Methods and Techniques for Close-range Photogrammetric Mapping of Eaves of Ancient Architectures

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Abstract: For tall buildings, ground-based laser scanner cannot obtain complete point clouds for parts above the cornice. Therefore in the mapping of ancient architectures, we use unmanned helicopter with a high-pixel digital camera to do the shooting and thus can get a complete point cloud model for the eaves.

In China, we have a large number and wide distribution of ancient architectures. Their eaves have something in common: two-slope roof or four-slope roof with rich decorations on the ridges. After lots of mapping tests, we can summarize typical low-altitude mapping methods, including the number and position of baselines, the setting of control points, as well as the shooting techniques for such special building elements as glazed tiles and Wenshou (animal decorations on the ridges) so as to reduce the difficulty of field work, increase efficiency and mapping success. The data standards of low-altitude mapping of eaves are as follows: the overall point cloud precision and resolution should reach centimeter level; the four sides should be complete with no blind zones; a complete 3D surface model should be obtained for such building elements on the ridge as Wenshou, with millimeter resolution and accurate real color information.

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Key words: mapping of ancient architectures, photogrammetry, unmanned helicopter

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1 INTRODUCTION

Ground-based laser scanner is a powerful tool to make high-precision mapping of 3D architectural objects. But it cannot obtain complete point cloud data for the upper part of architectures. Ancient Chinese buildings usually have complicated structure and ornaments on the top, so this technical shortfall cannot be neglected. How to obtain data of the top has become an urgent task.

Low-altitude photogrammetry based on an unmanned helicopter platform helps to fill the gap in low-altitude

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high-precision mapping and has been largely applied in soil historic sites, linear heritages and other projects. Compared with ground work, it is superior in terms of operational efficiency and data integrity. Can we use it in the mapping of the eaves of ancient Chinese buildings? What's the requirement on hardware and equipments? What's the difference in operation method? What results can be achieved? Research in this specific field is almost a blank. The author has got some preliminary experience from the mapping experiments.

The author participated in the mapping of Jichang Garden of Huishan Moutain in Wuxi city and Huaxiaozi Temple. Since architectures in south China are usually dense and covered by trees, laser scanner cannot obtain complete data for the eaves. So we tried low-altitude photogrammetry to get point clouds of the eaves, and combined it with ground-based laser scanner and manual survey. The following are what we have learned in the experiments:

1. The mapping of ancient Chinese buildings requires the coordination of large and small helicopter platforms.

Unmanned helicopters have different types, ranging from several-hundred kilograms to a few dozen grams. In accordance with mapping tasks and camera performance, we used the 12-kg, 4-kg and 1.5-kg helicopters together. A 12-kg helicopter with a 1.8-meter rotor can be equipped with a satellite navigation system, a high pixel SLR camera and can do high-precision mapping of an entire eave in a relatively ample airspace. A 4-kg electric helicopter with a 1.2-meter rotor uses optical positioning equipment and mini SLR camera to do close-range survey of the eaves or key parts in a small airspace crowded with trees. A 1.5-kg helicopter usually adopts multi-rotor to further reduce the size to 40cm. It can only carry a mini camera and is mainly used in close-range shooting of details. Although its mapping precision is not very high, it can still be used quite often because many ornamental designs on ancient Chinese buildings are drawn manually according to the pictures.

Only by combining the three types can we achieve safety, environmental adaptability and data integrity. In the earlier mapping of Chengde Mountain Resort, we took only a 12-kg helicopter. In the shooting of the ridge beasts of lakeside Yanyu Pavilion, the helicopter had to take off and land from the veranda floor, running the risk of bumping into buildings(Fig. 1). With this experience, we took a small four-rotor helicopter to map the temples in Huishan Mountain in Wuxi and thus greatly reduced the flying difficulty. At the tree-covered side of Xiangtang Hall of Huaxiaozi Temple, this four-rotor helicopter, making use of the narrow space between the trees and the mountain, managed to get stereo pairs by moving horizontally on top of trees, obtained pictures of current situation (Fig. 2) and made point cloud models accordingly(Fig. 3).

Fig. 1 12kg helicopter in the veranda

Fig. 2 taking pic for the hall of Temple

Fig. 3 point cloud of the hall

2. Complete mapping of ancient buildings' eaves requires at least four baselines (air routes).

First, there are specific requirements on shooting angles. In land mapping, an air route may cover tens of square kilometers while the mapping of ancient buildings is much more complicated. Since the eaves are multi-faceted and the horizontal, slanting and vertical surfaces have many details, vertical shooting alone cannot obtain complete point clouds. We experimented on the four-sided honorific arch of Huaxiaozi Temple and found that slanting 30-40 degrees downward, we could shoot both the vertical main ridge and the inclined eave surface, get relatively complete point clouds and use two pictures to get point cloud data of several surfaces on the top(Fig. 4).

