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Digital characterization of the surface texture of chinese classical garden rockery based on point cloud visualization: small-rock mountain retreat

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Abstract

The Rockery is often a key element of a Classical Chinese Garden. It's exquisite detailed physical characteristics a major contributor to artistic value, aesthetic appeal, and the carrier of historical and cultural heritage values. Poets and scholars have often described the beauty of these places in classical gardens in qualitative terms but lacked the quantitative tools to provide replicable metric descriptions. The highly complex forms and surfaces, irregularity, and fragility of garden rockeries has challenged authors to accurately describe the characteristics of these qualities using traditional methods and tools. This article presents a new method of digital characterization approach based on laser scanning and point cloud visualization, which can quantitatively detect and represent the pattern of rockery surface textures. It offers a replicable accurate quantitative descriptor of the Classical Chinese rockery. The Small-Rock Mountain Retreat, a nationally protected rockery garden in China, has been used as a case study. It contains original historic elements and more recently restored areas. Two characteristics of rockery surfaces, including the well-proportioned density and space, and the proper contrast between solid and void, were analyzed by examining four attributes: (1) surface complexity; (2) contour curvature; (3) shape variation; and (4) the interweaving of lightness and darkness. The findings demonstrate that, despite some similarities between the restored portion of the rockery and the historical remnants, there are variances in the richness of the details and the balanced distribution of shape change. The digital characterization approach introduced in this article offers a new perspective for recording and in turn safeguarding Chinese garden rockeries and other irregular cultural heritage objects.

Keywords Garden rockery, Point cloud visualization, Surface texture, Digital characterization, Chinese classical garden, Irregular heritage objects

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Introduction

Traditional rockeries in Chinese classical gardens are artworks representing natural landforms. They are created by assembling rocks in compact combinations to form miniaturised hills, mountains, and terrains in a garden setting that can be viewed and visited [1]. In China, as a garden component with a history of more than 2000 years, the rockery not only has significant historic and artistic value, but also profoundly reflects the aesthetic preferences and economic environment of different feudal dynasties, and is an important symbol of

Chinese traditional landscape culture [2]. Rockwork is also the most complex technique in garden engineering, which contains rich scientific knowledge and traditional craftsmanship. It is because of the rockeries' complexity, irregularity and fragility, its preservation, monitoring and assessment has always been a challenge in garden heritage practice [3]. The conservation of rockery skills and the protection of historical relics mostly relies on the experience and oral teaching of master craftsman [4]. The heritage science of rockery conservation and the corresponding technical system have not yet been established. Conventional analysis and evaluation methods cannot meet the needs of rockery monitoring and management today.

The rapid development and application of digital technologies in recent decades have enhanced the documentation and conservation of cultural heritage [5]. Laser scanning, in the practice of digital heritage documentation, is often integrated with other technologies such as close-range photogrammetry to provide appropriate solutions for surveying cultural heritage environments and features [6, 7]. In terms of the conservation of rockery heritage and other irregular heritage features, digital surveying technology has greatly improved data acquisition and solved the problem of the accuracy of rockery mapping [8–10]. Point cloud mapping has also been integrated with GIS to provide thematic archival drawings for heritage environments [11], and to support heritage restoration projects [12]. 3D printing tools have expanded the methods and formats for rockery representation [13]. The space syntax method and 2D maps have been used to quantitatively examine the spatial features of rockery heritage [14]. Overall, the digital analysis of garden rockeries has mainly focused on data acquisition, digital twin model construction, and extraction of key feature point measurement, which provided important evidence for identifying the characteristics of rockeries. However, most digital analysis is still based on the "selective measurement", that is, to recognize the characteristics of rockeries with the support of the data of limited feature points. The logic behind such analyses is the same as that of conventional methods, and both have the limitation of ignoring a large number of shape details. The advantage of digital 3D information has not been fully utilized in digital characterization.

In the conservation of cultural heritage in different categories, the use of point cloud data for visualization and statistical analysis has become an important heritage evaluation method and trend [15]. Point cloud model rendering methods and techniques have been used for visualization of heritage sites [16]. Multi-modal presentation and the advancing computer graphics display technologies have been applied for the representation and interpretation of archaeological evidence [17, 18]. More integrated digital approaches such as artificial intelligence have been used to analyze point clouds and to monitor heritage deformation [19, 20]. The 3D visualization of laser scanning models has also been increasingly used for community promotion and communication [21]. Point cloud technology is not only an important means of mapping and recording heritage, more and more studies aim to deepen the understanding of heritage through the interpretation of data characteristics. However, these important applications and progress have not yet been reflected in the conservation of Chinese garden rockeries.

In heritage practice, there is an urgent demand in the effective monitoring and assessment of garden rockeries in China. The restoration and reconstruction of garden rockeries in China has continued since the 1950s [22]. Almost all of the existing rockery heritage has undergone restoration or reconstruction over the past decades [22], and such practices will continue as site discoveries and historical materials emerge. How to systematically provide technical descriptions and in turn evaluate the quality of rockery restoration and reconstruction according to the principles of authenticity and integrity is a key issue. Meanwhile, since the rockery is composed of natural rocks and mostly located outdoors, the erosion, weathering, deformation and other threats of the surface features also put forward requirements for efficient monitoring and management. How to establish description and assessment standards and the corresponding technical support is an important task for heritage practices in China.

Research aim

The overarching aim of this research is to make full use of 3D information to explore an innovative approach for digital characterization of rockery heritage in Chinese classical gardens. We hope to achieve this goal by answering the following three research questions: (1) How to build 3D models to simulate the surface features of the rockery heritage? (2) What are the main objects and corresponding technical workflows of rockery point cloud visualization? (3) Compared with traditional approaches, what are the innovations and breakthroughs of methods based on point cloud visualization?

The characteristics of garden rockeries and its conservation

The goal of building Chinese classical garden rockeries is to poetically and compellingly recreate miniaturised elements of the natural environment. The highest pursuit is that "though it is set out by man, it must look like wrought by nature" [1]. Surface texture refers to the combination of shapes, edge lines, patterns and other features formed by the changes in the surface shape, which is one of the most important historical characteristics of garden rockeries. The surface texture of the traditional rockeries must contain rich and varied forms to reflect the natural flavor, but it needs to have an overall harmony and unity. Lines should be arranged like tactful brush strokes in Chinese traditional landscape paintings [1]. The pieces of rocks should be combined skillfully by taking individual parts and the whole scene into full account [22].

