Space Configuration and Movement Pattern of Chinese Traditional Settlement

A case study of Wangkou, Wuyuan County

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Abstract

While most research on Chinese traditional settlements has predominantly focused on interpretation and re-interpretation of Confucian cultural ideas, syntactic analysis revealed that these settlements were configured with variability to social and economic processes of settlement growth and evolution. A centrality process similar to the one described by Hillier was observed, in which communal buildings like ancestral halls and shops tended to be concentrated on the integration structure as well as certain strategically vantage locations of a settlement. This raises a question of whether the spatial structure may have a social implication on settlement growth and evolution.

This paper reports a case study of Wangkou, a quasi-market town in Wuyuan county, China. Space syntax theories and methods are applied to the modeling of pedestrian movement pattern of the settlement. Pedestrian movement data were observed on weekdays by using gate count method from randomly sampled street segments. Statistical correlations are explored between configurational measures of settlement layout and movement densities in order to find out how far the spatial structure per se can impact or determine pedestrian movement, and which spatial variable gives the best correlation with movement rate.

Research findings reveal that movement densities in Wangkou are largely correlated with the global properties of space configuration in general, and the choice measure of the shortest routes in particular, rather than the location of particular attractors like shops and institutional buildings. The case study also suggests when the "practical choice" of space for through movement largely agrees with the "theoretical" choice structure of a settlement whose pedestrian is mainly composed by local residents, the choice measure would be likely to produce a better correlation with pedestrian movement in that settlement.

1. The Study of Social Cultural Aspects of Chinese Traditional Settlements

A key issue on research of Chinese traditional settlement forms is to investigate spatial patterns of settlements in relation to social cultural context in which space was created. Although it is generally acknowledged that space and society are impacted on each other, thus creating our perception of human aspects or the quality of "placeness" of traditional built environments, few study could be able to show the ways in which spatial forms and social processes of traditional settlements are actually interrelated with each other to give rise to settlement growth and evolution.

While most research on Chinese traditional settlement forms has predominantly focused on interpretation and re-interpretation of Confucian cultural ideas, syntactic analysis revealed that these settlements were configured with variability to social and economic processes of settlement growth and evolution. A centrality process similar to the one described by Hillier was observed (Hillier, 1999), in which communal buildings like ancestral halls and shops tended to be concentrated on the integration structure as well as certain strategically vantage locations of a settlement (figure 1). It has been argued that the evolutionary process of these settlements were

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Edited by Daniel Koch, Lars Marcus and Jesper Steen, Stockholm: KTH, 2009.

126:1

driven by the alternating impacts of two social forces on the evolutionary process: the attempt to imprint social ideology in the local geometry of settlement layout by a lineage community; and the pervasive presence of certain local controlling mechanisms ¨C micro scope building activities guided by established praxes that would generate global morphological patterns across cultures (Wang, 2006, 2008a & 2008b; Ye & Wang, 2003 & 2005).
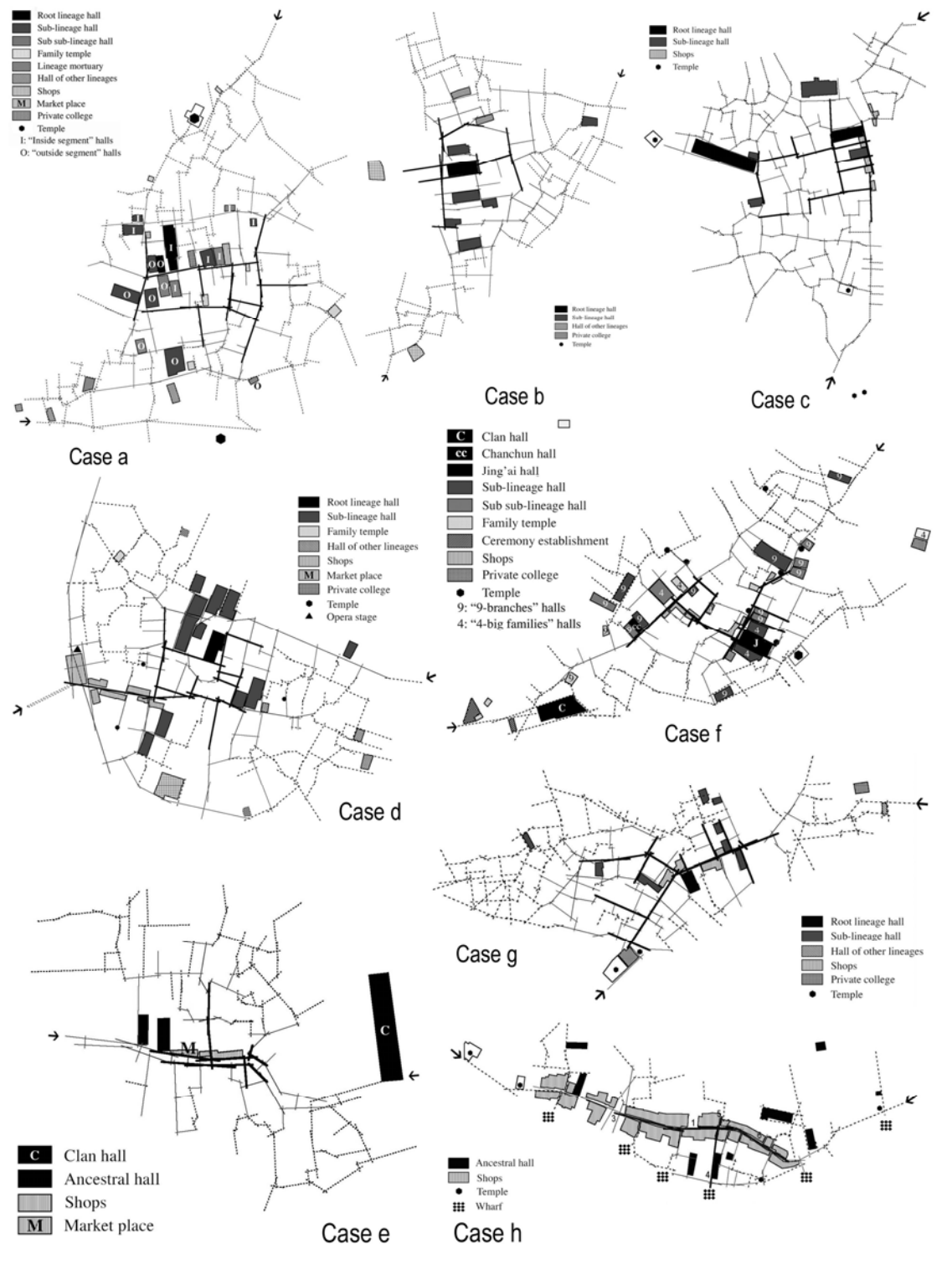

