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A Digital Mapping Modeling Method Applied to Imperial Garden Rockery

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Abstract: Rockery is the most important and unique skill in Chinese traditional gardening. Because of its complex form, rockery has been difficult to accurately survey. Based on the previous research results, this paper mainly introduces a digital mapping modeling method applied to the Imperial gardening stone rockery. This method is applied to the three-dimensional laser scanning technology and shows this method through experimental research. In this paper, we select the Yingluo Rock which is the representative stone in bluestones for surveying and mapping gem rock in bluestone rockery is selected for surveying and mapping. And the process of Surveying and mapping is introduced, including experimental data acquisition, data reconstruction, texture mapping and two-dimensional image generation. The results of the experiment are displayed and analyzed. Then we get the advantages and limitations of 3D laser scanning technology in the modeling and mapping of bluestone.
Keywords: Imperial garden; bluestone; rockery; digital mapping; digital modeling.

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1. RESEARCH BACKGROUND

Rockery is the most important and unique link in the traditional Chinese gardening. As the important achievement of Rockery, rockery is manually piled by materials such as soil and stone. The fundamental principle of rockery is to “make the real false and the false real”, which means to express mountains in nature through the artificial technique, which is more general and essential than the real mountains. Its formations are diverse: it can be piled in group or landscaped independently [1].

Rockery has always been difficult to measure accurately due to the complicated and inconstant shape. In ancient times, stone can only be expressed in the form of painting while the development of artificial surveying and mapping techniques in modern times has made the surveying and mapping of rockery possible; many surveying and mapping achievements have emerged [2]-[3]. However, most of the results of rockery surveying and mapping are attached to buildings as the recapitulative outline in two dimensions, the complicated three-dimensional relationship of rockery remains difficult to express [4].

The three-dimensional laser measuring technique and oblique photography measuring technique have developed rapidly and been widely applied in cultural relics research and archeology works in the recent years [5]-[12]. Explorations have also been made in rockery research through the three-dimensional digital technique. For example, Zhang Bo’s team (2010) of North China University of Technology made many explorations and attempts [13]. GU Liana et al. (2016) attempted the digital surveying and mapping with the rockery in Summer Palace as an example to explore the possibility of UAVs surveying and mapping rockeries [14]. Yu Mengele et al. (2017) took Suzhou Huanxiu Villa and Ouyang Rockery as an example, attempted to collect rockery information by using three-dimensional laser scanning and close-range photogrammetry techniques at the same time of discussing the result expression [15]. Zhang Singing et al. (2018) took Suisun as an example to explore the digital measuring methods and the modes of result expression that are applicable to the private gardens [16]. Hu Jibe et al. (2018) took Garden of Qianlong Emperor as an example to compare the various measuring methods for imperial garden rockeries [17]. According to the current research, the measurement and performance of rockery need to be further explored. The imperial gardens in the Qing Dynasty represented by three mountains and five gardens are representative works in the Chinese gardening history. Mockeries in three mountains and five gardens are unique in terms of volume, form, content, and materials. Therefore, in this paper, the bluestone mockery in imperial garden of Beijing is selected as the research object to make discussion on the modelling methods for its digital surveying and mapping.

2. SURVEYING AND MAPPING EXPERIMENT ON ROCKERY WITH THE THREE-DIMENSIONAL LASER SCANNING TECHNIQUE

The common digital mapping technique currently used can be divided into the three-dimensional laser scanning technique and oblique photography measuring technique. In which the three-dimensional laser scanning technique obtains the observation distance by calculating the time difference according to the principle of laser ranging. It is capable of obtaining massive point cloud data of the measured object accurately and efficiently without contact. As a newly emerged technique in the recent years, the oblique photography measuring technique determines the three-dimensional relationship of the space by calculating the different coordinate positions of the same feature point in the digital photo of the measured object to obtain the three-dimensional model of the measured object.

