A Dimensional Comparison between Classical Chinese Gardens and Modern Chinese Gardens

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Abstract: Garden designers and scholars are interested in metrics that define the differences and similarities between traditional design and modern designs. This investigation examines the similarities and differences of classical Chinese gardens and modern Chinese gardens. The comparison is accomplished by ordinating the design elements and basic normative planning and design principles for each garden. Three classical Chinese gardens in Suzhou, Jiangsu, China and five modern gardens in Xiamen, Fujian, China were selected for study. A mathematical method called Principal Component Analysis (PCS) was applied in this research. The objective of this method is to define the dimensions that characterize the gardens and plot these gardens along the dimensions/gradients. Seventy-five variables were selected from a literature review, site visits, and site photos. According to the results of the PCA, there are potentially seven meaningful dimensions suitable for analysis, which explain 100% of the variance. This research focused on studying the first three principal components, explaining 81.54% of the variance. The first two principal components reveal a clear pattern between the two sets of environments. The results indicate that the first principal component can be a way to identify the difference between classical Chinese gardens and modern Chinese gardens. The second and third PCA dimensions assist in characterizing the variance amongst the modern environments. Thus study suggests that it is possible to employ metrics to classify landscape environments and in this study the results support the heuristic normative beliefs of planning and design experts who attempt to classify these environments without science-based evidence.

Key words: Landscape Architecture, Environmental Design, Historic Gardens, Contemporary Gardens, Horticulture, Historic Preservation.

1 Introduction

Scholars who study built environments are often interested in examining the similarities and differences between these spaces. However, the studies are often intuitive and not reliably repeatable, being dependent upon the experience and opinions of the investigator [1]. The study team was interested in examining less heuristic forms of analysis for built environments. The full discourse concerning this study is described in an environmental design masters thesis by Yiwen Xu, completed in the summer of 2015 [2]. Western planning and design schools are engaged in studying and comparing traditional designs with other historic design precedents and with modern built environments.

Classical Chinese gardens have a long history, and many people believe that they are representations of Chinese artistic characteristics and cultural values. As Maggie Keswick said, “Chinese history is littered with the corpse of gardens” [3]. The unique style and elements of classical Chinese gardens like the nature-like landscape, the use of poetry and paintings, and the rich and varied spaces, attracting many

people from all over the world. Even though the classical Chinese gardens are special and a long-standing art, they have been mysteries for a long time because there has been relatively litte study about them until last few decades. Publications about classical Chinese gardens written by scholars like Maggie Keswick and Chen have helped to provide more insight concerning these environments [3, 4]. In contrast, Japanese gardens have been extensively studied and reported [5]. The difference in the volume of literature between the two has been attributed to access [6]. Scholars have had access to Japanese environments for hundreds of years while access to Chinese environments was restricted during the Qing Dynasty, followed by civil unrest, World War II, and a civil war in China. It was only in the mid-1970s that access by scholars to China began to be available with increased activity starting in the 1990s and 2010s. However, modern scientific study of these environments has been slow. While the classical Chinese garden design inspires every planning and design school in China, designers often simply repeat normative ideas expressed by Chinese scholars, 'passed-on' from generation to generation. The analytic scholarly investigatory methods prevalent in the West have not been commonly practiced by the planning and design university community in China. However, with some Western scholars greatly interested in China and through Chinese governmental programs in China, visiting scholar exchanges and Asian students studying in the West, scholarly scientific methods to investigate these environments has been forthcoming. This investigation is an attempt to study these environments by applying scholarly techniques typically found in Western academic approaches.

2 Classical Chinese Garden Design

2.1 Design Theories and Principles

English landscape designers had independently derived a natural style towards garden creation and estate management and were enthused by the Chinese application of a 'natural style.' English interest in Asian style was known as *Sharawadgi*, popularized in the 1680s, derived from contact with Japan and at times affiliated with the general Chinese informal style [7]. The first reported English garden employing features of Chinese style is Grove House, Old Windsor, Berkshire developed in the 1730s, deriving some of the ideas for the garden from the French chinoiserie design, a fusion of Western and Chinese ideas [7]. French Jesuit missionaries had greater access to China, resulting in a greater exchange of materials and ideas, leading to the chinoiserie style by the French. Chinese planned and designed environments were highly promoted in the West with the publication of a document by William Chambers [8]. However, Chambers may have never actually seen a Chinese garden and was only responding to paintings he had seen while in Guangdong Province depicting Chinese environments (9). The garden at Nuneham in the United Kingdom is often cited as a Western design partially influenced by Chinese garden style [7]. Yet informed and thoughtful planning and design knowledge alluded the West.

