

# Facade measurement of building along the roadway based on TLS and GIS of project supervision

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**Abstract.** In view of the traditional surveying and mapping, such as total station measuring tape measure method is applied to building facade measurement of low operation, data precision, incomplete information, etc. as well as large quantities of urban and rural landscape building facade renovation project fund accounting, planning management and project controls. Research based on point cloud data map facade map site plan, based on the UAV remote sensing image, using c#+AE integration facade renovation management in the whole process of data and business processes to develop GIS system, for the urban road construction project planning, management, provides a quick and precise integration technology platform, "city double repair" in the current urban renovation related engineering information management has practical value.

## 1. Introduction

Facade reconstruction measurement of building along the road is to measure of old buildings, provide the original information for design data[1-2], and use traditional tape measure with hand painting, total station, and other surveying and mapping methods in the face of the problems such as the old buildings' complex structure, difficult collection, incomplete information, etc. Unmanned Aerial Vehicle (UAV) remote sensing technology for spatial data acquisition is a new method developed after spaceflight, aviation remote sensing technology, which can achieve real-time transmission of image, with the remote sensing image to fast acquire the high-resolution and high-definition ground target objects. At the same time, it has low cost and good mobility, which effectively supplements and enhances the shortage of the satellite remote sensing and manned aerial remote sensing[3]. Terrestrial Laser Scanning (TLS) is measuring the time needed for laser transmission or phase difference between two points for spacing, and using the principle of for the conversion of triangular geometry for scanners space position and scanning angle to get the cloud data of the surface point of the object, and it is a non-contact measurement method with wide[4-5]. There are important values in architectural measurement modeling, deformation monitoring, fine mapping of ancient buildings, digital cultural heritage and digital urban planning, etc [6-8].

In recent years, the application of UAV technology to architecture has become an important research topic by domestic and foreign scholars. Metni and Hame successfully used the UAV system



to monitor and repair bridges and construction applications[9]; Rathinam et al. used the visual technology of UAV to detect the linear structures of pipeline, road and bridge, canal, power grid, etc.[10] Du Caihong took the application of UAV to Ningxia region of the Yellow River as example, using the UAV photogrammetry data processing system (GodWork) to verify the current UAV image accuracy can meet the needs of the current image processing [11]. Stamos and Aleln from Switzerland used 3D laser scanning techniques to reconstruct the St. Pierre's cathedral[12]. P.K.Allen and I.Stamos et al. successfully developed a relatively comprehensive 3D laser measurement system, which uses the 3D data information obtained to produce the results needed for the construction project [13]. Zhao Xu et al. used 3D laser scanning data to extract and construct the 3D information model of large cultural relics in Yungang grottoes[14]. Li Bijun used 3D laser scanner to acquire the space geometric data of buildings, and filter the information on the parts of the buildings from the point cloud data for analysis, assisting in smooth progress of construction[15]. These research work has received good results, but so far, there is no the report on database system management based on aerial image and point cloud data that is applied in the building reconstruction project.

In March 2017, Xiamen was in the second batch of ecological restoration city repair(hereinafter referred to as "city double repair") pilot among 19 cities. To realize quick measurement of building facade and serve the whole cycle management of the facade, based on the actual work of the building facade renovation on the both sides of the 30 km part of Tongji Road and Binhai West Avenue in Tong'an District, Xiamen, this paper took the UAV remote sensing images combined with 3D laser point cloud data to map site plan, facade, etc. and eventually build facade measurement and GIS platform of supervision with the complete process materials including integrated UAV remote sensing maps, facade measurement results, planning design and reform effect pictures, etc, with the reference for the city "double repair" building facade renovation project.