Figure1

Integration (Rn) maps of a sample of Huizhou traditional settlements overlapped with major functional elements, with their 10% integration cores shown in bold black.

Since these communal buildings are major social generators of traditional settlement, there is evidence suggesting the configurational regularities underlying settlement growth and evolution have a social and functional implication. This immediately raises a question of whether the

Proceedings of the 7th International Space Syntax Symposium
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126:2

syntactic structure of settlement layout has an impact on the ways in which spaces are actually used in these settlements. This paper reports a case study of Wangkou, a quasi-market town in Wuyuan county, China. Space syntax theories and methods are applied to the modeling of pedestrian movement pattern of the settlement. Pedestrian movement data were observed on weekdays by using gate count method from randomly sampled street segments. Statistical correlations are explored between configurational measures of settlement layout and movement densities in order to find out how far the spatial structure per se can impact or determine pedestrian movement, and which spatial variable gives the best correlation with movement rate. It is hypothesized that if the syntactic structure of settlement layout can be shown to have a relevance to pattern of space use, then the processes in which the patterning of settlement forms was interrelated with social dynamism of settlement growth and evolution can be better understood and argued.

2. A Brief History Background of Wangkou

Wangkou is located to the east of the township of Wuyuan county (which was under jurisdiction of Huizhou Prefecture before 20th century), Jiangxi Province, southeast China. The settlement covers an area about 11 hectares. Two rivers converge at the east of the settlement, winding its course west to the county township. According to local genealogy, the settlement was originally built by a group of Yu families in Song dynasty (1109 AD).

Wangkou was an important transport node of both land and water routes connecting Wuyuan county and surrounding towns and cities. In 1375 AD, government officials of Ming dynasty established a post office near the settlement. Convenient transportation and riverfront location brought out tremendous opportunities for establishing trade in the settlement. From late 16th century to late 19th century, Wangkou had been a famous quasi-market town engaged in trading, transportation, goods storage and distribution, as well as a residential settlement for people working there. In its golden ages, there were 18 wharves used for goods circulation along the riverfront, with a series of streets linking them to the heart of the settlement (figure 2).
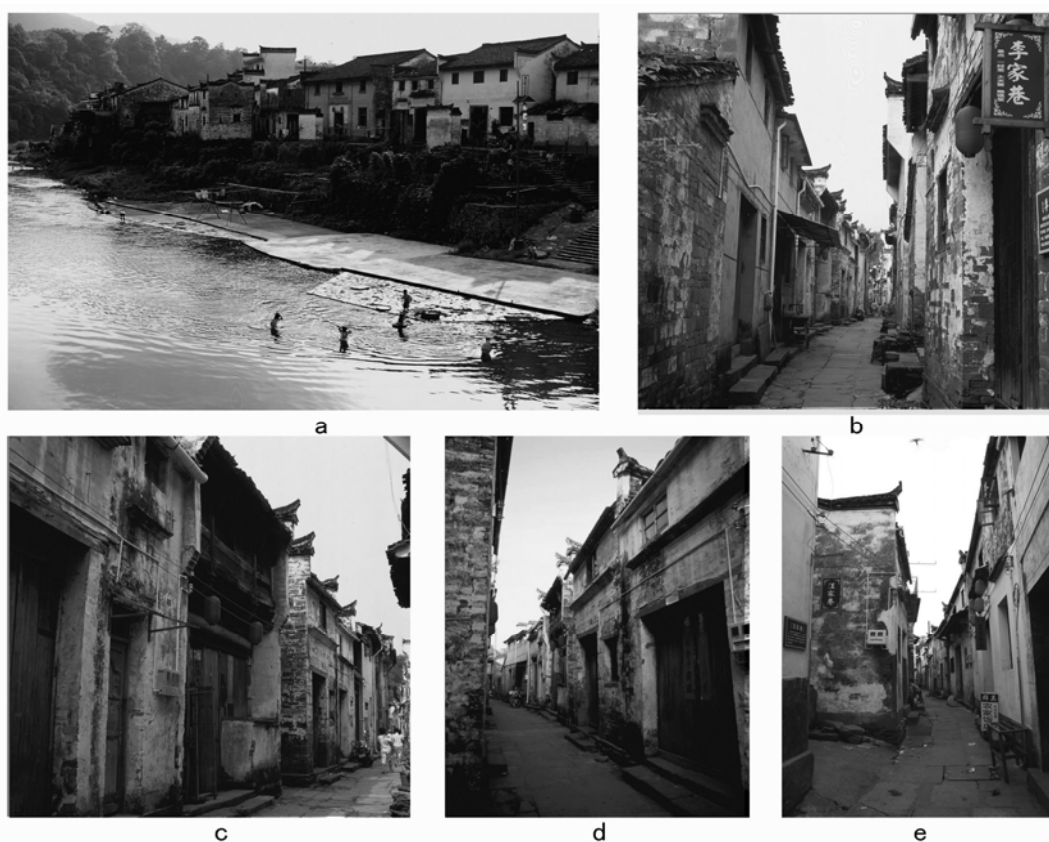