Figure 1. Real scene of Yingluo Rock in Jingyi Garden, the Fragrant Hill
(Photographed by the author)

2.1 Research object of experiment

The materials of imperial garden rockeries represented by three mountains and five gardens are mainly composed of Bluestone and Tangshan Stone. Both materials come from Tangshan, a suburb of Beijing. Bluestone is deposited fine sandstone with a lamellar morphology, rich surface texture and high color purity. The most famous bluestone rockery is the Yingluo Rock in Tingyi Garden of the Fragrant Hill. Yingluo Rock is semicircular rockery piled up by a group of bluestones. The entire rockery group consists of three parts, the main mountain is located deep in green, the secondary mountain is in front of the waterfalls and blind platform and the accessory mountain is an independent peak on the southeast of the main mountain. Each group of Yingluo Rock contains at least three piled stones; despite the large number of layers of piled stones, the stones are evenly distributed and echoing each other. There stands old tress in great numbers in the surrounding area while there are buildings such as pool and Qing in Pavilion in front of the rockery. Yingluo Rock is typically representative in terms of both the completeness of the rockery and the complexity of the environment; hence the case selected for the bluestone rockery in the imperial garden.

2.2 Experimental device

The main device for the experiment is FARO Focus3DX 330. As a phase ultra-long high-speed three-dimensional scanner measuring distance from FARO, it can scan objects as far as 330m away in the direct sunlight. The integrated GPS receiver is adopted to facilitate the data application. The device parameters are as follows (Table 1):

Table 1. Major parameters of FARO Focus3DX 330 (Drawn by the author)

Title	Content
Type	FARO Focus3DX 330
Weight	5.2kg
Dimension	240×200×100
Range	0.6m to 330mm
Speed	976,000 p/s
Laser grade	Grade 1
Wavelength	1550nm
Range error	±2mm
Pixel of integrated color camera	70,000,000

2.3 Experimental procedure

The scanning plan is formulated according to the shape characteristics of the Yingluo Rock and the existing conditions in combination with the results of field scanning for constant adjustment. It mainly includes three steps: data acquisition, data reconstruction, and two-dimensional image generation (Table 2). The data acquisition will be carried out firstly, during which the data integrity must be ensured; afterwards, the point cloud model will be reconstructed in three dimensions. The three-dimensional reconstruction includes point cloud demising, reconstruction hole-filling and model compaction, and also, the texture mapping will be carried out on the model. Finally, a series of two-dimensional images are generated on this basis.

3. EXPERIMENTAL PROCESS

3.1 Data procurement

3.1.1. Field investigation

Observation and investigation on the external environment of site must be conducted before measuring the experimental data to understand the site information as well as the favorable and adverse conditions in the site. According to the field investigation of Yingluo Rock, it is discovered that Yingluo Rock is located in a relatively low-lying environment. Compared with the high-topography environment, the climatic environment of Yingluo Rock is more suitable for surveying and mapping. The small wind speed and weak lighting have prevented the influences of some uncontrollable factors on the experiment; however, the scanning might be interfered as there are many trees around the Yingluo Rock, among which, most are casuarinas such as cypress etc. As a result, we carry out the measurement task on an autumn day with soft sunlight instead of during making the investigation during the vigorous period of trees in summer. Nevertheless, there are still some uncontrollable messy points during the measurement in addition to the large interferences of plants to the measurement. These must be solved through the post processing.

