ISSN: 1648-6897 / eISSN: 1822-4199

VILNIUS TECH
Vilnius Gediminas Technical University

JOURNAL of ENVIRONMENTAL ENGINEERING & LANDSCAPE MANAGEMENT

2024
Volume 32
Issue 2
Pages 152–168
https://doi.org/10.3846/jeelm.2024.20972

MEASURING TOURISTS' VISUAL PERCEPTION OF GARDENS AROUND TAIHU LAKE RIM AREA BASED ON MULTI-SOURCE DATA

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Highlights:

- objective analysis of the physical appearance of the garden environment and establishment of the indicators for evaluating garden space elements;
- there are homogeneity and heterogeneity among different modern gardens around Taihu Lake;
- the significant changes of natural garden elements and artificial garden elements are the key factors leading to the evaluation of tourists' visual perception;
- landscape planning needs to consider people's visual perception of landscape elements.

Article History:

- received 24 December 2022
- accepted 10 January 2024

Abstract. Tourists' visual preferences are of paramount importance for the local garden environment assessment. However, the diversity of garden elements presents challenges in achieving uniform assessments. This study focuses on 65 modern gardens around Taihu Lake (太湖), utilizing image semantic segmentation and the Semantic Differential (SD) method to evaluate tourists' visual perceptions, identifying 16 perceptual indicators associated with garden elements. The research findings indicate the following: (1) Modern gardens in different cities (Wuxi, Suzhou, Huzhou) offer distinct visual experiences to tourists. (2) Through quantitative analysis of garden elements and tourists' visual perceptions, it is revealed that middle and high-rise vegetation, hydrology, architecture, and sketch elements enhance visual aesthetics, while main road and low-rise vegetation elements result in less pronounced perceptions. This study quantitatively explores the complexities in evaluating garden aesthetics and serves as a bridge between qualitative and quantitative aspects for future garden environmental impact assessments.

Keywords: garden environment, visual perception, image, element, tourists, environmental impact assessment.

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1. Introduction

The rapid pace of urbanization is projected to drive the global urban population to surpass 60% by 2050 (Y. Zhou et al., 2019). Nevertheless, this trend is accompanied by significant challenges, including the depletion of natural resources and the effects of climate change (Qureshi et al., 2010a, 2010b; Song et al., 2019). These challenges have adverse effects on people's lifestyles, potentially resulting in health issues like depression, anxiety, and even threats to human lives (Song et al., 2019). Research has revealed that when assessing urban heat resilience (HR) and studying the influence of the urban built environment on extreme heat events, vegetation is of paramount importance for reducing surface temperatures and enhancing heat resilience (Xi et al., 2023). Moreover, the expansion of urban green spaces and their integration into urban planning and design can improve a city's energy efficiency (C. Li et al., 2023). Consequently, green spaces in urban areas play a pivotal role in improving the quality of urban life, promoting health, and contributing to environmental amelioration (Gozalo et al., 2018; Helbich et al., 2019; Kabisch et al., 2015; Y. Zhou et al., 2019). Urban gardens, as a part of these "green spaces," are of paramount significance in people's everyday lives as they provide opportunities for interactions with nature and social engagement. These spaces exert a substantial therapeutic effect on human physical health, mental well-being, and emotional health (Godbey et al., 2010; Hand et al., 2017; Irvine et al., 2013; Mitchell, 2013; Richardson et al., 2013; Tzoulas et al., 2007; Wendel et al., 2012; Yuen & Jenkins, 2020). These benefits can be derived not only through visits to these urban gardens but also through active perception and experiences (Hadavi, 2017; Wan et al., 2020). Hence, to better

cater to the public's needs, it is crucial to gain a deeper understanding of how people assess and perceive urban landscapes, ultimately enhancing public satisfaction. This will facilitate more efficient planning and management of urban green spaces to better serve urban residents.

Over the years, researchers have strived to investigate how tourists perceive and assess garden landscapes (Coeterier, 1996; Cong et al., 2021; Qiu et al., 2021). However, these studies have primarily relied on qualitative data collection methods, such as focus groups and semi-structured interviews, often lacking clear quantitative or computer-assisted approaches for assessing landscape quality (Fletcher et al., 2014). Structured questionnaires in this area exhibit specific limitations, encompassing labor-intensive processes, sample size constraints, incomplete user data, and the potential for authenticity issues due to subjective elements in questionnaire design (Laaksonen et al., 2006; Peng et al., 2020). Moreover, the evaluation of garden landscapes by visitors has largely been conducted through qualitative analysis methods. Qualitative methods often demand a substantial investment of time and human resources, involving a relatively intricate data collection and analysis process, and they can potentially introduce subjective biases, including those of the researchers (Hägerhäll et al., 2018; Qiu et al., 2021). Although qualitative insights are valuable, they may not directly reflect the aesthetic preferences of the public and the cultural context of garden landscapes.

In order to address these challenges, there has been a growing body of quantitative research in recent years, focusing on the measurement of urban physical environments and the assessment of landscape experiences, all from the perspective of tourists (Coeterier, 1996; Cong et al., 2021; Peng & Huang, 2017; Qiu et al., 2021; Wu et al., 2018). Digital and quantitative methods help mitigate the subjectivity of landscape assessment, reducing its reliance on personal judgments (Joly et al., 2009). In recent years, significant advancements have been made in computer vision technology, particularly in deep learning techniques for content recognition in images (Goodchild, 2010; F. Zhang et al., 2018a, 2018b; B. Zhou et al., 2017). These techniques have gained widespread attention and demonstrated success in multiple domains due to their robust capabilities in automatic image feature learning and representation (Hinton et al., 2012; LeCun et al., 2015). The emergence of deep learning technologies has prompted attempts to apply them to quantify human perception of large urban areas (Yao et al., 2019; F. Zhang et al., 2018b). While human perception of urban landscapes is inherently subjective, evidence suggests that leveraging street-view images and deep learning models to quantify human perception of urban areas is indeed feasible (Dubey et al., 2016; Yao et al., 2019; F. Zhang et al., 2018b). Empirical studies related to human perception of urban landscapes continue to grow (Dai et al., 2021; M. Liu et al., 2019). However, these studies predominantly rely on feature analysis of street-view images (Wei et al., 2022). Nevertheless, garden images possess unique elements and attributes that significantly distinguish them from street-view images. Therefore, the application of deep learning techniques in the field of garden image perception assessment is still relatively nascent and warrants further research and exploration.

In this study, we will focus on the modern gardens in the vicinity of Taihu Lake. The modern gardens around Taihu Lake area include many world cultural heritage sites, national key parks and national key cultural relic protection units. The area has a large number of tourists and dense surrounding population. Therefore, the research on visual perception evaluation of modern landscape in the area around Taihu Lake is conducive to the understanding and recognition of the heritage value of modern landscape from all walks of life, as well as to stimulate the development of related modern landscape culture industry and tourism. Our research will primarily concentrate on the gardens along the shores of Taihu Lake, with three principal research objectives: (1) Evaluate the visual perceptions of different city gardens (Wuxi, Suzhou, Huzhou) from the perspective of tourists. (2) Quantify the environmental factors of garden landscapes. (3) Analyze the correlations between garden landscape environments and perception. These objectives will be achieved through the utilization of image semantic segmentation techniques, SPSS correlation analysis, and survey data. To achieve these objectives, we will utilize image semantic segmentation techniques, SPSS correlation analysis, and survey data. This study aims to provide an objective assessment of tourist preferences for garden landscape perception, offer a clear snapshot of the current state of modern garden landscapes in the Taihu Lake region, and provide valuable insights for the future development of modern gardens in the Jiangnan area.

2. Theoretical framework

Landscape visual perception research emerged in developed countries in the 1960s and 70s, coinciding with studies on landscape aesthetics and resources (Brown et al., 1986; Ortolano, 1984; X. Zhou, 1995). The theories and methods for landscape evaluation gradually matured during this period. Gardens are engineered to create environments that blend artistic elements, offering visitors a place where they can perceive information through observing the garden surroundings. This process elicits a range of psychological responses (Han & Zhu, 2021; Lynch, 1960; Nasar, 1990; Kaplan & Kaplan, 1989; Tuan, 1977). This interaction signifies the perceptual and cognitive engagement of visitors within their surroundings (Bell, 2012; Chen et al., 2021), aligning with what Kant referred to as "aesthetics" (Kaplan, 1987). Kant's aesthetic theory emphasizes the correspondence between the visual perception of landscapes and the emotional and cognitive responses it evokes. This correspondence is evident in how specific scenery patterns can elicit particular emotional responses and cognitive patterns in visitors.