In terms of restoration and reconstruction, it is impossible to return a damaged rockery to a known earlier state, because we cannot find two natural stones with the same appearance. The main feature of rockery restorations lies in the inseparability of craft and art in practice, and the restoration of the rockery must lie in the continuation of its characteristics and the inheritance of engineering skills [23]. In the history of Chinese garden protection, in order to better continue the garden culture and tradition, almost all rockery remains have undergone different degrees of restoration or reconstruction, but the results are mixed because of a lack of reliable characterization and evaluation standards [22, 23]. The focus of the analysis is whether the new part continues the characteristics of the historic relics. From this point of view, the appearance features of rockeries are composed of a large number of shape details, and traditional methods based on limited feature points cannot provide sufficient data to support corresponding analysis. At present, the international guidelines barely address the practice-related issues and technicalities [24]. There are many studies on the principles of restoration and reconstruction, but the research on detailed methods and evaluation indicators is very limited [25].

Based on the advantages of laser scanning and point cloud visualization in shape details, we proposed a new method for rockery surface texture analysis. The conventional feature point analysis workflow has been replaced by the identification of spatial patterns through examining the digital model as a whole. We propose a new method of description and analysis, the Point Cloud Visualization Approach (PCVA). The PCVA consists of five steps (Fig. 1):

(1) Desk study: exploring the heritage value of the rockery, identifying the scale and complexity of the value-contributing features, and then determining the scope and accuracy of digital analysis;
(2) Data acquisition: collecting high-precision rockery point cloud data, and building a complete digital twin model through data processing;
(3) Data processing: creating digital images of rockery through the systematic projection and visualization of the point cloud model;
(4) Pattern identification: extracting image features, identifying principles and patterns of the images with designed algorithms, and then building the correlation between image patterns and rockery surface characteristics;
(5) Digital characterization: setting up analysis factors according to rockery evaluation criteria, and quantitatively characterize rockery surface texture.

Materials and methods

Case study: the small-rock mountain retreat

The Small-Rock Mountain Retreat (SRMR) is located in Yangzhou, Jiangsu Province, China. It is part of Heyuan, a national protected historic garden built between the eighteenth and nineteenth centuries. It is believed that this rockery was originally designed by Shi Tao, the great artist of the Qing dynasty (1636–1912) [26]. The garden was gradually abandoned in the middle and late Jiaqing reign (1796–1820), and the owners of the rockery and the surrounding gardens have changed several times over the next 100 years. Although the garden has undergone many changes, the main part of the rockery has survived and was discovered and recognized as a cultural heritage in 1962.

SRMR, facing south in front of the posterior wall of the garden, is a rectangular wall-hugging rockwork (Fig. 2). The rockery is made of stacked Taihu Lake stones, covers an area of about 238 square meters. The main peak rises from its western end to impose its steep presence upon the pond at its foot, and the highest point is about 875 m. Below the peak stands the so-called "mountain retreat", a two-bay square stone chamber hidden in the rockery body, which is a metaphor for the intention of the designer to live in seclusion in nature [1].

The surface of SRMR has two main characteristics, one is the well-proportioned density and space (Fig. 3). The designer and crafters of the rockery had taken great pains in selecting rocks and put them together according to their sizes, textures, and veins, following the principle of a painter's texturing brush strokes derived from natural peaks [27]. In the era when waterways were the only means of bulk transportations, Yangzhou, as a city without quarriable mountains, could only rely on small pieces of Taihu Lake stone transported from Suzhou and other places as the material for making artificial mountains. This was a challenge for artificial mountain crafters and called for higher stone-pilling expertise. Therefore, the texture of the SRMR is very detailed and the density is very well controlled to ensure that the whole mountain

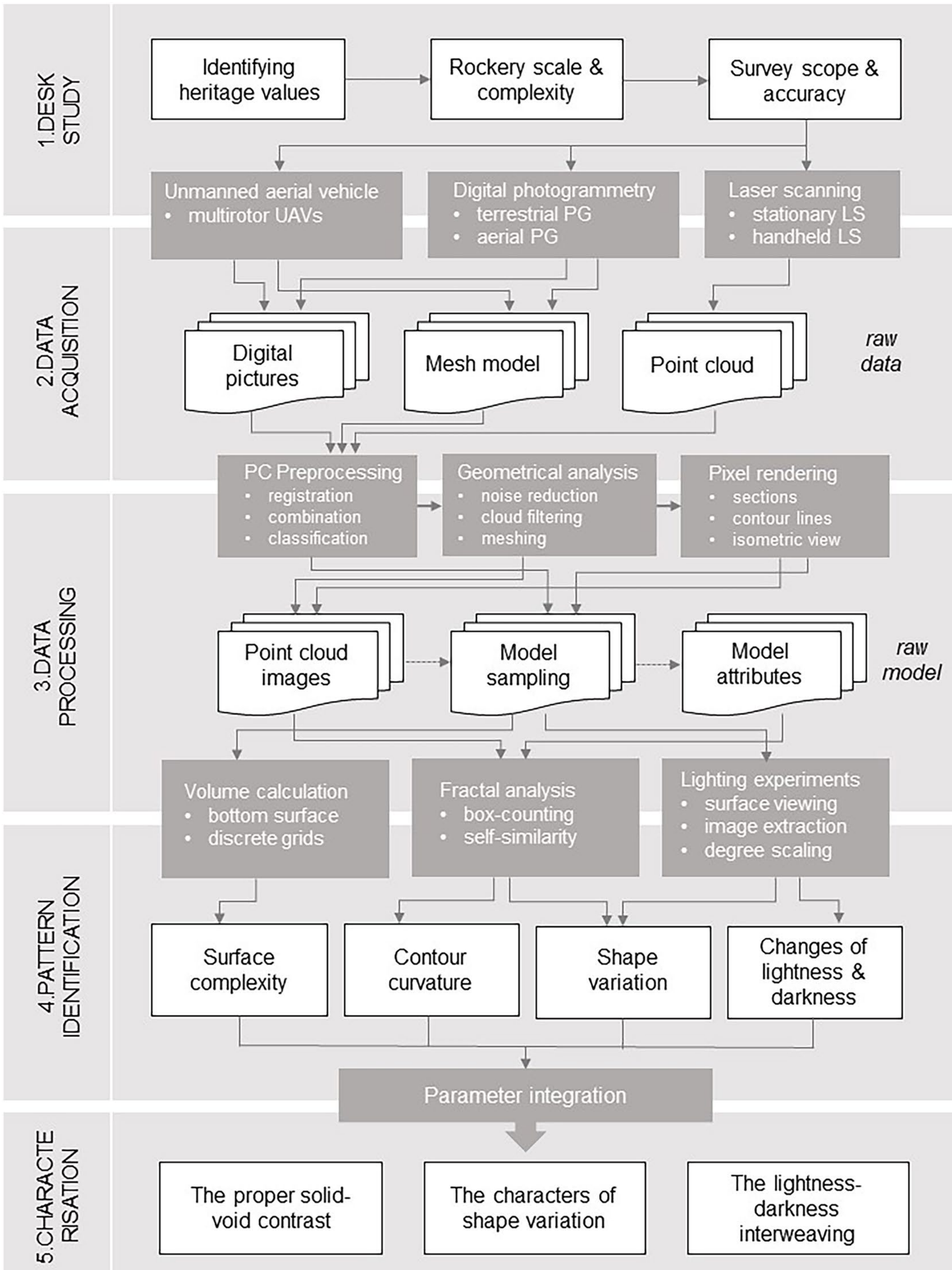

Fig. 1 The workflow of digital characterization of garden rockery heritage

looks seamless. The proper contrast between solid and void is another important characteristic of SRMR (Fig. 3). Shi Tao is a great master of Chinese traditional arts, especially in controlling the contrast and balance between tangibles and intangibles in his landscape paintings. This theory and techniques were well applied in the design and construction of the rockery, the shape of the rock is well handled, and rich light and shadow contrast effects are obtained through the changes of convexity and concave [28].