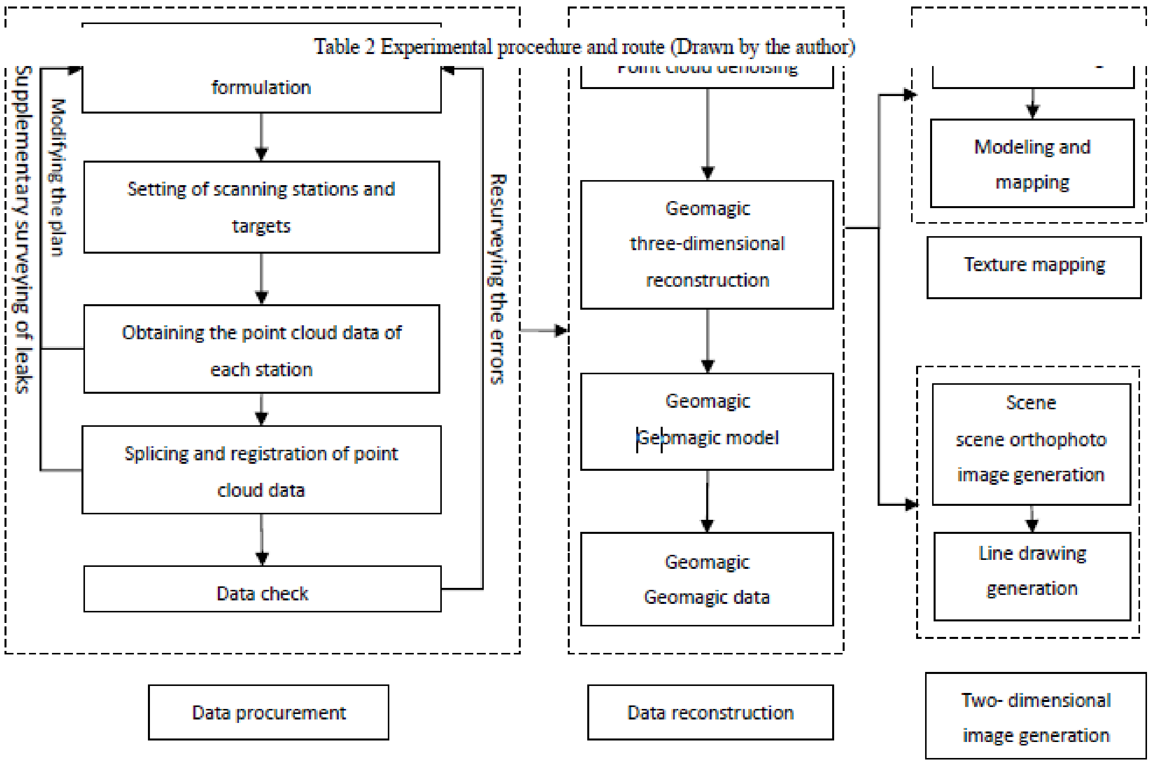

Table 2. Experimental procedure and route (Drawn by the author)

3.1.2. Scanner station setting and data procurement

During scanning the research object with the three-dimensional laser scanner, a scanner station shall be installed first according to the height of rockery and Set the scanner station according to the height and turning of the rockery. In addition to ensuring the integrity of point cloud data of rockery for the dead angle-free scanning, there must be certain degree of overlapping among the point cloud data above 15%. In this experiment, 14 stations are set around the Yingluo

Rock. During jointing the stations, the standard spherical target provided by FARO shall be adopted for measurement. The target is set to provide the unified reference coordinate at the time of jointing models with the software later; each scanning shall make sure at least three targets can be scanned. Also, at the time of changing stations, it shall ensure that at least three targets will be scanned b the neighboring stations. In this experiment, 6-8 targets are set at each station. Scanning shall start after the scanning stations and targets are set. The laser intensity is set by default, the scanning resolution is set as 1/4 of the accuracy. The research object with accurate digital model only is insufficient to reflect the materials of rockery; the digital model needs to be texture-mapped relative to the real color and texture information. The relative real color and texture information are required to make texture mapping on the digital model. In this experiment, camera with 600×1200dpi resolution built in the FARO scanner is adopted for shooting while the scanning time of each station is about 20 minutes.

3.1.3. Splicing and registration of point cloud data

After the point scanning is completed, the data shall be imported into the dedicated software SCENE that matches the FARO scanner; and the point cloud data are jointed and registered in SCENE to optimize the and the data of the jointed point cloud project; afterwards the point cloud model in the format of .xyz will be exported. The accuracy of registration is about ±3mm.

