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D-SITE

Drones - Systems of Information on Cultural Heritage for a spatial and social investigation

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PREFACE

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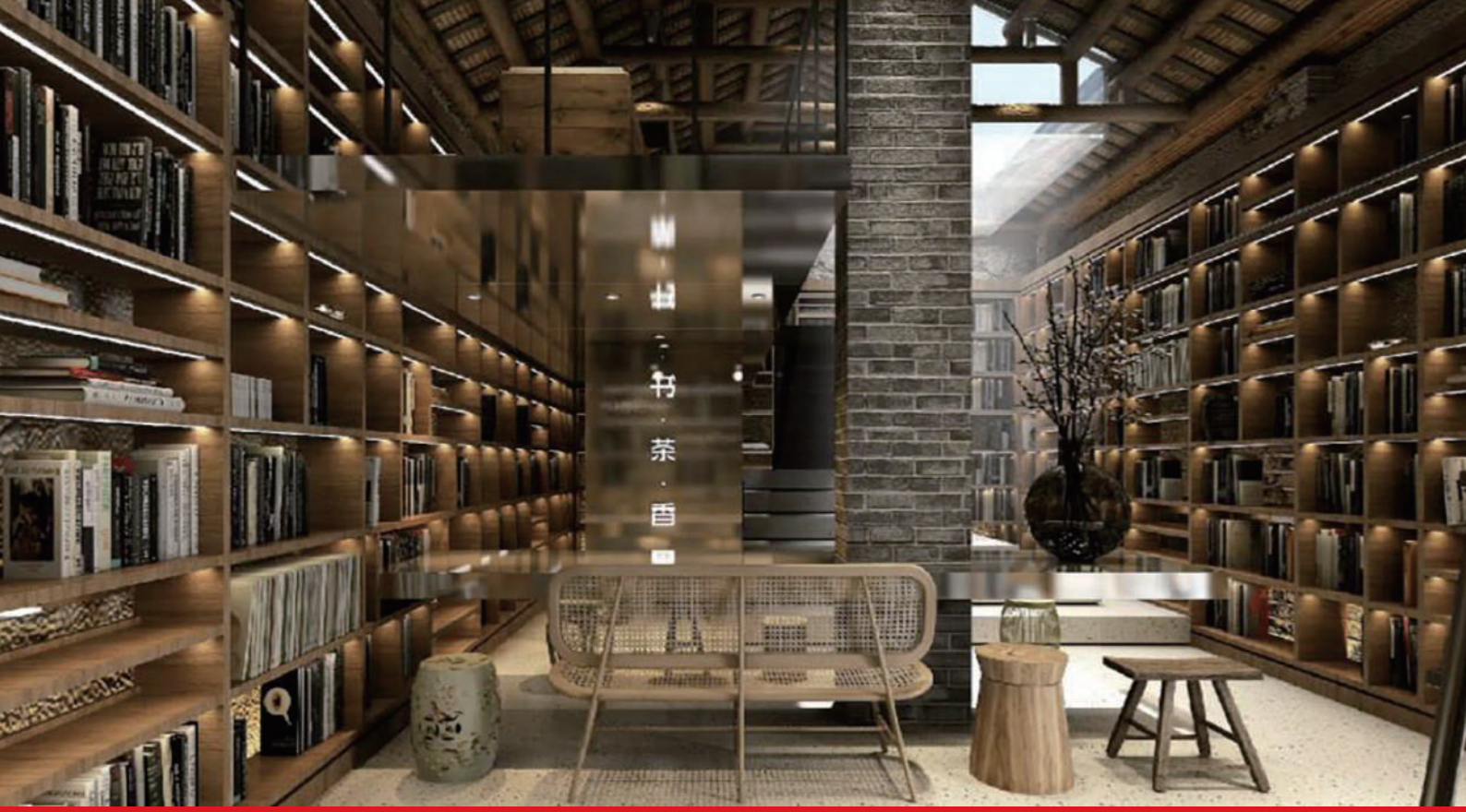

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UAV photogrammetry technology, Architectural heritage Preservation, Protection design.

ABSTRACT

This paper introduces the application of UAV photogrammetry in different stages of architectural heritage protection, such as the investigation of the current situation around the architectural heritage, the acquisition of site information, and the architectural heritage revitalization design. The collected data is processed not only to provide reference data support for cultural relics conservation projects, but also as a reference for long-term heritage monitoring in archives. With continuous development of the field of UAV technology, the working methods and ideas introduced in this paper will become an important scientific and technological protection means in the protection of architectural heritage.