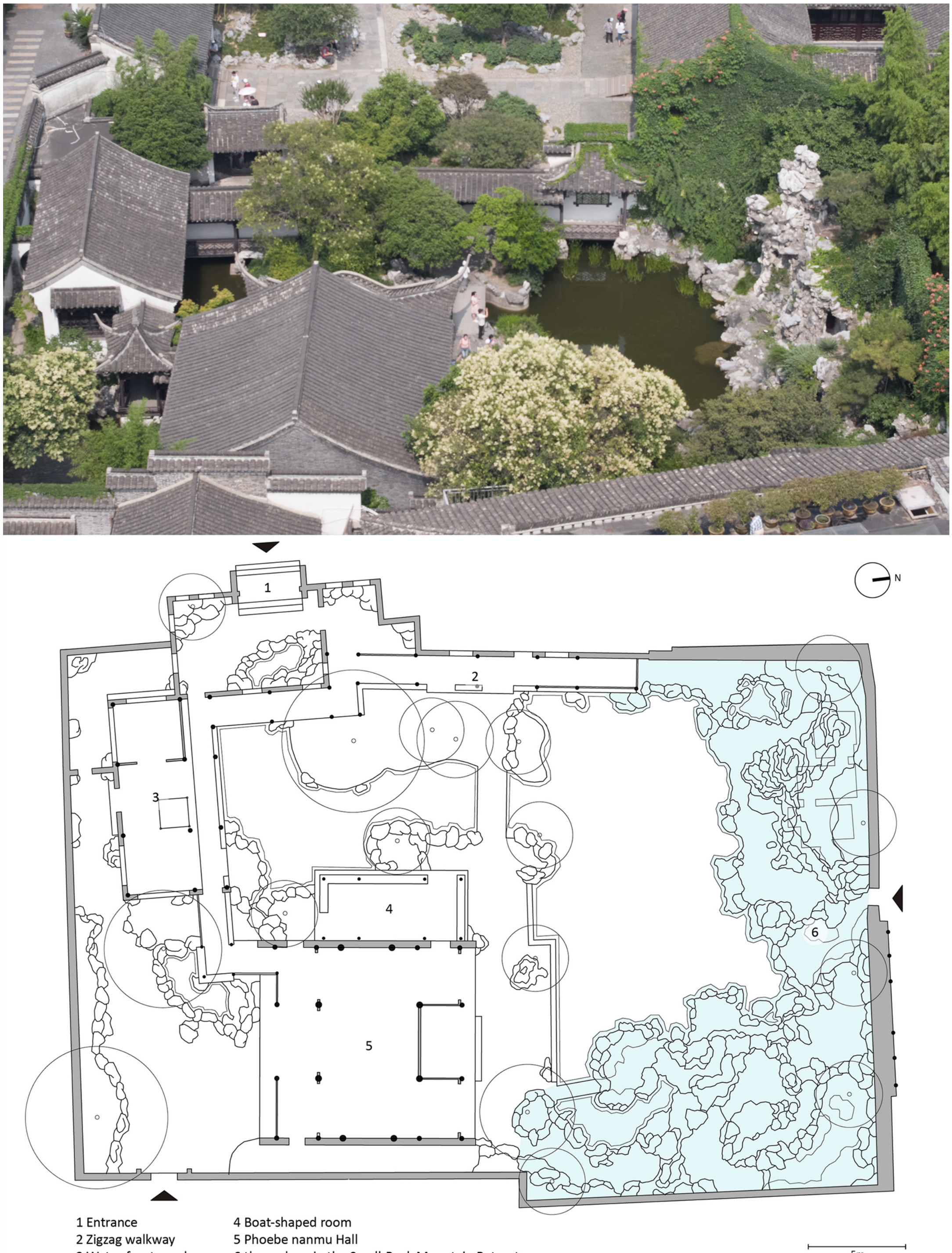

Fig. 2 The aerial image and the map of SRMR

When SRMR was discovered by CHEN Congzhou in 1962, the western main peak and the eastern cave remained, but the other part of the rockery had collapsed (Fig. 4). The restoration project was organized by local management department in 1989, which has fully protected the historical remains, and connected them by applying local Taihu Lake stone stacking techniques to form a completed artificial mountain. Shi Tao's paintings and the oral history from the garden owners' family were used as evidence during the restoration. However, the

Fig. 3 The image of the SRMR

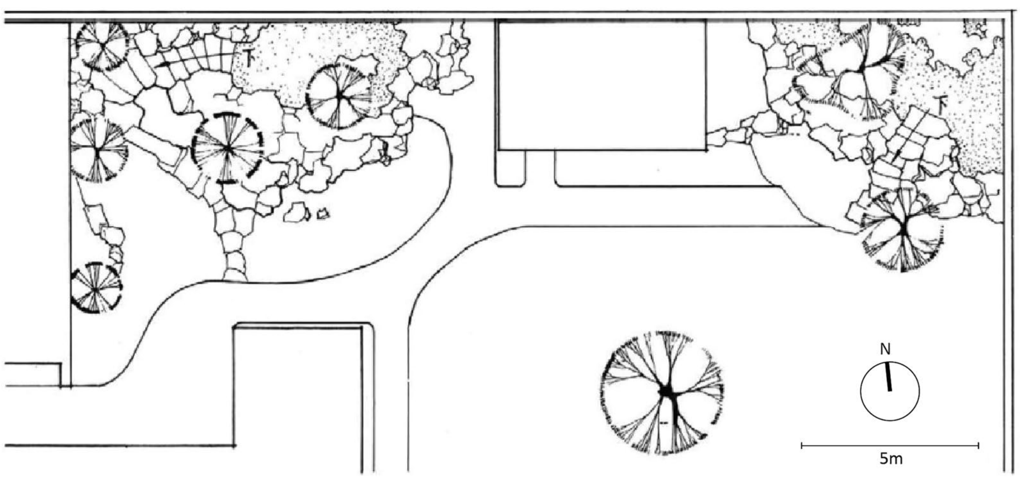

Fig. 4 The survey map of the historic remnants of SRMR in 1962 [29]

evaluation of the results of the rockery restoration was mixed, in which the point of contention is that whether the restored parts continue the characteristics of the historical remains. Therefore, SRMR provides an appropriate case for us to explore the digital characterization approach.