Landscape Visual Quality (LVQ) reflects the intricate interplay between landscape features and the percep-

tual and emotional processes of observers (Daniel, 2001; de Val et al., 2006; Lothian, 1999). To accurately measure LVQ, previous research has developed various evaluation methods. These methods include assessing how park landscapes influence public aesthetic preferences, constructing quantitative models of the relationship between visual quality and landscape elements through regression analysis (Acar et al., 2006); employing the POE method for comprehensive evaluation of urban waterfront landscapes, involving public participation, and using the AHP method to construct urban landscape assessment models (J. Cao et al., 2020; Lifang et al., 2008). Furthermore, the field has expanded from single visual quality assessment to multidimensional, multisensory, and multiscalar simulation research (Tang & Liu, 2015). Additionally, the use of the Semantic Differential (SD) method, which employs language-based descriptive scales, has delved deeper into the psychological perceptions of evaluators to provide a more comprehensive assessment of public preferences (J. Cao et al., 2020; Yang et al., 2004). These methods have gained increasing application, enriching the toolbox of landscape visual quality evaluation.

To explain the physical environmental impact factors behind visual perception, Routledge introduced the concept of the "Three-Place Elements": location, locale, and sense of place (Agnew, 2011; Routledge, 1993). Research has long attempted to quantify a sense of place, using various processing methods to establish the physical appearance of urban spaces (Gebru et al., 2017; X. Li et al., 2018). Since the 1960s, the concept of urban form was introduced by Lynch, who conducted extensive surveys to create psychological maps of citizens' visual perceptions of the city and identified five elements of urban form: paths, edges, districts, nodes, and landmarks (Lynch, 1960; Peng et al., 2020). More recently, the emergence of big data has brought about datasets encompassing various urban landscapes, streets, and imagery, offering new opportunities for quantifying physical aspects of garden landscapes (F. Zhang et al., 2018b; Gebru et al., 2017; Rattenbury & Naaman, 2009). With the advent of street-view imagery, these assessments come closer to the human perspective, covering multi-scale street scene information. Extensive analysis of street-view imagery allows for an objective and quantitative evaluation of urban features. Through automatic analysis and extraction of visual features from urban street-view imagery (Dubey et al., 2016; Joly et al., 2009), some researchers have employed automated techniques to quantify human perceptions (Dubey et al., 2016; Kruse et al., 2021; Naik et al., 2014; Salesses et al., 2013; Yao et al., 2019; F. Zhang et al., 2018b). As a result, the emergence of street-view imagery has made it possible to quantitatively assess park perceptions on a large scale.

This study significantly diverges from prior research in several key aspects. Building on earlier investigations, our approach involves the application of image semantic segmentation for the quantitative and objective evaluation of garden landscape images. This methodology serves to alleviate the subjectivity associated with human judgment while simultaneously simplifying the intricate process of data collection. Secondly, while preceding studies predominantly focused on urban street scene datasets, our research is primarily centered on garden landscape images, thus introducing a unique emphasis on garden environments that enrich the field of landscape perception. Lastly, our study emphasizes the intricate interplay between the physical attributes of garden landscapes and the complex dynamics of human perceptual experiences. This approach acknowledges the substantial impact of the physical characteristics of garden landscapes on how individuals perceive and interact with them.

3. Methodology

3.1. Research scope and data setting

This study takes Chinese modern gardens in the cities of Wuxi and Suzhou in Jiangsu Province and the city of Huzhou in Zhejiang Province as cases. Modern Chinese gardens developed in the context of semi-feudal and semi-colonial society from 1840 to 1949. They are influenced by traditional classical gardens, and they represent a new era in garden development. The modern gardens in the Wuxi, Suzhou, and Huzhou areas have a particular natural environment and social background.

They are mainly located near Taihu Lake (太湖). The greatest concentration of garden distribution is in the Jiangnan region. This study investigates 65 modern gardens (Figure 1) and finds that the modern gardens in this region cover a large area and have a rich configuration of internal spatial landscape elements. Together, they constitute a complete representative garden that can be used to study the visual image elements of the gardens. This area is well-known in China. Tourists come from various cities in China. It is representative to take tourists from Jiangnan area as the research object.

The research was conducted from October 3 to 4, 2019, which was a holiday with a large number of tourists, vigorous vegetation, abundant garden elements and sunny weather. According to the completeness, popularity and element richness of the gardens, the research team selected 3 gardens from Wuxi, Suzhou and Huzhou respectively, namely Hengyun Villa (横云山庄), Meiyuan Garden (梅园), Qianlu Garden (潜庐), Small Lotus Village (小莲庄), Library garden (藏书楼), Yiyuan Garden (宜园), Yiyuan Garden (怡园), Qiyuan Garden (启园) and Tuisiyuan Garden (退思园). A total of 9 modern gardens were taken as experimental objects. A total of 2,294 garden images were taken and collected. The representativeness of the photos was assessed and 1,260 images were judged to be valid.

The Semantic Differential Method (SD method) questionnaire was used in this experiment, primarily distributed randomly to tourists and local residents, with the survey focusing on the visual experiential assessment of landscapes. While the number of questionnaire samples is generally preferred to be as large as possible, practical constraints often come into play. "Social Survey Methods" provides

