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Cultural impacts on traditional Chinese garden design:

A configurational comparison between traditional Chinese imperial and private gardens using space syntax

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ABSTRACT

Based on former qualitative studies, traditional Chinese imperial garden (TCIG) and private garden (TCPG) arguably have different cultural backgrounds and spatial properties. However, few studies have analysed configurational differences between TCIG and TCPG quantitatively and linked their different cultural contexts to these differences.

This research thus tries to reveal the cultural impacts on the spatial configuration of traditional Chinese gardens by comparing TCIG and TCPG cases quantitatively. The study is processed in two sections: theoretical exploration and comparative case studies. In the first section, we try to link the different cultural backgrounds of TCIG and TCPG with corresponding garden spatial properties and use proper metrics to match these spatial properties. Four dimensions of traditional Chinese garden spatial properties are identified qualitatively based on previous studies: strong and weak programme, wayfinding system, visual relationship and spatial depth. During the process, four corresponding hypotheses about the spatial property differences and predicted results of quantitative studies are proposed. In the second section, four hypotheses may be demonstrated through visibility graph analysis (VGA) in space syntax theory by comparing three samples from each garden type. Our results indicate that TCIG and TCPG differ in all four dimensions, which are further explained by their respective cultural contexts.

This research has two main contributions. Firstly, it has demonstrated configurational differences of TCIG and TCPG quantitatively and linked these differences to related cultural backgrounds.

Secondly, this study has built a framework to analyse traditional Chinese garden space with space syntax, which can be used in further studies.

KEYWORDS

traditional Chinese garden, space syntax, visibility graph analysis, cultural impact, configuration

1 INTRODUCTION

Traditional Chinese gardens have been developed along with the history of China for a long time since Qing Dynasty (221 B.C.to 207 B.C.). *Yuanye* ("园冶" in Chinese, "*Craft of Gardens*" in English), written by Chen Ji in 1631, is the first systematic study to describe traditional Chinese gardens (Ji, 1631). In this book, Ji emphasized the importance of spatial configuration in traditional Chinese garden design, and proposed that how spaces are organised is one of the most essential aspects for traditional Chinese gardens design (Ji, 1631). In the last century, a series of studies have further refined the theoretical basis of traditional Chinese gardens, providing detailed studies and descriptions of Chinese gardens at the aspects of both cultural background and spatial properties (e.g., Liu, 1979; Tong, 1984; Chen, 1984; Peng, 1986; Zhou, 1990; Zhang, 1991; Tong, 1997).

Traditional Chinese imperial garden (TCIG) and private garden (TCPG) are two main types of traditional Chinese gardens. They have different cultural backgrounds and spatial properties: TCIG design is related to imperial power culture, and the spaces reflect the symbolic meanings of imperial power; while TCPG design is related to Chinese landscape culture and seclusion culture, trying to reconstruct the natural environment experiences (Peng, 1986; Zhou, 1990).

Despite of their important contributions, most former studies heavily relied on qualitative methods such as visual comparisons and subjective descriptions, yet failed to analyse the layout of traditional Chinese gardens in a quantitative way. In 1984, Hillier and Hanson developed the space syntax, which provides a series of theories and methods to analyse the space configuration in a mathematical manner (Hillier and Hanson, 1984). Hillier and Hanson's theory has been widely applied in many fields, such as architectural design, urban design, etc. In recent years, some scholars have also started to use space syntax as a quantitative tool to analyse the traditional Chinese gardens (e.g., Li, 2011; Yu, Gu & Ostwald, 2016; Tceluiko & Bazilevich, 2018; Zhang, Lian & Xu, 2020). However, these studies use space syntax to analyse one garden, rather than forming a framework for comparative studies between gardens.

This paper seeks to fill two research gaps: firstly, it uses space syntax technique to quantitatively compare the spatial attributes of imperial gardens and private gardens and to develop a framework for related garden space comparative research. Secondly, it attempts to link the cultural contexts of TCIG and TCPG with spatial properties, using cultural impacts to explain the

differences in space configuration that exist between the two types of gardens. To achieve these two objectives, an in-depth comparison on spatial attributes was conducted between three TCIG and three TCPG samples using visibility graph analysis (VGA).

2 LITERATURE REVIEW

2.1 Differences in cultural backgrounds between TCIG and TCPG

Some scholars have studied the differences in cultural background between imperial gardens and private gardens (e.g., Peng, 1986; Zhou, 1990; Zhang, 1991). Among them, Zhou's research on the cultural contexts of traditional Chinese gardens is the most influential and representative. Zhou defined three cultural dimensions of the Chinese garden: the unity of heaven and man, the Chinese landscape aesthetics and the seclusion culture (Zhou, 1990). Of these three dimensions, the unity of heaven and man - as a cultural interpretation of imperial power - is the main cultural context of the imperial gardens, while Chinese landscape aesthetics and seclusion culture are the main cultural context of the private gardens. The different cultural backgrounds ultimately lead to the layout of the two types of Chinese gardens separately.

Unity of heaven and man. The legitimacy of the emperor in ancient China was thought to derive from a divine appointment, and imperial power was closely linked to the idea of the unity of heaven and man. Royal architecture in ancient China tried to reflect that imperial power was appointed by the heavens and had a high degree of prestige through symbolism. This is evidenced in the studies of both the Forbidden City and the Temple of Heaven (Zhu, 1999; Gu, 2004), where the imperial architecture space is powerful symbolic of politics. Such a view of architectural space has also influenced the imperial gardens and is a central idea in their cultural philosophy (Zhou, 1990).