Figure 2
Landscapes of Wangkou. a: an overview of the settlement seen from the southeast; b~e: street views of the Main (shop) Street.

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126:3

Benefited from huge opportunities in trading, Yu families had enjoyed sustained economic growth and prosperity. Population became many times of the original size, with several branch families (sub-lineages) segmented from the root lineage. The huge wealth generated from trading business had also provided the financial base for mass construction of quality settlement. As a result, the physical structure of the settlement also expanded substantially. In addition to a large amount of luxurious merchant houses, a number of communal buildings such as ancestral halls, private colleges and temples had been gradually constructed.

Like many lineage-based settlements in southeastern China, the physical fabric of Wangkou is composed by a large number of two-story courtyard houses of varying size, a small number of communal buildings intermingled with the residential buildings, and a web of streets and alleyways winding about clusters of buildings. There were more than one hundred shops in the settlement, most of which were concentrated on the Main street winding parallel to the river course. These buildings take the typical form of "shop houses" which combine functionalities of dwelling and trading. Although the street pattern appears to be highly irregular, the Main Street seems to well define the street structure by providing the only direct east-west circulation within the settlement, with a series of perpendicular streets linking it to various residential quarters. Today, most shops are clustered around the central sections of the Main Street, offering a variety of services mainly for local residents (figure 3).
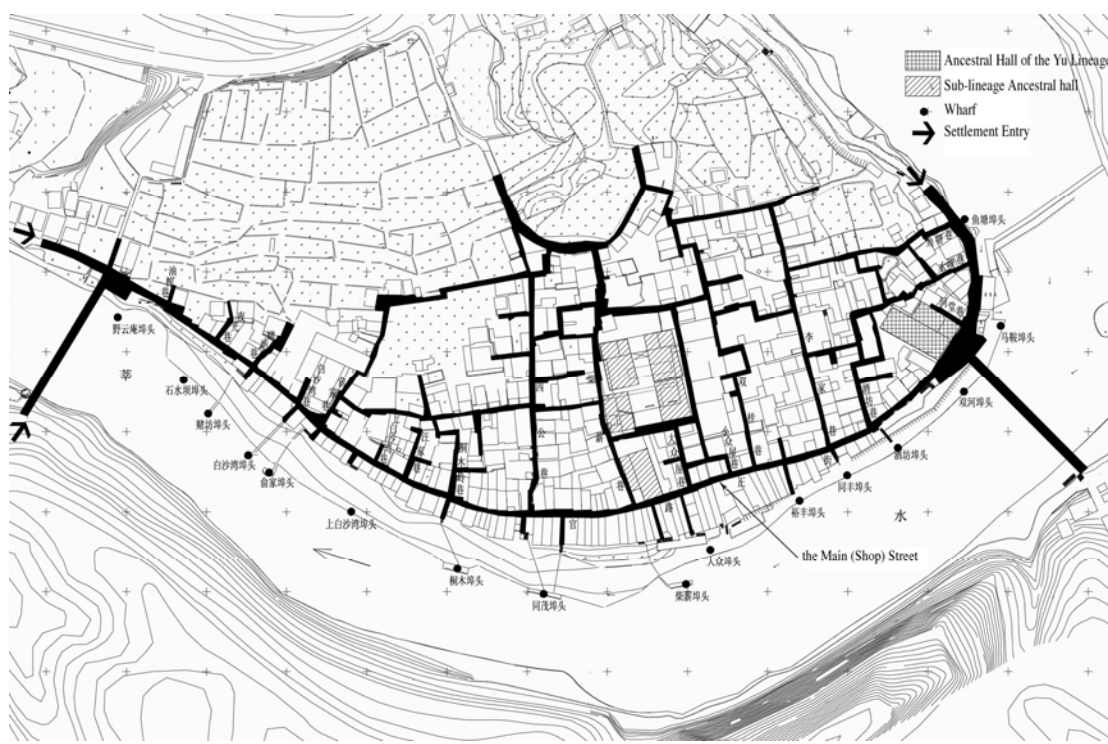

Figure 3:
The figure ground map of Wangkou, with street network shown in black.

