Wayfinding in traditional Chinese private gardens: a spatial analysis of the Yuyuan garden

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Abstract: This paper presents a study of wayfinding in a Traditional Chinese Private Gardens (TCPGs). One of the most well known features of the TCPG is its network of indirect pathways. These pathways shape the experience of the space and contribute to its perceptual and aesthetic properties. When walking through a TCPG, the pathway chosen is one of the dominant factors affecting a visitors’ spatial experience of the garden. But such is the complexity of the TCPG that understanding how people navigate through these spaces is relatively difficult. Therefore, this research explores the choice of walking paths in a TCPG using a mathematically derived analysis of the plan. One historic TCPG, the Yuyuan Garden, has been selected as a case study. The method used for the analysis is based on convex mapping, a Space Syntax technique. Three measurements derived from this analysis are extracted to capture essential topological patterns in the TCPG. The results identify the main paths and sub-paths people are likely to take when walking in this garden. Through this process the paper demonstrates a method for capturing the social and spatial properties of the TCPG and provides possible new insights into the properties of these important heritage sites.

Keywords: Traditional Chinese private gardens; wayfinding; space syntax.

1. Introduction

The Traditional Chinese Private Gardens (TCPGs) is recognized as a special type of landscaped space with a particular set of characteristic properties. Developed primarily in the sixteenth and seventeenth centuries, and distinguished in part by its rich spatial arrangement and its associated aesthetic properties, today the TCPG is accepted as having unique aesthetic and experiential properties (Peng, 1986; Tong, 1997). Past researchers have typically analyzed the TCPG from various qualitative perspectives (Chang, 2006; Li, 2011; Lu, 2009, 2010) although a small number of studies have also considered their spatial properties using quantitative methodologies. Despite this past research, the spatial properties that make TCPGs unique have rarely been measured and generalized mathematically. Without such a set of measures, the characteristics of TCPGs cannot be replicated in contemporary landscape design practice or maintained as part of the restoration process for these heritage structures.
One of the most important features of the TCPG is its complex network of arborescent paths, allowing visitors to choreograph their own experience of the TCPG to suit their particular needs. It is this property of the TCPG, pedestrian wayfinding, that is the focus of the present paper.

The particular choice of path is an important factor that affects visitors’ spatial experiences when walking in a TCPG. However, where most models of wayfinding in architecture and design are concerned with optimal or functional pathways, the TCPG poses a different problem, that of excessive choice. This paper uses a Space Syntax technique to develop a deeper understanding of the mathematical complexity of wayfinding in the TCPG. Using one well known TCPG – the Yuyuan Garden – as a case, the paper explores the properties of pathways in TCPGs. In particular, this paper is focused on measurements of access topology relative to spatial types, within the TCPG.

This paper commences with a background to both TCPGs and to Space Syntax, before the method used for developing the results is described. The majority of the paper consists of the presentation of the results for the Yuyuan Garden along with a discussion of how these might be interpreted.

The results of this research are necessarily limited by three factors. First, as only a single case is examined, the results cannot be generalized to comment on other TCPGs. A larger sample, possibly divided by region or dynasty, could be used to develop a more nuanced set of results as part of a future study. Second, this is a study of planar properties, without taking into account the three-dimensional geography of the gardens. However, as wayfinding in visually dense environments is generally undertaken topologically, rather than geographically, this is a reasonable starting point for a study. Finally, only one measure, access topology, is examined in this paper. Future research will include additional factors, and multi-factor approaches to understanding wayfinding in the TCPG.

2. Background

2.1. Traditional Chinese private gardens

The typical TCPG features a dense network of paths and spaces, punctuated with artificial landscape features, ponds and small streams, paved squares and covered corridors or bridges. All of these features are organised in a relatively constrained and clearly defined area (Figure 1). Researchers have analysed the specific properties of the TCPG from various qualitative (Hunt, 2012; Tong, 1997) and quantitative perspectives (Chang, 2006; Li, 2011; Lu, 2009, 2010; Wang & Wang, 2013) and have identified the importance of understanding their dense spatial configurations and the changing vistas experienced during wayfinding (Li, 2011; Peng, 1986). For example the qualitative studies of Keswick (1978) and Zhou (1999) explore the spatial character of TCPGs from a historical and social perspective. Conversely, in a quantitative approach, Chang (2006) studied the Lin-family garden using Space Syntax techniques to examine 310 spatial units using convex map analysis. Chang’s study effectively provided a new way of understanding the spatial characteristics of this garden-type in terms of their spatio-functional qualities. Lu (2009, 2010) undertook research into the spatial properties of the Yuyuan Garden using a combined method drawn from Space Syntax and Shape Grammar. Lu’s study developed a formal language for examining Chinese private gardens as well as demonstrating an effective approach to linking the physical system to cognitive processes. In a related manner, Li (2011) studied the visual-perceptual character of the Lingering Garden also using Space Syntax techniques. Li’s study was focused on visual analysis using convex mapping and measures for integration. However, that study did not conduct a
quantitative analysis addressing the type of large-scale planning and connectivity issues, that are often described as the most critical spatial features of the TCPG.