Shanshui - Chinese landscape aesthetics. The desire and love for natural landscapes in Chinese culture became prominent and prevalent from the Wei and Jin dynasties (265-420AD), leading to a concept known as Shanshui aesthetics or Chinese landscape aesthetics. Such a culture about landscape had given rise to various art forms along with Chinese history, including landscape painting, landscape poetry and so on. Traditional Chinese gardens are also one of the art forms that have been spawned by the Chinese landscape aesthetics and have continued to develop in this cultural wave. The development of Chinese landscape culture has impacted both imperial and private gardens (Zhou, 1990).

Seclusion culture. The culture of seclusion originated from and is closely linked to the Chinese landscape aesthetics. The culture of seclusion and the Chinese landscape aesthetics are intertwined and complement each other; many artistic creations about Chinese landscapes are at the same time mostly related to the idea of seclusion. Based on Zhou's studies (Zhou, 1990), in ancient China, this culture was prompted by the idea that a large number of literati were bored

with life in the city and the officialdom and wished to find a moment of clarity in nature. Under the influence of such a culture, many literati began to build gardens in the city to coexist with nature in the city, and this was the birth of the private garden (Zhou, 1990). Because of the seclusion culture, the aesthetics of Chinese landscapes had more important influences on private gardens than on imperial gardens.

2.2 Manifestations of cultural differences on spatial properties

Different cultural contexts have different influences on the spatial properties, and the culture of imperial power and seclusion culture can lead to differences in the design of architectural spaces. Some scholars have argued that the architectural spaces associated with imperial power are symbolic, which are a manifestation of order and dominance, and that the spaces are often strongly programmed (Liu, D., 1979a; Zhu, 1999; Gu, 2004). Peng's studies of space in traditional Chinese gardens also suggest that TCIG layouts are more strongly programmed than layouts in TCPG (Peng, 1986). Zhou also put forward a similar point of view, proposing that TCIGs are more solemn and symmetrical (Zhou, 1990).

The cultural background of the private gardens is mainly the Chinese landscape aesthetics and the seclusion culture. The space of TCPG tends to mimic the natural environment, giving the ancient literati a sense of co-existence with nature. Many scholars have studied the space of TCPG, with similar conclusions (e.g., Tong, 1984; Chen, 1984; Peng, 1986; Zhou, 1990; Zhang, 1991). Of these studies, Peng has the most systematic and detailed description of the spatial properties of TCPG (Peng 1986). In the studies, Peng proposed that TCPG layouts have more complicated path systems, visual relationships and more levels of space in depth, creating a lively natural landscape for those ancient literati (Peng, 1986). Chen also mentioned that that the paths in TCPG are twisty and complex, and the nested courtyard spaces are connected in depth (Chen, 1984). Zhou corroborated some views of Peng through his exploration of Chinese ancient literature, arguing that TCPG paths are tortuous and sight lines are constantly changing in people's movements (Zhou, 1990). Zhang further emphasized the position of sight design in TCPG, believing that the constantly changing sight fields and visual depth are the keys for TCPG to imitate the natural environment (Zhang, 1991).

In summary, because of the symbolism of imperial power, the layouts of TCIG may be more strongly programmed than TCPG layouts. Meanwhile, to mimic the complicated natural environment, achieve the Chinese landscape aesthetic and provide natural retreats for Chinese literati, TCPG may have more complex path systems, various and changing visual relationships and spatial sequences in depth than TCIG.

3 METHOD

Having explored the different cultural contexts of TCIG and TCPG through the literature review, this study adopted VGA analysis (Turner et al, 2001) to quantitatively compare the different spatial properties corresponding to the different cultures in four dimensions: strong and weak programme, wayfinding system, visual relationship, and levels of space in depth. Further, indicators in the space syntax theory were matched to the corresponding spatial attribute dimensions to give a framework for quantitative comparison in the next stage. Four hypotheses and predicted results were proposed based on the theoretical framework. The hypotheses were analyzed one by one using pre-determined metrics, and final conclusions were drawn. The purpose of this was to discover whether the layouts of TCIG and TCPG differ from each other, and how the differences correlate with their different cultural contexts.

3.1 Measuring the difference between TCIG and TCPG in spatial properties

Space syntax is the collective term for a range of theories and methods for studying architectural and urban spatial configurations (Hillier & Hanson, 1984). The quantitative analysis of garden space is based on the theory of space syntax, and the former qualitative theoretical studies of TCIG and TCPG space expect to be demonstrated quantitatively by specific metrics in spatial syntax theory. In previous quantitative studies of garden space, VGA in spatial syntax has been used to analyse the accessibility and complexity of path systems and visual relationships (e.g., Li, 2011; Yu, Gu & Ostwald, 2016; Zhang, Lian & Xu, 2020). Therefore, VGA analysis was chosen as the main tool to compare the spatial properties of TCIG and TCPG. Based on previous qualitative theories on the spatial properties of traditional Chinese gardens, the quantitative comparative study of TCIG and TCPG spaces is divided into four dimensions: strong and weak programme, path system, visual relationship and spatial sequence.

Strong and weak programme. Hillier clearly defined strongly programmed and weakly programmed buildings, with strongly programmed buildings operating according to some specific rules, while weakly programmed buildings perform more freely and randomly (Hillier, 1996). From a qualitative point of view, TCIG is more strongly programmed than TCPG (Peng, 1986), and specific spaces in TCIG may be solemn and symmetrical, and dominate its overall layout because of their symbolic meaning of imperial power (Zhou, 1990). The syntactical metric *control* (Hillier & Hanson, 1984) reflects the degree of control of specific space over other spaces and were used to evaluate and compare TCIG and TCPG layouts regarding the strong and weak programme. *Integration* (Hillier & Hanson, 1984) as an indicator of spatial accessibility was also used to analyse whether there is a clear prominent space within a garden. A normalized version of integration, *integration [HH]* (Hillier & Hanson, 1984) is used in VGA analyses, in order to compare values from different cases. In Cai and Zimring's research of nursing units, the dispersion of the integration values is used to judge whether there is a hierarchy in the spatial layout (Cai and Zimring, 2019). The current study used the standard deviation of the integration and control values to further evaluate whether there is a hierarchy of space, i.e., whether particular spaces have strong degrees of control over the whole layout. Furthermore, since both

path systems and visual relationships can influence the level of the programme in the garden, both knee-level and eye-level VGA analyses were carried out.