The best remaining groups of traditional Chinese gardens are to be found in the city of Suzhou (Soochow), in Jiangsu Province. When these gardens were built, there were not considered to be the best of the best of existing Chinese gardens. But most of the top Chinese gardens during the time from the Ming and Qing dynasties were eventually destroyed, often because of war. Even after WWII, these gardens remained in somewhat some obscurity, usually in quite poor condition. Since then, the Suzhou Development Company, a governmental supported business has been and continues to restore historical environments in the Suzhou area. This company restored many of the gardens in Suzhou and made them available to the public and for tourism purposes. These gardens are now considered to be the best of what remains and are highly visited.

Classical Chinese gardens are well known to pursue a "natural" approach to landscape design [10]. Ji Cheng, a famous garden designer of the Ming dynasty, defined the essence of Chinese garden

building as “Though man-made, the garden looks like it is springing from nature.” His definition demonstrates that garden building is a creative process based on the high degree of extraction and artistic generalization of nature [11]. In Chinese gardening, nature is not the object to be tamed and altered, but the model to be imitated and learned from [12].

The sense of space is also the most important artistic character of Chinese garden. As the space of gardens is limited, the designer will use all methods to increase the landscape’s feeling of depth, to create the gardens’ space rich and variable, in order to turn the limited space into infinite dreamland and increase visitors’ interest to the gardens [11]. The gardens are divided into units of large and small sizes to create spatial changes. However, Even the space is divided into several landscape units, there is always an opportunity to perceive a segment of the hidden view, resulting in “divided not separated” [13]. The visual techniques, such as borrowed scenery, framed scenery, opposite scenery and contrast are always used to make the space rich and variable.

The other unique characteristic of the Chinese garden is its deep implication with painting and poetry. When the designer or owner builds a garden, he will put spiritual significance into the scene of the garden, hoping that visitors will be sympathetic and emotionally touched by these scenes, which are what ancient people called “emotional realm” or the “artistic realm” [14]. It is very common in Chinese garden design that every hill, every pond, every pond, every plant or every tree has a profound implication and is thought provoking [11]. If one cannot understand the spiritual significance affiliated to the landscape scene, then one cannot achieve a sympathetic touch and an emotional resonance [15].

2.2 Design Features and Their Applications in Classical Gardens

There are five key elements in Chinese gardens: water, rock, pavement, architecture and planting, and each element had its own distinctive characteristics and relative importance within the hierarchic scale, which put architecture first, followed by water and rocks, then plant material [16 & 17].

There are many kinds of architectural structures in the classical Chinese gardens, including halls, towers, pavilions and walkways, all of which categories are subdivided according to peculiarities of which categories are subdivided according to peculiarities of function and design [18]. Rockery and water are important elements in Chinese gardens in order to create a nature-like landscape [3, 19]. If the rock is the backbone, then the water is the vein of the garden [18]. Rock is a symbol of virtue, stability, and endurance; water represents lightness and communication [20]. Plants retain importance as unifying garden elements that blends the artifacts with their surroundings, and they serve as components of a scenic composition or as a foil in garden scenes [13]. The pathway is designed to induce the visitor to investigate the series of unexpected scenes in the entire garden [21]. In addition, when constructing Chinese traditional landscape, attention is always paid to utilizing the elements of weather [19]. The views change not only with “every step forward” but also with the seasons, weather, times of day, age of the plantings, and even the beholder’s mood [13]. Therefore, all these elements are important to constitute a unique classical Chinese garden.

Figure 1. Beisi Ta, North Pagoda, located to the north of the garden, is “borrowed” as part of the magnificent scenic view of the Humble Administrator’s Garden. (Copyright ©2013 Yiwen Xu all right reserved used by permission).

Figure 2. Moon Comes with Breeze Pavilion by the central pond in the Master of the Nets Garden. Copyright ©2015 Yiwen Xu all right reserved used by permission).

Figure 3. The Cloud-Capped Peak (Guanyun Feng) in the Lingering Garden is the most renowned Taihu Rock in China. (Copyright ©2015 Yiwen Xu all right reserved used by permission).

3 Modern Chinese Garden Design

3.1 The Impact of Western Design Theory

Since the end of 20th century, the design theory of west modern landscape had been introduced into China, many international famous landscape designers and groups came to China, they enriched the theories and practices of China landscape [22]. Due to the differences in natural conditions, historical origins, social environments, cultural backgrounds and religious factors, the gardens in China and the West developed in a diametrically opposite way from the very beginning [23]. Chinese traditional landscapes created an ideal natural recreational living space by imitating nature, but Western landscape designers often satisfied people's living needs from natural space by arranging natural elements more formally [19]. The geometrical gardens of the west present a strong artificially created order in opposition to nature, human power expressed by organizing nature under the control of human will [13].