## **2. Site-plan drawing based on aerial-photo data**

### *2.1. Advantages of site-plan drawing based on aerial-photo data*

In the process of drawing the site plan of Tongji Road in Tong'an District, Xiamen, using low air UAV aerial photography can obtain the remote sensing image data quickly, efficiently and extensively, and the drawing of the site plan is carried out on the image graph. At the same time, the measurement and drawing are made for the buildings on the both sides of Tongji North Road in Tong'an District, Xiamen. The purpose of measuring the site plan, on the one hand, the corresponding edge of each building can take matching data management for 2D graph. On the other hand, through the correspondence between Facade and site plan of the road buildings, more intuitive understanding of the whole situation of the road can be realized, providing the data source with good integrity for the Facade reconstruction of the buildings in the future.

### *2.2. Site-plan drawing based on aerial-photo data*

Based on the orthogonal projection of UAV aerial data's spatial resolution at centimeter level, it can fully display the distribution and surrounding environment of the buildings with facade renovation, and reproduce the position of each facade clearly at the same time, providing positioning information basis for the implementation and result integration of facade measurement. In this paper, the facade measurement for the buildings on the both sides of Tongji Road in Tong'an District, Xiamen was taken as work object. Since the renovation objects are the Facade of the buildings on either side of the main road, it is planned that the route acquired by UAV remote sensing image is 200m along the road as the aerial-photo area, as shown in figure 1 that is about aerial-photo area and the aerial-photo route plan.

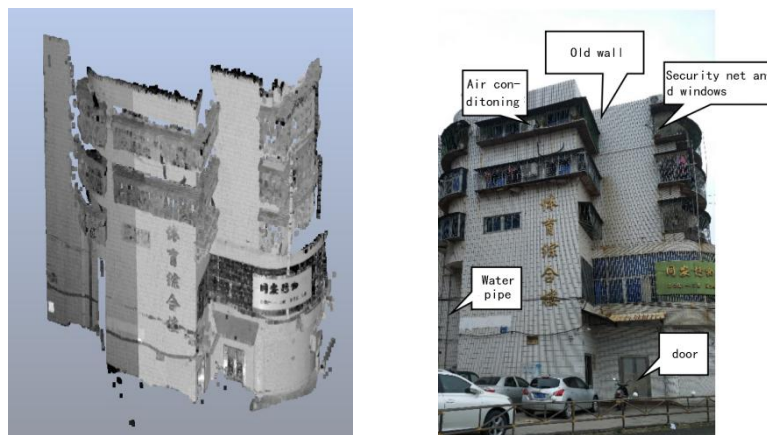


**Figure 1.** Aerial-Photo area

### 3. Acquisition of facade results based on point cloud data

#### 3.1. Fieldwork measurement of the facade of 3D laser buildings

The 3D laser scanner can obtain the complete data of the facade of the buildings and ensure the accuracy and quality of the data, which cannot be obtained by traditional measurement methods. For each side of a building, the objects of each side include doors and windows, shop recruit, billboards, air conditioning, water pipes, power lines and building texture elements, etc. As shown in figure 2, point cloud data obtained through 3D laser scanner can fully display all kinds of information on the building facade.



(a) Point cloud data of buildings      (b) Physical photo of buildings

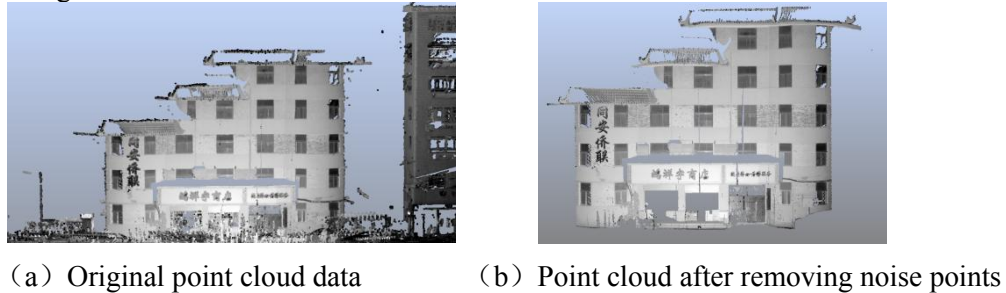
**Figure 2.** Objects of the building facade reforming

#### 3.2 Interior work of the facade of 3D laser buildings

**3.2.1 Preprocessing of point cloud data.** The preprocessing of point cloud data collected by 3D laser scanner is mainly used in FARO scene software. Preprocessing process mainly includes the import of original point cloud data, noise point removal, registration and connection, filtering simplification and the export of original Facade's point cloud data, etc., of which the purpose is to make the point cloud data of different scanning sites accurately match and unified to a specific coordinate system, so that various kinds of information extraction, 3D physical modeling and quantitative analysis can be made for the research object.