Wayfinding system. Based on previous qualitative research, path systems of TCPG tend to be more twisty and complex than those of TCIG, as TCPG layouts would need to mimic the winding roads in the natural environment to create complex tour experiences (Chen, 1984; Peng, 1986; Zhou, 1990). This to some extent reflects the difference in their wayfinding systems, i.e. TCIG has better wayfinding systems than TCPG. In Yu, Gu & Ostwald (2016) study of TCIG, they used knee-level *intelligibility* (Hillier et al, 1986) to evaluate the sense of mystery in TCPG. In fact, the mystery they analysed is the complexity of wayfinding system described in this paper. The analysis of the wayfinding system can be divided into two dimensions. In terms of the local dimension, the *connectivity* (Hillier & Hanson, 1984) as an indicator of the size of the local field of view can be used to judge whether the wayfinding system is good or not in local spaces. The measure connectivity is normalized in following analyses, in order to compare values from different cases: For a graph G, normalized connectivity is calculated as the number of cells visible from a specific cell, N(vi), divided by the total number of cells, V(G).

$$Normalized\ Connectivity = \frac{N(v_i)}{V(G)}$$

As for the global dimension, the intelligibility can describe whether visitors can effectively understand the whole layout, reflecting the goodness of the wayfinding system from a global perspective. In this section, all analyses are knee-level analyses, as the wayfinding system is mainly constructed by the path system.

Visual relationship. In order to simulate the experience of walking through the natural environment, TCPG is supposed to have more complex visual relationships than TCIG, according to former qualitative research (Peng, 1986; Zhou, 1990; Zhang, 1991). In Yu, Gu & Ostwald (2016)'s study of TCIG, they studied the visual relationship in TCPG with the metric *occlusivity* (Benedikt, 1979). In the current paper, just like the wayfinding system analysis, the visual relationship analysis was also divided into two parts: local dimension and global dimension, evaluated by occlusivity and intelligibility separately. Both attributes were examined at eye-level to reflect the visual relationship. The metric occlusivity was used to judge the complexity of the local visual relationships, as it indicates how previously unseen space may be revealed during movement (Benedikt, 1979). A normalized version of occlusivity, proportional occlusivity (Koutsolampros, 2021), is used in the comparative case studies. From a global view, the metric eye-level intelligibility was used to determine the visual complexity as it evaluates whether the entire layout is easily understood by visitors.

Levels of space in depth. Hillier and Hanson mentioned topological depth in their syntactical analysis of architectural space (Hillier and Hanson, 1984). Some buildings introduce visitors to deeper spaces to complete spatial experiences, exchanges of knowledge and educational processes (Hillier and Hanson, 1984). And there are also outdoor spaces with deep topological

depth in cities, such as residential areas. Peng's concept of levels of space in depth in TCPG (Peng, 1986) are very similar to Hillier and Hanson's concept of topological depth (Hillier and Hanson, 1984), guiding visitors into deep spaces that simulate the experience in a natural environment. Visual *step depth* (Turner, 2004) from the main entrance of each layout was performed to compare the topological depth of TCIG and TCPG cases. From previous qualitative analysis (Chen, 1984; Peng, 1986; Zhang, 1991), TCPG cases tend to have deeper spaces to visit and thus greater visual step depth values than TCIG cases. The visual step depth analyses were carried out at both knee and eye level.

In summary, four dimensions for quantitative comparisons of the TCIG and TCPG space configurations and associated metrics are identified. Four corresponding hypotheses and related predicted results are presented in Table 1.

Table 1. Hypotheses proposed, related metrics and result predictions.

Hypothesis	Metric	If the hypothesis is true
H1: TCIG's space configurations tend to be more strongly programmed than TCPG.	1) Knee-level and eye-level VGA integration [HH]. 2) Knee-level and eye-level VGA control. 3) Standard deviation of VGA integration [HH] and control.	*TCIG cases' knee-level or eye-level related values (integration / control / standard deviation) will be higher than TCPG cases.*
H2: TCIG layouts have better wayfinding systems than TCPG.	1) Knee-level VGA normalized connectivity. 2) Knee-level VGA intelligibility.	*TCIG cases' knee-level related values (normalized connectivity, intelligibility) will be higher than TCPG cases.*
H3: Visual relationships in TCPG are more complicated than those in TCIG.	1) Eye-level VGA proportional occlusivity. 2) Eye-level VGA intelligibility.	*TCIG cases' eye level proportional occlusivity values will be lower than TCPG cases, while intelligibility values will be higher.*
H4: TCPG layouts have deeper topological depths from the main entrance than TCIG.	1) Knee-level and eye-level visual step depth from the entrance.	*TCIG cases' knee-level or eye-level step depth values will be lower than TCPG cases.*

