

# RESEARCH ON THE APPLICATION METHOD OF HISTORICAL BUILDING PROTECTION UNDER THE INTEGRATION OF MULTIPLE TECHNOLOGIES

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## ABSTRACT:

With the development of society, the protection of historical buildings has been paid more and more attention. In recent years, China has increased the surveying and mapping of historical buildings. This paper takes the historical building protection project in Zhejiang Province, China as an example. This paper introduces the method of combining UAV aerial photography, 3D laser scanning, close-range photogrammetry and traditional surveying and mapping techniques. Mapping and information collection of historical buildings. And on this basis, the content and methods of quality inspection of historical architectural achievements are introduced. Guarantee the reliability of historical building archives and data quality. This will play a supporting role in the future repair and maintenance of historical buildings.

## 1. INTRODUCTION

Surveying and mapping of historical buildings is an important part of fieldwork research methods. It is a necessary process to recognize, verify and protect the ontology form of historical buildings. Europe engaged in historical building surveying and mapping earlier, mapping of historic buildings began as early as the Middle Ages (Liu et al., 2013). In the United States, after the establishment of the National Conservation and Education Commission in 1978, the surveying and mapping activities of related historical buildings were carried out (Joan et al., 2018). The surveying and mapping of historical buildings in China started relatively late. In 1982, the survey mapping and filing of historical buildings were carried out in some areas. Traditional historical building surveying and mapping mainly use rulers, laser rangefinders, levels, total stations and other equipment for information and data collection. The whole process consumes a lot of manpower, material resources and time. It is difficult to achieve the ideal effect in the accuracy of obtaining fine patterns. There is also the risk of causing damage to historical buildings in the surveying and mapping project. With the rapid development of photogrammetry technology in recent years. Using a combination of drone aerial photography, 3D laser scanning, close-range photogrammetry and traditional surveying and mapping techniques. It can more accurately and efficiently complete the measurement of historical buildings. In order to achieve the purpose of protecting and researching historical buildings.

## 2. LIMITATIONS AND SOLUTION

From past experience, using traditional or single

mapping methods to collect data on historical buildings will encounter many difficulties. And it is difficult to achieve perfect results. In recent years, according to the operating environment conditions. Choose different equipment suitable for field operation, integrate and collect the data of each part of the historical building. In the way, historical building data can be acquired more comprehensively and efficiently. And can meet the relevant accuracy requirements (Wang et al., 2020; Liu et al., 2021).

### 2.1 Limitation

First of all, traditional methods such as total station, rangefinder, and sketch drawing are inefficient for historical building surveying and mapping. It is difficult to draw accurately the fine historical building lines. The investment in construction period, manpower and material resources is relatively large. In fact, when using drone aerial photography and close-range photography for historical building surveying and mapping. If the surrounding environment of the building is complex, there are a lot of trees, weeds and other objects occluded, or shaded by eaves. UAV aerial photography and close-range photography with visible light as the collection feature will be disturbed. And it is difficult to achieve the purpose of effective data collection. Furthermore, when using 3D laser scanning technology for data collection. It is only valid within a certain range, the range is generally 1~500m. And with the change of the reflective ability of the tested equipment and building materials, the acquisition range will also be affected (Wang et al., 2014; Ramzanali et al., 2018). For residential buildings with relatively compact walls and irregular layout of objects in the building. This method should cause scanning blind

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spots. Using the method of close-range photogrammetry, although it can obtain more accurate building data. But the workload of the internal industry is large, the human input is more.

### 2.2 Solution

On the basis of UAV and close-range photogrammetry. Using 3D laser scanning to penetrate the characteristics of vegetation. By optimizing the algorithm to effectively capture the point cloud data behind the vegetation. And through multi-angle placement of 3D laser scanners for observation. After completing the establishment of the 3D point cloud model after the occluded object. Combined with the close-range shooting mode, some facades and building feature points are used. For data collection in small and hidden spaces. We can use a combination of traditional total station, rangefinder measurement and manual sketching. For the data collection of complex patterns and textures. We can obtain them through close-range photogrammetry. Finally, through multi-technology combined production. Using multi-source data fusion technology, data integration is carried out on the whole picture of historical buildings to achieve the purpose of solving the above problems.

## 3. MULTI-TECHNOLOGY INTEGRATION

The method used in the historical building surveying and mapping under the multi-technology fusion studied in this paper is mainly based on the aerial photogrammetry of the unmanned aerial vehicle as the main technical means. Combined with multi-source data fusion such as ground base station 3D laser scanning, close-range photography data collection and traditional surveying and mapping data collection. Multi-directional, full-view surveying and mapping of historical buildings. 3D models, DOMs, general plans, floor plans, elevations, sections and other results of historical buildings are formed.

