constructing nature environment.

It can be seen from the above that the spatial layout of the two villages is suitable for the purpose of their functions and meets the needs of civil' daily life. It is necessary to consider the characteristics and functions of the civil for their future planning and construction rather than blindly developing for development. Space syntax is a theoretical method of spatial analysis and the analysis results of Xiazhuang Village and Shijia Village can reflect the complexity and multilateralism of rural settlement space to a certain extent. It is hoped to provide reference for the current village reconstruction.

REFERENCES

[1] Hillier B, Hanson J, "The Social Logic of Space," in *Cambridge University Press*, 1984.
[2] Zhang Yu, Wang Jianguo, "Recall The Space Syntax", in *Architects, China*, no 4, pp 33-34, 2004.
[3] Duan Jin, Hillier B, "Space Syntax and Urban Planning", in *DongNan University Press*, NanJing, 2007.
[4] Chen Yong, Ni Lihong, Dai Xiaoling, "Analysis of Walking Spatial Structure of Ancient Town in South China: A Case Study of Tongli", in *Architects*, China, no 4, pp 76-83, 2013.
[5] Chen Zhongguang, Xu jiangang, Jiang Haibing, "Research on Multi-scale Spatial Analysis of Historic Districts-An example of the Sanfang 7 Lane Historic District in the states", in *Urban Planning*, China, vol 8, pp92-96, 2009.
[6] Dalton R C, "Space Syntax And Space Cognition", in *World Architecture*, China, no 11, pp 41-45, 2005.
[7] Wang Haofeng, "The Spatial-functional Dynamism and Settlement Morphology of Huizhou's Traditional Villages", in *Architects*, no 4, pp 23-30, 2008.
[8] Duan Jin et al, "Space Research I: World Heritage Xidi Ancient Village Spatial Resolution.", in *Southeast University Press*, pp 27-39, Nanjing.