3.2 Comparative case studies

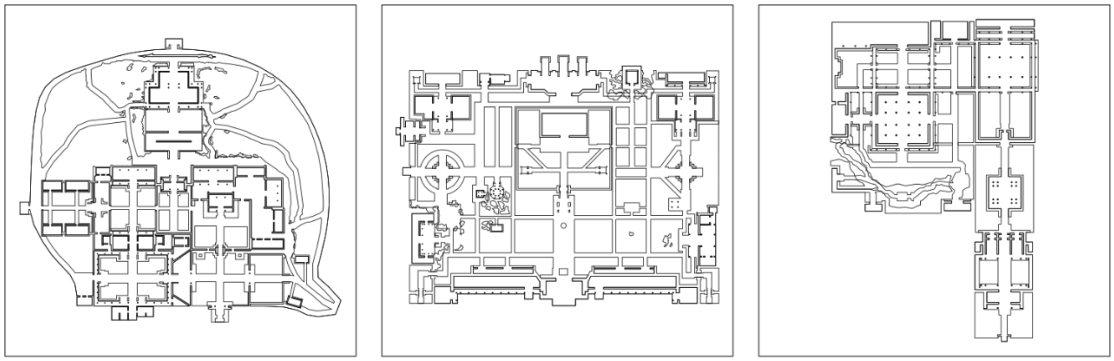
To test the hypotheses above, a comparative study was conducted on three TCIG cases and three TCPG cases. In previous quantitative studies of traditional Chinese garden spaces, scholars generally selected only one garden, making the current comparative study meaningful and representative. The cases chosen for this study are also representative, as shown in Table 2 and Figure 1: three imperial gardens (SLGSP, IGFC, JGFC) from Beijing, the capital of China during

the Qing and Ming dynasties (1368-1912AD), and three private gardens (LY, ZY, WY) from Suzhou, where some of China's most famous private gardens are located. Of the three TCIG cases, two are from the Forbidden City and one from the Summer Palace, both very famous royal places in ancient China. Technical drawings for all the cases are drawn from previous scholarly fieldwork on traditional Chinese gardens: original plans of the three TCIG cases are from Liu, T's investigation (Liu, T., 2018), and original plans of three TCPG cases are from Liu, D's investigation (Liu, D., 1979b). In the following studies of the hypotheses, the data for TCIG are marked in orange and the data for TCPG are marked in blue.

For VGA analyses, the original plans of all cases have been redrawn according to the needs of the study in two dimensions: knee-level and eye-level. The knee-level model removed all obstacles for walking and mapped the edges of all roads and accessible spaces in the plans, which was built to analyse the path system. The eye-level model focuses on the edges of visual areas, which consist mainly of the boundaries of buildings, built to analyse the visual experience. A series of data analyses were ultimately conducted based on plans of these two dimensions. In the following space syntax layout analyses, the colours moving from blue to red represent the values of variables in the same plan from high to low. The series of measures identified above to test the four hypotheses are calculated, and the detailed data of VGA analyses are listed in Table 3.

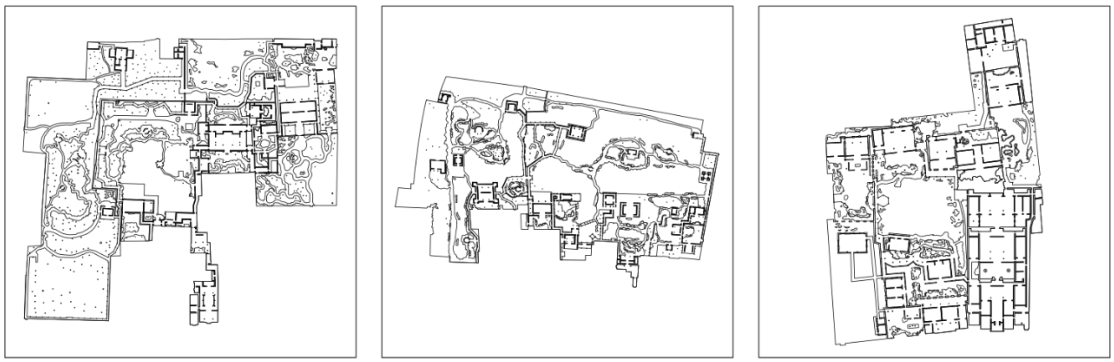
Table 2. Selected TCIG and TCPG cases for comparative case studies.

Garden Type	Region	Garden
Imperial Garden (TCIG)	Beijing	South Lake Garden in the Summer Palace (SLGSP) Imperial Garden in the Forbidden City (IGFC) Jianfu Garden in the Forbidden City (JGFC)
Private Garden (TCPG)	Suzhou	Liu Yuan (LY) Zhuozhen Yuan (ZY) Wangshi Yuan (WY)



South Lake Garden in the Summer Palace (SLGSP) | Imperial Garden in the Forbidden City (IGFC) | Jianfu Garden in the Forbidden City (JGFC)

Traditional Chinese Imperial Garden (TCIG)



Liu Yuan (LY) | Zhuozhen Yuan (ZY) | Wangshi Yuan (WY)

Traditional Chinese Private Garden (TCPG)

Figure 1. Layouts of selected TCIG and TCPG cases for comparative case studies.

Table 3. VGA data on selected TCIG and TCPG cases.

Garden Type	Garden	Knee-level Mean Integration [HH]	Eye-level Mean Integration [HH]	Knee-level Maximum Control	Eye-level Maximum Control	Standard Deviation of Integration [HH]	Standard Deviation of Control	Knee-level Mean Normalized Connectivity	Knee-level Intelligibility	Eye-level Intelligibility	Eye-level Mean Proportional Occlusivity	Knee-level Mean Visual Step Depth	Eye-level Mean Visual Step Depth
Imperial Garden (TCIG)	South Lake Garden in the Summer Palace (SLGSP)	3.46	6.62	2.36	2.00	0.60	0.297	0.319	0.023	0.58	0.62	4.40	2.84
	Imperial Garden in the Forbidden City (IGFC)	4.03	10.58	2.19	1.79	0.93	0.297	0.301	0.026	0.90	0.71	3.38	1.88
	Jianfu Garden in the Forbidden City (JGFC)	5.18	6.63	2.47	2.03	1.24	0.288	0.408	0.058	0.65	0.70	2.95	2.53
Private Garden (TCPG)	Liu Yuan (LY)	1.33	4.61	2.12	2.02	0.27	0.245	0.183	0.010	0.52	0.86	13.77	9.08
	Zhuozhen Yuan (ZY)	1.36	8.60	2.18	1.77	0.20	0.270	0.058	0.013	0.73	0.85	12.82	4.20
	Wangshi Yuan (WY)	2.33	4.59	2.05	1.82	0.40	0.234	0.158	0.017	0.40	0.66	6.02	4.34