Due to the influence of Western landscape design, function for the public is gradually being seen to be more and more important in the design of landscape in China. Chinese traditional landscape was always the place for few literati to self-communion and spiritual satisfaction, and the material function never became the main function in Chinese traditional landscape [19]. Nowadays, the designers in China gradually pay more attention on the innovations of function in landscape design. According to Wang, the landscape must have functional value to satisfy people's material and mental needs [24].

However, the globalization has led to a homogenization in public space design, the dominance of Western traditions of landscape architecture applied in non-Western settings has been questioned [16]. Landscape architecture projects are having less and less connection to the history and tradition of Chinese culture [25].

3.2 Reinterpreting Tradition in Modern Garden Design

As the globalization result in a same style of landscape design and the loss of cultural identity in China, many scholars started to investigate how to apply the design elements and principle of classical Chinese garden in modern garden design. Borrowing ideas for modern landscaping designs from Chinese traditional landscaping thinking is not only the requirement of the time and the nation, but also the crystal of encountering and conflicts between modern life and Chinese traditional culture [26]. However, applying classical Chinese garden design elements and principles in modern gardens does not imply that the modern garden design should directly

replicate classical Chinese gardens, but to make variation on and adjust traditions in order to best fit into the contemporary context [25 & 27].

3.3 Toward Sustainable Open Space

As the world population continues to grow and as global urbanization continues to unfold, problems on landscaping are becoming more serious, and our ecosystems and landscapes will be increasingly domesticated and designed. Developing and maintaining sustainable landscapes have become one of the most challenging and imperative tasks for scientists and stakeholders of all sorts [26].

Sustainable environmental design is not alien from Chinese tradition, because the founding premises of the Chinese garden are the same as those principles inspiring the current conception of a sustainable environment. Though the ancient Chinese had no idea about ecosystem, they just believe man and nature should live in harmony, and the garden design should learn from and be in harmony with the nature [12 & 21].

Also, in recent decades, new ecological concepts from western countries, such as green infrastructure and sustainable design, have gradually been accepted by more and more Chinese scholars. Advanced ecological strategies and design concepts that are needed more than ever before are encouraged and applied to every single project [25].

Figure 4. The zigzag whitewashed walls bring people similar experience of visual transition and spatial atmosphere as the classical Chinese gardens. Bamboo Garden, Xiamen. (Copyright © 2007 Chunfeng Lee all right reserved used by permission).

Figure 5. The straight path and row upon row of plants in modern Chinese landscape design. Dongsha Lake Park, Suzhou. (Copyright ©2014 Kun Zhang all right reserved used by permission).

Figure 6. Expansive lawn and geometric plantings in Versailles, France. (Copyright © 2007 Jon Bryan Burley, all right reserved used by permission).

4 Methodology

4.1 Purpose of Study

Some researchers advocate that contemporary Chinese landscape design must balance the relationship between the traditional Chinese-style and the contemporary Chinese-style design environments [28]. Comparing the classical and modern Chinese garden is an effective way for designers to understand the suctions and patterns of these gardens and help designers to discover the ways to integrate traditional Chinese design elements into modern designs. Most classical and modern Chinese garden design comparative studies were undertaken through heuristic method by scholars' personally stating of design theories and principles, which tended to be

more subjective. Little quantitative research has been undertaken, however, that uses mathematic method to compare gardens. Thus, this research will exam the difference between classical and modern Chinese garden by using a mathematic method named Cluster Analysis which is an exploratory data analysis tool for solving classification problems. The objective of this study is to find out the similarity and difference in design elements between classical Chinese gardens and modern Chinese gardens. The result of this research can help researchers and designers understand the Chinese garden design better, and provide a kind of guidance for them to see if traditional design elements could still effectively serve a modern design inspiration.

4.2 Study Sites

In this research, three classical Chinese gardens in Suzhou and five modern gardens in Xiamen were chosen to compare. The traditional Chinese are generally classified into two major types: the private gardens of the south and the imperial gardens of the north. Imperial gardens of the north tend toward staidness and resplendence consistent with a sense of palatial grandeur [13]. Suzhou, a city located in the middle part of China's Yangtze River Delta, has been famous for its classical gardens for many centuries. During the Ming and Qing periods the city was a gathering place for the nation's leading poets and painters, which may account for the number of outstandingly beautiful gardens which brought fame. There is a saying that "South-east gardens are the best in the world, and Suzhou gardens are the best in the south-east". Therefore, this study focused on the Suzhou gardens for the classical part. The three classical gardens that were selected for this study are the Humble Administrator's Garden, the Master of the Nets, and the Lingering Garden. All the three gardens have been registered on the World Heritage List by UNESCO since 1997.