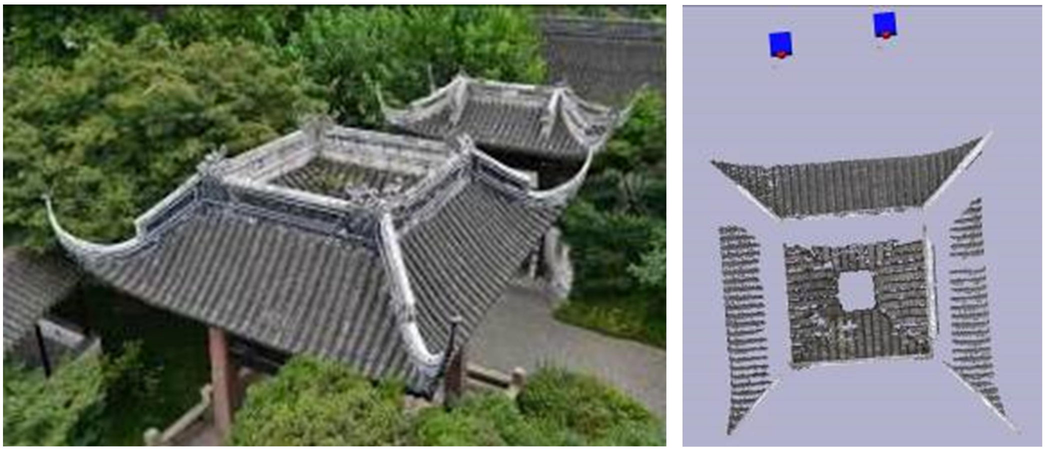

Fig 4. four-sided honorific arch of Huaxiaozi Temple and point cloud by one baseline

From this example, we can see for a hipped roof, two photos (ie. one baseline) are not enough. Some parts of the roof are blank. To get point clouds for each surface, we need at least four baselines or eight photos. In the mapping of Linfan Pavilion of Jichang Garden, the author tried two air routes, narrowed the distance and took more photos to improve the density of point clouds. As can be seen from the model's screenshot, some parts at the bottom are missing because blocked by trees the air route has to incline slightly upwards. However, as a whole, the point clouds are more complete. Point clouds of two sides are well joined. Narrowing shooting distance helps to achieve better point clouds. Even the facial details of figures at the end of the vertical ridge can be seen clearly. It can be inferred that with four routes we can obtain an almost complete roof model, the fineness of which can be adjusted by shifting the position of baselines.(Fig 5)

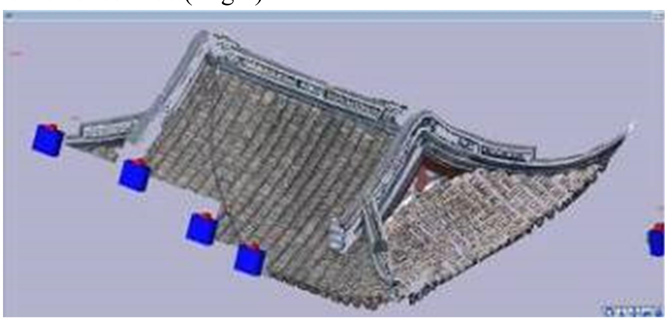

Fig 5. point cloud of Linfan Pavilion by two baselines

3. It should be combined with ground-based mapping equipments.

First, used independently, this kind of photogrammetry is unable to obtain an accurate absolute coordinate system. Before and after the shooting, we need a total station to obtain the absolute coordinates of at least three feature points of the roof and enter them into the model for subsequent processing and use. Second, based on the same control network provided by the total station, point clouds obtained respectively from low altitude photogrammetry and laser scanning can be joined and used to completely map and present architectures. A laser scanner is good at scanning interior space and parts under the eaves, which happens to be a weakness of photogrammetry. Therefore the two are mutually complementary and should be used together to achieve the best result.(Fig 6)


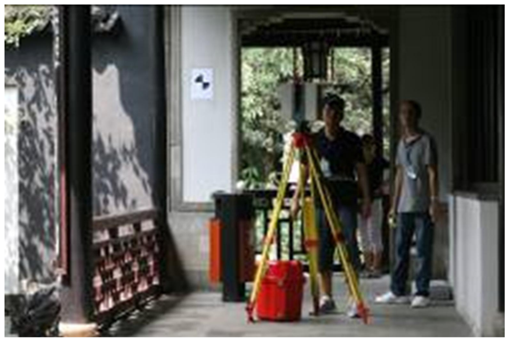

Fig 6. total station and laser scanner in Jichang Garden

2 PROBLEMS TO BE SOLVED

In mapping experiments, we found the following problems:

1. Photogrammetry cannot generate high-quality point clouds for independent and slender objects like a cornice.

Photegrammetry proves to be ineffective on slender objects and we have not come up with any good solutions.

2. Point cloud processing software is mostly designed for laser scanning purposes and does not accept color information obtained by Photogrammetry.

The common point cloud processing software has not been optimized for photogrammetry. With monochromatic point clouds, students are unable to distinguish between different components. To make photogrammetry a means of survey during their internship, we have to introduce some appropriate software to bridge the gap between different technical means.

3. It is difficult to set control points for rooftops.

To set a certain number of mark points on the roof, namely, target spots, will further improve mapping accuracy and reliability. But to set them on a tall roof is very difficult because that requires climbing up the roof, which is dangerous and may cause damages to the roof. Therefore we need to find a better way to deal with this problem. Can we use an unmanned helicopter to set the target spots? How? The author intends to make further attempts.

3 CONCLUSION

Photogrammetry combined with small and mini UAV platforms is applicable in the mapping of ancient buildings' eaves since it is light, convenient and highly efficient. When this operation method is mature enough and used in combination with a laser scanner, the mapping technology of ancient Chinese buildings can be greatly improved. To achieve that, we need to do further experiments.