4 RESULTS

4.1 H1: TCIG's space configurations tend to be more strongly programmed than TCPG

As shown in Figure 2, layouts of TCIG were demonstrated to be more strongly programmed than that of TCPG, as the knee-level VGA average integration values and maximum control values in the TCIG cases are generally higher than those in the TCPG cases. The higher the knee-level average integration and maximum control values, the higher the accessibility of specific spaces and their substantial control over other areas. These characteristics make TCIG's space configuration strongly programmed. At the same time, the knee-level VGA average integration values and maximum control values of TCPG's layouts are lower, and there is no such prominent space with high accessibility and strong control ability in their layouts, making TCPG's layouts relatively weakly programmed. As shown in knee-level integration graphs (Figure 3), TCIG cases demonstrate a series of highly integrated spaces, leading the spatial order of the entire garden. The cultural context of imperial power may have influenced the spatial configurations of TCIG, which needs a symbolic core space to lead the entire layout and reflect the majesty of royal power, making TCIG cases more strongly programmed than TCPG cases. TCPG cases, on the other hand, seek natural experiences where there may be no specific space with strong integration and control over the overall layout.

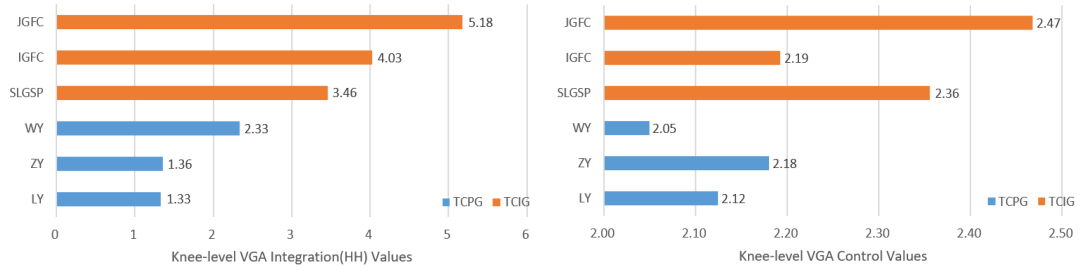


Figure 2. Knee-level VGA average integration (left) and maximum control (right) values of TCPGs and TCIGs.

To describe the discrete trend of these values in different layouts, the standard deviations of each garden's knee-level integration and control values are calculated. It can be found that the standard deviations of the data of TCIG's cases are generally higher, as shown in Figure 4, suggesting that spaces in TCIG have considerably greater differences in accessibility and control, thus a clear hierarchical order. Although in TCPG, Liu Yuan (LY) and Wangshi Yuan (WY) also have specific spaces that have higher knee-level integration values (Figure 3) than the surrounding areas, their deviation values are not very high, so that there is no noticeable spatial hierarchical difference. Such spatial hierarchies in TCIG's cases further prove that TCIG space configurations are more strongly programmed than TCPG.