Data acquisition and processing

In this study, we used laser scanning tools to collect spatial information of SRMR. A Leica BLK360 rack-mounted laser scanner and a GeoSLAM ZEB-REVO handheld laser scanner were combined to ensure the accuracy and the integrity of data in confined rockery spaces [30]. The data acquisition process demonstrated that the handheld laser scanner has higher flexibility to cover the extremely complex surfaces of the rockery. The point cloud data was then imported into the CloudCompare 2.12.2 program after registration, combination and clean up in Leica and GeoSLAM preprocessing programs. Outliers were then removed and noise reduction was conducted by point cloud filtering, and the points of plants in the model were separated using the CANUPO plug-in in CloudCompare. Further data processing was conducted to manually refine the classification results. Based on the processed point cloud model, a mesh model was then created using Artec 3D Geomagic Wrap 2017 software for further analysis (Fig. 5).

Data analysis and visualization

Based on data integrity, restoration process, and the characteristics, we selected two sample surfaces on the digital models for quantitative analysis and comparison. Sample A is a key part of the historic relic peak that is believed to have been built in the eighteenth-nineteenth century and

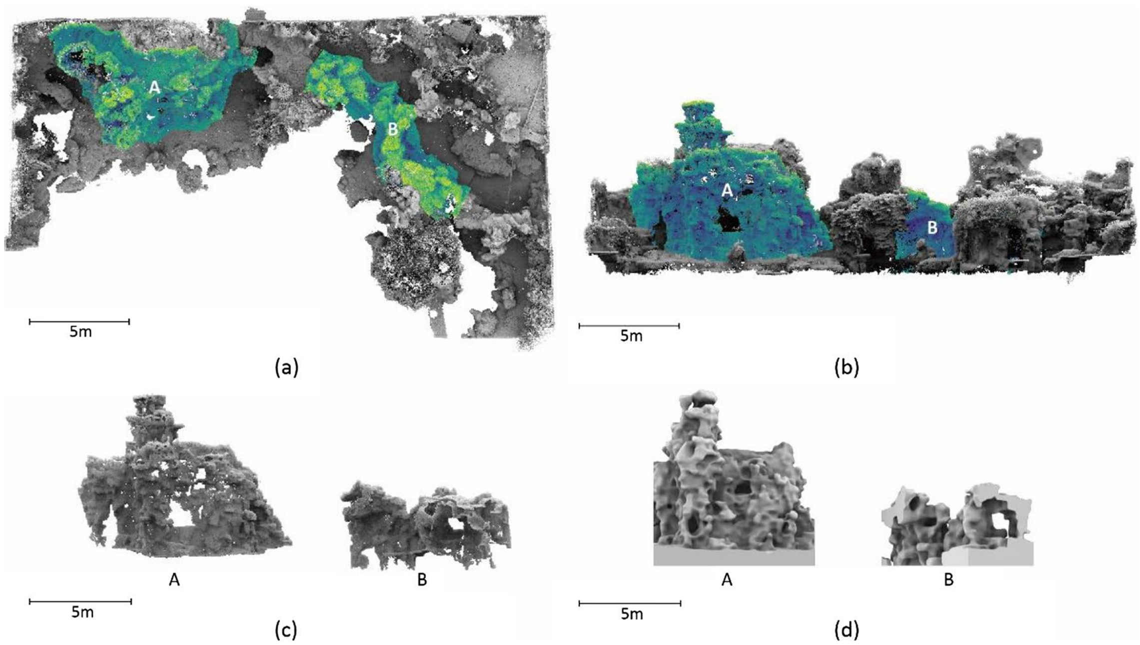

Fig. 5 The point cloud model and the mesh model of SRMR with the sample areas highlighted

reflects the characteristic of the "small stone mosaic, the well-proportioned density and space" of SRMR. Sample B is the key part of the restoration completed in 1989. The analysis and comparison of the two samples were performed using both the point cloud data and mesh model data. From the perspective of the overall structure of the rockery, sample A is the main part, and sample B is the subordinate part. While there are obvious differences in their shapes, what we want to examine is whether their surface textures are similar, that is, whether the recently restored part inherits the historical characteristics of ancient remains, and whether the characteristic can be expressed by quantitative means.

The attributes of surface complexity and the contour curvature were examined to analyze the characteristic of the well-proportioned density and space. The rockery texture density is formed by its small stones as materials and traditional stone stacking techniques, and has distinct historical and local features. The complexity of surface is an attribute demonstrating the basic units and the pattern of the rockery texture. Therefore, we analyzed the complexity of the rockery surface by calculating the ratio between the area of the sample surfaces and the volume they occupied. The larger the ratio, the larger the surface area per unit volume and the more complex the corresponding surface texture. On the premise of non-overlapping and complete data, four representative cubic units were selected from the two sample areas, based on the side length of 2 m (Fig. 6).

The areas and volumes of the point cloud model in the cell space were captured by CloudCompare. In terms of the technical parameters, the volume was calculated by dividing the bottom surface of the point cloud into discrete grids with side length of 0.02 m. The volume of each grid was then calculated and summed up. The calculation formula of surface complexity, k, is as follows:

$$k = \sum_{i=1}^{n} \frac{s_i}{v_i}, \quad n = 4$$

Based on the identification of surface complexity, we hope to use the contour curvature to analyze the pattern and similarity of the surface texture, and then evaluate the characteristic of well-proportion. The contours of the digital model were extracted and the box-counting dimension method from Fractal Theory was used to analyze the self-similarity of the contours, so as to capture the unity and consistent of density and space [31, 32]. The contour lines were extracted in CloudCompare. In terms of the technical parameters, some ten 0.01 m-thick point cloud segments were intercepted at 0.2 m spacing in sample A and B (Fig. 7). The maximum edge length of 0.25 m was used as it can retain most of the transitions.