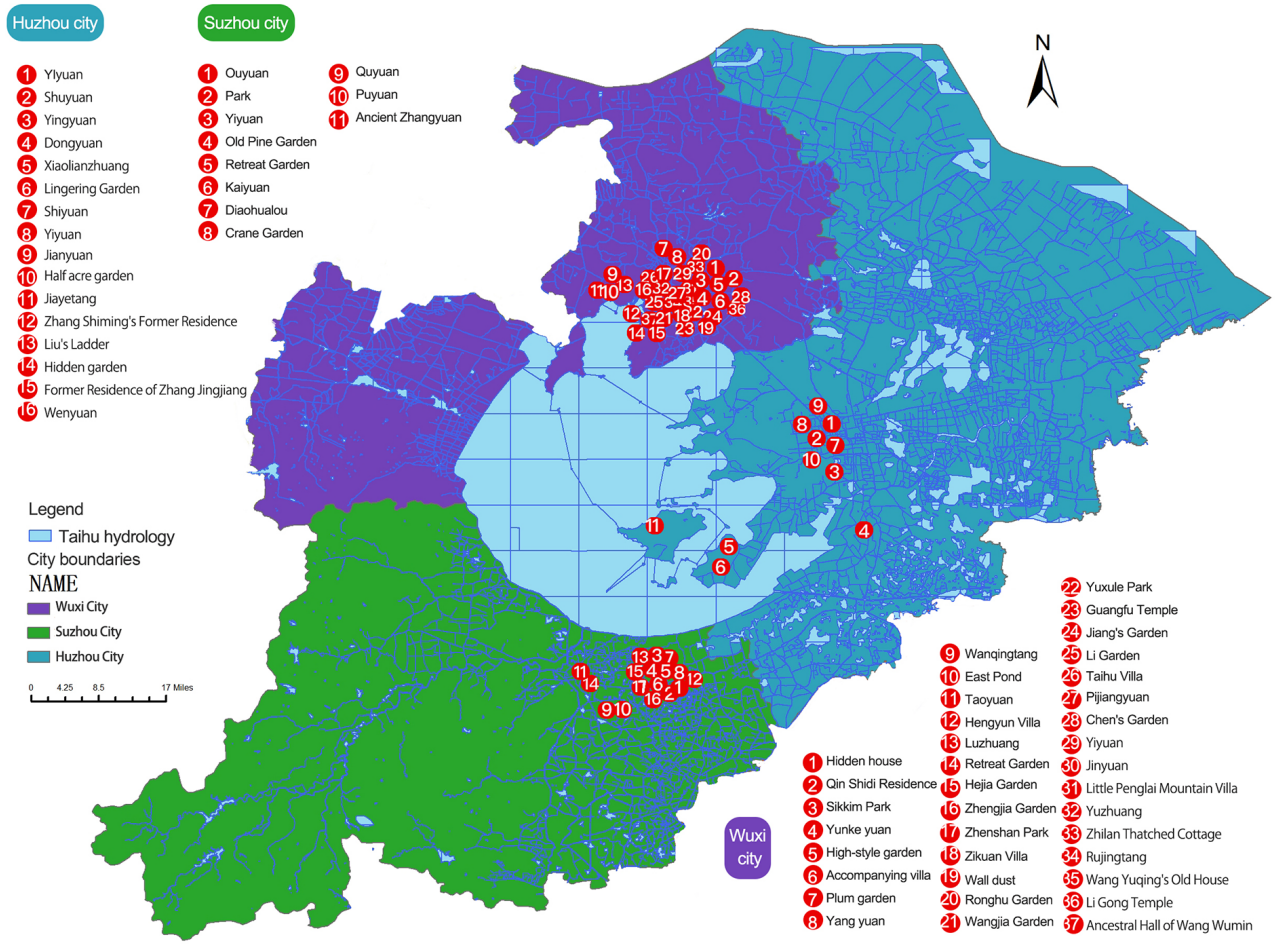


Figure 1. Distribution of modern gardens around Taihu Lake

an analysis of the relationship between samples and the margin of error and establishes a minimum standard. With a necessary sample size of 25, the margin of error is ±20% (J. Zhang, 2004). In psychological research, sample sizes of 30 or more are typically referred to as large sample experiments, as they are deemed to have higher reliability (Luo et al., 2022). This survey encompassed garden samples from three different regions: Wuxi, Suzhou, and Huzhou cities. It had an extended duration and required significant research intensity. The study involved a total of 43 participants, with each questionnaire containing evaluations for nine gardens. Therefore, each participant provided assessments for nine gardens, resulting in a total of 387 questionnaire responses. During the experiment, each of the 43 participants received one questionnaire and assessed the scenes based on the images provided in the questionnaire. The participants conducted simultaneous evaluations of the nine gardens, adhering to the actual locations. However, two participants failed to complete evaluations for all nine gardens, and one questionnaire was lost during the process. Consequently, three questionnaires were considered invalid, leaving 40 participants with valid questionnaire responses. A total of 360 valid perceptual evaluations were collected, with an effective rate of 93.02%.

Through the basic analysis of tourist and resident characteristics (see Appendix A), the results show that the proportion of male and female tourists is equal; Most of the tourists are young people aged 21–29. The education background of the respondents is mostly students, followed by retirees; Most of the tourists are residents of Jiangsu and Zhejiang provinces.

3.2. Garden image collection

The garden images in this research were collected by capturing standardized images to obtain data. Image setting standards, Picture resolution: 5760*3840; Camera compass heading: 0, 90, 180, 270; Image level scene: 90°. Sampling points were set for fixed-point shooting according to the garden area and the internal road network to ensure that the images covered every part of the garden. Figure 2 shows a fixed-point image of Suzhou Yiyuan Garden. The spatial layout of the garden allows for its division into three spaces and 25 fixed points. A 360-degree image of each fixed point was captured, a total of 40 images; 86 images were taken according to the spatial visibility range of the garden, and finally, effective screening and labeling were carried out.

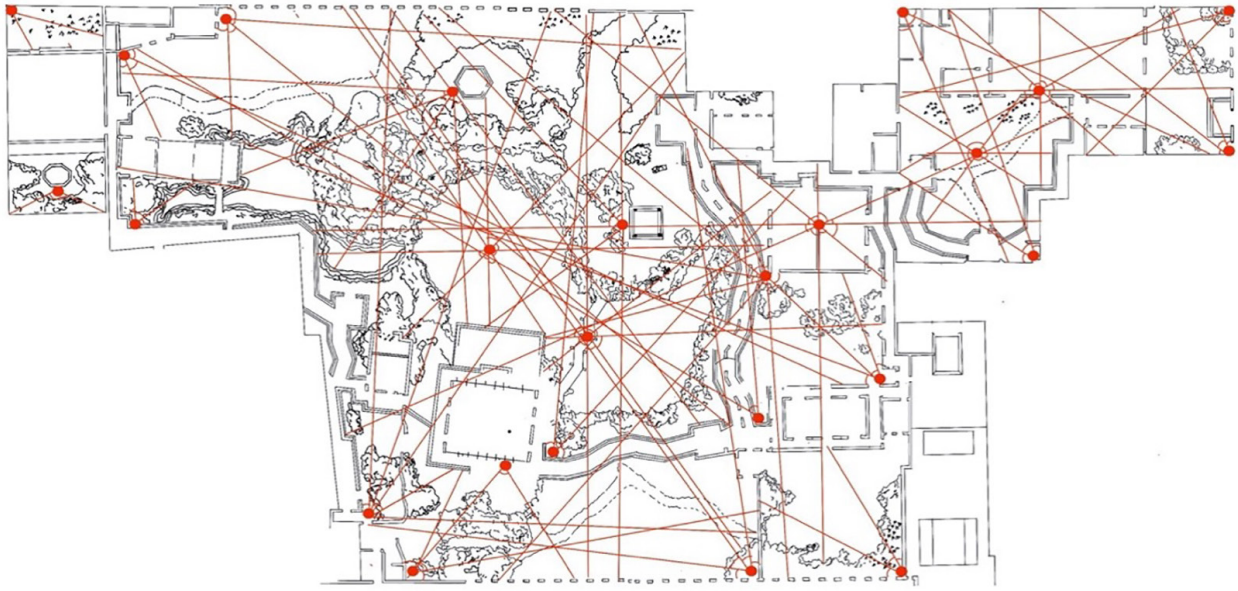


Figure 2. Fixed-point shooting path of Yiyuan, Suzhou City

The screening process involved the following principles: (1) Avoid having one overly prominent element in the image; (2) The number of elements in the image is moderately distributed and should be between 3 and 9; (3) Avoid the repetition of large areas of the same element between images. After the screening of the photos, the valid elements were evaluated.

3.3. Visual perception score setting

In this study, the data of image visual perception evaluation were collected by local tourists and residents as the experimental objects. Through the actual collection of on-site photos, tourists evaluated the photos during the actual scene tour. The evaluation method uses SD (Semantic Differential), also known as semantic analysis method, which mainly quantifies psychological feelings through the description of positive and opposite words (Jiao et al., 2013). The SD method, introduced by Charles Egerton Osgood in 1957, is a distinctive quantitative evaluation technique designed for measuring human perception (Osgood et al., 1957). It has found extensive application in research related to fields such as architecture, landscapes, and planning (J. Cao et al., 2004; Y. Liu & Xu, 2011; Yang et al., 2004). The reliability and effectiveness of this method have been corroborated through numerous studies. A prominent advantage of the SD method lies in its use of adjective pairs to gauge individuals' intuitive feelings. This facilitates the conversion of participant feedback into data, making it amenable to subsequent statistical analysis (Y. Liu & Xu, 2011). This approach assists researchers in gaining a deeper understanding of participants' visual preferences, emotional experiences, and their perception of garden landscapes.

While there are alternative methods available, such as open-ended questions and focus group discussions, these approaches have certain limitations (Dearnley, 2005; Fletcher et al., 2014). These limitations include the need for additional time to process textual descriptions, increased complexity in interpreting subjective information, and elevated workloads, among other factors. Additionally, in this study, we attempted to extract data from user-generated content within social media, including text-based posts and photo ratings. However, it proved challenging for users to comprehensively assess garden landscapes across the three regions of Wuxi, Suzhou, and Huzhou simultaneously to gather data regarding their behavioral preferences. Therefore, we opted to employ the SD method for on-site data collection of perceptual information and the establishment of quantifiable metrics, making it an ideal choice for this study of garden landscape perception in the Taihu Lake region.

This study takes the visual perception of tourists and residents as the research perspective, and summarizes the top 20 adjectives that are frequently used in the SD method in the scientific research literature that meet the requirements (Guang, 2020). 16 pairs of adjectives (Lei, 2020; Luo et al., 2022) were determined based on the applicability of garden feature evaluation and related experts. They are comfort (E1), pleasure (E2), relaxation degree (E3), sense of security (E4), attractive force (E5), aesthetic feeling (E6), sense of nature (E7), perceived hierarchy (E8), sense of space (E9), sense of rhythm (E10), sense of order (E11), quiet feeling (E12), factor richness (E13), vegetation diversity (E14) sketch significance (E15), dynamic sense (E16). The seven-level scale was adopted (J. Zhang, 2018; Zuo & Xiaohua, 2019), which were very poor, poor, below average, average, above average, good, and very good. The axis was set symmetrically with 0 as the center, that is, the score was set as –3, –2, –1, 0, 1, 2, 3 (see Appendix B).