Application of UAV photogrammetry technology in the process of architectural heritage preservation

1. Introduction

With the rapid development of the modern economy, the scale of urban construction has expanded rapidly. Many historic buildings are being destroyed, so the effective measures must be taken to protect them and efficiently repair and utilize them.

The establishment of 3D model archives for historical buildings can better provide protection strategies and guide repair design.Using UAV photogrammetry technology to establish a 3D real scene model can not only greatly reduce the production cost of 3D modeling, but also improve the production efficiency. Compared with traditional manual modeling and 3D laser scanning modeling, The UAV photogrammetry has its own unique advantages, making up for the shortcomings of traditional modeling method.

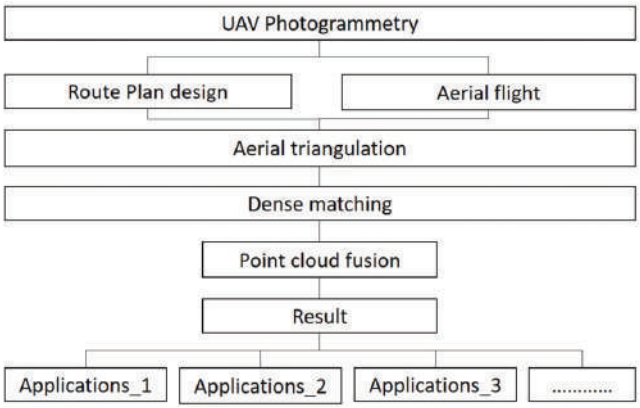

Figure 1. The workflow of UAV photogrammetry for architecture heritage conservation.

It provides more scientific and efficient technical means for the mapping, archiving and protection of historical buildings, which is of great significance to the protection of historical buildings.

In this paper, we mainly discuss the method of using UAV photogrammetry technology to model of historical buildings, and introduce the application of UAV photogrammetry technology in the process of architectural heritage protection based on project cases of different scales. Such as the investigation of the current situation around the architectural heritage, the acquisition of site information, and the architectural heritage revitalization design.

2. The characteristics of UAV photogrammetry technology

Generally, the UAV photogrammetry technology mainly involves three aspects: data collection, data processing and data application. Through the camera lens mounted on the flight platform, the real image information of the ground objects is obtained from different perspectives, and then the vectorized 3D model of the real scene is constructed through the data processing software. UAV photogrammetry technology mainly has the following characteristics.

2.1 The main advantages of UAV photogrammetry technology

Using the drone to collected the data freely in the air and avoiding the limitations of ground operating conditions,

field data collection is completed by only one drone controller. Moreover, the data collection process is fully automated without manual control of flight attitude and manual shooting.

During data processing, importing remote sensing data into the corresponding software can realize fully automatic 3D modeling, such as Pix 4D, Photoscan and Smart 3D. The efficiency of modeling speed is greatly improved, comparison of the traditional manual modeling (Lo Brutto et al. 2014).

The point cloud model obtained by UAV photogrammetry obtains directly the plane coordinates, height, slope, area, volume and other attribute information of the objects in the 3D model. It makes up for the limitations of traditional artificial modeling with low simulation degree and unreal geometric spatial data information (Morena et al., 2021).

UAV photogrammetry data is rich in achievements. In addition, the result data also includes Digital Surface Model (DSM), Digital Orthophoto Map (DOM), Digital Line Map (DLGs) and point cloud data, which makes it possible for subsequent applications and multi-technology integration. (Liu et al., 2018)

With the increasing popularity of drone, it is also getting cheaper and more versatile. Compared with expensive instruments such as 3D laser scanners, the economy is significantly improved.

2.2 The main disadvantages of UAV photogrammetry technology

Compared with the traditional measurement technology, the UAV photogrammetry technology has the advantages of low economy, high accuracy and efficiency. Under certain conditions, the following limitations still exist.

The UAV photogrammetry is greatly affected by the intensity of light since it is a measurement technology based on photo images. When the light is dark or changing rapidly, the collected data process cannot be modeling. Thus, it is not suitable to work during the night. And the UAV cannot operate in strong winds or in no-fly zones, while the 3D laser scanners are available in this extreme situation.