For the modern part, the gardens designed for 2007 Garden EXPO in Xiamen, China were selected in this research. Many well-known Chinese landscape architects were invited to participate in garden design for this Garden EXPO. These modern gardens combine both classical and modern garden design principals and elements. The five modern gardens that were chosen for this study are: Bamboo Garden, Net. Wet. Garden, Learning Garden, Sugar Cane Garden and Landscape New Wave Garden.

4.3 Data Collection

All the traditional and modern Chinese gardens' elements were chosen from literature review and site photos. There are 75 variables totally. The data selection noted the gardens' attributes of different types of architectures, water, rocks, pavement, plants, locations, design principles and other related garden design elements. Then, check the existence of each elements in each garden. If the garden contains the element, then it can get one point for this element, otherwise, it gets zero. Table 1 presents the list of the 75 variables included in the study.

Table 1 The list of the 75 variables employed in the study to assess the ordination of the gardens.

1. The Great Halls (ting tang)
2. Covered Stone Boat (fang)
3. Viewing Towers (lou ge)
4. Studies (shufang)
5. Covered Walkways (lang)
6. Pavilions (ting xie)
7. Viewing terrace
8. Black tile pavement
9. Brick paving
10. Cracked Ice Stone paving
11. Pebbles area
12. Mosaic pave with special pattern
13. Whitewashed walls
14. Grey Stone Walls
15. Openwork brick walls
16. Curved top walls
17. Zigzag wall
18. Meandering walls
19. Bamboo paved pathway
20. Boardwalk

Table 1 continued, The list of the 75 variables

employed in the study to assess the ordination of the gardens.

21. Curved Pathway
22. Straight Pathway
23. Zigzag Bridge
24. Semi-circular bridge
25. Straight Bridge
26. Wall holes with symbolized shape
27. Lattice window
28. Moon Gate
29. Wood carvings
30. Glass carvings
31. Brick carvings
32. Reflecting Pond
33. Stream
34. Fish pond
35. Wetland
36. Island
37. Artificial mountains
38. Sculptural rocks
39. Pond bank rocks
40. Taihu rocks
41. Trees
42. Shrubs
43. Ground covers
44. Turf area
45. Pine
46. Bamboo
47. Plum
48. Magnolias
49. Camellia
50. Crepe myrtles
51. Sweet osmanthus
52. Peony
53. Willow
54. Lotus
55. Reed
56. Sugar cane
57. Moon
58. Clouds
59. Rain
60. Wind
61. Shadow
62. Originally private
63. Public
64. Located in suburban
65. Located in urban
66. Design concept
67. Poem and painting concept
68. Naturalness
69. Varied spaces with visual devices
70. Borrowed scenery
71. Enframed scenery
72. Opposite scenery
73. Contrast
74. Deep implication
75. Abstract geometrical composition

4.2 Analysis Techniques

Cluster analysis is used to determine clusters of similar objects, to find out which objects in a set are similar or dissimilar [29]. Group similar objects into categories, so that the objects can be understood more easily and the data can be analyzed more efficiently. The method facilities data reduction by grouping variables with similar association. The grouped variables reveal latent underlying dimensions that may not seem obvious upon first examination during formative investigations.

To begin the cluster analysis, a statistical analysis software system called SAS was used to generate the principal components analysis (PCA) of all the elements. A principal component analysis is a technique that linearly transforms an original set of variables into a substantially smaller set of uncorrelated variables that represents most of the information in the original data set [30]. The output of PCA typically includes the eigenvalue for all the dimensions in the data set, eigenvector coefficients, means and standard deviation of all the variables. Then standardize the data first to give all variables with the same weight during analysis. It will then transform it to have zero mean and unit variance. Thus, the score of each observation in every meaningful principal component can be calculated by using the standardized data. The equation is given below

(Equation1):

$$\text{Garden score} = \left[\left(\frac{X_1-\bar{X}_1}{SD_1}\right)k_1\right] + \left[\left(\frac{X_2-\bar{X}_2}{SD_2}\right)k_2\right] + \ldots\ldots + \left[\left(\frac{X_{74}-\bar{X}_{74}}{SD_{74}}\right)k_{74}\right] + \left[\left(\frac{X_{75}-\bar{X}_{75}}{SD_{75}}\right)k_{75}\right] \quad (1)$$

Where:

X_n = Each Value of Variable

$\bar{X}_n$ = Mean of the Variable

SD_n = Standard Deviation of the Variable

k_n = Eigenvector Coefficient

After applying the equation to get the score of each garden in each principal component, compare the gardens by placing the scores on a scatter graph. The pattern of their intersecting points can graphically show relationship patterns. If there are gardens that can be grouped as a cluster together, it means these gardens are "closer" to each other than they are to the gardens in another cluster or group. Therefore, these garden clusters can be used to identify the similarities and differences of the gardens.