As the result, ten longitudinal contour lines were extracted respectively with the redundant segments were manually removed (Fig. 7). For the fractal dimension calculation of contour lines, we used box dimension calculation method, taking different box side lengths, ε, approaching 0, and count the number of boxes required

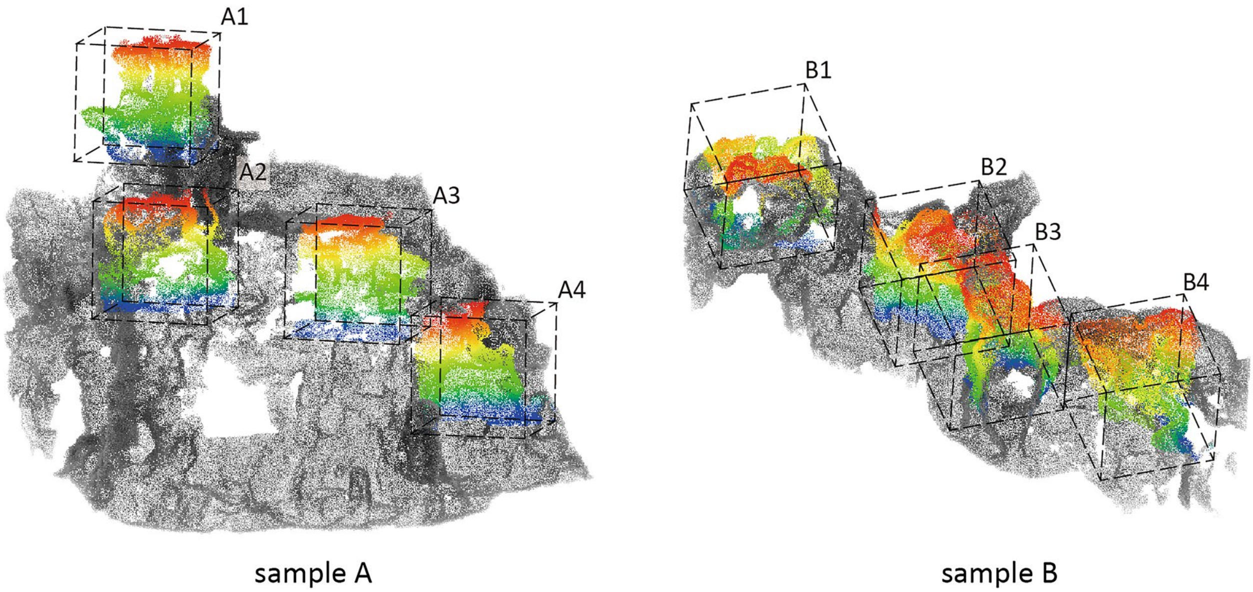

Fig. 6 The four representative cubic units selected from the two sample areas

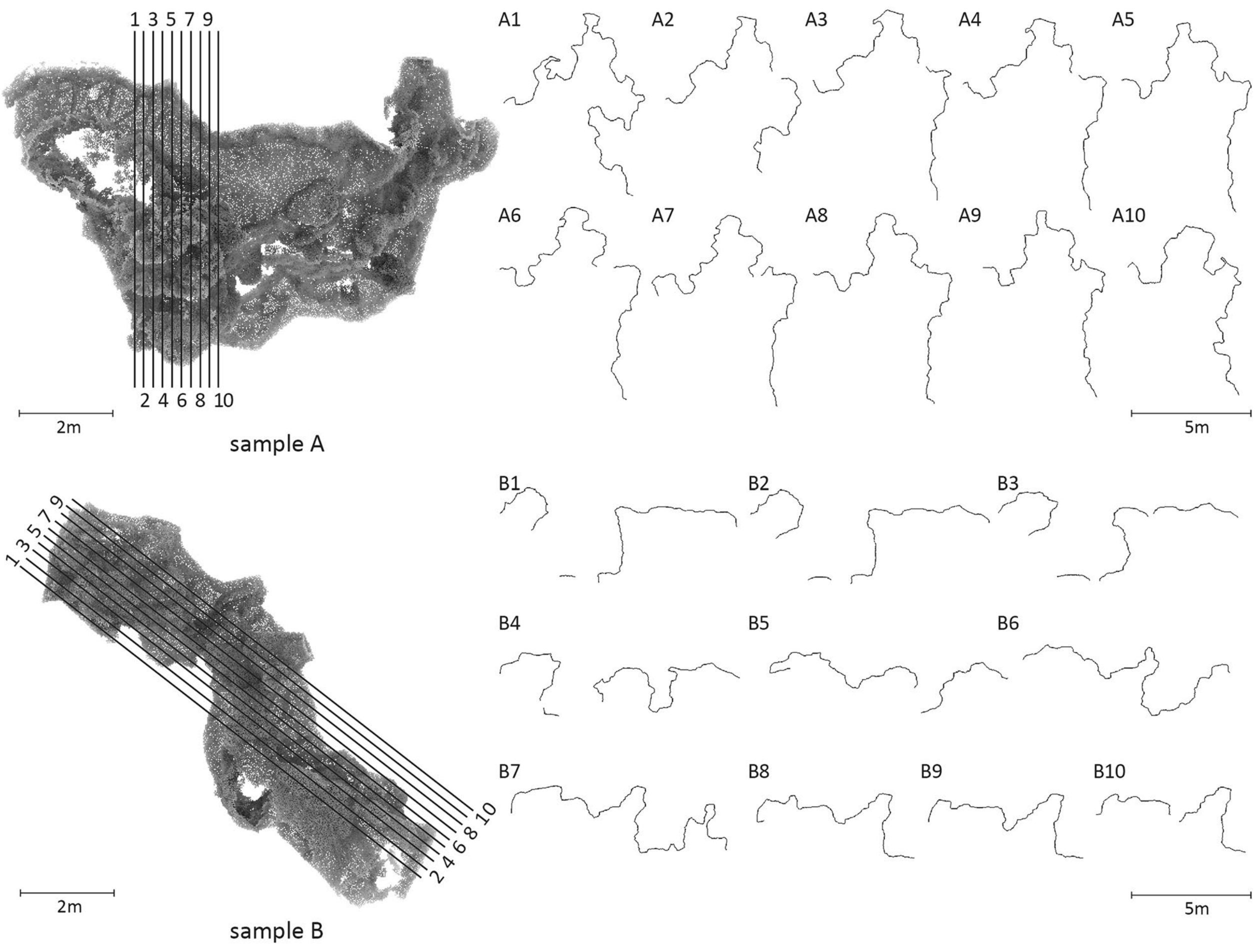

Fig. 7 Extracting contour lines in sample A and sample B

for covering the figure, $N_i(\varepsilon)$. The logarithmic ratio of that to the number of boxes in the unit length, $1/\varepsilon$, is called box dimension. The contour curvature, d, is defined as a quantitative index to show the overall irregularity and complexity of the contours. The average value of the box dimensions of multiple contour lines extracted from the samples was taken as the overall contour curvature, d. The calculation formula is as follows:

$$d = \frac{1}{n}\sum_{i=1}^{n}\lim_{\varepsilon\to 0}\frac{\log N_i(\varepsilon)}{\log\left({}^{1}\!/_{\varepsilon}\right)}$$

The Fractalyse 3.0 software was used to calculate the box dimension, and the minimum box side length was set as 0.1 m and the maximum length was 1.6 m, to fit the characteristic of the sample areas. The highest and lowest values were removed during the process to reduce the impact of extreme data. The average value of the box dimension of the contour lines was used as the indicator of curvature.