### 3.1 Overall Technical Route

The overall technical route follows the measurement principle of "from the whole to the part ". The main contents include control measurement, aerial photography data collection, traditional measurement data collection, 3D laser scanning field collection, close-range photography field collection, interior data fusion, general plan, plan, elevation, plan view production, etc. The overall technology roadmap is shown in Figure 1.

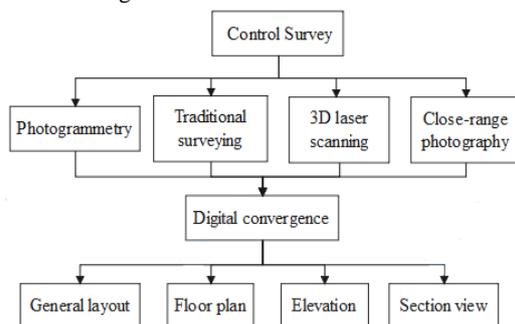


Figure 1. Overall technical route

### 3.2 Data Collection and Processing Methods

#### 3.2.1 UAV aerial photography data collection and Processing:

UAV aerial photography data collection is the main technical means to obtain DOM of historical buildings and oblique photography 3D model data. It has the characteristics of high precision, rich information and strong current situation (Niu et al., 2020; Qian et al., 2021). It can provide good data support for digital topographic maps of historical buildings. At the same time, it can more vividly reflect the historical buildings. DOM data collection is mainly generated automatically by software through the procedures of route design, image control point layout, UAV DOM image collection, photo puncture points, and air three calculation. The oblique photography 3D model data can truly reflect the appearance, location, height and other information of historical buildings. Mainly through the flight route design, area coverage design, image control point layout, UAV oblique photography data collection, aerial three calculation, image preprocessing, 3D model production and data fusion and other programs are automatically generated by software (Chun et al., 2020; Alberto et al., 2020). The above two collection methods both use low-altitude drones for data collection. See Table 1 for details of UAV index parameters. The generated point cloud model is shown in Figure 2.

Parameters	Parameter values
Head lap	≥53%
Side lap	66.7%
Strip deformation	≤3%
Flight height/m	200
Coverage /image	≥50%
Angle of inclination/°	≤3
Rotation angle/°	≤25

Table 1. UAV flight parameters

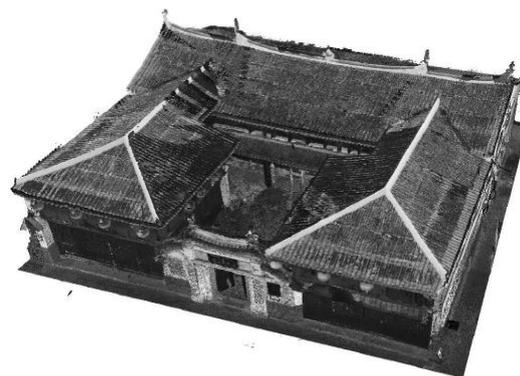


Figure 2. Point cloud model

#### 3.2.2 Traditional Measurement Data Collection and Processing:

Traditional surveying data collection is the main technical means for obtaining the general plan and floor plan result data of historical buildings (Fargas et al., 2021). Mainly use total station, RTK, rangefinder, using digital surveying and mapping with on-site sketches. Mapping of various elements within the conservation area of historic buildings. And on this

basis, in accordance with the professional requirements of historical building surveying and mapping. Through the detailed mapping of the spatial distribution information of architectural objects, as well as the description of other historical elements. Under the Autocad 2020 software platform, the method of artificial internal drawing is adopted. Form thematic topographic maps. In this way, the overall description of the spatial distribution of historical buildings. The topography and the surrounding environment can be realized.

### 3.2.3 3D Scanning Data Acquisition and Processing:

3D laser scanning technology can effectively avoid the large-scale occlusion of historical buildings. At the same time, it can carry out detailed and accurate data collection for building structures in small spaces. Provide accurate model data for elevations, sections, and DOM of historic buildings. The data acquisition process includes control measurement, scanning station deployment, target deployment, point cloud data acquisition, texture image acquisition, field data inspection. After we imported the data obtained in the field into the Trimble Real Works software, the point cloud data with poor quality was removed artificially. The point cloud data is optimized and exported to provide reference for subsequent drawing work.