(1) Denoising simplification. The main procedure for the removal of noise points is to project the point cloud data onto the orthogonal plane, and based on elevation information of the point cloud, to

adopt the way of human interaction to eliminate the scattered points floating around the building and in the air, as shown in figure 3 for the effect before and after denoising simplification of point cloud data of the building facade.

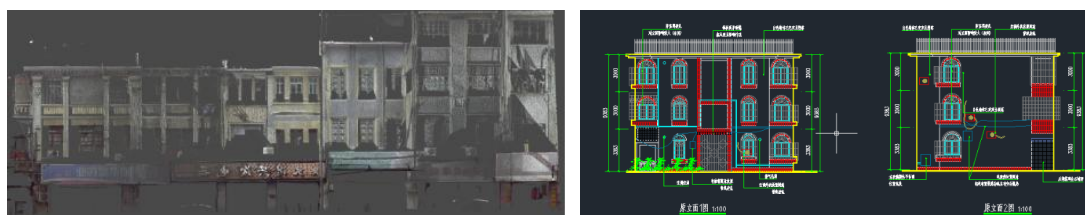


**Figure 3.** Removal of the noise points of laser point cloud

(2) Registration and connection. In this paper, the method of artificial registration with target is adopted, and the registration method is fast and accurate. After the registration of building facade on the point cloud data, both have three-dimensional measurable coordinate information of the space point, which can be more accurate, more intuitive for all kinds of spatial information of building facade including windows and doors, billboards and the position of air conditioning and so on.

**3.2.2 Two-dimensional drawing of building Facade.** In the drawing of building facade, first, the coordinates of the point cloud data should be defined to make the point cloud Facade as orthographic projection image, and then the two-dimensional information extraction is carried out, to ensure the surface integrity and accuracy of structural line. After that, the image data of the corresponding buildings collected from the actual scene can be used to produce the two-dimensional drawing of each surface of the building by Tangent software.

RGB color information of each pixel of the live-action images integrates with laser point cloud data, realizing the display of true color of the target's point cloud data. As shown in figure 4 (a), it is the orthographic point cloud of the true color of the building Facade in some commercial area on Tongji North Road. Based on point cloud data of the building facade, the two-dimensional line drawing of the building Facade is carried out, and this method not only is characterized by high precision, high efficiency. The 1:100original facade diagram of a building based on point cloud data is as shown in Figure 4 (b).

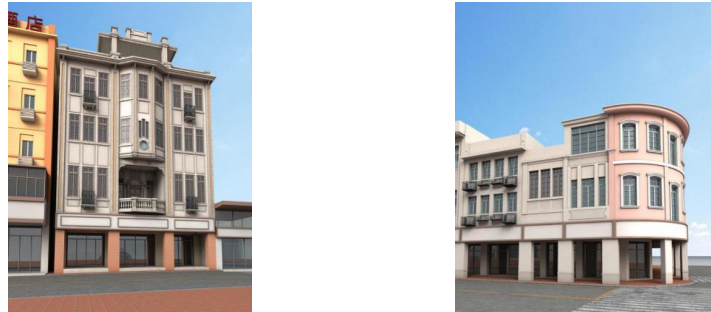


(a) The orthographic point cloud of the true color of the building (b) Original facade of building

**Figure 4.** Acquisition of the two-dimensional line drawing of the building facade

**3.2.3 Appearance design of building facade.** The main idea of 3D modeling based on 2D line drawing is to use the structure line to generate the plane, and import the CAD file of 2D line drawing into 3DMax software to complete the real 3D modeling of the building. Based on point cloud data, it can be concluded that the 2D line drawing of building components have the associated relationship in location. The complete building structure is obtained by rotating capture, creating 3D physical model one by one. In accordance with the requirements of project planning, the field photos of the building Facade are completed through photoshop, making the building facade more clear and beautiful. Then, by using the processed photos, the three-dimensional physical model is made for stickers, finally

obtaining the real 3D model design of the complete building construction. As shown in figure 5, it is the design of the facade of the building with historical features.