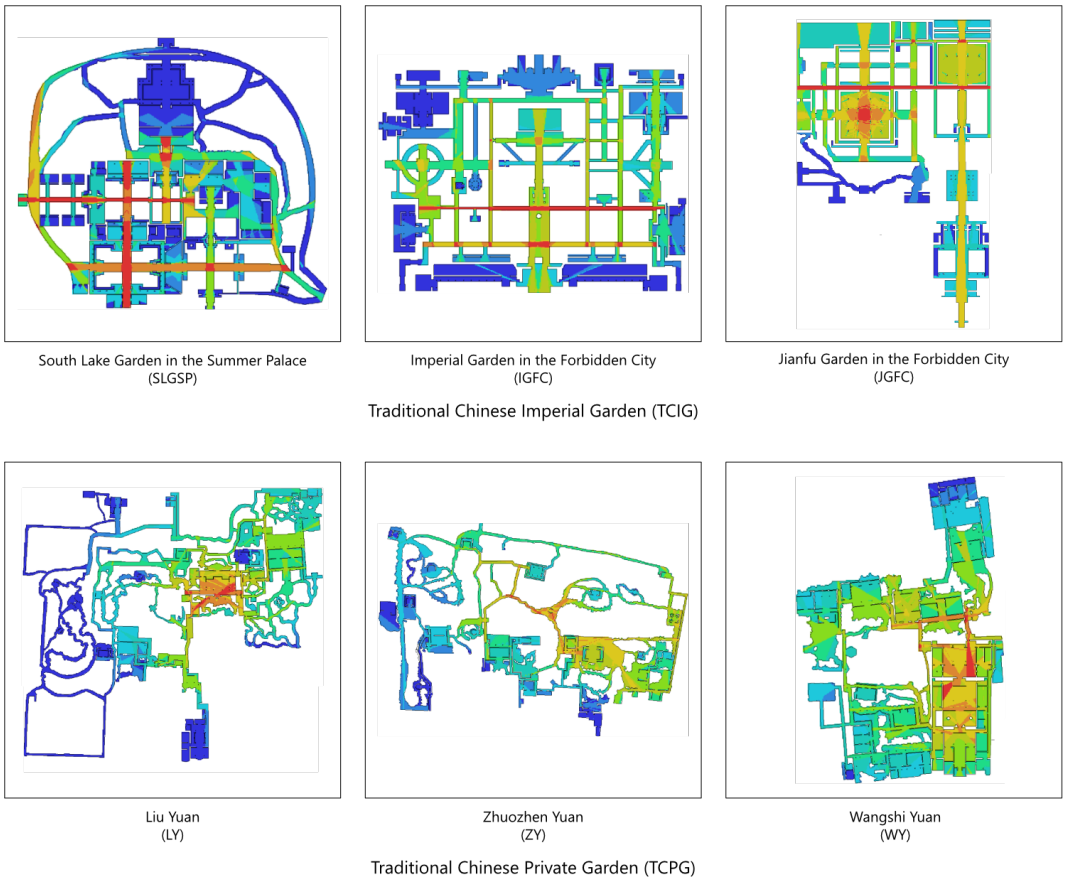


Figure 3. Comparison of knee-level integration of TCIGs (top) and TCPGs (bottom).

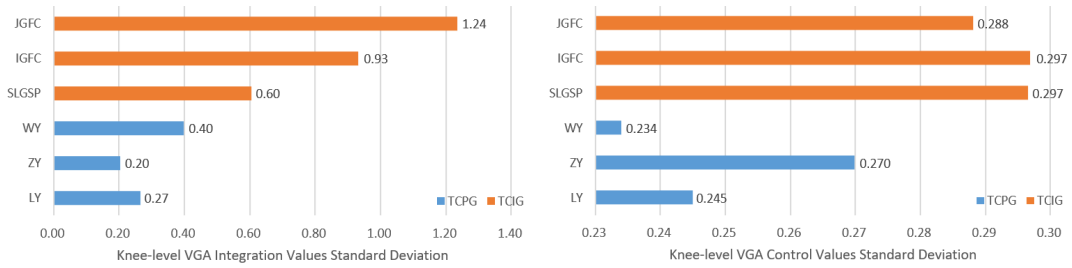


Figure 4. Standard deviation of knee-level integration (left) and control (right) values of TCPGs and TCIGs.

However, the layouts of the two types of gardens do not have considerable differences in average integration and maximum control values at the eye level (Figure 5). Therefore, we can conclude that TCIG's strongly programmed layout is mainly brought by path design (accessibility) but not by visual design (visibility).

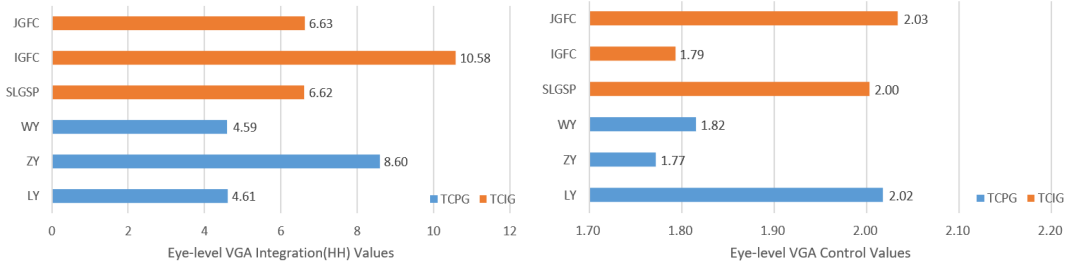


Figure 5. Comparison of eye-level average integration (left) and maximum control (right) values of TCPGs and TCIGs.

4.2 H2: TCIG layouts have better wayfinding systems than TCPG

Wayfinding systems were examined through normalized mean connectivity and intelligibility, both at knee level. When all cases were put in a matrix against these two measures, the pattern becomes clear, as shown in Figure 6. Overall, the TCIG cases occupy the upper right corner of the diagram, with higher connectivity and intelligibility values than TCPG, meaning that TCIG layouts tend to have larger isovist areas, and the whole layouts are easier to recognize and understand by visitors. In contrast, TCPG cases tend to be in the lower-left corner, with lower connectivity and intelligibility values, indicating that more complicated path systems were designed in TCPG layouts. A reason for this contrast can be that TCIG cases favour clear and recognizable path systems to create dignified and orderly spaces for the imperial power, whereas TCPG cases favour complex path systems to form rich space exploration experiences related to the seclusion culture. The ancient people who advocated seclusion culture yearned for living with natural landscapes, hoping that the path systems in the private gardens were very irregular, like the paths in nature. Poor wayfinding systems with complicated paths in TCPG layouts could create experiences of being lost and immersed in nature.

