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RESEARCH ON THE 3D DOCUMENTATION SYSTEM OF CLASSICAL CHINESE GARDENS IN SCENIC AREAS – TAKING KUNSHAN SUIYUAN AS AN EXAMPLE

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ABSTRACT:

Classical Chinese gardens built in scenic areas have characteristics in rich scales, multi-type elements, and a complex development history. Due to the designed landscape characteristics of "hidden the garden in bigger landscapes", it is often difficult to obtain high-quality heritage information through traditional surveying approaches. The aim of this research is to establish a digital 3D documentation technology system for the classical gardens in scenic areas. Suiyuan Garden, a classical Chinese garden with a history of more than 300 years, was used as a case study. We have integrated UAV low-altitude photogrammetry, handheld laser scanning, ground-mounted laser scanning, macro structured light scanning and other technologies to obtain the 3D data, and to build a digital twin by developing the technical workflow and data standard. The innovation of the research lies in: 1) We used a variety of digital mapping methods to record the pattern between the garden and the surrounding landscape; 2) We adopted a combination of handheld and ground-mounted laser scanning systems to build spatial structures and better cover the ground spaces; 3) We established a workflow for the conversion from point cloud to mesh model for different garden features, which can improve the usability of 3D heritage information; 4) We used the 3D cultural heritage modelling approach to improve the standards of the digital conservation of historic plants. The outcomes of this research could be used as the basis for the construction of Historic Landscape Information Model (HLIM) in the near future.

1. INTRODUCTION

As a kind of "historic designed landscape", classical Chinese gardens have rich historic, artistic, and cultural values. The design ideas and construction techniques contained in it not only represent the aesthetic pursuit and technological level of specific periods, but also have important enlightenment significance for today's garden design and construction (Chen, 2018). Therefore, recording and documenting classical Chinese gardens is of great significance for the conservation, management and dissemination of heritage information and values (Yang et al., 2018). At present, however, most of the documents of classical Chinese gardens are still limited to traditional formats based on 2D drawings and photographs, and a considerable number of sites have not established complete archives, which not only causes the risk of heritage information loss, nor can it support the effective use of heritage knowledge (Liang et al., 2018).

The rapid development of digital mapping and 3D technologies provides unprecedented opportunities to build high-quality documents of classical Chinese gardens □ Yang et al., 2018□ . We can observe gardens with an unprecedented perspective, precision, and frequency today. However, the practical guide for local heritage documentation work has not been established. The classical Chinese gardens have specific characteristics and constituent elements, which are different from architectural heritage, archaeological heritage, monuments, and other heritage types. Although some scholars have begun to use digital technologies to study the survey and recording of classical Chinese gardens, most of the cases and experiments were conducted within an urban context (Gu et al., 2016, Yu et al., 2017, Zhang, et al., 2018), and there has not been sufficient research and practice on the classical Chinese gardens in the scenic areas.

Scenic areas near towns have been the first choice for Chinese people to build gardens since traditional times. These areas have good connections with human settlement and with high-quality scenery. The interaction between nature and human settlement have been achieved through the design and construction of gardens. Classical Chinese gardens in scenic areas are therefore one of the important cultural heritage types in China. The terrain, vegetation and other elements around the gardens have important contributions to the characteristics of the heritage and need to be recorded as important objects. The interior of these gardens has a man-made natural environment, and pools are often used to symbolize lakes and seas in nature, and rockeries are often used for mountains (Chen, 2018). Therefore, it contains many non-linear and complex spatial elements other than buildings. These elements need to be measured and mapped by special data collection and processing methods to achieve accurate documentation. It is necessary to build a 3D documentation technology system for this garden heritage in China.