(a) Effect on the historical building facade Reform (b) Effect on the commercial building facade reform

**Figure 5.** Effect on the building facade reform

Through the site plan of the buildings on both sides of the road, the overall distribution of the buildings on both sides of the road can be found. By looking at the graphic plane of the house, the serial number of all facades of the building can be viewed. Then, in the corresponding effect drawing of the building Facade, all Facade pictures of the building can be quickly and accurately found. Through the “integral-detailed” “general plane – detailed Facade”, the results of the reconstruction and measurement of the road buildings’ Facade are completely and accurately filed. Through the corresponding filing of the building facade pictures and the road site plan, it makes measurement results more complete, intuitive, and vivid, and also provides the most accurate and fastest query data source and important technical support for subsequent building facade reform.

#### **4. Design and construction of GIS platform of facade construction supervision**

##### **4.1 Design of GIS platform of facade construction supervision**

*4.1.1 System function design.* The main purpose to develop the building facade data management system is to conveniently manage a huge amount of facade data results, and make name, point cloud data, CAD plane and CAD 2D elevation lines of each building correspond one by one to constitute a complete data management pattern, so as to be convenient for management and archiving, provide data for subsequent work.

Based on the system, in terms of the functions of browse query and data management to achieve the goal of building Facade management information system position in initial stage and present stage, the main function is divided into three types, including remote sensing image browsing, data query, graphics library management, and so on.

(1) Remote sensing image browsing: load remote sensing image of reconstructed Facade building complex; browse, zoom in, zoom out, wander, change base map, and select layer for selected images.

(2) Data query: By clicking on the point coordinate of the reconstructed Facade building, the system can select the corresponding layer elements to carry out related object data query, and cooperate with the related fields to make related queries.

(3) Graphics library management: The image data is stored in the database; through the system operation the external graphics image is imported, and the image is deleted and replaced; the progress of the project is reviewed.

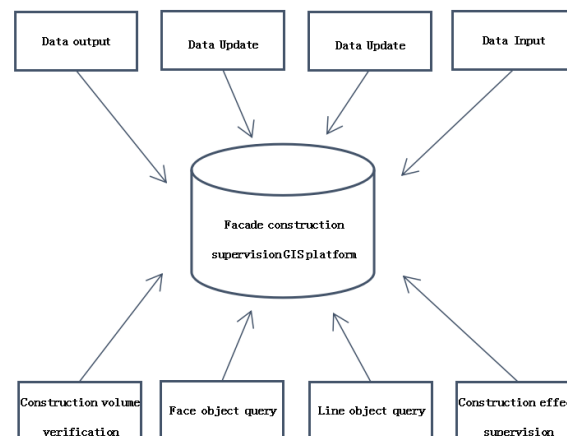
*4.1.2 System structure design.* Platform selection: to meet the project requirements, the system design uses Windows operating system, PC equipment, ArcGIS Engine Runtime as the current computer hardware and platform of software operation.



Application environment selection: the system design uses Microsoft Access database as the data management center of the system and make the ArcGIS secondary development tool and Access database connected to achieve the system design function demand.

Application module design: the system design is divided into image browsing module, data query module, image library module. Through the functional requirements for the rationalized distribution, it makes the system functional modular with integrity.

After consideration, for the design of the system structure, it selects the Microsoft Access database, ArcGIS engine secondary development tool, Visual Studio platform and ArcGIS 10.2 operating environment to meet the system structure design requirements. The functional structure of the GIS platform of building Facade supervision is as shown in figure 6.