3.4. The establishment of garden visual elements

The generation of garden visual elements mainly combines the five categories of elements in the natural landscape: sky, mountain, hydrology, vegetation, and biology (Yu, 1987) with the six garden spatial element categories of mountains, hydrology, vegetation, architecture, exhibits, and roads. When the overlapping parts were deleted, seven garden visual element categories remained (Figure 3). We classified the landscape elements in more detail by screening the 10 detailed objects that appear most frequently in the seven element categories. Finally, we identified the 14 basic elements that constitute the environment of landscape visual elements (Figure 3).

3.5. Identify sensitive visual elements

As a branch of machine learning, deep learning uses Convolutional Neural Network (CNN) to automatically learn from massive data with semantic category labels and extract image features to achieve pixel-level classification of images. It has become the mainstream method of image semantic segmentation (H. Cao et al., 2019; Liang et al., 2020). At present, research suggests that utilizing the pooling module in the Pyramid Scene Parsing Network (PSPNet) effectively integrates information from above and below the image (Lin et al., 2022). ADE20 data set (B. Zhou et al., 2017) was used to train PSPNet to obtain the proportion of sky and vegetation elements of Fu Dao landscape elements in images. In this paper, there are abundant elements in gardens, and only ADE20 data set (B. Zhou et al., 2017) can not identify the 14 elements in gardens in detail. Therefore, this paper uses manual annotation method to extract elements. The dataset was annotated using the Labelme Semantic Segmentation annotation tool (Torralba et al., 2010). Labelme is an image annotation tool developed by MIT, which can mark images at the pixel level (Xu et al., 2022). Outline the image boundaries that need to be marked to form a closed target outline. After annotation, save the json file, which includes the target category, target boundary coordinate value and the filling color of the target area. In order to ensure the accuracy of the annotation, the jason file is visualized by scripting after the annotation is completed. By comparing the visual annotation drawing with the original drawing, the inaccurate regional annotation can be corrected to ensure the accuracy of the element range annotation. Annotated index of landscape elements data (Figure 4), each element category corresponds to an independent index identifier. GT (Ground Truth) graph (Y. Zhang et al., 2015), also known as truth graph, is a marked graph with different RGB values after pixel level labeling of the original graph. Each area of different elements in the graph corresponds to different categories of target objects in the original graph. This paper mainly uses the semantic segmentation data set of landscape architecture to segment 14 elements such as small pieces, vegetation (high-rise, middle-rise and low-rise) and mountains (as shown in Figure 3), so as to realize the positioning and segmentation of garden elements in Suzhou in modern times.

In order to improve the accuracy of segmentation of image elements, all the landscape elements were manually extracted from 1260 images, and the element categories of landscape images were obtained through Labelme annotation. The proportion of each annotation category in the image was obtained by Boolean operation, and the proportion data of all the image elements were finally obtained.

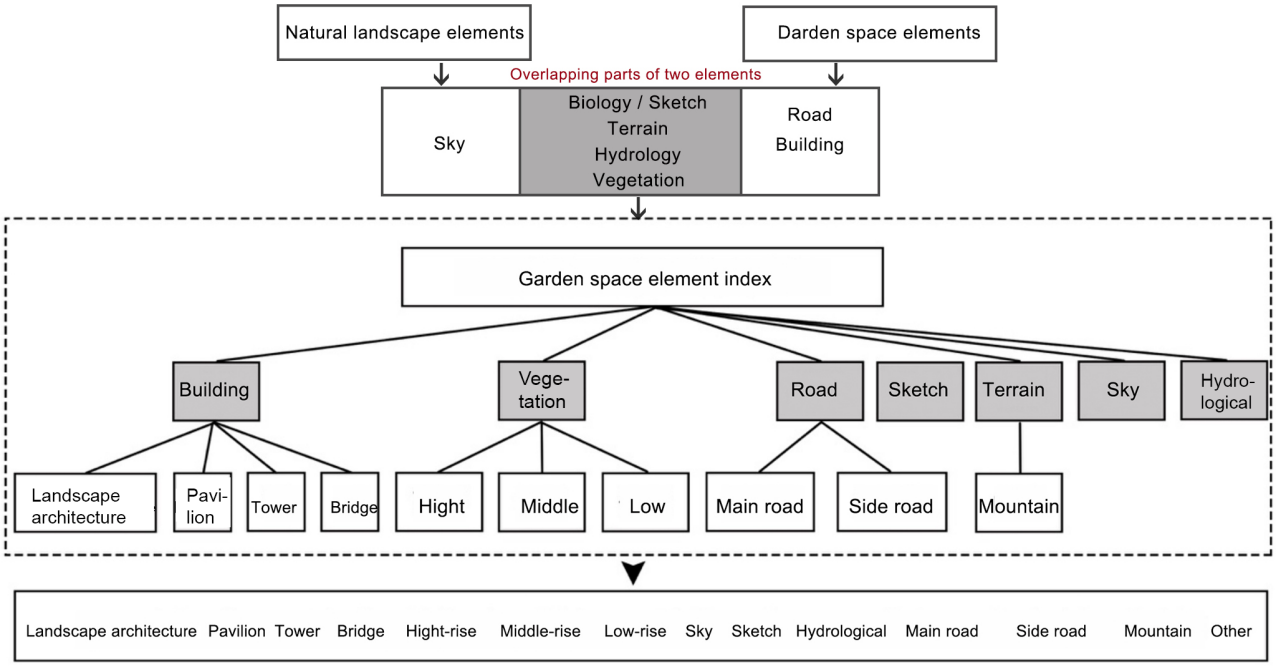


Figure 3. Extract fourteen visual elements of garden space

Figure 4. Example of dataset annotation

4. Research results

4.1. Visual perception results

First, by calculating the SD comprehensive mean to draw the evaluation curve, we can see that the scores of the 16 evaluation factors are between 0 and 2. The comprehensive evaluation of the tested people on the modern gardens around Taihu Lake region is generally above, indicating that the tourists' satisfaction with the viewing experience is relatively high, and this region has certain tourism value. Secondly, by comparing the SD values of different regions, it can be seen clearly that tourists' visual perception of Wuxi city's modern gardens is superior, especially in terms of comfort, naturalness and pleasantness. The perceived values of the modern gardens in Suzhou city are in the middle of the rating range, while the perceived values of the modern gardens in Huzhou city are in the low rating range. Figure 5 shows clearly that the