5 Results

Table 2 illustrates the eigenvalues for the garden elements variables from the SAS software program. The first seven principal component eigenvalue are greater than 1.0, so they are qualified for further study. All other principal components' eigenvalues are 0 and thus are not considered. The first two eigenvalues comprise over 71 percent of the variance in the garden elements variables.

Table 3 gives the calculation results of all the garden scores in first seven principal components after plugging the variable values, means, standard deviations and principal component coefficients into the equation 1. The eigenvectors for the first three principal components/eignevalues are listed in Table 4. The coefficients comprise the variable k_n in equation 1.

Table 2 Principal Component Analysis eigenvalues of the covariance matrix from the SAS Software Program.

	Eigenvalue	Difference	Proportion	Cumulative
PRIN1	41.5124321	31.774282	0.5766	0.5766
PRIN2	9.7381501	2.2806378	0.1353	0.7118
PRIN3	7.4575123	1.8862912	0.1036	0.8154
PRIN4	5.5712211	2.4732904	0.0774	0.8928
PRIN5	3.0979307	0.289999	0.043	0.9358
PRIN6	2.8079317	0.9931095	0.039	0.9748
PRIN7	1.8148221	1.8148221	0.0252	1
		……		

Table 3. Garden scores in first seven principal components.

	Humble Administrator's	**Master of the Nets Garden**	**Lingering Garden**	**Bamboo Garden**	**Net. Wet. Garden**	**Learning Garden**	**Sugar Cane Garden**	**Landscape New Wave**
PRIN1	8.124	7.265	7.386	-4.109	-5.770	-3.342	-3.342	-3.853
PRIN2	-0.543	-0.548	-0.453	2.524	-4.285	4.658	-3.227	2.533
PRIN3	0.119	-0.248	-0.064	1.852	3.630	-0.021	-4.997	-0.913
PRIN4	1.105	-0.962	-0.060	4.865	-1.019	-2.000	1.044	-2.719
PRIN5	0.867	-0.765	-0.217	0.325	-0.285	-2.772	0.250	2.787
PRIN6	3.219	-2.459	-0.919	-0.936	0.177	1.092	-0.154	-0.104
PRIN7	0.799	2.046	-2.815	0.131	-0.013	-0.091	0.025	-0.073

The scatter graph can be used to visually identify clusters. Figure 1 reveals the relationship of all the eight classical and modern gardens, based on the garden scores in the first two principal components. The horizontal axis shows the scores of the first principal component, and the vertical axis shows the scores of the second principal component. Since the plot of the scores on the first two principal components for the gardens can reveal a clear pattern of clusters already, this research focused on studying the first two principal components for the garden comparison.

Table 4. Eigenvector coefficients.