**Figure 6.** The functional structure of the GIS platform

## 4.2 Construction of GIS platform of facade construction supervision

**4.2.1 Source of system database.** The system mainly uses the geodatabase model, and the map objects in the graph are designed by using the main interfaces such as Imap and IGraphicsContainer, etc. The main database of system design includes basic database, spatial database, resource database, planning database, etc.

(1) Basic database: Basic data includes vector data and raster data.. The specific data directory is shown in table 1.

**Table 1.** Basic data

Type of data	Thematic types	Thematic elements
Vector data	Building distribution	Towns and villages
	traffic	Tongji Road
	Building facade point cloud	Doors, windows, pipes, billboards
	Building facade two-dimensional line drawing	Doors, windows, air conditioners, walls
	Building type	Hut, building in the room, broken room
Raster data	Digital remote sensing image	Aerial video along the route
	Building facade image data	Picture

(2) Spatial database: Spatial database mainly includes UAV orthophotoquad of housing complex, subject image after cutting, plane design, etc. Based on the spatial database construction, it provides the foundation of spatial data for the system, and is associated with the function development of the system. The function of the database system is realized based on spatial database as benchmark.

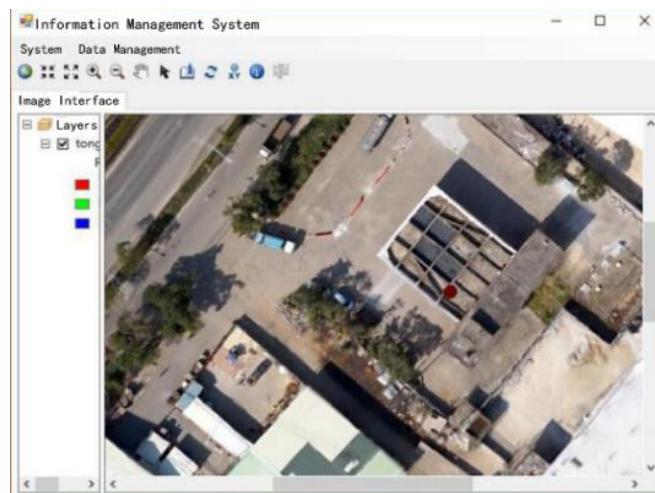
(3) Resource database: Resource database mainly manages various data on the building including the name, the geographical position and the house number and so on of the building, as well as the building surface information including scanning data, CAD elevation data, construction audit and so on, to realize the visual display of the facade information. At the same time, the information of this part is displayed in the data interface of the system.

(4) Planning database: Planning database will manage and store building data before reform, planning pictures, pictures after reform, etc. to realize the system of audit work for building facade renovation. This part in the system interface is displayed and operated in query function module.

**4.2.2 Realization of system database.** The external facade database management system is divided into three parts: image interface module, data management module and data interface module.

(1) Image interface module: The main interface of the system shows the remote sensing image of the building with the reformed external facade, and users can browse, enlarge, narrow, wander, change base map and select layer for the selected maps.

In image interface module of the system, users can choose to view the building needing reform the facade, and by clicking on the location of building, the system will relate the coordinate data of the building to spatial database information, resources database information, planning database information of the building. Figure 7 is the operation diagram of the system image interface module.