Figure 1: Yuyuan Gardens in Shanghai (http://www.nipic.com/show/1/62/3909654k374f806b.html).

2.2. Space syntax

As the previous section demonstrated, of the small number of quantitative studies that have been undertaken into the mathematical properties of the TCPG, by far the most common approach is to use Space Syntax techniques for extracting information. Space Syntax is a collective name for a number of techniques used for analysing the topological properties of space, such as permeability and intelligibility, for which the space is abstracted into a graph (Hillier & Hanson, 1984). Extensively developed over the last few decades, Space Syntax methods have been widely applied in research in urban planning, architectural design and landscape design, amongst other areas. One of the strengths of the Space Syntax approach is that it provides a way of understanding architectural and urban spatial configurations by translating their properties into topological graphs, which can then be mathematically analyzed (Ostwald, 2011; Ostwald and Dawes, 2013). Space Syntax techniques combine unique mapping approaches with Graph theory mathematics in order to capture different spatial properties (Ostwald, 2011). Generally, Space Syntax has three approaches to abstracting space (architectural, urban or landscape) into a graph: convex mapping, axial mapping and isovist mapping (Klarqvist, 1992).

The first of these three, convex mapping, is the primary approach used in the present paper. In its original variant it partitions space into a set of convex shaped (visually-defined geometry) boundaries which are then represented by the nodes of the corresponding graph (Ostwald, 2011). The connections between the spaces then become the vertices in the graph. While this process is purely geometrical, a variation of convex mapping uses social boundaries (that is, based on hosted or functional activities) instead of geometrical boundaries to define the “convex” spaces and, thence, to produce the nodes and vertices of the graph (Peponis and Wineman, 2002). Convex graphs are particularly useful for understanding the organization of space in terms of permeability and accessibility (Ostwald, 2011). For this reason, past attempts to understand the TCGP have tended to use the functionally or socially defined variation of convex mapping to extract mathematical information from the TCGP. This is also the approach taken in the present paper. However, it must be acknowledged that such permeability graphs are not often used for studying wayfinding, with axial mapping techniques being preferred. However, the axial maps are, by definition, concerned with finding the ‘fewest’ and ‘longest’ paths or vistas through space, being an optimal network of connections (Hillier 1995). However, passage through the TCGP is not completely governed by such considerations and thus, as the starting point for a new analysis, the functional or social variant of convex space mapping offers a reasonable method for
considering wayfinding and intelligibility. Furthermore, as the next section reveals, a variation of the method is used to focus the method on aspects of spatial choice.

3. Analysis method

This paper uses the social or functional variation of the convex mapping technique, where the spaces are defined by their associated activities rather than their geometric features (Peponis and Wineman, 2002). Given that wayfinding is the focus of this paper, the defining activity for determining the graph is the role of a space in terms of movement and navigation. For this reason, the space of the TCPG is divided into two distinct sets of elements: narrow pathways which are mainly perceived as a connection between two points, and any other elements in which a person might stop for a social for functional reason. The latter spaces include the intersections between pathways in the garden as well as “fat” spaces (that is, those with higher ratio of area to perimeter) such as squares and buildings. The end of pathways (either a dead-end or exit from the system at an entry) is also considered to have the quality of a pause or stopping point and thus it too is identified as a space. The resultant spatial graph can then be made in two ways. Firstly, the pathways can be treated as nodes in the graph and the stops (intersections and buildings) as the edges which connect the paths. The inverse is also possible by considering the intersections as the nodes of the graph and pathways as the edges. The focus of this paper is on the latter approach, where stop points or places where decisions can be made about movement are the nodes, while the (segments of) pathways between any adjacent two of them are represented by the edges of the graph. In this variation, the shape of a pathway (straight, curved or broken) does not affect its connecting function as long as there is no possible detour from the pathway except from its ends.

