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Building Facade Acquisition and Restoration Generation Method Based on Point Cloud Plane Boundary Extraction Algorithm

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Abstract: In response to the current problems of slow acquisition speed, unclear images, and great difficulty in the restoration of building facades, this article analyzed the acquisition of building facade information and performed noise segmentation, texture correction, color adjustment, and texture cutting on the original building images. The process of building facade restoration was optimized based on the method of obtaining the facade. The building image was generated into a facade image and further analyzed using edge detection and contour extraction. The point cloud plane boundary extraction algorithm was used in the acquisition and restoration of the building facade to study the depth value of the building facade. This article analyzed the errors, structural similarity, operating time, and computational complexity in obtaining and repairing building facades. The study found that the efficiency of building facade acquisition under cloud images on the second day was 82.40%-94.50%, an increase of 11.57% compared to the first day. The efficiency of facade image restoration was 80.40%-94.70%, an increase of 14.57% compared to the first day. The information acquisition and repair generation of building facade images under digital technology and cloud images have significantly improved the running time and have also had a positive effect on user interaction and experience satisfaction.

Keywords: Building Facade Acquisition, Building Facade Restoration, Digital Technology, Cloud Image, Point Cloud Plane Boundary Extraction
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1. INTRODUCTION

Due to the rapid development of digital cities, the demand for three-dimensional (3D) modeling of cities is also increasing. With the rapid growth of computers, remote sensing, and other technologies, the rapid extraction and reconstruction of three-dimensional landscape facades have become possible, and their applications have penetrated all aspects of social life. At present, the application of satellite remote sensing and aerial photography technology in Earth observation, although its accuracy is constantly improving, is often obscured by other buildings or plants and cannot be fully displayed due to the limitation of observation perspective. This article combines digital technology and cloud image fusion to achieve automatic drawing of building surface contours to solve the occlusion problem of building surface contours, providing theoretical support for accurate drawing of building surface contours and information extraction of building surface contours.

Building facades are important images for analyzing the overall structure of a building, and their clarity and completeness both affect the acquisition and restoration of facades. Many scholars have conducted relevant analyses on the acquisition and restoration of building facades. Guoqing Zhou proposed an optimization method for selecting building facade texture images from the image streams collected by three tilted cameras on a drone [1]. Michele Russo analyzed a close-range photogrammetric survey conducted on the facade of a huge historical building in Bologna, pointing out a good level of accuracy, and confirmed this through the validation of the results through laser scanner surveys [2]. Ekaterini T. Delegou proposed a multidisciplinary approach to the diagnostic research process, quantifying the degree of building materials and decay for each monument facade. Based on facade orientation and historical data, the correlation and better understanding of the impact of the environment on building materials were completed [3]. Wu Jie proposed a new technical framework that utilized crowdsourcing photos and two-dimensional generation of 3D building facade information to address the high-cost issue of current urban building 3D reconstruction. The proposed 3D reconstruction method represents a multi-source data integration process [4]. Barbara Sacchi focused on identifying best practices for protecting building facade images in terms of effectiveness, harmfulness, and durability, especially in terms of light aging and thermal humidity aging [5]. Jose Barros-Ribademar designed an automated method for detecting and characterizing street point cloud occlusion obtained using mobile laser scanning. The proposed method consisted of four main stages: point cloud alignment, rasterization, occlusion point cloud generation, and visibility analysis. The method was tested using point clouds from a dataset [6]. Suvari Anıl determined the average values related to color density by obtaining samples of natural and artificial color changes in tuff, and found that the colors obtained at the end of environmental color mapping can be used for traditional house facades within the range of facade reinforcement activities [7]. The above research has analyzed the acquisition and restoration of building facades, but there are still problems with long running time and low efficiency in information acquisition and restoration.

Cloud images and digital technology have a wide range of applications in the acquisition of architectural images, which can quickly obtain elevation information and image contours. Many scholars have analyzed the application of cloud images and digital technology in architectural images. To address the main obstacles of the lack of security and privacy assurance in cloud based image processing systems, Zhang Qin studied the design goals and technical challenges of constructing a cloud based privacy protection building facade image processing system [8]. To examine the pathological manifestations of building exterior walls, Ramiro Daniel Ballesteros Ruiz reported on the use of drones as visual data collection tools in the construction, engineering, construction, and facility management industries. The activity protocol includes image collection and processing stages, as well as a detailed analysis of the collected visual data [9]. Soycan Arzu examined the behavior of methods related to building facade drawings in creating artificial images and applied them to real photography sets of models obtained under different types and cameras [10]. Gardzinska Anna introduced the implementation of ground laser scanning technology as a non-invasive method while providing the ability to transmit captured image elements with high precision [11]. Tugba SARICAOGLU introduced a comprehensive strategy for obtaining orthophoto images using ground laser scanning and photogrammetry techniques [12]. The above studies have all discussed the application of cloud images and digital technology in building facades, but have not analyzed the restoration of building facades under cloud images.