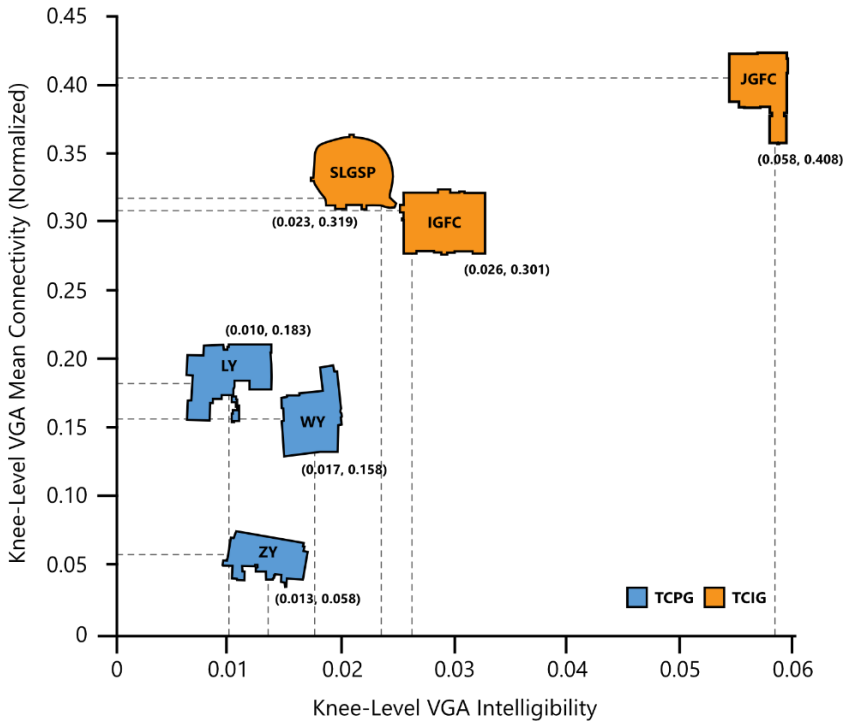


Figure 6. The matrix of three TCIGs' and three TCPGs' layouts, comparing their knee-level intelligibility and mean normalized connectivity.

4.3 H3: Visual relationships in TCPG are more complicated than those in TCIG

Visual relationships in TCIG and TCPG cases were tested by two eye-level measures: mean proportional occlusivity and intelligibility, both of which indicate the complexity of the garden's visual relationships. A higher occlusivity value indicates that the visitors' view changes more as they move, and a lower intelligibility value indicates that it is more difficult for visitors to understand the overall layout through the view.

A matrix chart of the inverse of the mean proportional occlusivity value versus the intelligibility value was created to show the complexity of the visual relationships in TCIG and TCPG cases (Figure 7). The visual inspection does not show a clear classification pattern and the layouts of TCIG and TCPG do not show significant differences in visual complexity when viewed separately in terms of occlusivity and intelligibility values. However, there is an underlying pattern where the fitted exponential curve for TCIG cases is closer to the origin than the one for TCPG cases. This suggests that TCPG cases tend to have lower intelligibility values than TCIG cases for the same occlusivity values, and vice versa. Thus, the overall visual relationships in TCPG layouts tend to be more complex than TCIG layouts in terms of both visual changes during visitors' movements and visual intelligibility.

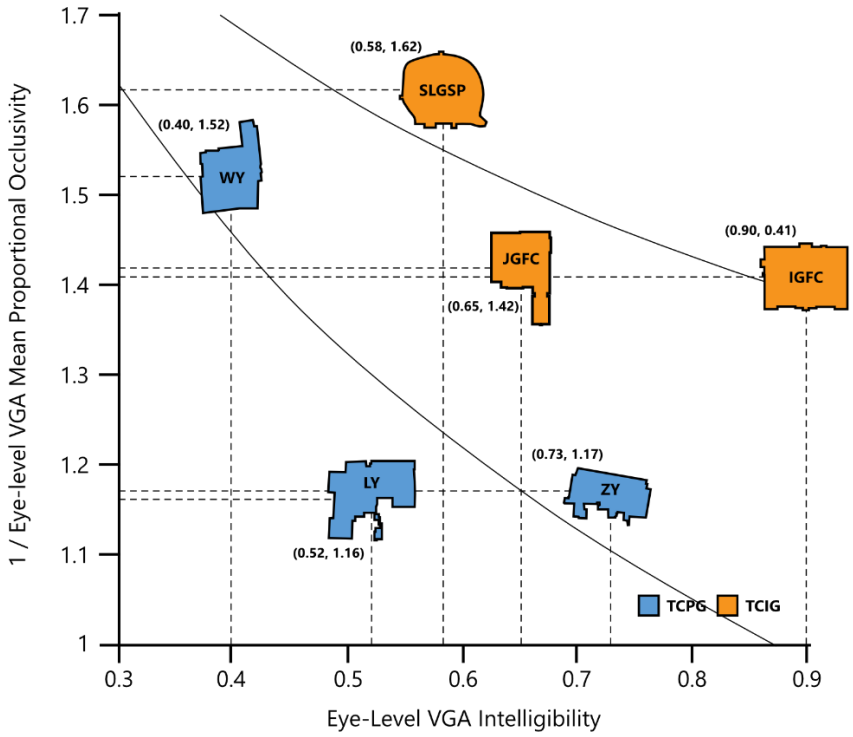


Figure 7. The matrix of three TCIGs' and three TCPGs' layouts, comparing their eye-level intelligibility and mean proportional occlusivity.

4.4 H4: TCPG layouts have deeper topological depths from the main entrance than TCIG.

Topological depth in TCIG and TCPG layouts are measured from garden entrances through both knee-level and eye-level step depth. We can see from Figure 8 that the step depth values for all TCPG cases are higher in both knee-level and eye-level VGA analyses than those for TCIG layouts. This apparent pattern shows that TCPGs are designed to have a greater hierarchy than TCIGs. The same trend in knee-level and eye-level VGA analyses shows that path system design and visual field design both have important influences on the depth of space. Under the imperial power culture, TCIGs tend to have shallower path systems and visual fields because these spatial properties make garden space simple and clear, reflecting the uniqueness and solemnity of imperial power. On the contrary, TCPGs prefer the deeper and more complicated spatial design to create more space knots for visitors to explore, catering to the Chinese landscape aesthetics and seclusion culture to create the experience of living in a deep forest environment.