3. Spatial Analysis of the Axial Structure

The axial map of Wangkou consists of 114 lines. Like other Huizhou's lineage-based settlements analyzed before, its axial map is composed by a large number of short lines and very few long lines. Table 1 sets out the first order syntactic properties of Wangkou's axial structure along with other Huizhou settlements analyzed in previous research. A quick review shows that the mean connectivity and mean R3 integration of these settlements are very close to each, indicating they share certain similarities in term of local syntactic properties. It has been suggested that these local similarities are in part related to the ancestral-hall-centered building tradition and "T-shaped" street intersection pattern dictated by fengshui practices in Huizhou Prefecture (Wang, 2006 & 2008b). The mean global integration (Rn) value of Wangkou is 0.9304, slightly higher than other settlements in the sample.
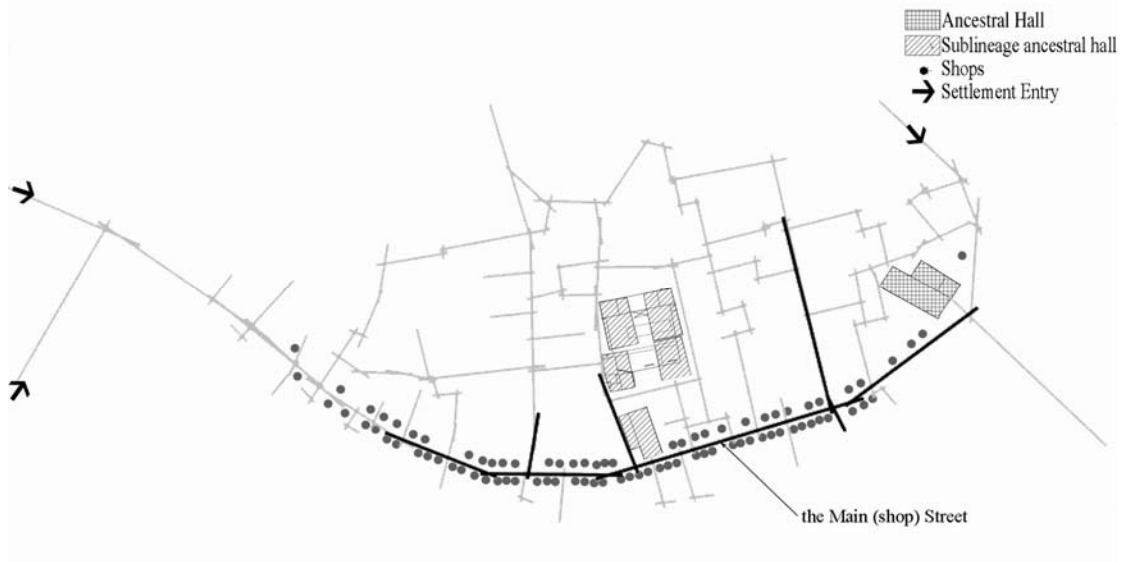
Proceedings of the 7th International Space Syntax Symposium
Edited by Daniel Koch, Lars Marcus and Jesper Steen, Stockholm: KTH, 2009.

126:4

Figure 4

The integration (Rn) structure of Wangkou overlapped with major functional elements, with the 10% integration core shown in bold black.