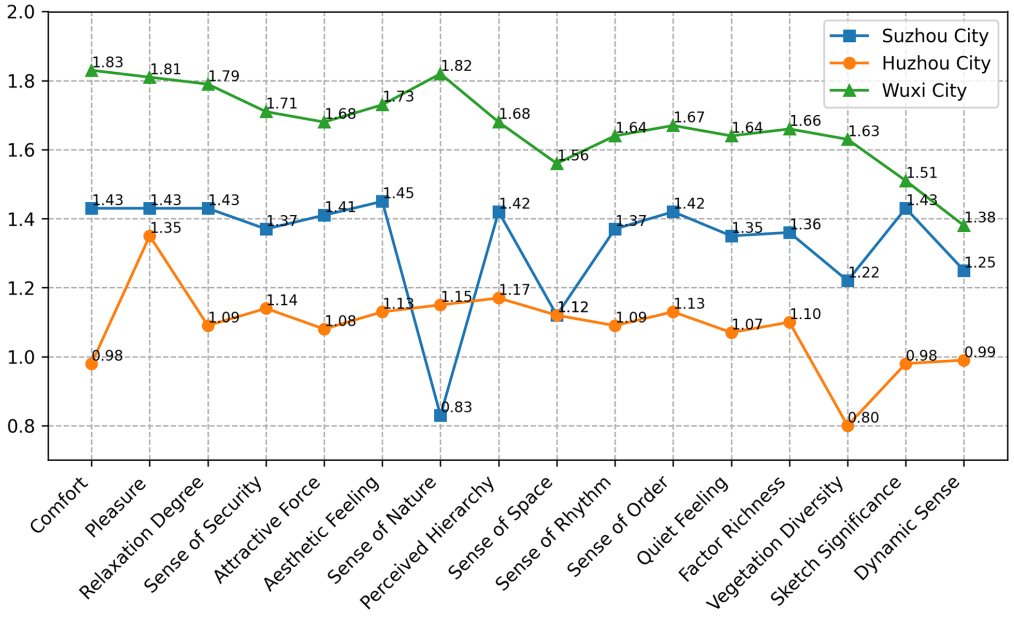


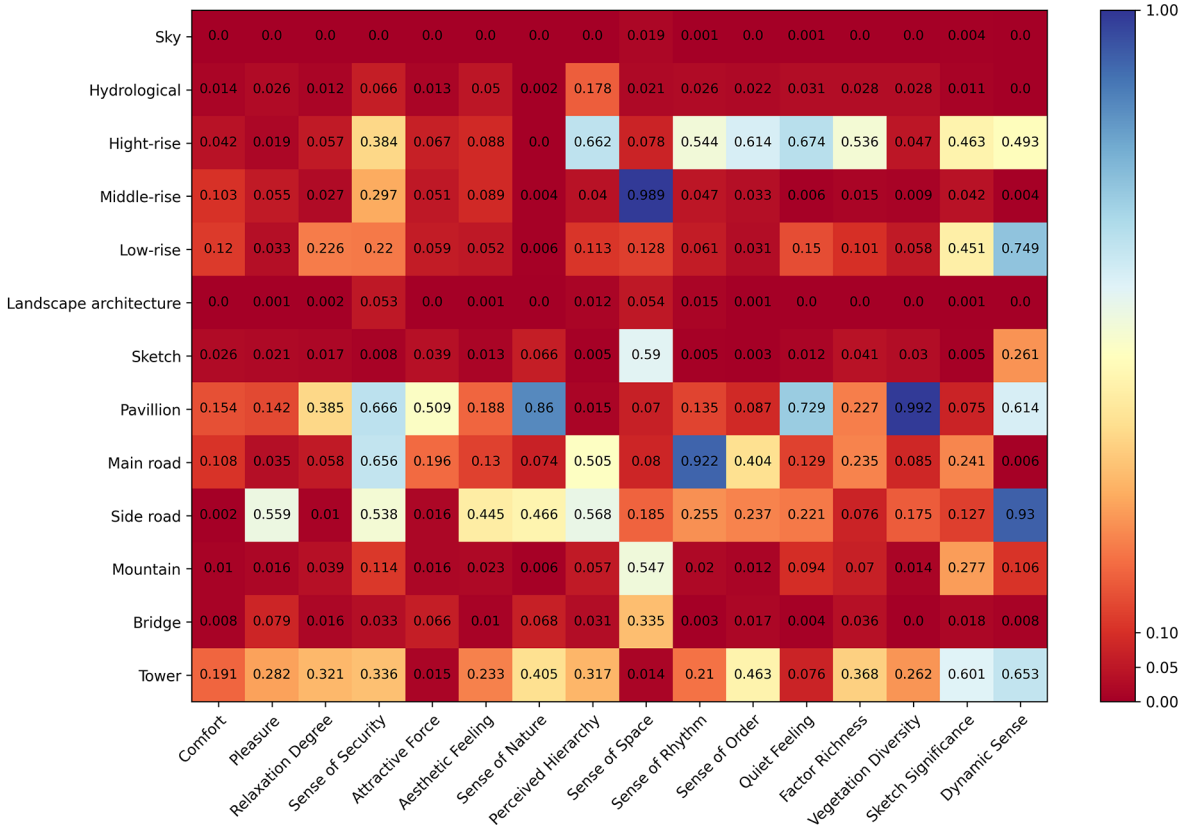
Figure 5. SD comprehensive mean value drawing evaluation curve of modern gardens in Taihu Lake Rim area

perception of naturalness in Suzhou city gardens is significantly lower than the same perception in other gardens. This indicates that visitors experience an impression of an artificially designed space. The total visual perception score for the naturalness of the gardens in Wuxi is high, reflecting a visual preference for gardens made naturally. In addition to the slight fluctuation of the difference between natural perception and spatial perception in the visual perception value of modern gardens in Huzhou city, people generally have a stable emotional state. The results of the study show that there are large differences in the visual perception evaluations of visitors to different regional gardens. In exploring the differences in the assessment results, this study extracts key elements and perception indicators for garden construction. Finally, the correlation analysis between the SD evaluation data and the proportion of image elements was carried out by SPSS software to find out the garden elements that affect tourists' visual perception evaluation and analyze the reasons.

4.2. Perception mapping of gardens

The purpose of observation of garden elements and visual perception evaluation is to analyze the key garden elements that affect the tourist experience. Through this method, measured data are used to objectively evaluate the suitability of garden element allocation, so as to improve the element allocation of garden landscape and make up for the defects of experience evaluation. In this study, based on Pearson correlation clustering and conditional probability, the correlation calculation of visual perception indicators was carried out to clearly quantify the relationship between visual perception and elements. Based on the Pearson correlation analysis results in Figure 6, among the 13 elements within the garden landscape, only a few elements show no correlation with the visual perception metrics. Most of the indicators exhibit significant correlations. The strength of these correlations is visually represented in Figure 6, where the color red signifies significant correlations. According to the proportion parameter of correlation factors in Figure 7, it is found that modern gardens around Taihu Lake as a whole can be concluded as follows: The effects of "Sky", "Hydrology" and "Landscape architecture" on visual perception were obvious, among which "architecture" showed a negative correlation. In particular, the coefficients r of "landscape architecture" in "sense of nature", "vegetation diversity" and "dynamic sense" were as follows: –0.516, –0.407 and –0.383, indicating that "landscape architectural" elements bring tourists poor visual experience. The main road and the side road also show negative correlation perception experience.

Secondly, from the correlation parameters of each index, it can be concluded that the parameters with greater correlation influence in gardens are: The coefficients "r" of "sky" factor and four visual perceptions ("Comfort", "Pleasure", "Sense of nature" and "Sense of security") were respectively 0.421, 0.365, 0.348 and 0.337. The coefficient "r"



Note: The significance level is indicated as follows: *p < 0.1, **p < 0.05, ***p < 0.01.

Figure 6. Pearson correlation coefficient of visual perception elements and garden elements index

of "hydrology" and "Dynamic sense" is 0.340. The correlation study shows that the sky and hydrology elements of modern gardens around Taihu Lake have better visual perception of tourists and bring tourists higher experience. Through the comprehensive use of the proportion data of garden elements and the correlation analysis of SD experimental visual evaluation data, the key factors affecting the visual comfort of tourists were found, so as to improve the specific technical strategies of landscape environment and provide scientific data sources for landscape designers.

4.3. Indicator recognition results

From the above analysis, it can be seen that the elements of "Sky", "Hydrology" and "Landscape architecture" of modern gardens around Taihu Lake area are highly correlated with the natural perception, comfort perception, richness perception and dynamic perception in tourists' perception evaluation. In this study, the natural and social cultural factors affecting tourists' perception and evaluation were respectively discussed in combination with 9 gardens, and the configuration and composition of landscape elements in line with tourists' visual perception needs were discussed.