2. THE CASE OF SUIYUAN GARDEN

Suiyuan Garden is located at the northern foot of Ma'an Hill (saddle shape hill) in Kunshan City, Jiangsu Province in south eastern China. As one of the famous classical gardens in the Jiangnan area of China, Suiyuan is a garden within the scenic area

of Tinglin Park and the Zhangjiagang River (Zhou et al., 2022). The garden today is protected as a Municipal Cultural Heritage Site of Huaian City. The history of Suiyuan can be traced back to the Huazang Academy in the Xuanhe period of the Song Dynasty (1119 CE). It has experienced several times of different owners in the Yuan and Ming dynasties and was repeatedly destroyed and rebuilt in the history. In the Kangxi years of the Qing Dynasty, Xu Qianxue purchased the garden and named it "Suiyuan" (Zhou et al., 2022). In 1983, the local government organized the restoration of it, and the landscape structure and garden features were restored according to historical records and cultural connotations. The garden today covers an area of about 2 hectares. The entire garden grows in a strip shape, about 300 meters long from east to west, and about 80 meters wide from north to south, of which the water area accounts for 1/3. The garden is surrounded and covered by woods at the foot of Ma'an Hill, and it contains rich landforms and water systems, various traditional buildings, stone bridges, corridors, and rich vegetation (Figure 1).

Suiyuan Garden was chosen for this research because it reflects the characteristics of classical Chinese gardens in scenic areas and the requirements of 3D documentation. Classical Chinese gardens built in scenic areas often require the integration of its landscape with the surrounding environment (Zhou et al., 2022). This characteristic means that most of the main garden components are blocked by plants and other elements, which makes it difficult for UAV image-based surveying and mapping. At the same time, gardens are often characterised by natural scenery, so they contain many elements such as terrain and water systems. The main goal of building these elements is to simulate nature that are often non-linear, so more flexible "mass capturing" methods are needed to fully capture the pattern of the garden. In addition, elements such as ancient buildings, plants, and rockeries form rich garden details, which are important elements that constitute the characteristics and experience of the garden. Therefore, it is necessary to achieve the accuracy of surveying and recording.

Figure 1. Suiyuan Garden is in the scenic area of the northern suburbs of the historic city of Kunshan

3. RESEARCH METHODOLOGY

This research was based on the theory of authenticity and integrity of cultural heritage, taking Suiyuan Garden as a case study, to explore an integrated digital 3D documentation system for classical Chinese gardens (Figure 2). According to the characteristics and attributes of the garden features, various sensors and platforms were applied to capture the spatial data at different scales. Combined with tools such as point cloud visualization, 3D semi-automatic modelling, and machine learning, the landform, buildings, rockeries, plants, and other elements of Suiyuan were digitally twined, and a 3D garden heritage document was constructed.

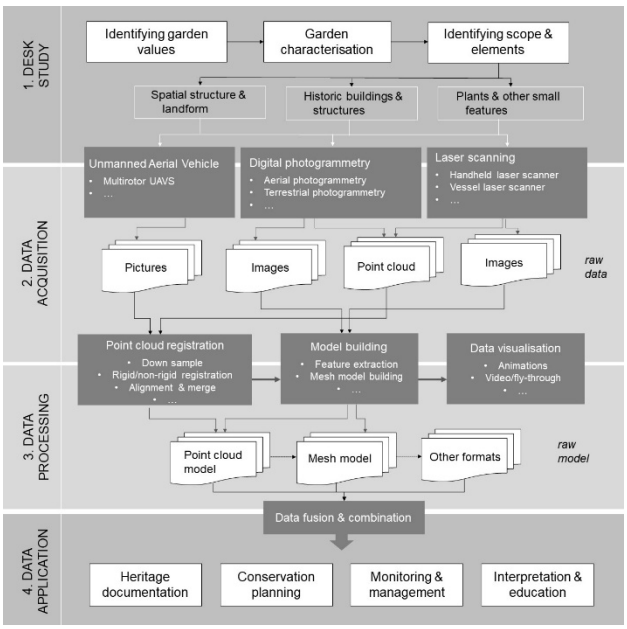

Figure 2. The digital documentation workflow for classical Chinese gardens in scenic areas

3.1 Digitally-assisted Documentation of Spatial Structure and Landform

Spatial structure refers to the pattern formed by the combination of various garden components. It is not only the feature of the garden with the most design connotation, reflecting the relationship between the garden and the scenic area, but also the structure of the entire 3D document. Traditional spatial positioning using GNSS methods cannot meet the accuracy and detail requirements of garden surveying and mapping.