Variables	PRIN1	PRIN2	PRIN3
The Great Halls	0.153	-0.046	-0.008
Covered Stone Boat	0.079	-0.023	0.006
Viewing Towers	0.153	-0.046	-0.008
Studies (shufang)	0.153	-0.046	-0.008
Covered Walkways	0.153	-0.046	-0.008
Pavilions (ting xie)	0.153	-0.046	-0.008
Viewing terrace	-0.055	0.228	0.076
Black tile pavement	0.110	-0.131	-0.204
Brick paving	0.153	-0.046	-0.008
Cracked Ice Stone paving	0.127	0.083	-0.008
Pebbles area	-0.089	0.115	-0.135
Mosaic pave with special pattern	0.106	0.155	-0.024
Whitewashed walls	0.104	0.157	0.060
Grey Stone walls	-0.013	-0.032	-0.130
Openwork Brick walls	0.058	0.130	0.297
Curved top walls	0.117	-0.034	0.002
Zigzag wall	0.122	0.024	0.059
Meandering walls	0.117	-0.034	0.002
Bamboo pathway	-0.058	-0.201	0.232
Boardwalk	-0.058	-0.201	0.232
Curved Pathway	0.069	-0.049	0.228
Straight Pathway	0.089	0.253	0.050
Zigzag Bridge	0.122	0.024	0.059
Semi-circular bridge	0.114	-0.035	-0.005
Straight Bridge	0.104	0.157	0.060
Wall holes with symbolized shape	0.122	0.024	0.059
Lattice window	0.153	-0.046	-0.008
Moon Gate	0.153	-0.046	-0.0078
Wood carvings	0.153	-0.046	-0.008
Glass carvings	-0.052	0.225	-0.018
Brick carvings	0.153	-0.046	-0.008
Reflecting Pond	0.058	0.201	-0.232
Stream	0.004	-0.035	-0.005
Fish pond	0.110	-0.178	0.146
Wetland	-0.075	-0.074	0.254
Island	0.078	0.041	0.070
Artificial mountains	0.153	-0.046	-0.008
Sculptural rocks	0.058	0.130	0.297
Pond bank rocks	0.153	-0.046	-0.008
Taihu rocks	0.153	-0.046	-0.008
Trees	0.089	0.253	0.050
Shrubs	0.107	0.155	-0.024
Ground covers	0.089	-0.066	-0.023
Turf area	0.002	0.125	0.058
Pine	0.127	0.083	-0.008
Bamboo	0.089	0.253	0.050
Plum	0.153	-0.046	-0.008
Magnolias	0.153	-0.046	-0.008
Camellia	0.153	-0.046	-0.008
Crepe myrtles	0.153	-0.046	-0.008
Sweet osmanthus	0.127	0.083	-0.008
Peony	0.153	-0.046	-0.008
Willow	0.153	-0.046	-0.008
Lotus	0.107	0.155	-0.024
Reed	-0.07	-0.074	0.254
Sugar Cane	-0.058	-0.130	-0.297
Moon	0.153	-0.046	-0.008
Clouds	0.111	-0.035	-0.013
Rain	0.117	-0.034	0.002
Wind	0.153	-0.046	-0.008
Shadow	-0.008	-0.021	0.162
Originally Private	0.153	-0.046	-0.008

Table 4 Cont. Eigenvector coefficients.

Variables	PRIN1	PRIN2	PRIN3

Public	-0.153	0.046	0.008
Located in suburban	-0.153	0.046	0.008
Located in urban	0.153	-0.046	-0.008
Design concept	0	0	0
Poem and painting	0.107	0.155	-0.024
Naturalness	0.055	-0.228	-0.076
Varied spaces with visual devices	0.0578	0.201	-0.232
Borrowed scenery	0.110	-0.178	0.146
Enframed scenery	0.058	0.123	0.297
Opposite scenery	0.089	0.253	0.050
Contrast	0	0	0
Deep implication	0	0	0
Abstract geometry	-0.153	0.046	0.008

The distribution of the garden scores on figure 7 suggests that there are three clusters of gardens. On the horizontal axis, the gardens are divided into two groups, one positive group and one negative group. The gardens in the positive group are: Humble Administrator's Garden, Master of the Nets Garden, and Lingering Garden, which are all classical Chinese gardens. The five gardens in the negative group are: Bamboo Garden, Net. Wet. Garden, Learning Garden, Sugar Cane Garden and Landscape New Wave Garden, which are all modern Chinese gardens. Therefore, the principal component 1 is the dimension can be used to identify the difference between classical and modern Chinese gardens. As well, the vertical axis separates the five modern garden gardens into two groups: one positive group and one negative group. The positive group contains Bamboo Garden, Learning Garden, and Landscape New Wave Garden. The negative group contains Net. Wet. Garden and Sugar Cane Garden. For the classical gardens, there are no further classifications, thus the second principal component can be considered as the dimension to identify the types of modern gardens only.

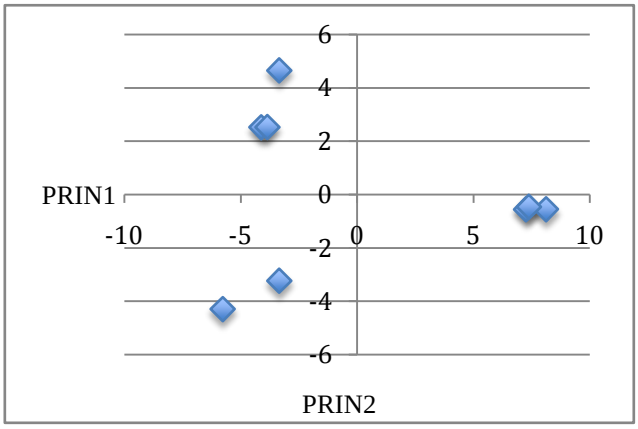

Figure 7. A scatter graph of the relationship of all the eight gardens, based on the garden scores in principal component 1 and 2.