In order to study the main application effects of digital technology and cloud images in the acquisition and restoration of building facades, this article analyzed the depth values of buildings through point cloud plane boundary extraction algorithms. In the experiment, the integrity, smoothness, and clarity of building facade acquisition and restoration were studied. The research results confirmed that cloud imaging and digital technology could improve the operational efficiency of building facade information acquisition and restoration, improve the quality of image acquisition and restoration, and also meet the needs of rapid and high-precision acquisition, processing, and mapping of facade acquisition and restoration work, providing a new, timely, and reliable image processing method for updating urban basic geographic data.

2. BUILDING FACADE ACQUISITION BASED ON DIGITAL TECHNOLOGY AND CLOUD IMAGES

This article analyzes the acquisition methods of building facades using digital technology and cloud images, mainly analyzing the acquisition of building facade information and the processing of building facade data.

2.1 Acquisition of Building Facade Information

When using digital technology and cloud image technology to obtain building facades, on-site measurements, and data collection are first carried out. Then, point clouds are concatenated, and their formats are converted using denoising and blocking methods. Finally, the elevation is drawn.

2.1.1 Site Investigation and Data Collection

Based on on-site investigation, corresponding observation points are selected based on site conditions. During data collection, the collected objects are placed within the scanning area of the cloud image collector to observe the point cloud overlap area between the two sites. At the same time, real-time mapping of the station layout and taking photos of the measurement points are carried out to ensure the smooth progress of subsequent data processing work.

2.1.2 Point Cloud Splicing

To eliminate the influence of visual obstruction and scanning distance of the scanner itself, the contour information of the building surface within the measurement area is accurately obtained. By setting up multiple stations, the point cloud data obtained by the stations is concatenated. The point cloud merging function is utilized to flip and translate the existing point cloud. The original point cloud data is pieced together, and error detection is performed until all point clouds of each building in the same area are pieced together to obtain the overall layout and other information of the building.

2.1.3 Noise Removal and Point Cloud Segmentation

When point cloud stitching is completed, the point cloud data within a single area usually reaches tens of billions of levels. In order to improve the efficiency of data processing, useless point clouds within a single area are removed and then partitioned to obtain simple and direct building plans and information on various elevations. On this basis, through methods such as rotation, translation, and scaling, the rotation, translation, and scale conversion of existing point cloud data are achieved to eliminate roads, trees, vehicles, etc., from nontarget point cloud data. The angle is adjusted in the order of forward and lateral projection, and the polygon clipping tool is used to segment unnecessary point clouds that have been removed. The point clouds of the top view and each elevation of the building are saved as an independent document. The specific noise segmentation of the building cloud image is shown in Figure 1.

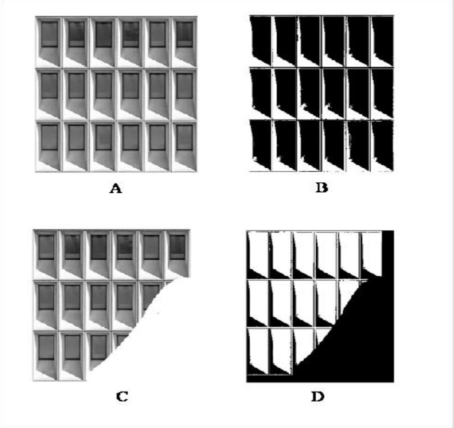

Figure 1: Image noise segmentation of building facades.

A: The original image of the building facade
B: The noise segmentation of the original image of the building facade
C: The original image of the building facade occlusion
D: The noise segmentation of building facade occlusion

Figure 1A shows the original image of the building facade, and Figure 1B shows the noise segmentation of the original image of the building facade. Figure 1C shows the original image of the building facade occlusion, and Figure 1D shows the noise segmentation of the building facade occlusion. After noise segmentation of building facade images, noise can be reduced, making the information on building facade images easier to obtain and helping to understand the content of building facade images. In addition, noise can affect the accuracy of building contours and structures in the acquisition and restoration of building images, and noise segmentation can improve the quality and accuracy of building reconstruction.

2.1.4 Format Conversion and Export

In the point cloud data of each facade, important building size information such as wall contour points and door and window corner points are measured, and the size information of each facade wall, door and window, and other features is annotated to complete size measurement and annotation of each facade information. By switching to the front view and zooming in to the full image, the file is exported as an image file on the main interface.