Three properties of the ‘stop-point, pathway graph’ are measured: integration \((i)\), choice \((C)\) and intelligibility \((I)\). Integration is a global value of each vertex (intersection) revealing the degree by which it is included into or isolated from, the whole system (Hillier & Hanson, 1984). In other terms, it relates to how much one space is accessible from other spaces, on average (Peponis and Wineman, 2002). Choice is the number of times a vertex is located on the (shortest) path between all other vertices in the system (Bafna, 2003). The choice value suggests the likeliness of the vertex (intersection) being passed through as well as its importance in decision making about movement. It is also possible to measure a local choice where for each vertex, the system is defined locally based on the vertices close to that vertex (that is, applying a maximum syntactic radius \(r\)) (Hillier, et al., 2007). The local choice identifies the focal points of the system. Finally, the intelligibility value suggests the overall clarity of the system (the garden in this case) as perceived by a user inside it (Klarqvist, 1992; Peponis and Wineman, 2002). Intelligibility is defined as a Pearson correlation between integration and the connectivity values of all vertices (the connectivity value of a vertex is the number of directly connected or adjacent vertices to that vertex) (Hillier et al., 1987).

Whereas most Space Syntax analysis is undertaken using DepthmapX (Varoudis, 2014) software, for the present research software produced by the authors has been used. This new software, Giraphe uses Dijkstra algorithm (Dijkstra, 1959) for finding the depths in the graph and applies the common calculations methods of integration and choice in Syntax algorithms (Hillier and Hanson, 1984) as displayed in Equations 1 and 2 respectively. In these equations, \(k\) is the total number of the vertices; \(MD\) is the mean depth of a vertex; \(V\) is a vertex and \(P_{ij}\) is the shortest path between \(V_i\) and \(V_j\).

\[
i = \frac{k-2}{2MD-1}
\] (1)
\[ C_a = \sum_{i=1}^{k-1} \sum_{j=i+1}^{k} (V_a \in P_{i,j} \rightarrow 1) \]  

(2)

The main difference between Depthmap and Giraphe is the more user-friendly interface and the more intelligible visualization of the latter in regard to the circumstances of this research. Another difference is that Giraphe does not apply a normalization coefficient for integration values, because such normalization is useful only for comparing different systems (i.e. gardens or buildings) (Hillier and Hanson, 1984) that is not a matter in this research.

4. A case study: Yuyuan garden

The Yuyuan Garden is located in the city centre of Shanghai, in southern China. It was built in the 16th century and has an area of around 20,000 m\(^2\). Parts of the garden were destroyed during the Second World War, although most sections have since been repaired or rebuilt. The Yuyuan garden is well known for its delicate and subtle planning and for its artificial mountain with water in its centre (Figure 2).

Three values for the Yuyuan Garden are calculated for pathways and intersections: average integration (I), average choice (C), and intelligibility (I) (Table 1). The relatively low intelligibility (I) result suggests that in the Yuyuan Garden, visitors find it difficult to understand the space as a whole. This supports the widely observed spatial property of TCPGs, where their features that are regarded as being “hidden” from view, or are a “surprise” to visitors (Li, 2011). These results may also be interpreted as indicating that the organisation of the entire garden is more likely to be understood in terms of intersections (I = 0.28) than pathways (I = 0.09). This also confirms the standard view in wayfinding

Figure 2: Yuyuan Garden plan.
theory (Ellard 2009) and the results developed by Ostwald and Dawes (2013) for the architectural
analysis of interiors.

Table 1: Convex map analysis results of pathway and intersections in Yuyuan Garden (Mean value).

<table>
<thead>
<tr>
<th>Item</th>
<th>Count</th>
<th>Mean integration (i)</th>
<th>Mean choice (C)</th>
<th>Intelligibility (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathway</td>
<td>215</td>
<td>12.91</td>
<td>1291.98</td>
<td>0.09</td>
</tr>
<tr>
<td>Intersection</td>
<td>141</td>
<td>8.25</td>
<td>714.12</td>
<td>0.28</td>
</tr>
</tbody>
</table>

In addition to the three global mean measures (Table 1), the integration (i) and choice (C) values for
individual intersections of the pathways were also determined. Choice value indicates the likelihood of a
point being passed through by a person while navigating in the garden (or a local portion of the garden).
The choice value was measured over three scales in the system. Firstly, the global choice was measured
by considering the garden as a whole, then considering the choice value for each intersection in a
locality limited to three \((r = 3)\) or six \((r = 6)\) intersections from it. Given the low intelligibility of the entire
organisational structure of the garden, it might be assumed that practical wayfinding within the garden
would occur at a local scale rather than relative to the whole system. Figure 3 shows the results for the
integration (left) and global choice (right) measures for Yuyuan Garden. Figure 4 shows the local choice
values, where \(r = 3\) and \(r = 6\). In each of the figures, the circles show the position of the intersection
while their size and darkness represents the value of the measures. The squares indicate the position of
the original entries to the garden. Two of the entries have now been closed; these are shown in grey.