The UAVs have high requirements on the technical level and flight experience of UAV operators, since UAV is aerial operations, and there are certain safety hazards in the operation methods. Working in crowded areas should be control risks and ensure safety.

3. Research Strategy

According to the technical characteristics of UAV photogrammetry, combined with the technical characteristics of surveying and mapping of architectural heritage renovation and conservation, the relevant operation flow chart is formulated as follows (Figure 1)

From the above workflow, it can be seen that the 3D modeling based on UAV photogrammetry includes two parts: field work and internal work.

The important work of field work is the data collection. Before the formal operation, it is necessary to collect and sort out the relevant information of the historical building, conduct on-site investigation and confirmation of the surrounding situation, study and select a suitable flight plan for route design, calculation of travel height and determination of overlap. Usually the UAV flight height is set to 20m higher than the building, and pay attention to flight safety (including not exceeding the

Figure 2. The point cloud model of He Xinwu.

local aircraft height limit and not enter no-fly zone), and then carry out parallel flight continuous photo sampling, data sampling from different perspectives, and the photo coincidence should reach more than 60%. The higher the number of photos, the higher the detail.
The internal work can choose different platforms according to the application needs of the project, such as Context Capture, Metashape Pro, Pixe4Dmapper and other mainstream tilt photography modeling software in the industry. And the internal work generally includes steps such as photos import, align photos, build dense cloud, build mesh and so on.

4. Application case studies

4.1 UAV technology in the investigation of the surrounding environment of architectural heritage research

In the process of revitalizing the architectural heritage, it is necessary to investigate the preservation status of the historical building, and specifically express the location, orientation and the surrounding environment, such as original buildings, traffic roads, greening, topography, etc. The operation method uses a total station for field surveying and mapping. When operating in a large area with a complicated environment, there is a problem of low work efficiency, and it is greatly affected by environmental factors. Hence, it is impossible to accurately grasp the layout of the entire building and the surrounding environment. Consequently, there is a lack of data information such as topographic maps and other historical buildings. Since the collected data are always fragmented, there is a lack of spatial layout records for the entire architectural heritage.
He Xinwu is a typical case of Hakka enclosures in Heyuan City, China. It is listed as a historical building protection unit. The 3D reconstruction model of the entire building space is quickly obtained through drone images (Figure 2). This enables the protection staff of cultural relics to have a clearer and more intuitive understanding of the layout and preservation status of the entire historical building. Based on the point cloud model, the corresponding general plane is also accurately drawn, and the surrounding environment is clearly expressed, as shown in Figure 3.
This method digitally documents the entire project, while the digital 3D model contains far more information than a flat photograph. It can be seen from the results that compared with traditional surveying and mapping, UAV has the remarkable achievement of high precision, rich information, intuitive and realistic, quick acquisition and good economy.
At the same time, the use of drone images to build 3D models has low cost and high speed. Moreover, it regularly collects images of historical building. After a period of monitoring, the images collected several times are compared to the models after 3D reconstruction. The development of disease and damage to historical building, the disappearance of traditional villages and ancient dwellings, the development of diseases of soil sites and the protection effect of protective measures, and the governance of

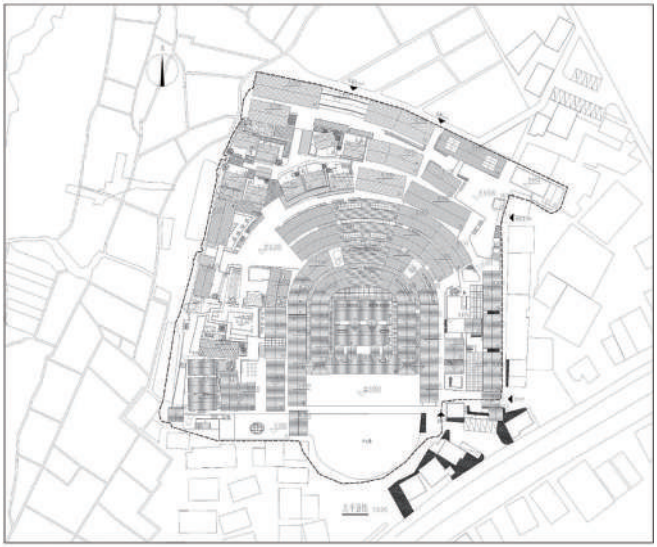

Figure 3. Block diagram of the proposed methodology.

the surrounding environment of the heritage are all clearly reflected, providing a new method for heritage monitoring. Especially for some earthen city wall sites with poor preservation and loose soil, UAV does not require staff to contact the body of the earthen site and avoids secondary damage to the site. Compared with the 3D laser scanning mapping method, it achieves a lower cost, low field workload and fast internal data processing.