This research combines digital photogrammetry and ground-based handheld laser scanning technology to capture the overall structure of the garden space. First, through the low-altitude close-range photogrammetry technology, a total of 5 UAV sorties were flown with a flight time of 62 minutes. Some 635 images were collected with the image overlap rate between 70-80%. The Bentley ContextCapture software was used for the follow-up calculations to obtain a 3D mesh model (Figure 3).

Figure 3. The survey scop and the mesh model of Suiyuan Garden created by digital photogrammetry

However, due to the high vegetation coverage of the garden, photogrammetry tools cannot obtain ground spatial information, and the spatial feature points on the ground cannot be accurately positioned. Therefore, we used a hand-held laser scanner to effectively supplement the 3D spatial data. A ZEB-REVO handheld laser scanning system was used to measure a total garden area of 20,652 square meters. Some 11 scans were made, each covering approximately 2,000 square meters, and finally a total garden area of 20,652 square meters were surveyed. By registering, refining, and merging the data from digital photogrammetry and laser scanning, a complete 3D point cloud model and a digital map of Suiyuan were created (Figure 4).

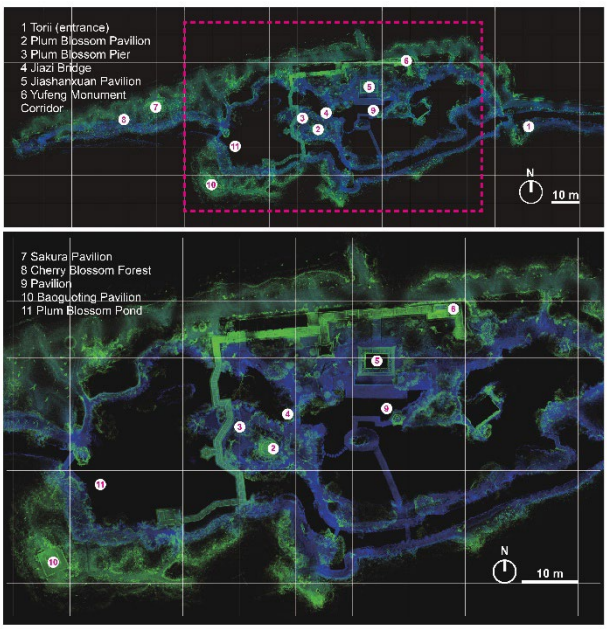

Figure 4. The plan of Suiyuan Garden extracted from the point cloud model

Since the Suiyuan Garden was built at the foot of Ma'an Hill, facing the city's moat (the Zhangjiagang River) in the north, and was built in layers in different historical periods, the landform of the garden is very rich and reflects important historical information. In order to record and visualise the spatial data of the garden, we used a CloudCompare v2.10. alpha software to process the 3D point cloud. Cloth Simulation Filter (CSF), a plugin tool to extract of ground points in discrete return LiDAR point clouds, was used to separate point clouds into ground and non-ground measures. The automatic computer separation and manual processing methods were combined to complete the digital simulation of the micro-topography of the garden.

The model constructed in CloudCompare v2.10. alpha software was then successively imported into the Geomagic Studio 12 and the Rhino 7 software, and the missing parts of the model were repaired, smoothed, and the invalid surfaces were removed manually to generate a complete landform model. In the Rhino 7 software, we divided the model vertically at 0.3 meters to extract contour lines. Then the Grasshopper tool was used to analyse the elevation and slope of the site, and to create the section diagram of the important perspectives. The results demonstrate that the difference in the north-south direction of the garden varies greatly, and it decreases from the side of the hill to the direction of the moat, and there are abundant height differences between them (Figure 5).