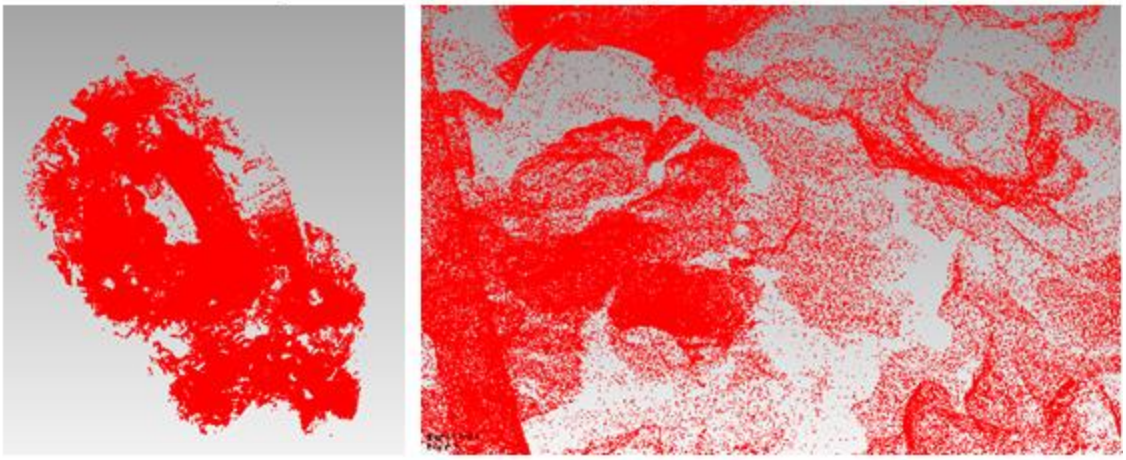

Figure 2. Complete and local point cloud model (Drawn by the author)

3.2 Three-dimensional model construction

In addition to the main rockery data, the point cloud data also include various types of data and other interference data of the surrounding environment. Therefore, during the three-dimensional construction of rockery, these data shall be processed separately. The procedures of which are mainly point cloud reconstruction, three-dimensional model construction and texture mapping etc.

3.2.1 Point cloud reconstruction

In this experiment, Germanic studio is adopted to export the data into a file with the extension. Xyz via the SCENE software and open it for processing. To ensure the accuracy of rockery contour, the extraction of point cloud is controlled at 50%. During the extraction, data not participating in three-dimensional construction will be deleted and demising processing on the point cloud will be performed to eliminate some interferences, thereby improving the accuracy of three-dimensional model construction. This process is manually performed and long time will be consumed.

3.2.2 Three-dimensional model construction

As the three-dimensional point cloud model only contains the spatial coordinate information of the measuring points while the large amount of data is inconvenient to communicate and display, the point cloud model shall be reconstructed through gridding to generate a corresponding three-dimensional geometric model. The procedures of which include cover, hole-filling, data compaction and model reconstruction.

The processed point cloud model is covered and encapsulated into a triangular grid model. There will be some errors and unclosed surfaces of the covered model in comparison with the actual model due to the complicated rockery shape in addition to influences of uncontrollable factors, i.e. tree obstructions, the influences of natural environment, i.e. scenery and influences of sundries etc. Holes shall be filled manually to restore the defective surfaces as far as possible according to the actual situation. In this experiment, the automatic method for hole-filling is compared by adopting both the automatic and manual processing methods. On the basis of adopting the most suitable automatic processing method in batches, some relatively obvious holes are mended while the complicated holes will be processed and filled through the independent hole-filling and bridging hole-filling with the help of appropriate tools and deletion tools. This is the most important and tedious part of the three-dimensional model construction. After the whole filling, the three-dimensional model and the point cloud model are compared to conduct the reconstruction and data compaction after controlling the error.