According to the analysis from the Figure 7, the elements with positive eigenvector coefficients in principal component 1 belong to the classical garden elements group, and the elements with negative eigenvector coefficients belong to the modern garden elements group. The elements with zero value indicate that they are the elements that all the eight classical and modern gardens contain in their designs. Similarly, the elements with positive eigenvector coefficients in principal component 2 can be categorized as the elements belong to one type of modern garden, and the elements with negative eigenvector coefficients can be categorized as the elements belong to another type of modern garden.

Figures 8 and 9 depict the plots of the gardens for the first and third dimensions and for the second and third dimensions. Larger scores in dimension 3 represents predominantly wetland environments and lower values represent walled environments containing sugarcane.

6 Discussion

6.1 Comparison of Gardens and Garden Elements

The most obvious difference between classical and modern Chinese gardens according to the resulting graphs, especially along principal component 1, is that in all three classical gardens,

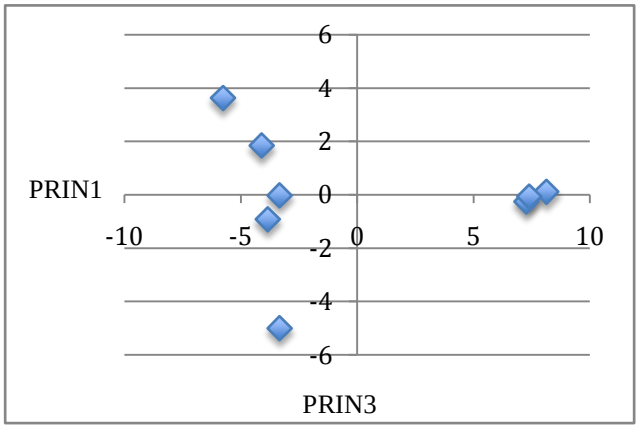

Figure 9. A scatter graph of the relationship of all the eight gardens, based on the garden scores in principal components 1 and 3.

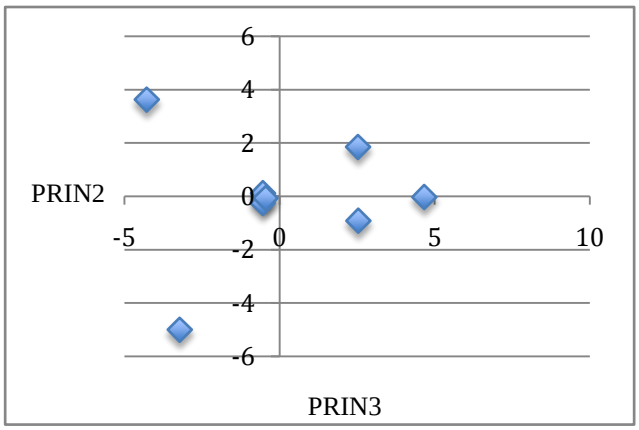

Figure 10. A scatter graph of the relationship of all the eight gardens, based on the garden scores in principal components 2 and 3.

the scores are very close but the five modern gardens' scores are relatively much more dispersed. As always, the classical Chinese garden designs were greatly influenced by Chinese landscape paintings and the three main schools of philosophies: Taoism, Confucianism and Buddhism. Although different classical gardens have different design concepts, their design elements and design principals are still very similar. Thus, there is not much variance among classical Chinese gardens. However, because of the global sharing, the modern garden designs were influenced by a variety of cultures and landscape designs all over the world. These modern gardens also contain the design principles and design elements from other cultures, such as the abstract geometrical composition, a basic design principal in western garden designs. Also, the rapid development of new technology can provide the opportunity for the designers to use more types of new materials and elements to produce the effects they want. Therefore, the modern gardens are not so similar compared to the classical Chinese gardens.

The next marked difference between classical and modern Chinese gardens is the architecture structures. In classical Chinese gardens, architectures are significant elements in their designs. There are many types of architecture in classical gardens. However, there is no any actual architecture in modern gardens. Modern gardens are more abstract. They use more simple structures like walls to divide space instead of architectures. For example, the bamboo garden focuses on using zigzag walls and wall holes through the site to create a variety of spaces and provide continues scenery change. Also, modern gardens create more open space as resting points like viewing terrace instead of viewing towers and pavilions for people enjoy scenic view. This might be because the classical Chinese gardens were originally designed for private residence and were played and lived in by few people, but modern gardens were designed for the public so they need more open space for much more amount of visitors.