Figure 8 shows the results of multiple regression analysis between perceptual indicators and visual elements, where each perceptual indicator makes a positive or negative object, and the length of each bar in the figure indicates the standardized beta coefficient, and * indicates the level of significance. We found that the garden elements in different areas have different effects on the perceptual indicators of tourists. For example, the mountain elements in the Hengyun Villa garden (c) have positive significance for the attractiveness and pleasantness indicators. The mountain elements are more likely to interest tourists in the garden in Hengyun Villa. In contrast, the main road element has a significant negative correlation with comfort and pleasure, indicating that the main road in this garden is unremarkable and is of little interest to tourists. Therefore, this garden should consider redesigning the main road to introduce elements that will attract visitors based on their perceptions. Also, the high-rise vegetation elements also produce a significant negative correlation, indicating that visitors have less visual pleasure in the high-rise vegetation elements of this garden, while the hydrological elements of the garden have a significant positive correlation with the visual dynamic perception. When we take the surrounding environment into consideration, we see that Heng Yun Villa is located next to Taihu Lake, dominated by Taihu Lake hydrology and the mountain landscape. The high-rise vegetation is taller and denser, blocking to a certain extent the visitors' view

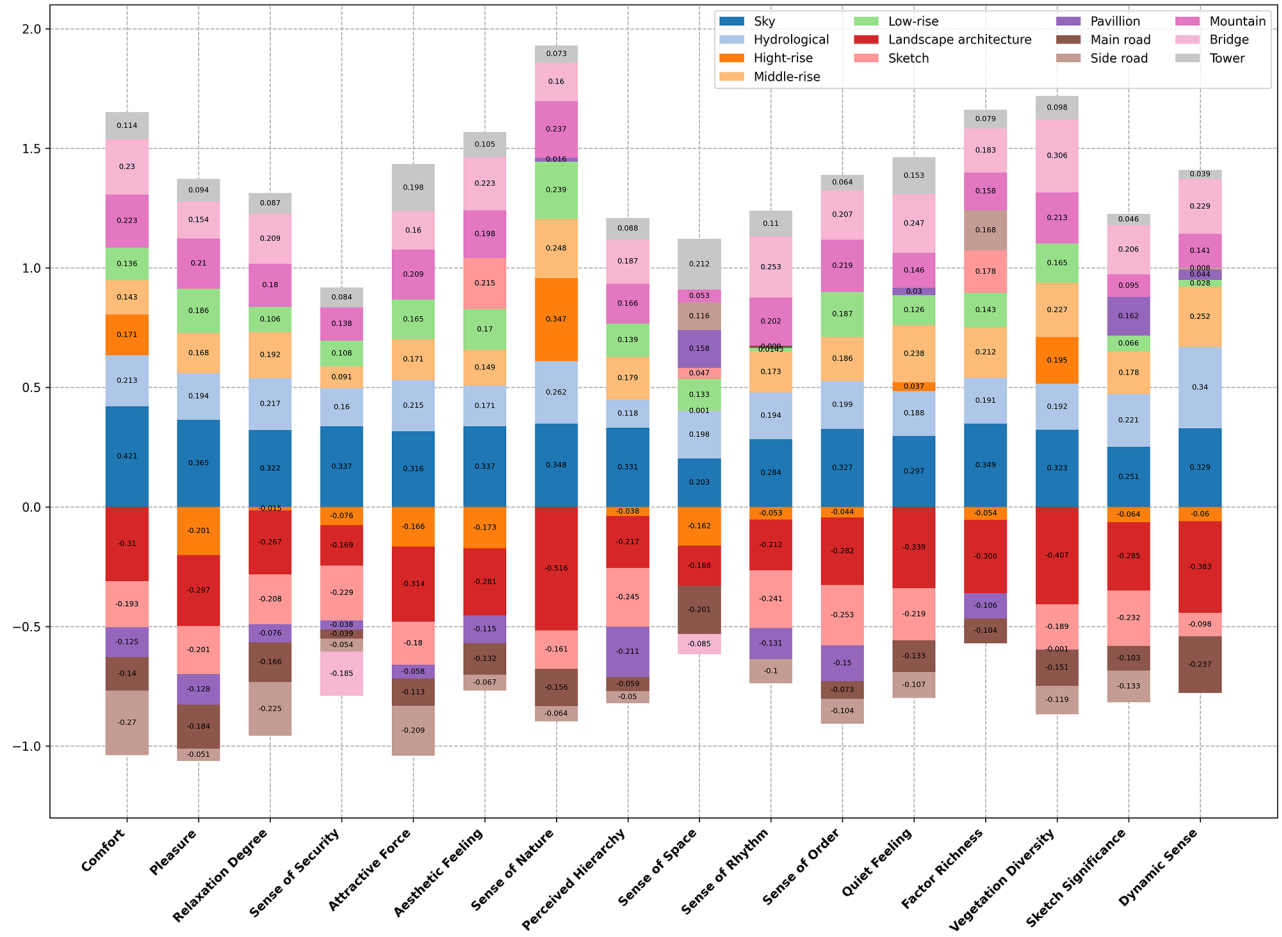
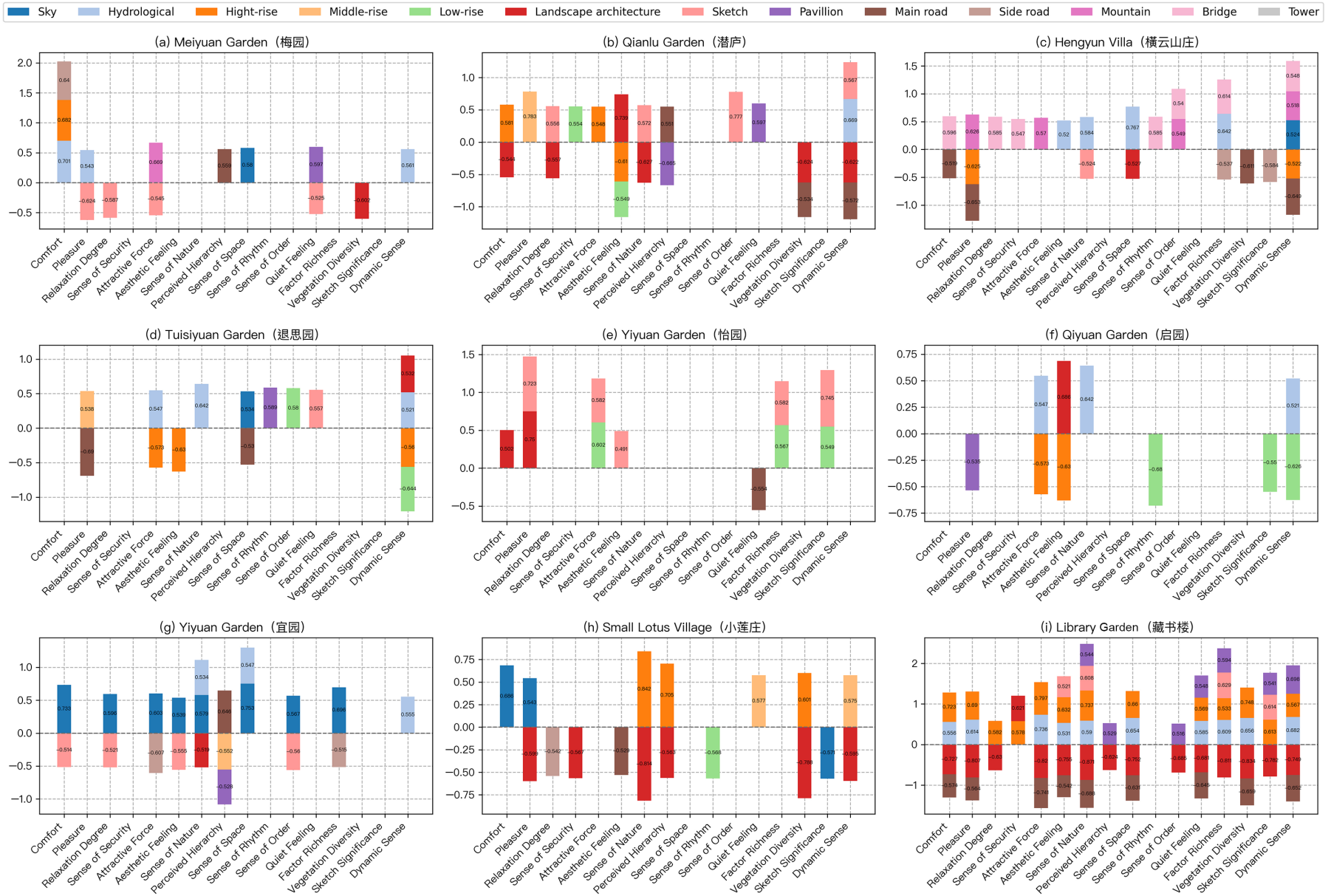


Figure 7. Comprehensive utilization of garden element proportion data and correlation analysis of SD experiment visual evaluation data



Note: The correlation coefficient analysis results between landscape elements and perception scores produced positive and negative visual perception respectively.

Figure 8. Pearson correlation coefficient analysis was conducted on 16 perception indicators based on the element data of 9 gardens

of the water scenery. Therefore, the main road in this garden should be redesigned to guide the visitors to where the line of sight is not obstructed, thereby enhancing the visual perception of the visitors.