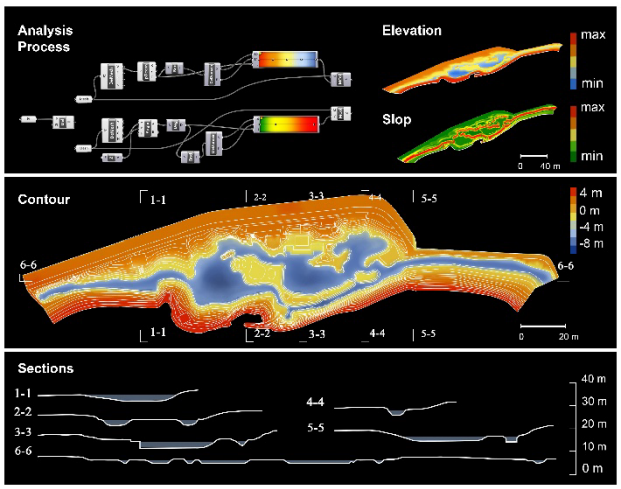

Figure 5. The landform analysis and visualisation of Suiyuan Garden

3.2 Historic Building Survey and Modelling

There are 11 traditional buildings in Suiyuan Garden, including halls, corridors, pavilions, and stone bridges that are typical constructions in classical Chinese gardens. Since buildings and plants in Chinese gardens are often combined to form a landscape, most of the buildings in Suiyuan are surrounded by plants. For surveying and mapping, it is difficult for most buildings to obtain complete spatial information through photogrammetry tools as there are features blocking them. Therefore, we adopted laser scanning as the main surveying and mapping method with scanners positioning at different locations to reach a high coverage of measurement. In order to ensure that details such as window grilles and carvings of buildings are completely captured, we selected a Leica BLK360 laser scanning system for data collection. The 3D point cloud of the interior and exterior spaces was obtained through multi-site scanning. The accumulative mapping was about 70 stations, and the scanning time reaches 350 minutes (Figure 6). In this study, we imported the point clouds of all buildings into the Trimble SketchUp Pro

2020 software, and performed semi-automatic modelling based on the Undet plug-in. It was clear that this process consumes a lot of labor and time, and it needs to be continuously compared with architectural photos during the modelling process to determine the separation of point clouds and the shape of each building component.

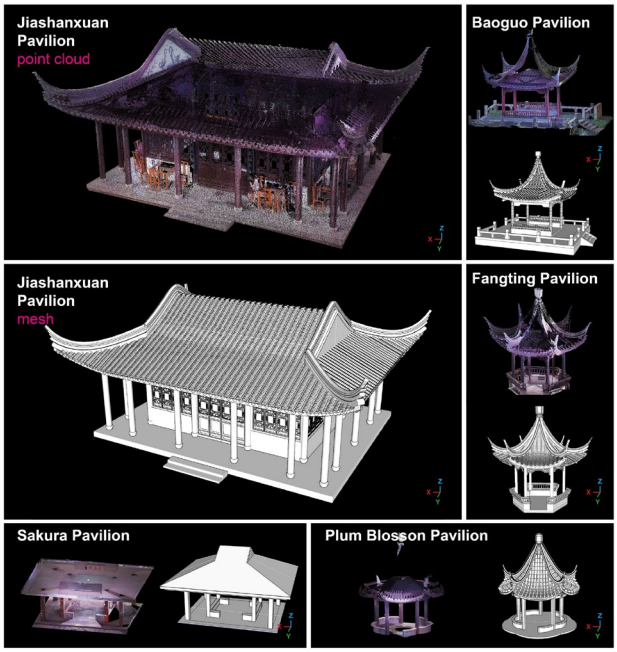

Figure 6. The construction of point cloud models and mesh models of traditional buildings in Suiyuan Garden