The use of plants is another major difference between classical and modern Chinese gardens. The plants in classical Chinese garden focus on providing mental, emotional pleasures and presenting beautiful and rich visual effects for people. Most of plants used classical gardens were given personified connotations. In addition, the variety of plants with rich and varied color changes can create distinctively seasonal landscape attractions in order to give people rich aesthetic experiences. However, the plants in modern gardens are more monotonous, they do not have various types of plants like the classical Chinese gardens. The modern gardens focus more on improving ecology and sustainability for the site by using right

plants. The native plants in Xiamen like sugar cane and reed are used as major plants in modern gardens, and wetland is also applied in modern gardens to colleting, storing and purifying stormwater. In addition, grass lawn is not much used in classical gardens, but modern gardens use it much more to achieve the effect of openness and simplicity due to the influence the Western landscape design.

Also, all the classical gardens in this research are originally private residential gardens located in urban areas, and all the modern gardens are public gardens located in suburban areas. The private gardens were designed for the privilege few, like gentleman scholars, the rich and ranked class of feudal society, and the common people were not able to visit these gardens. Thus, the garden's service objects are extremely limited. However, the modern gardens were designed for the public, and have to meet the functional requirements of the public. The design elements such as meandering and narrow pathways, zigzag bridges, and artificial meandering streams will not easily accommodate large numbers of people and activities inherent in large groups. They need more open space and more convenient pathway for people to go through. Moreover, since this research used two different types of gardens, the further study can choose same type of garden to compare to identify the difference, for example, compare traditional private gardens with modern private gardens, or compare traditional public gardens with modern public gardens.

In addition, the final result suggests the five modern gardens can be subdivided into two groups. One group contains Bamboo Garden, Learning Garden, and Landscape New Wave Garden. The other group contains Net. Wet. Garden and Sugar Cane Garden. By analyzing the positive and negative elements in principal component 2, there is no clear character that can summarize these two different groups. Both groups contain variety kinds of elements. According to the result of this research, I suppose the difference between these two groups is one group has more hardscape, and the other one is more naturalistic style. Since the positive group contains the structural elements with straight lines and geometrical forms, such as zigzag wall, straight pathway, zigzag bridge, and straight bridge, the gardens in this group provide people a more artificial environment. The two modern gardens in negative group seem more naturalistic style. Although this group also contain the artifact features like walls, paved pathways, and bridges, but the shape, form or texture are more naturalistic compared to the positive group. For example, this group contains walls like curved top walls and meandering walls, which are endowed with curvilinear configuration derived from nature. The pavements are made by the more naturalistic materials, such as boardwalk and bamboo paved pathway. Besides that, the negative group includes more variety of plants and natural elements, such as moon, clouds, rain, wind, and shadow.

In addition, investigators have employed spatial autocorrelation and fractal measures to construct and predict traditional Chinese garden design patters [31]. such approaches could be employed in assessing modern gardens.

6.2 Limitations and Suggestion for Future Research

Firstly, The five modern gardens are divided into two categories in this research, but there is no any clear character that can summarize these two different groups. This may be because the access to information on the five selected modern gardens is limited. The literature review and site photos for the data collection are not enough. In addition, due to the bad maintenance of the selected modern gardens, many garden elements had been destroyed or even closed when this research was taken. It is hard to get enough information about the modern gardens from the site visiting and site photos. Thus, the further study can focus on studying the modern gardens. More data collection methods should be applied for the study. Also, except these five gardens in Xiamen, involve more modern garden observations in the further research to figure out the difference between these two groups.

Secondly, in this research, the result shows the modern gardens are more dispersed, and the three classical gardens are very close. The small number of classical gardens selected for this research may be the reason. Due to the time limit there are only three classical gardens were selected for the research. However, there are many other attracting classical gardens in Suzhou, built during the time period from the Northern Song to the late Qing dynasties, can also be used for future research, such as the Surging Waves Pavilion, the Lion Grove Garden, the Garden of Cultivation, the Couple's Retreat Garden, and the Mountain Villa with Embracing Beauty. In addition, this research only took the scholars' private classical gardens in Suzhou as observations. The future research may expand the research to other classical gardens, such as the imperial garden in northern part of China, to test if the classical Chinese gardens are still very close or they will spread out more.

Thirdly, the selection of garden elements used in this research was based on researcher's own understandings and opinions according to the published literature review. This circumstance may have resulted in the data selection is biased on researcher's own opinions. Thus, the variables collection needs to be improved. The study should involve more people's opinions, like garden design specialists. Agreement on the extent and types of garden elements needs to be established in further research.

Finally, according to the result of this research, equations can be developed to identify if a garden is classical or modern Chinese garden. Future researchers can select more classical gardens and modern gardens to test the equation. Check if the selected modern or classical garden contain the elements on the list, then substitute the data in the equation. Consequently, check if the garden score from the equation can present the right type of the garden. If the equation can work successfully, then it can be a standard equation to identify Chinese garden types.

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