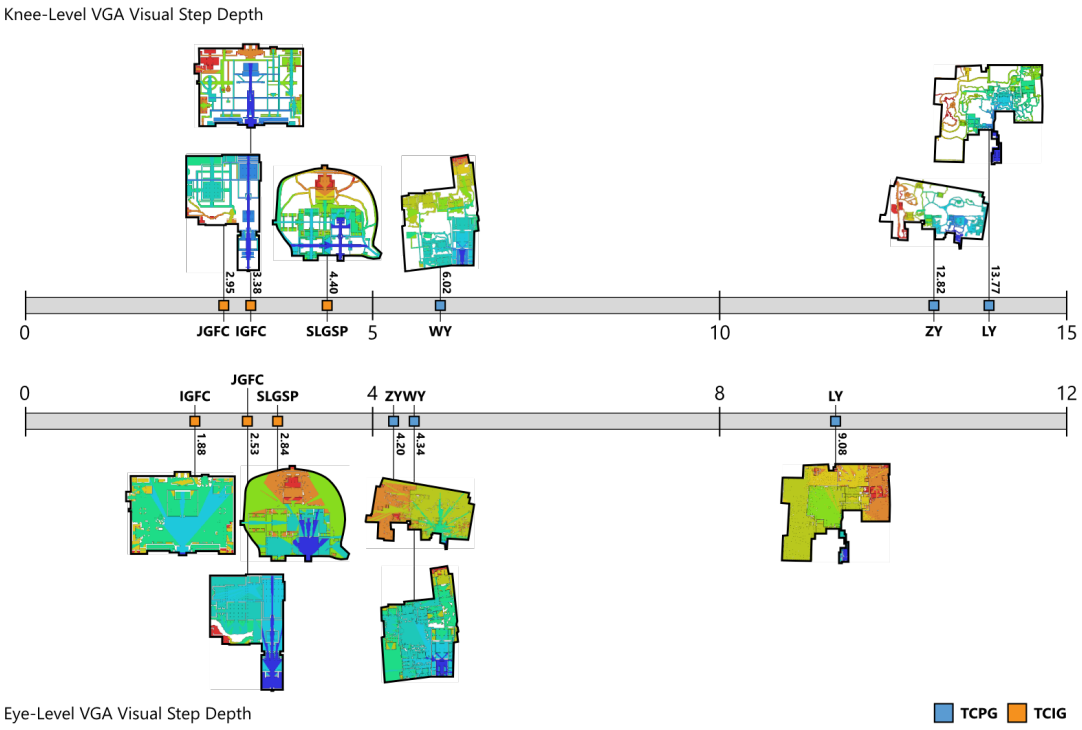


Figure 8. Comparison of knee-level (above) and eye-level (below) VGA step depth values of TCIGs and TCPGs.

Path design and visual field design may have different degrees of influence on the overall topological depth of the garden. Zhuozhen Yuan (ZY) is a case to illustrate this because there are big differences between knee-level and eye-level VGA step depth values in ZY. Compared with other cases, knee-level VGA step depth value (12.82) in the layout of ZY is significantly higher than that in eye level (4.20), as can be seen from the Figure. Such data shows that many levels of space in depth that visitors experience in ZY is more derived from the path system design rather

than the visual field design. Compared with the visual field design, the spatial depth brought by the path system occupies a leading role in the construction of ZY's tour experience.

5 DISCUSSIONS AND CONCLUSION

Based on the above analysis results, it can be argued that different cultural backgrounds between TCIG and TCPG have led to significant differences in their spatial configurations. VGA analyses have confirmed that the spatial configurations of the two types of gardens differ in four dimensions: strong and weak programme, wayfinding system, visual relationship, and topological depth. TCIG layouts are more strongly programmed than TCPG ones, manifested in higher knee-level VGA average integration values, maximum control values, and standard deviation values of these two metrics than TCPG cases. TCPG has more complicated wayfinding systems from global to local perspectives than TCIG because TCPG layouts have lower knee-level intelligibility values and higher average connectivity values. Furthermore, TCPG spaces have more varied visual relationships than TCIG spaces, and TCPG tends to have a lower intelligibility value under the same occlusivity value than TCIG and vice versa. Finally, TCPG layouts have deeper topological depths, with higher visual step depth values than TCIG layouts, both at knee-level and eye-level.

The differences in the spatial configuration of these two garden types are closely related to their specific cultural backgrounds and design ideologies. To highlight the symbolic meaning of imperial power, TCIG needs symmetrical, unified and solemn spaces. At the same time, TCPG is influenced mainly by the Chinese landscape culture and seclusion culture, requiring free layout and more complicated spatial organization to create natural environment experiences.

5.1 Contributions

This study is one of the earlier attempts to systematically quantify the layouts of traditional Chinese gardens and has two main contributions. First, it quantitatively compares imperial gardens (TCIG) and private gardens (TCPG) on spatial properties, which are related to the cultural backgrounds of these two types of gardens. This research also combines knowledge from multi fields, including Chinese philosophy, traditional Chinese gardens and space syntax theory, linking abstract cultural contexts with quantifiable spatial properties. Secondly, this paper establishes four dimensions for studying traditional Chinese gardens using spatial syntax, namely strong and weak programme, wayfinding system, visual relationship, and topological depth. These four dimensions closely integrate the concepts from space syntax theory with traditional Chinese garden space properties. The methodology can be further applied in related studies.

5.2 Limitations and future work

There are several limitations of this paper. The first is that the sample size of this paper is too small, which makes the conclusions less universal. More samples are needed to validate the findings statistically in the future.

Secondly, the map used for VGA analysis may not be precisely accurate to represent the actual spatial environment in the gardens. This is especially true for the eye- and knee-level map. For example, in the eye-level model, we did not consider the plants in traditional Chinese gardens as the obstacle of visibility. Similarly, the topography of some gardens is undulating, which is challenging to take into account in spatial analyses based on plans. In future research, scholars should conduct site survey trying to ensure that the basic map can accurately reflect the human perception in the setting (i.e., what can be seen and where can be reached).

Furthermore, since the current study mainly focused on the space configuration, the actual size of the gardens is not fully considered. In fact, gardens with different sizes may have different impacts on the experience and perception of visitors, and this point deserves further investigations in future studies.

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