![Figure 3: Yuyuan Garden plan. Circles show the position of each intersection while their size and
darkness represents the global value of either integration (left) or choice (right). Squares represent entry
points.](image)

The integration results (Figure 3) suggest that the middle of the garden is the most integrated area,
which means that the middle part is more topologically accessible in the garden, in comparison to other
parts. It is, based on this data, more likely to feature important places for gathering, because it is easier to access from other parts of the garden. Around the middle part of the garden, there are various water ponds, with bridges, covered corridors and pavilions on top of the water. It would appear that in the original planning, the middle part of the Garden may well have been intended to be an important place, most probably for family gatherings.

The Global choice analysis (Figure 3) indicates that there is one clear main path identified by connecting the high-choice intersections. The path extends from the north-west to the south-east corners in Yuyuan Garden. The result suggests that this is the main path visitors are likely to move through. Interestingly, the main attractions in the Yuyuan Garden are in fact located along this path. While not definitive, this does suggest that this analytical approach is valid for extracting spatial characteristics from the plan graph. Furthermore, at the end of the main path there is an artificial hill with a pavilion on it, which may have been intended as an important viewpoint to draw visitors along the path.

The local choice values, for a syntactic radii of 3 (Figure 4), also identify other significant intersections in the structure of the TCPG (marked by numbers 1 and 2). Furthermore, the significance order of the intersections along the main path has changed (marked by numbers 3 - 6). By connecting these important local nodes, two other paths are identified which detour from the main one. Interestingly, these two paths meet each other again and flow towards the north entry. It is also noteworthy that the closed entries are not directly engaged in these paths. From the results for a higher syntactic radius of 6, the main path can still be identified, however, the significance of the two minor paths is reduced.

Figure 4: Yuyuan Garden plan. Circles show the position of each intersection while their size and darkness represents the local value of choice, with a syntactical radii of 3 (left) or 6 (right). Squares represent entry points.
Just as it is possible to correlate the data developed from this analysis with several actual properties of the Yuyuan Garden, so too, some of the results can be understood in terms of patterns present in the garden. For example, a close review of the important choice points along the main path suggests that most (5 out of 6) points are located at least one intersection away from the entry to a building (Figure 5). In a completely functional plan, the buildings would be expected to be closer to the main path, but this result confirms that the organizational structure of the Yuyuan Garden relies in indirect connections, or perhaps a strategy wherein buffering occurs between active functions (walking and navigation) and passive functions (resting, indoor socialization and private activities).

![Figure 5: Yuyuan Garden plan detail. Example of relationship between major intersections and buildings through minor intersections.](image)

5. Conclusion

This paper presents a spatial analysis of the Yuyuan Garden in terms of wayfinding and focussing on choice-points or intersections considered as part of both a global and a local spatial structure. These points are critical to the navigation of the space in a topological sense. Through this research some principles of spatial planning and design in the Yuyuan Garden are revealed, along with a potential new insight into the visual and geometric character of TCPGs.

Three main observations can be made using the method adopted here. First, a main path is identified in the Yuyuan Garden which, based on the syntactical model, people are more likely to use when navigating through space. The main attractions are actually located along this path offering a direct correlation between the mathematical model and the actual garden. Second, some important intersections along this pathway, where people are likely to pass through or visit, are located one intersection from a building. This pattern occurs in 83% of the cases considered (relative to the main path). Third, the measured intelligibility values for the Yuyuan Garden are relatively low, which means that when people are walking in the garden, it is difficult for them to understand the space of the garden as a whole. However, at a more local level, the network of high-choice positions, suggests that the garden is more intelligible as a collection of small-scale connected subsystems.
These three findings further suggest some principles (either intuitive or conscious) which may have been followed when the garden was originally planned. It is possible that the designer started by defining a main pathway, and then allocated important attractions and structures along it, but not immediately adjacent to it, drawing people away from the primary path, by way of secondary paths, to specific locations. However, while these observations are supported by the mathematical analysis, they cannot be extrapolated to cover other TCPGs. This is a pilot study of just one case analysis, nevertheless, a future study comparing using this method, and a larger sample size, may be able to reveal or generalise these important, but elusive properties of the TCPG.

References