3.2.3 Texture mapping

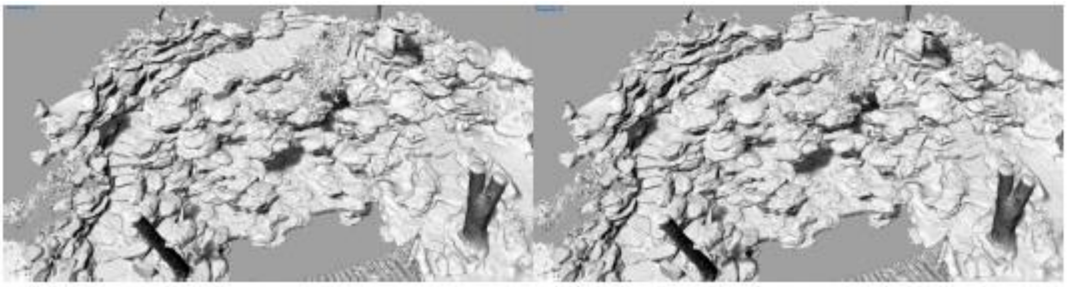

Figure 3. Three-dimensional model construction of Yingluo Rock (Drawn by the author)

Texture is the color information attached to the surface of the grid model; texture mapping is to form a material model by establishing the correspondence between various vertices of the model and the pixels of the image. To be specific, the three-dimensional model generated in the previous procedure is adopted to adjust the model into the viewpoint corresponding to the photo and then importing the photo, the photo will be automatically mapped onto the model by the software. There will be textures on the model that are roughly the same with patterns of the original materials.

Figure 4. Comparison of the model after texture mapping and the real scene (The left is model and the right is real scene) (Drawn by the author)

3.3 Generation of two-dimensional drawing

Figure 5. Generation and drawing of two-dimensional drawing of Yingluo Rock (Drawn by the author)

Although the three-dimensional model can intuitively represent the objects being surveyed, sometimes the two-dimensional maps are also required to express and analyze the landscape features of the measured area more accurately while making up for the deficiencies in the three-dimensional models to get the drawings more accurate and facilitate the following communications. There are two ways to make the two-dimensional maps. The first one is to export the o orthographic images with FARO SCENE, the second one is known as line drawing for short.

3.3.1 Orthographic image drawing

In this experiment, the FARO SCENE is adopted to export the orthographic images. The point cloud model after texture mapping is adopted as the collective projection of point cloud. Specifically, SCENE is adopted to slice the complete point cloud model after being jointed; the obtained model slices shall be adjusted at different views for checking to select the appropriate angle to export the orthographic images; generally, time of exporting shall be determined by the accuracy of the exported images.

Figure 5. Orthographic image drawing (Drawn by the author)

3.3.2 Line drawing

The line drawing method to process the three-dimensional model-exported images with the drawing software. The specific procedures are as shown below. To export the two-dimensional images of the three-dimensional grid model on different angles and direction; or it can be sectioned to export the section image. To insert the exported images into the AutoCAD in the same way of inserting the grating images; the contour lines and typical lines of stones or historical buildings are described with the spline curve or polyline, after which, the images and ready outlines are put into Photoshop for amplification processing to get the final drawing.

4. ANALYSIS ON EXPERIMENTAL RESULTS

The data and image results of Yingluo Rock in Jingyiyuan of the Fragrant Hill obtained in this experiment mainly include the three-dimensional grid model, three-dimensional point cloud model, orthographic image drawing and two-dimensional line drawing. Here and now, the experimental results are analyzed from accuracy, consumed time and other aspects.

4.1 Three-dimensional model

The accuracy validation and comparison validation of the point cloud model and the three-dimensional grid model are conducted in this experiment. The overall maximum error in the point cloud jointing is -2.87 mm, which is within the error range allowed by the experimental device itself. The overall maximum error between the point cloud model and the three-dimensional grid model is +1.97 mm, so that surveying and mapping accuracy of the Yingluo Rock made by the FARO Focus3DX 330 adopted in this experiment is satisfactory.