### 3.2.4 Close-range Photogrammetry Data Collection and Processing:

Close-range photogrammetry is the use of high-resolution digital cameras. With the help of modern measuring computer technology. It is an auxiliary measurement method for historical building surveying and mapping (Clyne K et al., 2021). It can better solve the drawing of complex graphics and patterns in historical buildings. Through the close-range photography method, high-resolution images are obtained close to photography. And extract the refined geographic information from the image in PHOTOMOD software. Semi-automated acquisition of textured model data, elevation DOM, contour maps, and more.

## 3.3 Historic Building Drawings and Achievements

### 3.3.1 General Floor Plan and Floor Plan Production:

The general floor plan and floor plan production is mainly to survey and map the full-element digital topographic map within the protection range of the historic building. The model mainly collects data through a combination of UAV aerial photography and traditional measurement. This article takes the production method of the general plan and floor plan of the historical building surveying and mapping project in Zhejiang Province, China as an example. This project mainly uses field collection and EPS point cloud model stereo mapping software to jointly map. EPS point cloud model stereo mapping software, also known as EPS geographic information workstation. It is a surveying and mapping geographic information system software independently developed by Beijing Qinghua Shanwei Company. It including functions such as GIS data generation, processing, database establishment and update. It can better combine point cloud data with CAD drawing technology, with simple operation and high accuracy. Use DOM as the base map to make the floor plan. Extract line data by means of

machine-assisted mapping. The floor plan obtained by this method is comprehensive in content, simple and efficient in operation. Generate a floor plan that meets the requirements, the general floor plan collection is shown in Figure 3 and Figure 4. The floor plan includes floor plans, roof plans, and elevation plans. It is necessary to fully express the internal spatial layout of the building. And collect and express the ground paving and historical building elements into the hall. Mainly based on on-site sketch drawing and actual measurement. With the assistance of outdoor 3D point cloud data. The site sketch and floor plan are shown in Figure 5.

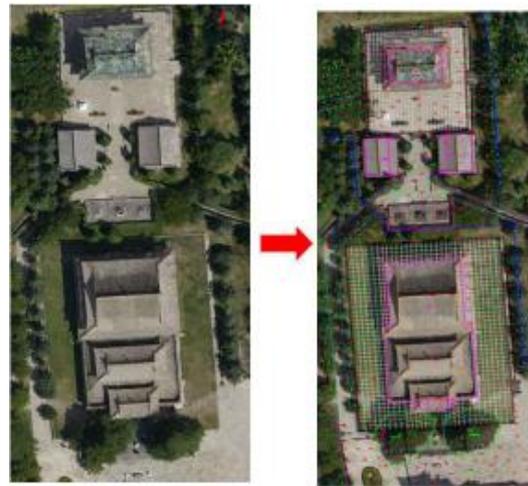


Figure 3. General floor plan collection



Figure 4. Internal software acquisition

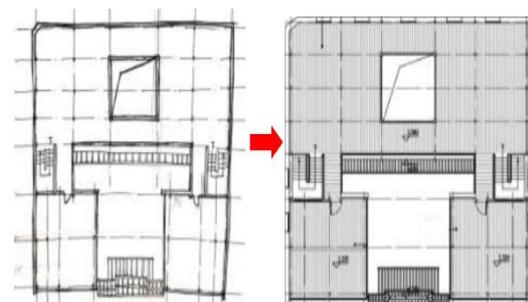
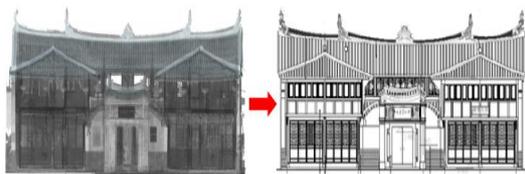


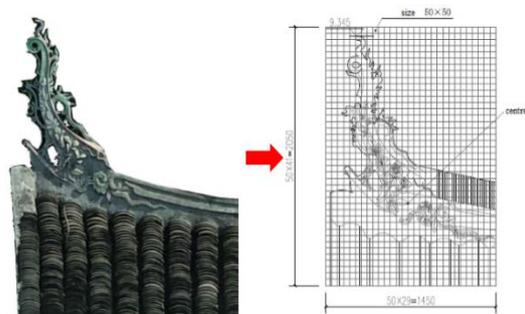
Figure 5. Sketch collection

**3.3.2 Elevation Drawing:** Elevation drawing needs to express the overall outline of the facade, the outline and details of the components, all the materials of the facade, and express the elements of the historical building. Its vector line drawing needs to be based on different properties. Through scientific layering, color separation management and line design. The model mainly acquires data through a combination of UAV oblique photography, 3D laser scanning and close-range measurement. Elevations of historical buildings are mainly drawn through point cloud DOM or DOM (Kobal et al., 2021; Wang et al., 2021). The feature information is artificially tracked and drawn under the EPS point cloud model stereo mapping software platform. Using this method to draw the elevation map can be more detailed and accurate. See Figure 6 for details.