4.2 UAV TECHNOLOGY IN THE ANALYSIS OF THE CURRENT SITUATION OF HISTORICAL BUILDING

The analysis of the current situation of the building is an important research topic in the restore process of the historical building, including the presumption of the original state, the evaluation of the complete and damaged condition, etc. Its main workflow is shown in Figure 4.

UAV photogrammetry is able to supplement the appearance data that is difficult to survey. It also analyzes and evaluates the damage status of each facade and the detailed structure of the building. Based on the comparison of the elevation of the 3D model and the survey, it coordinates and investigates the structural problems of the current state of the building, including wall distortion, roof deformation and so on. Therefore, UAV photogrammetry technology is an effective supplement to the current structural damage assessment of the building.

During the surveying process of Chiesa Collegiata di Santa Maria della Scala, due to its large volume and multi-layered sloping roof, the roof areas and wall areas are difficult to survey accurately. However, by using the 3D point cloud model from the UAV photogrammetry, the damage situation of each part of the building is clearly detected, and the three-dimensional visual expression of the disease analysis is realized.

The damage status of the building body is analyzed from various perspectives, including damaged tiles, damaged gutters, severely weathered walls, and damaged waterproof materials. It effectively replaces the on-site climbing survey, and improves the work efficiency of the damage condition assessment. The obtained partial damage analysis diagram is shown in Figure 5.

At the same time, based on the point cloud 3D model, the respective elevations is also exported as a reference for the reconstruction and repair of the later elevations, as shown in Figure 6.

In addition, for the architectural heritage surveying and mapping with complex shapes and high precision requirements, it is necessary to comprehensively use a variety of techniques as follows:

- Global positioning system: It is used to establish a permanent measurement control network as a reference for the comparison of surveying and mapping data in different periods (adding a time dimension to the surveying and mapping data), and to provide data for safety monitoring by changing trends;
- High-precision photogrammetry: it uses for the surveying and mapping of murals and color paintings, and can produce high-definition orthographic projection maps as the base map for

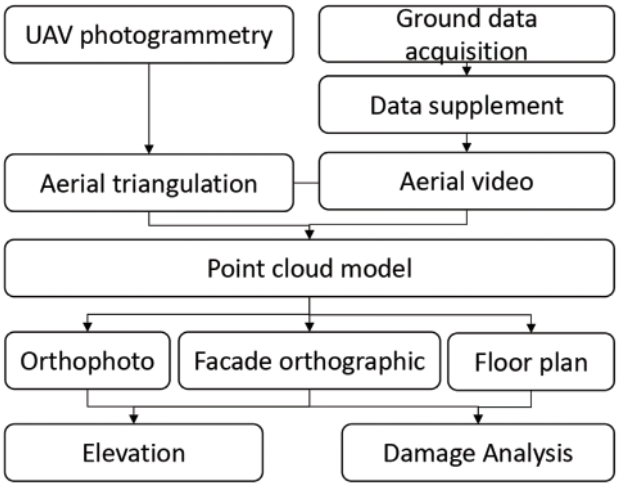

Figure 4. The workflow of UAV photogrammetry for analysis of the historical building.