3.3 Plant Survey and Modelling

Plant modelling is always a challenge in garden heritage survey and documentation. For the various types and shapes of plant elements in Suiyuan, this study applied an innovative point cloud processing algorithm to automatically generate mesh models through point clouds. This new approach based on skeleton refined extraction was developed by the team member and it was the first application in the context of classical Chinese garden documentation. Studies have proved that this skeleton refined extraction method has higher accuracy and detail richness than the TreeQSM method (Raumonen et al., 2013) and AdTree method (Du et al., 2019), especially can more accurately reconstruct branch details and better address missing data issues (Li et al., 2022).

In the complete 3D point cloud data of the garden obtained in the first stage, we identified and extracted the 3D point cloud of 241 individual trees. The 3D point cloud data of 55 trees were then selected based on factors such as characteristic contribution, data integrity, and diversity. Afterwards, we used the skeleton refined extraction method to carry out modelling experiments on the sample plants. The results show that our 3D modelling method can quickly and accurately complete the construction of the mesh model, and realize the high-precision simulation and reconstruction of heritage garden plants (Figure 7).

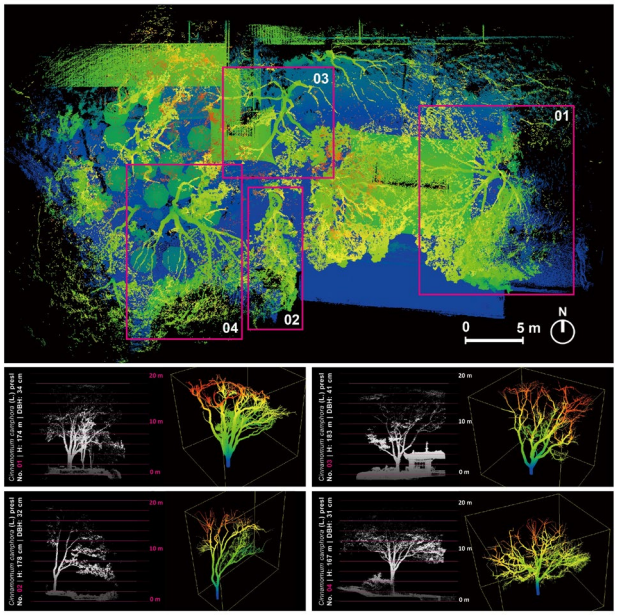

Figure 7. The modelling process of historic tress in Suiyuan Garden

4. FINDINGS AND CONCLUSIONS

This study explores and demonstrates an integrated system of digital recording and documentation technology for classical Chinese garden in scenic areas. In view of the multi-scale, multi-element, and high-complexity characteristics of these gardens, the system integrates sensors and data processing platforms in a targeted manner, and builds a complete workflow and the corresponding technical parameters. The contributions of this research are mainly reflected in the following aspects:

1) The characteristics of classical Chinese gardens in scenic areas are often reflected in the relationship between the garden and the surrounding landscape at different scales, so we used a variety of digital mapping and visualization methods to record this pattern.

2) Classical Chinese gardens often have a high vegetation coverage rate and rich topography and water systems, so it is difficult to obtain comprehensive spatial data only through UAV photogrammetry. Therefore, we adopted a combination of handheld laser scanning and rack-mounted laser scanning, which can quickly build a spatial data structure and better cover the ground spaces.

3) For classical Chinese garden, sometimes the point cloud data is too heavy to be used and visualised. This research establishes the workflow and standards for the conversion from point cloud model to mesh model for different types of garden features, which can improve the usability of 3D heritage data.

4) This research uses the 3D cultural heritage modelling approach to survey and document historic plants in classical Chinese gardens, and innovatively applies the latest point cloud algorithm to build more accurate 3D models of plants, which is expected to improve the methods and standards of the digital conservation of classical garden plants.

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