The positive correlation perception indicators also come from different elemental forms, mainly related to different regions. For example, the modern gardens in the Wuxi city area (a) Meiyuan Garden, (b) Qianlu Garden, and (c) Hengyun Villa are close to Taihu Lake. Therefore there is a greater interest in natural elements such as hydrology, mountains, and vegetation. The modern gardens in the Suzhou city area (d) Tuisiyuan Garden, (e) Yiyuan Garden, and (f) Qiyuan Garden show the positive visual perception of elements formed by the artificial design of vignettes and middle-rise vegetation. The modern gardens in the Huzhou city area (g) Yiyuan Garden, (h) Small Lotus Village, and (i) Library garden have sky, hydrology, and high-rise vegetation elements, giving them higher visual perception. This study not only identifies correlations between elemental indicators and visual perception but also identifies the specific perceptual indicators of elemental types and visual perception evaluation. As shown in (j) Yiyuan the sky and hydrology elements make for positive responses in visual perceptions of comfort (0.737), sense of space (0.753), relaxation degree (0.596), and aesthetic feeling (0.539). In contrast, the landscape architectural and sketch elements show negative perceptions in evaluations of aesthetic feelings (−0.555), comfort (−0.514), and relaxation degree (−0.521). The relationship between specific output elements and perceptions in this study clearly identifies specific visual preference elements and feelings, and provides configuration strategies to support the selection of elements in garden planning and design.

5. Discussion

This study uses quantitative research methods to define the link between the physical environment of gardens and tourists' visual perception by collecting images of nine gardens. The results of the study summarize the top six of tourists' preferences for the elements of modern gardens in Wuxi, Suzhou, and Huzhou cities that are highly correlated with visual perception, as Figure 9 shows.

The high-rise vegetation, mountains, and hydrological elements in the modern gardens of Wuxi present visitors with a sense of open visual space, rely on natural geographical advantages to enrich the natural elements of the gardens, and provide a comfortable and pleasant garden environment for visitors. Wuxi's modern gardens cover a relatively large area. The overall road space is relatively empty, which, in combination with the consistency of the architecture and the relatively few vignettes, greatly affects the walking experience of visitors. This leads to the architecture, sketch, and main road elements in the gardens presenting negative perceptions among visitors.

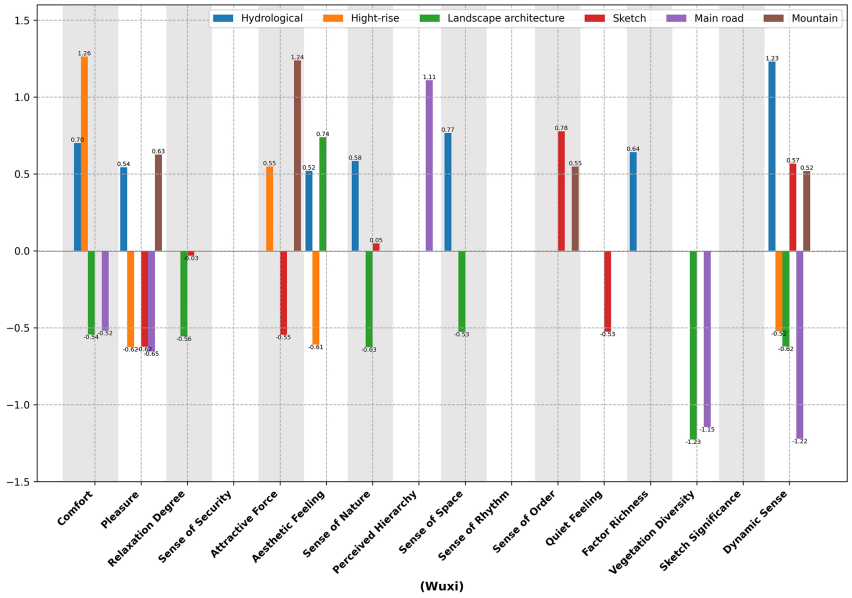
The sketch, landscape architecture, and hydrological elements in the modern gardens of Suzhou give visitors a rich, pleasant, and aesthetically pleasing visual perception. Influenced by the local classical gardens, the configuration of modern garden elements is based on the overall layout of the garden owner's design and incorporates cultural memories. The influence of the cultural background of the garden and the cultural experience conveyed by the sketch mean that the architecture and the hydrological elements dominate, making visitors resonate emotionally with the configuration of elements and greatly enhancing their visual perception scores. The modern garden in Suzhou is more compact in terms of its design elements. Therefore, the use of high-rise vegetation and fences makes the overall space of the garden less open, giving visitors a closed and uninteresting negative perception of the main road, the low-rise vegetation, and high-rise vegetation elements.

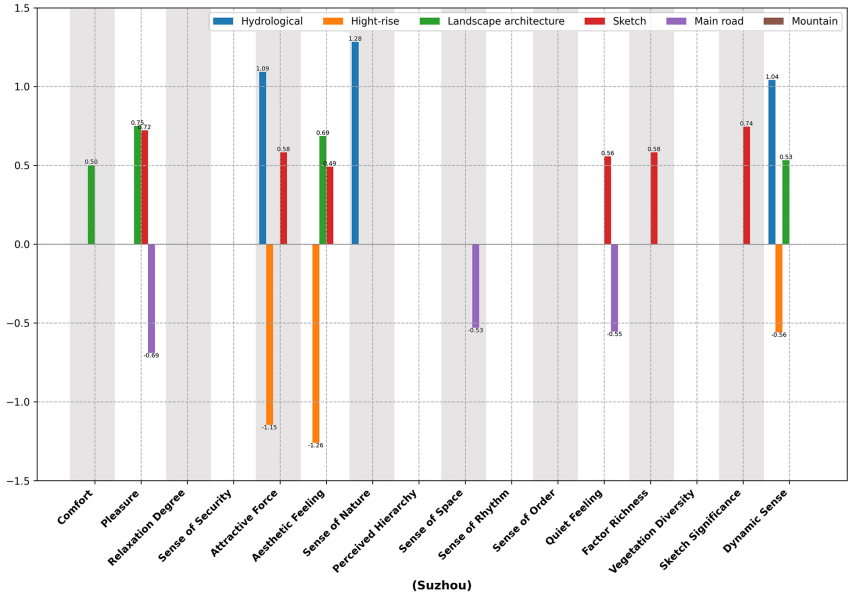
The high-rise vegetation, hydrology, and sky elements in the modern gardens of Huzhou offer visitors a rich visual environment and comfortable visual perception. However, the landscape architecture, sketch, and main road give visitors a visual perception of an artificial, and thereby less aesthetically pleasing, design. As the perceptual scores in Figure 9 show, the positive and negative correlations between landscape architecture and high-rise vegetation elements are high. By combining the extraction of photo elements, we can see that the layout of modern gardens in Huzhou is mainly divided into two parts: "house" and "garden". The main elements are the architecture and the garden. The architectural elements dominate the garden, and the overall architectural appearance tends to be similar, with frequent use of fences and high-rise vegetation. The result is a negative perception of dullness, homogeneity, and unpleasantness in the visual perception of visitors. In contrast, the sky and hydrological elements provide an open visual space, and visitors can walk through the high-density architectural space into the "garden," creating a psychological feeling of enlightenment.

From the above comparisons, we conclude that visitors to the modern gardens in the overall Taihu Lake area prefer natural gardens, gardens with various landscape changes, and two different forms of "house" and "garden," separate gardens in a garden. Through correlation analysis of the proportion of elements in different areas and visual perception, we explore the physical representation of visitors' visual emotions and the need to retain natural landscape elements in garden design and improve any monotonous or boring artificial design elements in the garden. This study uses image semantic segmentation methods in combination with garden images to decompose the semantic information of garden elements in an automatic and effective way to measure visitors' perceptions of the garden environment. Combined with statistical data analysis, this study identifies the elements associated with visitor perception scores in different garden environments. It indicates the positive and negative effects of element configurations on visual perception.