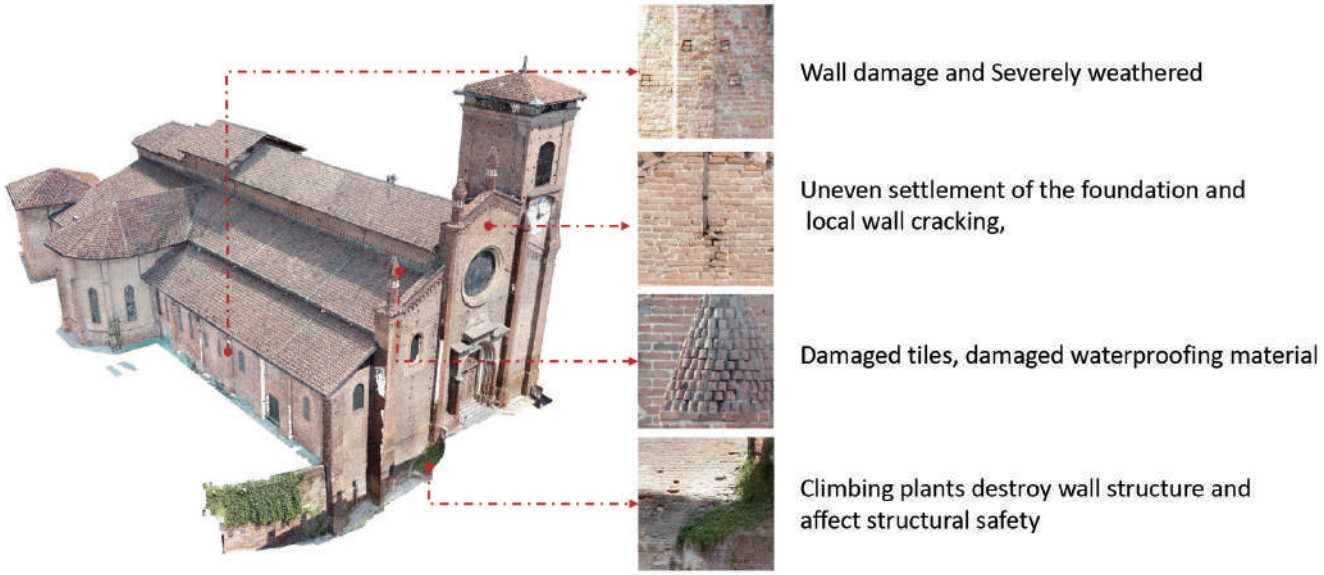

Figure 5. The damage analysis of Chiesa Collegiata di Santa Maria della Scala.

disease analysis;

- Non-destructive testing: using ray, ultrasound, infrared imaging and other technologies to collect information, it is invisible to the naked eye (wall defects, surface strength, foundation conditions, etc.).

4.3 UAV IN THE REVITALIZATION AND RENOVATION OF ARCHITECTURAL HERITAGE

In the process of revitalization and transformation of architectural heritage, the three-dimensional point cloud model obtained by drones technology realizes the actual expression of the design site and design plan. It not only helps designers adjust their plans, but also provides decision-makers with an intuitive and visual presentation of the effects.

In the project of reconstruction of Cantonese residential in Shenzhen, China. In order to create a unique book bar space, which is suitable for young people, without destroying the original building structure, based on the on-site 3D model obtained by the drone technology, the texture relationship between the original building and the surrounding environment is fully presented. The layout relationship between the new and the old buildings, the coordination relationship between materials and colors by importing the plan model into the UAV to construct the 3D point cloud model are detected. At the same time, the newly built space is well integrated into the existing village environment without destroying the original old buildings, which promotes the gradual protection and renewal of the entire building.

In the process of revitalization and reconstruction design of architectural heritage, it is necessary to accurately capture on-site data. Traditional two-dimensional planes and photo records are difficult to precisely express the situation of the site. For some seriously damaged ancient buildings, due to its structural problems, there is the difficulties in building ontology mapping and disease investigation. Generally, scaffolding is erected