Figure 4 is the integration structure of Wangkou's street network, with lines colored from gray to dark indexing values from low to high, and with bold dark lines showing the (10%) integration core of the settlement. The integration core consists of 8 axial lines, forming a distinctive linear pattern and extending itself in east-west direction along the Main Street, with several strong integration links branching from the street to penetrate into surrounding residential quarters. The linear integration core is largely overlapped with the Main Street, where most shops of the settlement are clustered around. The location of the integration core is rather "shallow" seen from the outside, with only one or two syntactic steps from the east settlement entry and waterfront wharves. This suggests a close relationship between the core and the water transportation. In terms of shape and location of integration core, Wangkou shows a great similarity to Yuliang (coded as Case h), another quasi-market town in Huizhou Prefecture. The similarity tends to suggest that there exists certain relationship between settlement layout morphology and economic activities.
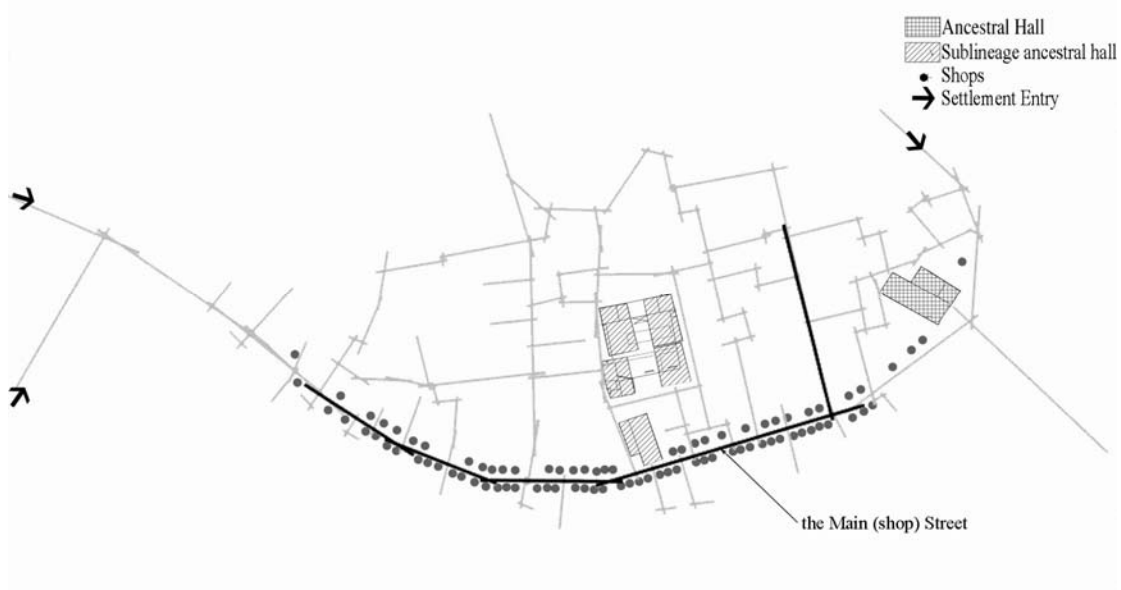

Figure 5

The (global) choice structure of Wangkou overlapped with major functional elements, with the 25% choice core shown in bold black.

Proceedings of the 7th International Space Syntax Symposium
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126:5

Figure 5 displays the (global) choice structure of Wangkou, with bold dark lines showing the top 25% accumulated choice values. An immediate finding is that the 25% choice core has a very high agreement with the 10% integration core of the settlement. This means that there are a few streets or street segments, which are not only the most accessible locations but also important constituents of the shortest topological routes within the settlement. In other words, they have both to-movement and through-movement potentials of the spatial system. Data analysis seems to confirm the graph appreciation. Those axial lines taking up the 10% integration core produce a very strong correlation between their Rn values and choice values ($r^2 = 0.8019$), which is much higher than the settlement as a whole ($r^2 = 0.4412$).

Table 2 tabulates the second order syntactic properties (measured by statistical correlations between local and global syntactic properties) of Wangkou's axial structure. As shown, choice property produces much stronger associations with local properties such as connectivity ($r^2 = 0.5065$), control ($r^2 = 0.4757$) and R3 integration ($r^2 = 0.4106$) than Rn integration property does ($r^2 = 0.1708$, 0.1108, and 0.2775, respectively). This means that choice of the shortest routes is a more reliable global property that can be inferred from local syntactic measure of an axial space in the settlement. Such configuration property tends to hold true in other settlements in Huizhou as well. As shown in Table 2, in 8 out of 9 cases, the strongest correlation between the first order syntactic properties is given by connectivity and choice.

It would be of some interest to notice here. While in urban areas the intelligibility property is considered the best indicator of the relation between the local and global properties of a layout system (Hillier et al., 1987; Peponis et al., 1989), in the case of lineage-based settlement in China, it turns out to be the connectivity and choice properties which correlate best among all second order measures. If the global structure of a layout is considered as "intelligible" because the global property of spaces in that system could be told by the local properties of these spaces, then what might be called the "intelligibility of Chinese lineage-base settlement" could probably be represented by the association between connectivity and choice.

The synergy (given by association of R3 and Rn values) of Wangkou's layout configuration is 0.2775 for the settlement as a whole. However, it becomes much stronger ($r^2 = 0.5075$) when only those spaces constitute the 10% integration core and its immediate neighbors (i.e. at the core+1 step) are considered in calculation. It indicates that spaces around these parts (usually the central quarters of a settlement) have a better definition and readability than other parts as well as the settlement as a whole. This configuration property appears to be also another commonality shared by the sample Huizhou settlements (Table 2).