2.2 Building Facade Data Processing

Real 3D data is utilized to obtain a dataset of building facades and facade windows in building facades. Based on the real 3D data, patch clustering clusters of each building included in the real 3D data are obtained, and the external contours of each building are identified and extracted. Based on the external contour of the building, the external contour of the building is calculated. Under pre-set constraints, the exterior contour lines of the building are extracted to obtain the exterior contour lines. Building facades are classified to obtain a dataset of hollow windows on building facades. By processing the template image of the reflective window, the template image is obtained. The template image generated by the repair is used to repair the building facade and obtain the repaired building facade.

When storing elements, only information about a single element is not enough. At the same time, all elements within the grid on the facade are numbered. During the renovation, based on the data of peripheral elements, the database is queried to find the most similar elements and arranged in the grid on the facade. The information of the unit itself is used to search for seed elements. The grid structure is used to determine the expansion direction during layout, and the grid spacing is used to determine the expansion distance of the unit.

2.3 Facade Texture Image Processing of Buildings

2.3.1 Pre Processing

The extraction of facade textures from cloud images is carried out. Through preliminary processing, the approximate range of texture collection can be determined, and rough adjustments can be made to colors and brightness. The specific texture image processing includes texture correction, texture cropping, and texture color adjustment, as shown in Figure 2.

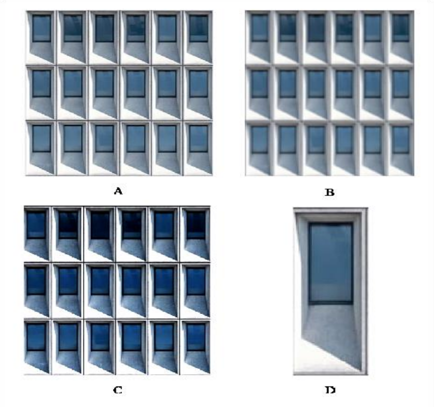

Figure 2: Texture rectification, cutting, and color adjustment of building facades.

A: Original building elevation
B: Rectification of building facade texture
C: Color adjustment of building facade texture
D: Building facade texture cutting

Figure 2A shows the original building elevation, and Figure 2B shows the texture rectification of the building elevation. Figure 2C shows the color adjustment of the building facade texture, and Figure 2D shows the cutting of the building facade texture. After texture rectification, the texture of the building becomes clearer and orthographic, which can avoid inaccurate image restoration caused by texture occlusion in the building facade image. After color adjustment, the image color of the building facade becomes more rich, which can increase the visual appeal of the image. In the texture cutting of building facades, the main method is to select the most frequently occurring part in the facade image, which can conveniently analyze the overall facade from local images in the facade image [13-14].

2.3.2 Texture Rectification

In cloud images, the texture of the building facade produces some tilting. Therefore, in order to obtain a true building facade, it is necessary to correct it to an orthorhombic shape. To solve the problem of cloud images being obstructed by other objects due to factors such as perspective during the shooting process, the damage in the texture of building facade images stored in the form of image data has been repaired for future 3D reconstruction, so it should be improved as much as possible.

2.3.3 Texture Cutting

Due to the large amount of texture data obtained from building facades and the presence of a large amount of duplication, it is necessary to classify and cut them [15]. Texture cutting is divided into two categories: textures with unique features and textures with a large number of duplicates. By adjusting and correcting colors, distinctive textures are processed. Local textures with repetitive properties are extracted and the entire texture can be obtained using texture stitching technology.

2.3.4 Texture Color and Data Adjustment

During the shooting process, due to factors such as light, weather, and time, there may be certain differences in color between the obtained aerial photos and the actual photos. Therefore, image processing software is used to adjust the contrast, brightness, and other aspects of the obtained texture. When using texture for 3D reconstruction, the texture size is appropriately adjusted according to the simulation requirements [16].

3. BUILDING FACADE RESTORATION BASED ON DIGITAL TECHNOLOGY AND CLOUD IMAGES

3.1 Building Facade Restoration Device Based on Digital Technology and Cloud Images

The building facade repair equipment used in this article mainly includes processing modules, generating modules, mask repair modules, and repair generation modules. The processing module utilizes real-life 3D data to obtain a dataset of building facades and facade windows in building facades. Based on the window data of the building facade, the position of the hollow window of the building facade is determined, and the mask image of the facade window is generated. The mask repair module mainly repairs the mask image of the facade window and obtains the repaired mask image [17]. The repair generation module uses repair to generate a model. Based on the repaired mask image, the building facade is repaired to obtain the repaired building facade.

3.2 Generation of Building Facade Restoration

Before the production of facade repair engineering, the first step is to establish a database of facade elements, which includes facade elements and their distance from peripheral elements. After calculating the frame structure of the facade and obtaining the facade, the facade is repaired and generated. The facade restoration section is mainly divided into three steps: facade data input, database retrieval, and element arrangement [18]. Firstly, a building is selected to analyze its bottom features, and then the facade is generated. The specific operation is shown in Figure 3.