The attributes of shape variation and the interweaving of lightness and darkness were examined to analyze the characteristic of the proper contrast between solid and void. Rockery is an art in which solid and void are integrated in the same space. We first analyzed the composition of solid and void elements on the rockery surface by identifying the degree of undulation and variation of the surface shape. The verticality of points in the digital model was calculated in CloudComplare with a radius of 1 m. The distribution trend of the verticality v of the point cloud model was used to quantify the richness of shape variation. By importing the point cloud verticality data into the MathWorks Matlab R2021a software to calculate the normalized standard deviation of point z values with verticality above 0.75, the shape variation richness index, r, was calculated by using the following formula:

$$r = \frac{1}{z_{max} - z_{min}}\sqrt{\frac{\sum_{i=1}^{n}\left((z_i - \overline{z})^2\right)}{n}}, v_i > 0.75$$

The change of lightness and darkness is an attribute that can intuitively reflect the solid and void changes on the surface of the rockery and its scene. We simulated the lighting environment by Rhino 6.0 software, conducted lighting experiments and image analysis for the mesh model, and then quantitatively compared the characteristics of the two sample areas. The common 60 degrees solar altitude angle was applied, and some 9 angles were selected in 9 equal parts within the 180° range in front of the viewing surface of the rockery. The images of lightness and darkness of sample A and B were then created. The dark areas in the images were extracted for further analyses (Fig. 8). The average value of the rotational inertia of each black area, I, in the lightness-darkness diagram against the overall center of mass was calculated by MathWorks Matlab, and the interweaving degree of the lightness and darkness under this light condition was measured by the following equation:

$$I = \frac{1}{n}\sum_{i=1}^{n}\left((x_i - \overline{x})^2 + \left(y_i - \overline{y}\right)^2\right)$$

Results and discussion

Evaluating the characteristic of the well-proportioned density and space

In terms of the surface complexity, the average value of sample A is 0.989, and the value for sample B is 0.863. The results show that both the surfaces of the two sample areas have high complexity, but the historic relic peak has a more complex surface texture (Table 1). In terms of the contour curvature, the curvature index of sample A is 1.102, which is higher than the 1.032 of sample B. In other words, compared with the historic relic peak, the restored part lacks shape variation and self-similarity (Fig. 9).

Evaluating the characteristic of the proper contrast between solid and void

In terms of the shape variation, the results show that the richness index of shape variation of sample A is 0.214 and sample B is 0.143. The result in sample B is 66.8% of that in sample A. According to the histogram of the verticality distribution of the point cloud, the points with higher verticality in the restored part model are concentrated in the middle section, while the points with same attributes in the historic relic peak show a tendency to gather at the top and the middle sections (Fig. 10). We used the Microsoft Excel 2016 software to count the points whose verticality is above 0.75, and use the polynomial fitting tools to identify the trend of the two sample areas. The trend lines of both samples have peaks, but there are two peaks in sample A and sample B has only one (Fig. 10). The calculation results demonstrate that the point clouds in both sample A and B have a tendency to gather and distribute vertically, which means their surfaces have a high degree of undulation. However, the differences in distribution pattern and trend line peaks proves that that the shape fluctuation of sample A is more abundant and has more layers than sample B.

In terms of the attribute of the light and shadow effect, the interweaving degree of lightness and darkness of sample A is higher than that of sample B under light conditions above 89% (Fig. 11). The average interweaving degree of sample A is 1.33 times that of sample

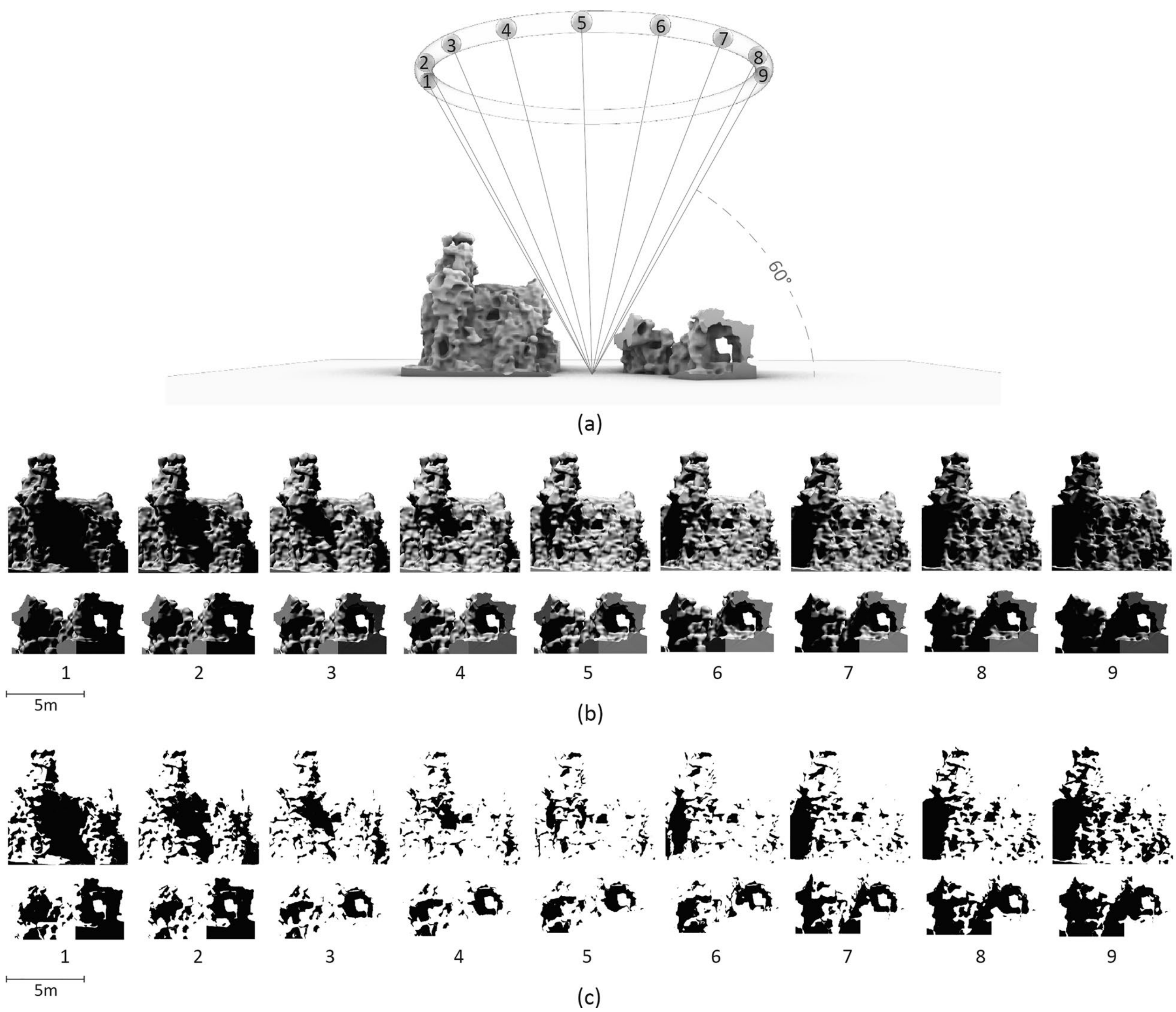

Fig. 8 The digital image of the sample areas in different lighting conditions: **a** light angles; **b** the image of lightness and darkness; **c** the image of dark areas