Table 3. Data conditions after the three-dimensional grid model optimization (Drawn by the author)

Model title	Number of vertices	Number of triangular meshes	Superficial area (m2)	Volume (m3)	Error with point cloud model (mm)
Yingluo Rock	1427701	2791550	927.5579	176.3875	1.97

During optimizing the point cloud model, the extraction and denoising of point cloud will exert certain influences on the feature points of its edge hence the accuracy of the triangular grid model due to the complexity of the rockery shape. According to the experiment, there will be obvious loss at the feature points of the rockery edge when the point cloud extraction is 10%, which makes the generated triangular grid model more smoothed. Therefore, the optimization of point cloud is of great significance to the accuracy of triangular grid model of the mockery.
During surveying and mapping the rockery mass, the complexity of the rockery mass and the surrounding environment always bring forth adverse effects on surveying and mapping, for example, there are more or narrower holes or crevices in rockery, the rockery is covered by plants, rocks and limited by other objects. These conditions will always result in the local or detail defections. These defections not only influence the methods and procedures adopted in the hole-filling link but also exert large influences on the accuracy of rockery model. Therefore, it is of great significance to select proper time and method for surveying and mapping according to the conditions of rockery.

The complexity of the rockery and the environment makes the natural light conditions that are originally changing more complex; what’s more, there will be obvious changes in conditions such as exposure and color temperature during the image shooting as it fails to make constant supplementation of light in daytime, hence the accuracy of texture mapping will be influenced. It is more accurate to refer to the methods in the fields of cultural relics and archaeology, which means to adopt the method of making constant supplementation of light in nighttime; however, sufficient conditions are required for completion.

4.2 Two-dimensional drawing

Two drawings are obtained in this experiment, namely the positive photography drawing and line drawing. The orthographic image drawing exports the slice of model, so it can be exported in various directions. The exported images are colorful, vivid, visual, intuitive and lively that can reflect the appearance lines, colors and textures etc. of the measurement target and even the seasonal conditions of the plants in garden. Although orthographic images are very similar to photographs, they can show parts that cannot be represented by photographs, for instance, they can express the cross-sectional images etc. However, as the image map is an operation performed by using a point cloud model with a large amount of data, it will take a lot of time for calculation to export an image with high accuracy.

The line drawing requires the operator’s second expression after understanding the measurement goal. The automation degree of the production is lower than that of the image map, the precision is also lower than the image map due to the human influence of the operator; also, the more complicated the shape of the mapping object, the more obvious the gap between the two of them will be. However, the drawing method and detail level of line drawing can be adjusted according to different surveying and mapping purposes and requirements; as the operation flexibility is greatly increased, the working efficiency can also be greatly improved along with the improvement of the operator's drawing efficiency and skills. In addition, in terms of expression effect of the figure, the line drawing can also express the spatial level and feature characteristics of the garden.

In summary, both methods have their unique advantages and disadvantages. Which method is adopted to depict an image shall be determined by factors such as time and operator's mastering of software.

5. CONCLUSION

After making a series of experimental studies and result analysis, it is discovered that the three-dimensional scanning technique has high accuracy and the model generated through surveying and mapping is vivid and lively to greatly improve the accuracy of rockery surveying and mapping, reflect the fine texture and complex spatial structure of rockery more detailed. What’s more, the obtained model data can be applied to various researches on rockery, they are of great significance to the restoration of rockery, integration of rockery and VR technique as well as the study on the methods for piled stone hill.

On the other hand, the limitations of the three-dimensional laser scanning technique can also be discovered, for example, objects obstructing one another will be difficult to find, the amount of data is huge while the work efficiency is low. As a result, when the obtained point clouds or images are used to construct the surface model, there will be problems such as large workload, complicated operation and incomplete model; the high price and heavy weight of equipment and the difficulty in handling are the restrictive factors. The scanning data processing is relatively specialized, great knowledge and skills of using hardware and software will be necessary. from the data acquisition to the application process. Need to master a lot of knowledge and hardware and software application skills. It is hoped that these limitations can be overcame by this technology in the future to simplify the data processing and make the surveying and mapping more efficient and convenient.

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