Settlement name	Case a	Case b	Case c	Case d	Case e	Case f	Case g	Case h	Wangkou
CN:Rn	0.2583	0.1236	0.1537	0.3129	0.3742	0.2998	0.1074	0.4324	0.1708
CV:Rn	0.0554	0.0339	0.0220	0.0482	0.0282	0.0460	0.0339	0.0731	0.1108
CN:CH	0.5073	0.4120	0.4261	0.5814	0.5162	0.5315	0.4488	0.4971	0.5065
CV:CH	0.2809	0.2679	0.2527	0.3170	0.1516	0.3140	0.2779	0.2329	0.4757
R3:CH	0.4474	0.4078	0.4166	0.4944	0.5033	0.4255	0.3342	0.4253	0.4106
R3:Rn	0.3269	0.2004	0.2620	0.4055	0.4502	0.4333	0.1794	0.5242	0.2775
R3:Rn (core+1)	0.4149	0.5239	0.4112	0.5924	0.5866	0.5589	0.6791	0.6865	0.5075

Table 2

Second order syntactic properties of Wangkou and other Huizhou settlements

Superimposing the integration structure with locations of major functional elements of Wangkou shows the social dimension map of the settlement (figure 4). A comparison of this map with maps shown in figure 1 immediately discloses that Wangkou shares quite similar configuration regularities to other Huizhou settlements in terms of distribution of functional elements and pattern of land use: most communal buildings of the settlement tend to be clustered around the most

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Edited by Daniel Koch, Lars Marcus and Jesper Steen, Stockholm: KTH, 2009.

126:6

accessible street frontages. The Main street displays a high degree of overlapping with both the 10% integration core and the 25% choice core. The coincident parts of the three are street locations where shops are most densely distributed. Meanwhile, a majority of ancestral halls are also found to concentrate on the 10% integration core, or just one step from the core.

4. Movement Data Observation

Pedestrian movement data were collected using the "gate count" method developed by space syntax research. Observation was carried out on several weekdays in July 2007 under average weather conditions. A total of 45 gates are selected for this case study. Their locations are shown in figure 6. Gate selection follows a "stratified random sampling" principle by first dividing the axial spaces of Wangkou into three groups according to the spread-out of the integration value among these spaces, then proceeding to select from each group a roughly equal number of spaces.
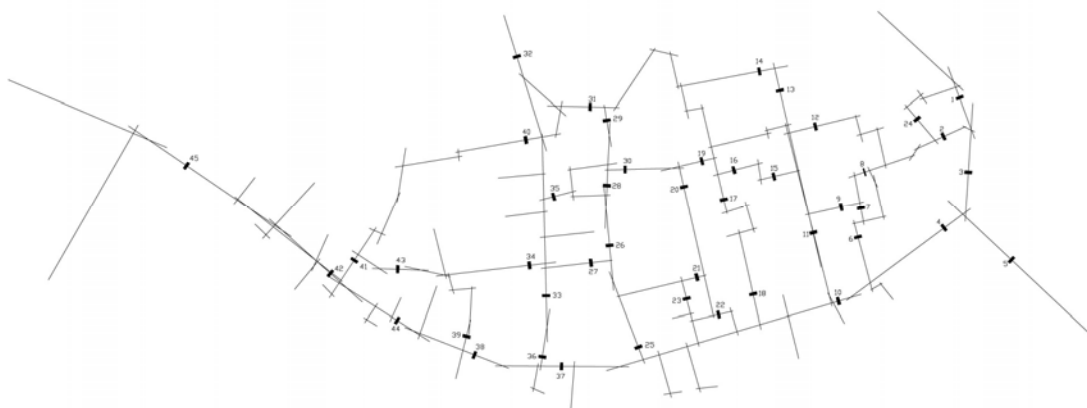

Figure 6
Gate locations of pedestrian movement observation.

After having decided the observation gates, each location was given an equal number of observations at approximately the same time of a day. The observation time covers most of the day time between 08:00 and 18:00. In each observation, an observer counted the number of pedestrian adults crossing a gate within 5 minutes, and then moved to the next gate and counted for another 5 minutes until a round of observation was accomplished. A number of rounds of observation were exercised and the data of each gate were averaged as observed movement rate in order to avoid any significant distortion about pedestrian uses of space in the settlement. Simple statistical techniques of linear association are explored to correlate observed densities of pedestrian movement of the sample gates with the syntactic values of these spaces in order to find out whether there is any relevance of the spatial structure of the settlement to the distribution and density of pedestrian movement, and which spatial variable gives the best correlation with movement rate.

5. Correlation Analysis of Pedestrian Movement and Syntactic Properties

The average pedestrian movement rate observed in Wangkou is 4.25 adults per 5 minutes. It appears to be no strong differentiation of pedestrian movement rates between rush hours (with an average of 5.02 adults per 5minutes for time periods 8:00 ~10:00am and 4:00~6:00pm) and the rest time of a day (with an average of 3.82 adults per 5 minutes). On the other hand, distribution of movement rates varies significantly among individual spaces to the extent that the 6 axial lines located on the Main Street have an average rate of 9.08 adults per 5 minutes, whereas a few sample gates have almost no adult passing through during observation.

Intuitively, there seems to be certain connection between the integration structure of the settlement and the observed movement rates of the sample gates: as light colors (low Rn values) in figure 4 tends to be associated with low pedestrian rates and dark colors associated with high pedestrian

Proceedings of the 7th International Space Syntax Symposium
Edited by Daniel Koch, Lars Marcus and Jesper Steen, Stockholm: KTH, 2009.