**Figure 6.** Elevation drawing collection

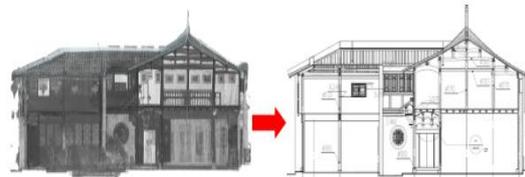
The fine texture map is part of the elevation map result. It is the result of data acquisition of fine textures such as patterns and structures with historical significance. Generally, the method of selection and drawing is used. It is necessary to select the structure and decoration that can reflect the historical style and local characteristics, and text annotation. It mainly collects the complex component information of traditional structure, construction technology and structural characteristics. It is generally expressed in axonometric exploded diagrams (Lin et al., 2021). Fine texture maps are generally drawn with sketches, on-site measurement and assisting in drawing operations in the form of on-site photos. For complex and important components, use handheld scanners or close-range modeling to capture. After the data is transferred to the drawing software, it is manually edited into a drawing in the office. The graph obtained by this method is more accurate. The collection results are shown in Figure 7.



**Figure 7.** Fine texture map

**3.3.3 Plane Drawing:** Sectional drawings shall express typical or historically and artistically valuable interior layouts. And complete the drawing of standard section material practices and the expression of historical building elements. The model mainly uses 3D scanning, close-range photogrammetry and traditional surveying

and mapping methods to obtain data. Mainly based on the overall model data, the section position selection is carried out in a three-dimensional environment. And use professional software to extract 3D profile data and select the projection surface. Project the 3D section line to the drawing projection surface to obtain the 2D line diagram of the section line. Then through the method of perspective, the distribution of beams and columns inside the building is drawn. Using this method, the plan view can be generated more simply. See Figure 8 for details.



**Figure 8.** Plane drawing collection

### 3.4 Accuracy Verification

Relative distance accuracy is particularly important for the accuracy of historic buildings. It reflects the accuracy of the relative relationship between the various parts of the historic building. Therefore, we organize the length data of 10 historical building projects. In the model generated by the above method, 20 lengths are selected for statistics. The difference  $\Delta S$  between the distance  $S_1$  collected on the model and the human-measured distance  $S_2$  is shown in Table 2.

ID	$\Delta S_1$	$\Delta S_2$	$\Delta S$
	m	m	m
1	24.47	24.39	0.08
2	12.15	12.11	0.04
3	13.00	13.04	-0.04
4	7.97	7.95	0.02
5	1.17	1.18	-0.01
6	4.14	4.16	-0.02
7	3.33	3.32	0.01
8	11.67	11.64	0.03
9	10.40	10.37	0.03
10	17.67	17.72	-0.05
11	15.31	15.35	-0.04
12	13.43	13.39	0.04
13	3.65	3.64	0.01
14	14.05	14.01	0.04
15	21.91	21.83	0.08
16	10.52	10.55	-0.03
17	22.88	22.96	-0.08
18	10.99	10.96	0.03
19	3.93	3.91	0.02
20	2.54	2.55	-0.01

**Table 2.** Length statistics table.

At the same time, we take the actual measurement value as the real value, and calculate the root mean square error of 20 detection distances to be 0.04m. The

specific calculation formula is as follows (1):

$$m = \pm \sqrt{\frac{\sum_{i=1}^n \Delta S^2}{n}} \quad (1)$$

Where: m = Mean square error of results  
n = Number of test distances  
 $\Delta S$  = Difference in distance

Through the verification of the root mean square error. We can obtain the model produced by using the data acquisition method under the fusion of multiple technologies. Accuracy can meet the needs of historical building survey work.

#### 4. QUALITY INSPECTION

##### 4.1 Check the Content

The quality inspection of historical building surveying and mapping results in China generally adopts the methods of full internal inspection and field sampling inspection. Implement the system of two-level inspection and one-level acceptance. The quality control of the results is carried out in the form of a combination of process inspection and final inspection. Among them, 3D model results and DOM results adopt process inspection. Final inspection is adopted for the results of general plan, floor plan, interior plan and plan view. At the same time, a comprehensive inspection of the correctness and completeness of the documents is carried out. The specific inspection contents are shown in Table 3.