6. Conclusions

Through the case study of modern gardens around Taihu Lake, it is found that tourists have different percep-





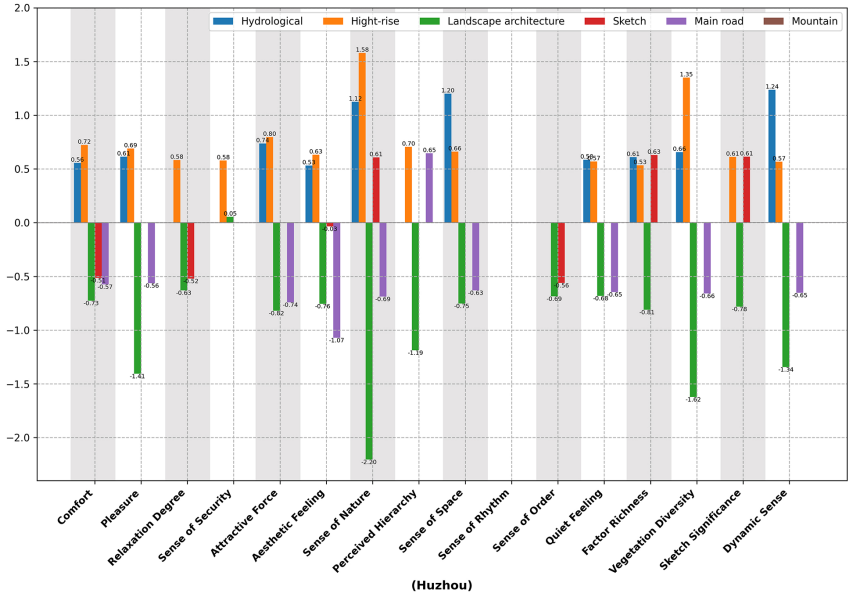


Figure 9. Comparison of scores of 6 indexes highly correlated with visual perception in modern gardens in Wuxi, Suzhou and Huzhou

tion of landscape environment of different gardens. On the one hand, it is due to the perception difference of garden site selection and garden planning. On the other hand, it is affected by the social environment and the identity of the garden owner. Through the quantitative analysis results, the key garden element indexes of modern gardens around Taihu Lake area were obtained. They are architecture, hydrology, high-rise vegetation, sketches, mountains, rivers, main road and sky, and have a strong correlation to tourists' visual experience. The method based on image semantic segmentation and SD experimental analysis can accurately reflect the positive or negative perception emotions of tourists caused by the construction of a certain landscape, and evaluate the heritage value experience of modern gardens.

According to the research results of this paper, tourists have strong natural perception, rich perception, aesthetic feeling, comfortable perception and dynamic perception of modern gardens around Taihu Lake. Therefore, in future garden planning, it is necessary to strengthen the supplement of natural landscape elements and redesign of natural elements such as mountain, hydrology, sky and vegetation, which is also the combination of characteristic elements in modern gardens around Taihu Lake. Enhance the regional characteristics of the garden. This study understands the landscape value of modern gardens from the perspective of tourists, stimulates the perception difference brought by gardens to tourists, and obtains accurate perception expression through comprehensive mean value, which provides strong objective evidence for this study. Therefore, in order to plan and manage modern Taihu Lake gardens more effectively, it is recommended to emphasize the preservation of natural landscapes and the enhancement of landscape quality. From the perspective of policymakers, this study suggests the implementation of a "one garden, one model" management approach. This approach would involve configuring garden landscape elements based on the perspectives of visitors and the general public, considering the unique landscape qualities of each garden, and further enhancing the aesthetic appeal and attractiveness of the gardens. This would contribute to providing a superior visitor experience while simultaneously preserving the natural environment and ensuring the sustainable development of gardens.

The study uses multiple sources of data analysis, such as field research, Pearson correlation coefficients, to provide an effective complement to traditional research methods. The degree of refinement in landscape design and research has increased significantly. The measurement of visual perception by other garden element indicators should also be considered, such as the possible visual differences between types of calligraphy and painting, plazas, and platforms. These approaches would provide further insights into visitors' perceptions of the landscape.

Research focusing on visual perception measures of landscape change in gardens can serve as a starting point for experiencing a place to observe a single viewpoint or appreciate a specific visual object and to learn more about culture, history, activities, and interactions with the surrounding environment. Future research on tourists perception will use vision as a starting point. The measurement of the visual perception of gardens may also be affected by seasonal changes and scale differences. Future research could require collecting more image samples, conducting evaluation experiments, and training models using test sets. The research sample should cover a diverse range, multi-scale, and multi-temporal garden space for garden inspection and image data collection.

Acknowledgements

This study was supported by the Guangdong Planning Office of Philosophy and Social Science, under Grant Number GD22CSH03.

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Appendix A

Personal Information

Name: Gender: Male ☐ Female ☐

Age: A.Less than 18years old B.19-25years old C.25-30years old D.31-40years old E. 41-50years old F.51-64years old G.More than 65years old

Occupation: A.The student B.The Company staff C.Civil Servant D.The tascher E. Entrepreneur F.Farmer G.Unemployed Vagrant H.Other

Educational background: A.High School Diploma or Equivalent B.Bachelor's Degree C.Master's Degree D.Doctorate (Ph.D.) or Professional Degree E. Associate's Degree H.Other

Please specify your status in this area:

A.Local resident B.Tourist (From _____)

Q1. How often do you visit gardens around Taihu Lake Rim area?

A. Once a day B.Once a week C.Once a monuth D.Seldom E.Never

Q2. What season do you like to go to gardens around Taihu Lake Rim area?

A. Spring B.Summer C.Autumn D.Winter

Q3. What type of transportation do you go to the gardens?

A. On foot B.By bicycle C.By bus D.Drive car

Q4. What area of gardens do you prefer to visit??

A. Wuxi City B.Suzhou City C.Huzhou City

Q5. Why you went to the gardens around Taihu Lake Rim area?

A. To enjoy the natural beauty and tranquility.

B.o learn about the cultural and historical significance of the gardens.

C.To spend quality time with family and friends.

D.To experience the local culture and traditions.

E.To engage in outdoor activities and recreation.

F.Other (please specify). _____

Q6. which parks are you satisfied with? (Multiple choice)

A. Hengyun Villa（横云山庄） B.Meiyuan Garden（梅园）
C.Qianlu Garden（潜庐） D.Small Lotus Village（小莲庄）
E. Library garden（藏书楼） F.Yiyuan Garden（宜园）
G.Yiyuan Garden（怡园） H. Qiyuan Garden（启园）
I.Tuisiyuan Garden（退思园）

Q7. When do you go to the gardens around Taihu Lake Rim area?

A. In the morning B.In the afternoon C.In the evening D.Unfixed time

Q8. What are your expectations for the future development of the park?

_____

Q9. Do you have any other comments, suggestions, or feedback?

_____

The questionnaire results

We conducted a survey using the Semantic Differential (SD) method to gather basic information about the contemporary garden viewing in the Taihu Lake region. After excluding invalid questionnaires, we obtained 40 valid responses. The survey revealed that the respondents included 21 females and 19 males, primarily in the age range of 21 to 29 years. The educational background of the participants was predominantly students, followed by retirees. Most visitors were residents of Jiangsu and Zhejiang provinces. The surveyed individuals often visited Suzhou gardens, mainly for tourism and relaxation purposes. Notably, we found that Retreat and Reflection Garden and Xiao Lianzhuang were more famous among the respondents, and they typically visited these gardens by walking or driving in the afternoon.

Appendix B

Perception assessment survey for contemporary gardens in the Taihu Lake region

We intend to conduct a study on the perception of contemporary gardens in the Taihu Lake region using the Semantic Differential (SD) method. Please evaluate the landscapes in the photos based on your personal perceptions and rate the perceptual factors (–3 to 3), which include comfort (E1), pleasure (E2), relaxation degree (E3), sense of security (E4), attractive force (E5), aesthetic feeling (E6), sense of nature (E7), perceived hierarchy (E8), sense of space (E9), sense of rhythm (E10), sense of order (E11), quiet feeling (E12), factor richness (E13), vegetation diversity (E14), sketch significance (E15), and dynamic sense (E16). Use the scale ranging from very poor, poor, below average, average, above average, good, to very good. The axis is symmetrically centered at 0, meaning the scores are set as –3, –2, –1, 0, 1, 2, 3. Please provide your ratings in the blank spaces in the table, and we appreciate your support and assistance.

Item / Photo ID	Comfort E1	Pleasure E2	Relaxation Dgree E3	Sense of Security E4	Atraction Force E5	Aesthetic Feeling E6	Sense of Nature E7	Perceived Hierarchy E8	Sense of Space E9	Sense of Rhythm E10	Sense of Order E11	Quiet Feeling E12	Element Richness E13	Vegetation Diversity E14	Sketch Significance E15	Dynamic Sense E16
1																
2																
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