126:7

rates. Statistical analysis confirms our graph observation. For the total 45 sample gates observed in this study, Rn property produces a rather strong correlation with the observed pedestrian flows ($r^2 = 0.480$, $p = 0.0001$). Local properties such as R3 integration, connectivity, and control produce only moderate association with pedestrian movement. Yet, the strongest association with pedestrian movement is given by choice measure rather than Rn integration ($r^2 = 0.609$, $p = 0.0001$). On the other hand, metric property such as axial line length gives the weakest association with pedestrian movement (table 3).

	M: CH	M: Rn	M: R3	M: CV	M: CN	M: Line length
Shops included	0.609	0.480	0.250	0.180	0.242	0.155
Shops excluded	0.338	0.292	0.078	0.027	0.037	0.029

Table 3
Association of pedestrian movement and syntactic properties in Wangkou (r^2)

Although statistical results reveal choice property is best correlated with pedestrian movement, its scatterplot map displays a rather uneven data distribution, with a few spaces on the top right corner taking up the highest values both in terms of choice and movement rate (figure 7a).
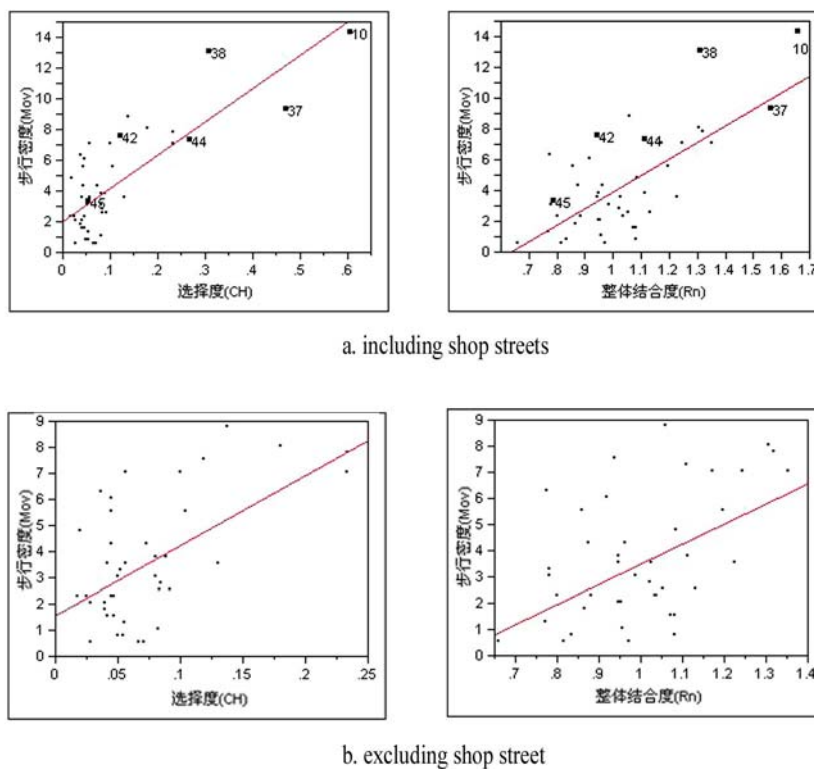

a. including shop streets

b. excluding shop street

Figure 7
Scatterplots showing correlations between pedestrian movement rate and choice and integration (Rn) properties, with (a) shop streets included (shown in numbered bold dots); and (b) shop streets excluded from analysis.

Most of these spaces are located on the Main street, and have a relatively higher concentration of shops. As a contrast, the scatterplot of Rn and movement rate shows a much even data distribution.

Proceedings of the 7th International Space Syntax Symposium
Edited by Daniel Koch, Lars Marcus and Jesper Steen, Stockholm: KTH, 2009.

126:8

The data distribution suggests that the presence of shop streets may have an important relevance to interpreting statistical analysis. Does the correlation analyzed above indicate the distribution of pedestrian movement densities is in the main predicted by settlement syntactic structure? Or is it largely a result of the location of particular attractors like shops and institutional buildings?

In order to arrive a valid conclusion that it is mainly the spatial layout, not some other factors, plays a more significant role in giving rise pattern of pedestrian space use, space syntax research has developed a comparative approach to field observation. The basic idea is to exercise observations under two generally different conditioning circumstances: weekdays and holidays, respectively (Hillier et al., 1993). Two sets of movement data, which are supposed to be able to reflect the differences between patterns of space use and pedestrian movement from different circumstances, are collected and then correlated with the same spatial variable — the syntactic properties of an urban layout — to determine if the spatial structure per se is mainly responsible for generating pedestrian movement, or, if the effect of some other variables should also have to be taken into account.

There is, however, a somewhat different situation in China's rural settlements. Unlike people living in cities, those who live in rural settlements do not seem to have any significantly different patterns of behavior or activity between weekdays and holidays. Therefore, an alternative of comparison is adopted in this case study by comparing two sets of correlation analysis: those before and after the shop streets are excluded in statistics. The comparative results are shown in table 3. Although correlations between movement data and spatial variables decrease to a certain extent when shop streets are excluded from the analysis, the strength of correlation given by spatial variables maintains a consistent pattern as before. The correlation of local properties and axial line length with movement is very weak, if not neglectable at all. Both global properties produce a relatively strong correlation with pedestrian movement, although to a lesser degree. The choice measure still gives rise to the best correlation with pedestrian movement ($r^2 = 0.338$, $p = 0.0001$), followed by Rn integration, which produces an almost equally strong association with movement ($r^2 = 0.292$, $p = 0.0004$). Each scatterplot map of these global properties displays a more even data distribution (figure 7b) than before. The consistency of results before and after shop streets are excluded from statistical analysis suggests that it is the syntactic structure of settlement, rather than some other variables, that is mainly responsible for giving rise to pedestrian movement in the settlement.