Table 1 Calculation results of surface complexity

Samples	Units	Volume (m^3)	Surface area (m^2)	Surface complexity	Average value
Sample A	A-1	2.588	2.937	1.135	0.989
	A-2	2.413	2.189	0.907	
	A-3	4.102	3.482	0.849	
	A-4	1.952	2.083	1.067	
Sample B	B-1	3.800	3.621	0.953	0.863
	B-2	3.522	2.942	0.835	
	B-3	3.015	2.406	0.798	
	B-4	3.663	3.178	0.868	

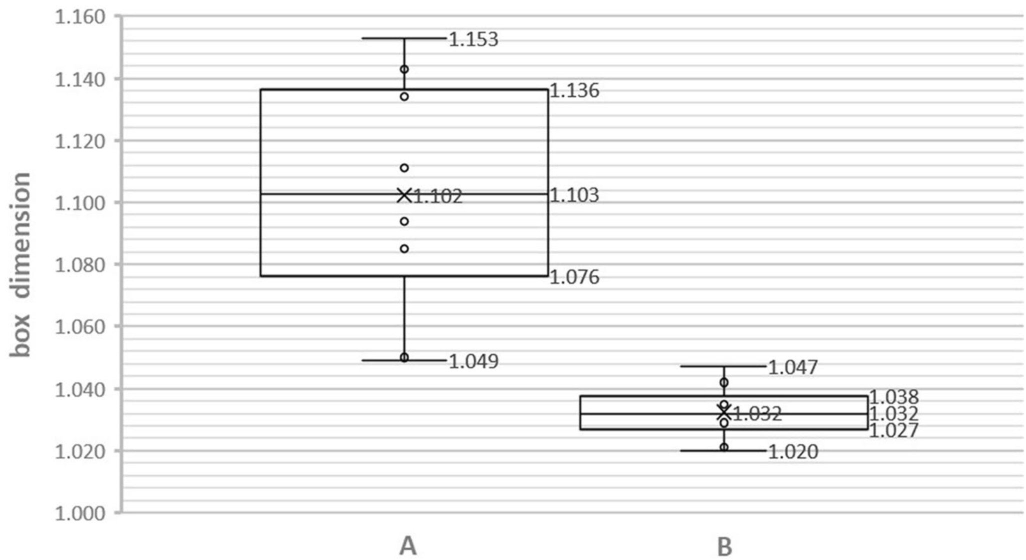

Fig. 9 The Box diagram of the contour lines of sample A and B

B. Under light conditions above 44%, the interweaving degree of sample A is 1.5 times that of sample B. Figure 7 shows that the distribution of the dark areas in sample A is more discrete and scattered than sample B under the same light condition. These differences demonstrated that the interweaving degree of lightness and darkness in the historic relic peak is higher than that in the restored part, with more significant characteristics of the contrast between the solid and the void.

The results show that the indexes of the four attributes of the restoration part of the rockery are all lower than those of the historical remains, but the reduction is within a certain range between 8 and 33%, and the average decline rate is 19.25% (Table 2). This phenomenon shows that the restored part can reflect the main characteristics of the historic remains, but does not fully inherit the characteristics of the historical surface texture. Among them, the gap of shape variation is the largest, which is reduced by 33%, the interweaving degree of lightness and darkness is reduced by 23%, the surface complexity is reduced by 13%, and the contour curvature is reduced by the least, only 8%.

These index changes respectively reflect the problems existing in the restoration of the SRMR. The reduction of the surface complexity means the increase of the basic unit size of the rockery surface texture and the reduction of the overall number of units. This may be because the selected individual rock was too large during the restoration process, and due to the use of more regular rocks. The traditional principles of using small rock were not fully implemented [1]. The contour curvature index has the lowest degree of decline, which shows that the stacking process of the rockery simulates the line trend of the historic peak as much as possible. While the unit size increased, the characteristics and patterns of the overall tortuous changes have not disappeared, which supports many of the current positive comments of the restoration. The decrease in the shape variation index reflects the decline in the uniformity of the shape fluctuations of the restored part, and some relatively flat surfaces appeared in the whole piece, which is also the most obvious difference between the restored part and the historic remains. This may be because Taihu Lake stones with a large volume and a flat viewing surface were partially used in the restoration, or the uneven changes between the stones were not fully considered in the process of making combination. The degree of interweaving of lightness and darkness is the overall surface feature obtained under the condition of simulating real lighting environments after integrating all the texture differences. Compared with the historic relic peak, the restored rockery has dropped by 23%, which reflects the changes of the other three attributes to a certain extent, but it also means that the overall spatial structure of the restored part is different from the historic peak, resulting the decreased abundance in the final light and shadow effect.

Although these calculation results need to be further combined with the evaluation of rockery restoration materials and techniques to more accurately identify the problems in the restoration, it can be concluded through quantitative analysis that, during the restoration process, the richness of texture details and balancing distribution of the shape variations have decreased.