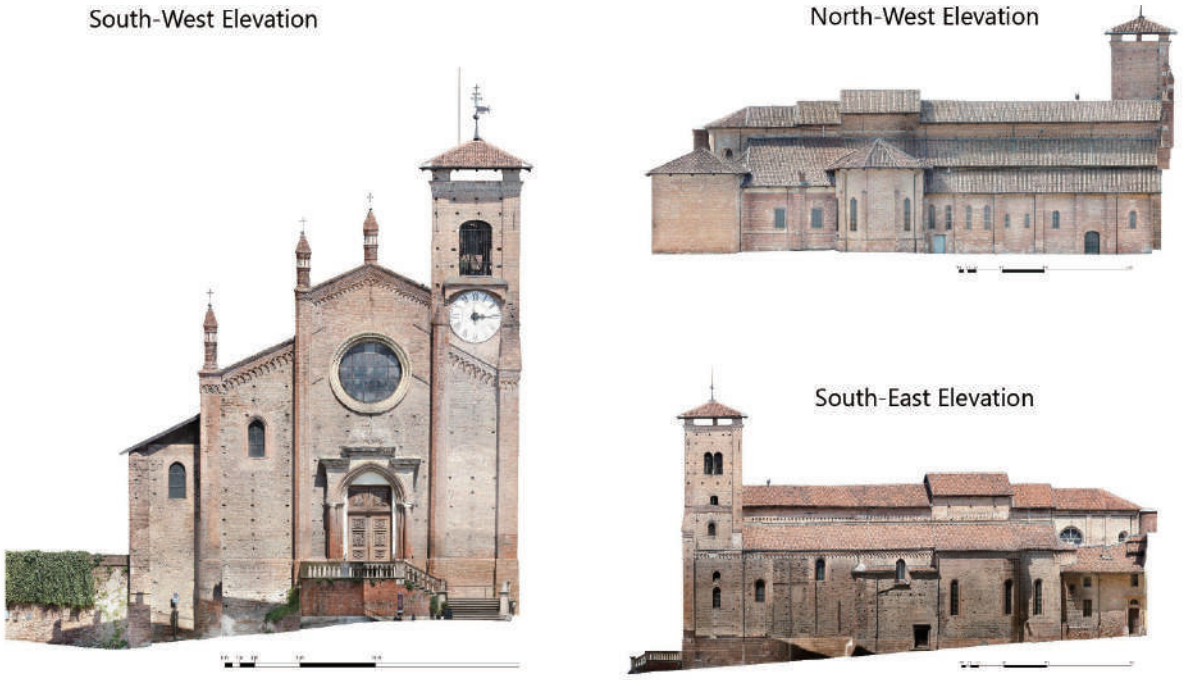

Figure 6. The elevation of Chiesa Collegiata di Santa Maria della Scala from UAV photogrammetry.

before building renovation process. The relevant staff conducts comprehensive surveying and mapping and disease investigation of the renovated buildings. These damaged buildings also have structural safety problems to a certain extent. UAV not only consumes human, material and financial resources, but also poses a threat to the life safety of surveying, mapping and designers. The 3D point cloud model is used for fine mapping of the size of each part of the building to be renovated, and it also measures the foundation settlement and the inclination angle of the building wall to provide accurate data for structural reinforcement. The 3D point cloud model is combined with the scheme design model to assist in the adjustment of the design scheme and realize the real-life expression of the design scheme. It also provides decision-makers with an intuitive and visual effect presentation to accelerate the progress of the design scheme.

In the revitalization and renovation design project of Fenghuang Village in Shenzhen, China, the designer intends to transform one of the severely damaged Cantonese houses into an open book bar that integrates with the original building. In order to preserve the wall texture of the original building to the greatest extent, retain the traces of the years and create an open reading space, on the premise of reinforcing the original wall, the designer builds a new functional module with a light steel structure skeleton, and places the main load-bearing structure on the ground to reduce damage to the wall. By considering the combination and comparison of the point cloud data model and the design scheme model, the relationship between the new structure model and the original site can be clearly mined, which improves the accuracy of the scheme, as show in Figure 7. Based on the real scene expression of the design scheme model in the point cloud model,

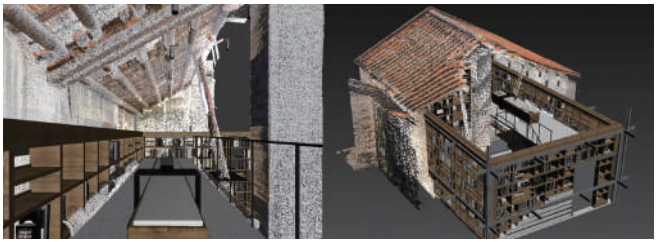

Figure 7. The point cloud model combined with the design model.

the fusion relationship between the design scheme and the surrounding texture, the layout relationship between old and new buildings, and the coordination relationship between materials and colors can be fully presented. The final design scheme is shown in Figure 8.

5. Conclusions

In the application of the protection of historical building, UAV photogrammetry technology not only improves the efficiency of cultural relics protection work, but also provides more accurate building and surrounding environment data. It is a major technical change to the way of mapping work and design renovation of historical buildings, which improves the traditional method of only relying on tape measures, rangefinders, and manual drawing. With the development of drone technology and the continuous progress of related software, UAV photogrammetry technology will be more widely used in the protection of historical buildings. It will become an important role in scientific and technological protection of historical buildings. In the future, the combination of UAV photogrammetry technology and BIM to establish a 3D model of historical buildings with high-precision and all elements. It will provide more complete and abundant information for the protection and revitalization of historical buildings.

Acknowledgements

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Figure 8. On the cover: The final design scheme of the project.

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