6. Discussions

In light of the analyses from this case study, some tentative conclusions can be made to characterize the spatial configuration of Wangkou in relevance to the pattern of pedestrian movement. (1) There is preliminary evidence suggesting that density and distribution of pedestrian movement in Wangkou are more related to the axial structure of settlement than to the location of particular attractors like shops and institutional buildings. The fact that association between global properties and pedestrian movement tends to be less strong when shop streets are excluded, seems to indicate that the presence of certain functional attractors in Wangkou has such an effect as to improve the association between these variables. (2) Global properties of the axial structure have a better correlation with, thus a better predictability on pedestrian movement than local syntactic properties and axial line length. (3) While it is argued that the "intelligibility" of settlements in Huizhou should be better represented by association between connectivity and choice, the choice property turns out to be the best predictor of pedestrian movement in the case study. (4) When shop streets are excluded from statistical analysis, the Rn measure produces an almost equally strong correlation with movement as the choice measure does.

These findings confirm once again the fundamental syntactic theorem already demonstrated by research of urban forms elsewhere, namely the distribution of pedestrian movement is a function of the syntactic structure of a layout system, indifferent of cultural context (Hillier et al., 1987; Peponis et al., 1989). The spatial structure modulated movement pattern in the case of Wangkou therefore offers a preliminary account for the configurational regularities (centrality process) of Huizhou settlements. It seems that mainly because of the impact on pedestrian movement the spatial structure of these settlements had attracted major functional elements like shops and

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Edited by Daniel Koch, Lars Marcus and Jesper Steen, Stockholm: KTH, 2009.
126:9

ancestral halls of a settlement to concentrate on spatially advantage locations during settlement growth and evolution. This process, driven by social economic activities, gave rise to morphological variability observed in the sample settlements.

On the other hand, the fact that the choice measure is more related to settlement pedestrian movement than the integration property does not quite agree with what has been found in certain European cities, but coincides with Ye Min's comparative research on Chinese and Swedish neighborhood morphology (Ye, 1993a & 1993b). Hillier explained why integration has been continuously identified as the best predictor of movement in urban space research. According to him, as far as cognition of a complex urban area is concerned, integration seems to be a property which is capable of people's intuitive grasp without presupposing a knowledge of that area as a whole; meanwhile grasp of the choice property of the area seems to require such a knowledge (Hillier et al., 1987).

Yet, it is found in Ye's research that, for a self-contained, closed system like neighborhood layout, the choice property correlates better than the integration with pedestrian movement. One of the reasons behind this phenomenon, according to Ye, is that pedestrians in a neighborhood tend to be composed mostly by the local inhabitants, which means that this user group can acquire a knowledge of that neighborhood as a whole by repeatedly exploring its spatial layout. He also suggested when the "theoretical (syntactic) choice" of spaces of a neighborhood largely agrees with the "practical choice" (popularity for through-movement that a space gains by occupying the particular position in-between functionally important localities or attractions) of these spaces, then the choice structure is likely to both reflect and actually decide how pedestrian movement will be distributed in the neighborhood (Ye, 1993b).

While Ye raised his observation as a hypothesis, this case study seems to lend a support to his observation. First, Wangkou, as a lineage-based settlement, is apparently a closed spatial system with well-defined physical boundaries. Its pedestrians are mostly composed by the local residents growing up from the settlement and thus possessing a knowledge of the settlement as a whole. Second, a closer examination of Wangkou's choice structure reveals that the highest choice values are always found on those street spaces that are actually significant for certain pattern of movement: they either have a high concentration of shops and institutional buildings or are functionally important in channeling settlement-wide movement between settlement entries. As the "theoretical choice" and the "practical choice" appear to be congruent with each other among quite a number of spaces in Wangkou , it is found that distribution of pedestrian movement becomes more predictable from the choice dimension than the integration dimension of settlement layout.

The fact that the choice measure is a more reliable indicator for predicting the distribution of movement is not only shown by correlation analysis, but also to some extent is suggested by the analysis of second order syntactic properties, which reveals that the choice value of spaces is one which can be always inferred from local properties better than the integration. The question is, if choice can be shown as the most relevant property for understanding the spatial formation of lineage-based settlement both in terms of structural "intelligibility" and the predictability of movement from space, then can we assume this property to be a crucial one that defines traditional settlements in Huizhou as a particular class of built forms? Due to the confinement of case study, this question is not easy to tackle at this moment. It is better to raise this question as a hypothesis to be tested in future research when more case studies on pedestrian space use and comprehensive research designs of comparative study are available.

Acknowledgement

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126:10

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126:11