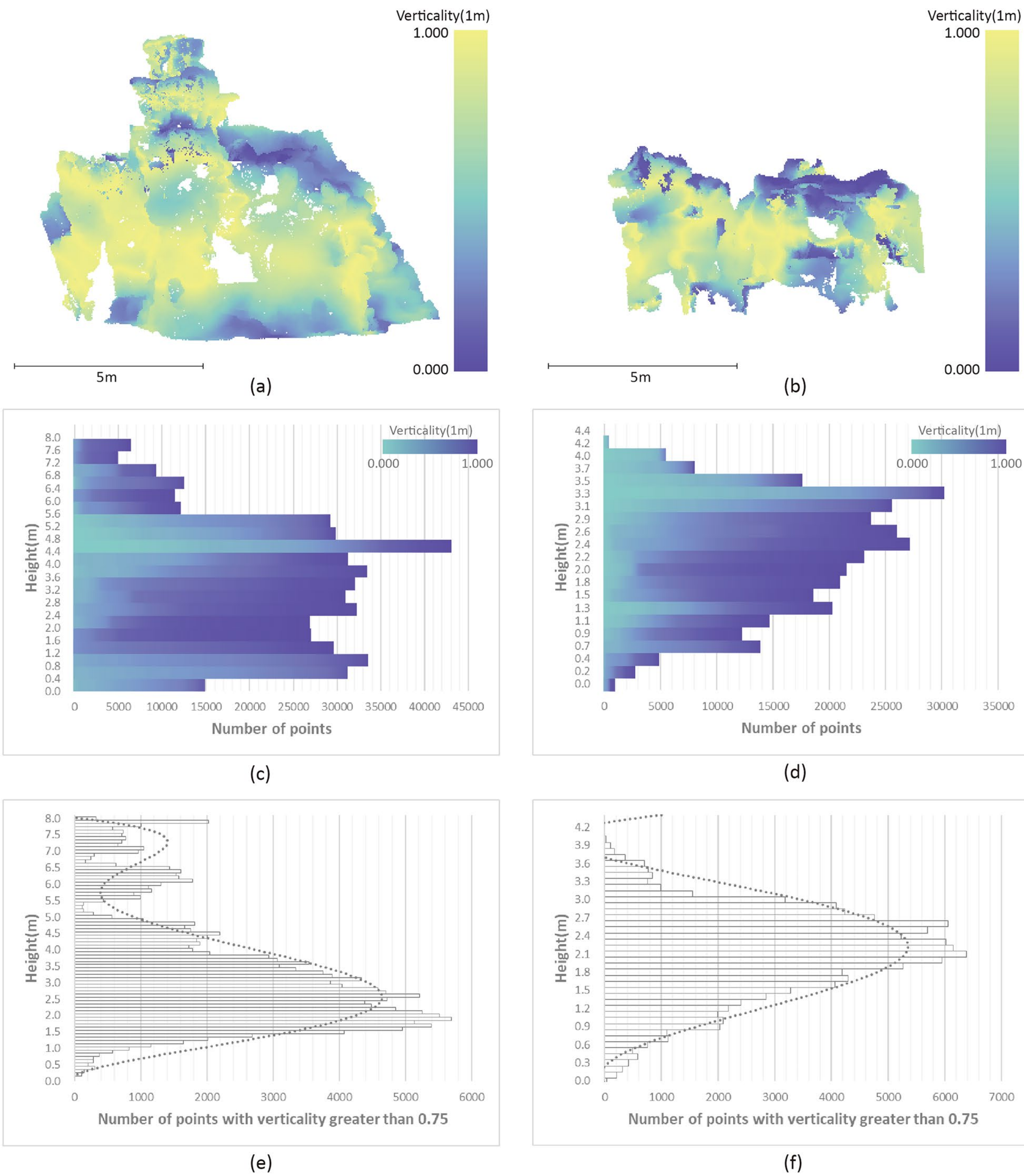

Fig. 10 Shape variation analysis: **a**, **b** Elevation view of verticality distribution of point cloud model of sample A and B; **c**, **d** Histogram of verticality distribution of sample A and B; **e**, **f** Histogram of verticality distribution of point cloud above 0.75 in sample A and B

Conclusions

This study establishes an innovative method for the description, analysis and evaluation of the surface texture of rockeries in Chinese classical gardens. This method is based on a high-precision 3D point cloud model obtained by laser scanning technology. The significant characteristics of the case study rockery, including the well-proportioned density and space, and the proper contrast between solid and void, were analyzed through

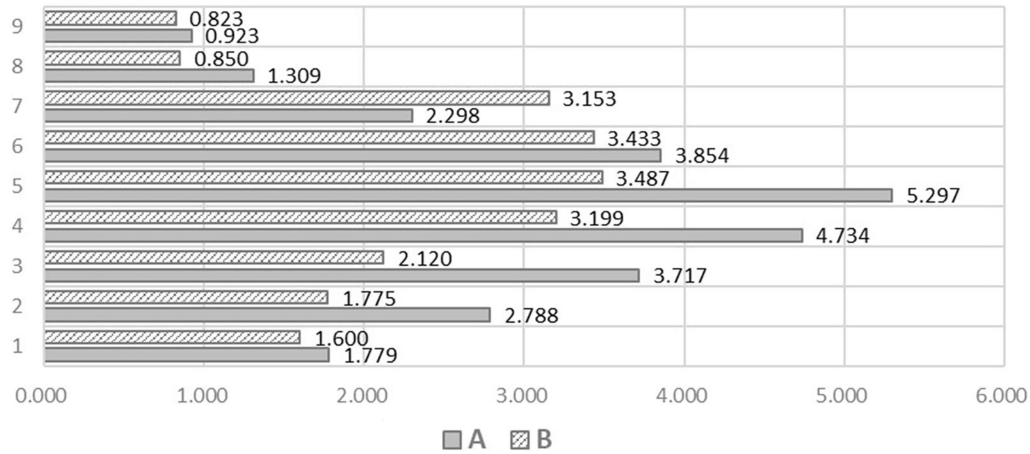

Fig. 11 Analysis of the interweaving degree of lightness and darkness

Table 2 Statistics on the change rate of each attribute index of rockery samples

Attributes	Sample A	Sample B	Difference	Rate of change (%)
surface complexity	0.989	0.863	0.126	13
contour curvature	1.102	1.032	0.088	8
shape variation	0.214	0.143	0.071	33
interweaving degree of lightness and darkness	2.976	2.271	0.705	23

examining the four attributes of surface complexity, contour curvature, shape variation, and the interweaving of lightness and darkness. We designed and implemented the PCVA including multiple algorithms and technical parameters, which can quantitatively calculate the indicators of each attribute. The primary innovation of the PCVA is that it breaks through the analysis logic based on limited feature point data in previous analyses, directly exploring the pattern of shape changes from the big data of the point cloud model. The PCVA makes full use of the information of digital twin technology and point cloud visualization. The advantage of a rich dataset provides new perspectives and systematic frameworks for the efficient analysis of the garden rockery and other irregular heritage components.

As a method of digital characterization, PCVA not only expands the localization of cultural heritage protection theories, but also contributes to the scientific and technological system of cultural heritage conservation. In Chinese gardens, changes are inevitable, and the identification, monitoring and control of changes are important heritage protection objectives. Aiming at the challenges in the protection of rockery heritage, in the process of analysis, we adopted a comparative method to analyze and present the characteristics and quality of the restoration based on the parameters obtained from the historical remains. Quantitative analyses are important approaches and technological breakthroughs for garden rockery evaluation. It can provide a good complement to the current qualitative methods.

Starting from the characteristics of local rockeries, this article selects samples and carries out attribute analysis, which reflects the local deepening of the methodology of international heritage protection. The article fully considers the practical need of restoration evaluation in Chinese classical gardens, and the different indicators designed in the paper can help us identify problems in restoration projects. The differences reflected in the data can be further compared with the materials, techniques, and processes of rockery restoration, as well as management, so as to better support the protection of cultural heritage.

Abbreviations

PCVA	Point cloud visualization approach
SRMR	Small-rock mountain retreat

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Not applicable.

Author contributions
CY designed the project and was the major contibutor in writing the manuscript. XH analyzed the point cloud data, and wrote the data analysis report. HW performed the data collection, and provided suggestions to the data analysis methodology. FH was responsible for the review and revision of the article. CW and LS participated in the process of data collection, and LS contributed to the manuscript editing and grammatical revision. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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