**Figure 7.** Operation image of system's image interface module

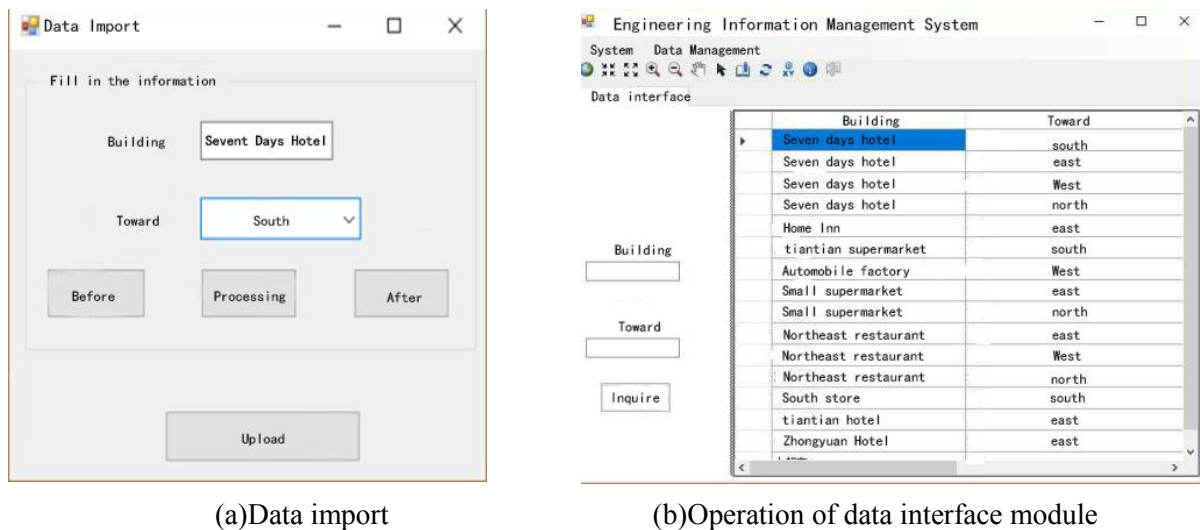
Upon operation in image interface, by clicking on the building, the system generates round taps in the related position in images. By calculating the coordinate range of the buildings in the coordinates, the system can retrieve the database information of selected buildings, and jump into the GIS database.

In the interface, it is to click on the wall to edit layer elements, load ArcGIS function, achieve the popup of corresponding metope information windows with the display of realistic picture. On the left side of data interface of the system, it is to input the name of the building to be enquired and the metope direction of the building, the Facade picture before and after reform can pop up.

(2) Data management module: This module is mainly responsible for the input and export of data and images in data interface module. To guarantee the normal work of facade renovation, after clarifying the building with facade renovation work, the basic information is acquired and the information is recorded in the database. When new data is added, data interface module takes the synchronous

updating of the form information. Click the upload button to import the data into the database. This function is shown in figure 8 (a).

(3) Data interface module: The module shows the information of the building with Facade reform in remote sensing images. According to the building name and the wall direction of the building, users will set the parameters, and then click the query system to jump to the query function of facade project. The operation of data interface module is shown in figure 8 (b).



(a)Data import

(b)Operation of data interface module

**Figure 8.** Data import and query interface

The query function of facade project is mainly used to display the facade pictures of the building selected in data interface before reform, in planning, and after reform. The function also provides the building point cloud data and backup data of CAD facade data for the system, and the audit of the Facade reforming work by the audit personnel is also completed in this part. Figure 9 shows the pictures of the building before reform, in planning, and after reform.



**Figure 9.** Pictures of the building before reform, in planning, and after reform

The point cloud data and two-dimensional facade data can be also downloaded. By clicking the two buttons above, the required data can be downloaded respectively. The system also provides a verification of the building Facade reform. On the one hand, it is whether the supervision and reconstruction achieve the design standards. On the other hand, it is whether the supervision construction work calculation is accurate. After the operation on the facade of each building, by



clicking update, the data can be saved. Realizing the objectification management of the three facades is the characteristic of this system.

## 5. Conclusion

With the buildings on Tongji Road in Tong'an District, Xiamen as research object, this study carried out the research on the management of the measurement data database system of the facade reconstruction project of the road building, with main design of the road building's site plan drawing and the acquisition of 2D data for building Facade, mapping Facade's site plan based on point cloud data and UAV remote sensing image, using C#+AE to integrate the whole-process data in the facade renovation and business process to develop GIS system, so as to provide fast and precise integrated technique platform for the urban road construction project planning and management, with practical value for current "city double repair" take engineering information management of urban renovation.

## 6. Acknowledgments

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