Project	Check the Content
General Floor Plan	<ol style="list-style-type: none"> <li>1. Correctness of coordinate system and elevation datum;</li> <li>2. Integrity of building location, outline and surround geographic elements;</li> <li>3. The overall size of the building, whether the relationship between the buildings is correct;</li> <li>4. Correctness of level, height and number of floors;</li> <li>5. Whether the drawing of surface elements is standardized.</li> </ol>
Floor Plan	<ol style="list-style-type: none"> <li>1. Comprehensiveness of floor plans, roof plans and elevation plans;</li> <li>2. Whether the expression of the interior structure is complete and correct;</li> <li>3. Indoor Material Correctness;</li> <li>4. Correctness of interior scene collection of important historical and artistic values;</li> <li>5. Annotation accuracy and comprehensiveness.</li> </ol>

Elevation Drawing	<ol style="list-style-type: none"> <li>1. All visible facades collected;</li> <li>2. The correctness of the spatial relationship of the building;</li> <li>3. Elevation profile, dimensions, material correctness;</li> <li>4. Whether the relative position accuracy of fine graphic texture meets the requirements;</li> <li>5. Whether the fine graphic texture content is complete.</li> </ol>
Sectional Drawing	<ol style="list-style-type: none"> <li>1. All visible facades collected;</li> <li>2. Sectional profile, dimensions, material correctness;</li> <li>3. The correctness of the collection of interior scenes or patterns of important historical and artistic value.</li> </ol>
Document	<ol style="list-style-type: none"> <li>1. Correctness of technical design and summary;</li> <li>2. Integrity of process data files;</li> <li>3. Integrity of model data and historical building condition records;</li> <li>4. Whether the results of the drawings are clear and complete.</li> </ol>

Table 3. Specific inspection contents

##### 4.2 Inspection Method

###### 4.2.1 General floor plan and floor Plan Inspection:

The general floor plan and floor plan results are mainly checked by a combination of field inspection and in-house inspection. The internal industry first integrated the general plan, floor plan and 3D model under the 3D software platform. Compare and check the lack of topographical elements of the floor plan and the correctness of the coordinate system and elevation datum. Then through the field measurement to check the overall plan, the position accuracy and elevation accuracy of the plan. And verify whether the collection of ground objects in the occluded area is correct during the internal inspection.

###### 4.2.2 Elevation drawing and fine texture inspection:

Elevations need to show more side details. Generally, the real 3D point cloud data is used for inspection in combination with field inspection. On the basis of obtaining the characteristic points of the internal industry. It can be combined with the field measurement of the field measuring instrument to check whether the size of the elevation map is correct. And check whether the content of the building facade is complete. For the inspection of the fine texture map. It is necessary to compare whether the expression of the important patterns in the historical building map is accurate after close-range photography shooting. And the correctness of the fine texture size is checked by on-the-spot measurement.

**4.2.3 Sectional drawing inspection:** Due to the fact that the sectional cover more and more complex details of historical buildings. Therefore, the elevation plan

view is generally checked by means of field verification. It is possible to check whether the size of the historical building survey drawing is correct through the rangefinder field. Combined with the feature points of 3D laser scanning data. Check that the contents of the historical building survey drawings are complete. And through close-range photography shooting, it is necessary to compare whether the expression of the important patterns in the historical buildings is accurate.

**4.2.4 Document Check:** The inspection of the data results is mainly through the way of internal inspection. Comprehensive inspection of image tone and contrast, sharpness and texture performance, appearance quality and image color through image processing software. Use the image edge software to check the color difference processing and edge accuracy during image stitching. Manually check whether the architectural mapping, 3D model, DOM, and point cloud data of historical buildings are complete. And whether the technical design book and summary are standardized.

## 5. END

This paper mainly studies and introduces the use of photogrammetry, 3D laser scanning, close-range photography and traditional surveying and mapping to obtain data on historical buildings. And the method was implemented in the historical building surveying and mapping project in Zhejiang Province. From the implementation results, the method of integrating various technologies can complete the surveying and mapping work of historical buildings more efficiently. And can provide accurate information file data. It provides more comprehensive and reliable technical data and basis for promoting the maintenance and protection of historical buildings in the future. Therefore, this technical method will be widely used in various projects of the protection of historical buildings in the world in the future. It provides an effective reference for the methods and methods of surveying and mapping of historical buildings in the world.

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