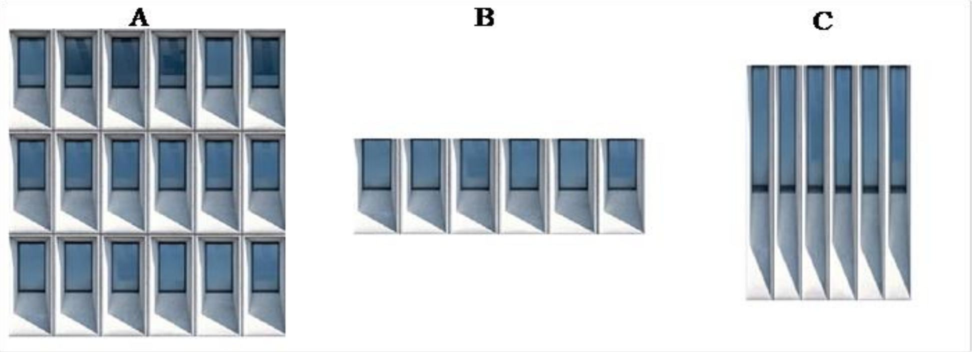

Figure 3: Building facade generation image.

A: Original buildings
B: Image of the bottom of the building
C: Building facade image

In Figure 3, A represents the original building; B is the image of the bottom of the building; C represents the building facade image. From the figure, it can be seen that the generated building facade image is stretched based on the original image, and the facade image can display the details of the building more clearly.

3.2.1 Facade Data Input

This article conducts data processing on the repaired facade and uses cloud images to reconstruct the facade to obtain the framework structure of the facade and estimate its longitudinal spacing. By extracting and simplifying images, the saved elements on the facade are encoded to obtain basic information. After the code is written, it can be stored to store the topological relationships between elements and the data information of the elements themselves. Topological relationships record adjacent elements between existing elements on top, bottom, left, and right. This article uses two methods, Canny edge detection, and Sobel operator edge detection, to detect the edges of building facades and obstructions. The specific edge detection is shown in Figure 4.

A: Canny edge detection of building facades and occlusion
B: Sobel operator edge detection for building facades and occlusion

Figure 4A shows Canny edge detection of building facades and occlusion. Among them, A1 is the original image of the building facade, and A2 is the edge detection of the building facade. A3 represents the original image of building facade occlusion, and A4 represents the edge detection of building facade occlusion. Figure 4B shows the Sobel operator edge detection of building facades and occlusion. B1 represents the original image of the building facade, and B2 represents the edge detection of the building facade. B3 represents the original image of building facade occlusion, and B4 represents the edge detection of building facade occlusion. The contour of the building facade and occluded cloud images are clearer after edge detection, making it easier to further obtain and repair the information of the building facade based on the contour.

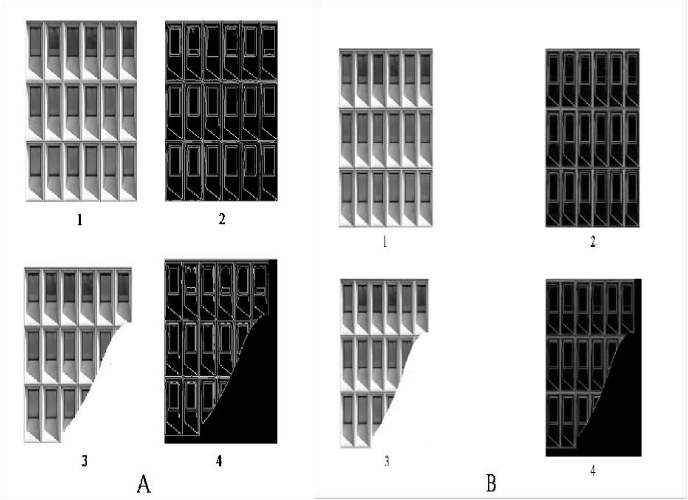

Figure 4: Different edge detection of building facades and occluded images.

3.2.2 Retrieval of Building Cloud Images

The search for databases can be divided into two stages. One is the search of unit topology relationships, which uses existing cloud map topology information to find cloud maps with high similarity from the database and search for peripheral code relationships of the searched units. Among these conditions, the most important are topological relationships and element codes. According to the corresponding rules, elements are extracted for similarity. The interrelationships between various elements and the information contained within each element are extracted based on their building facade images. Two types of images, namely building facade images and missing building facade images, are used for contour extraction. The specific process is shown in Figure 5.

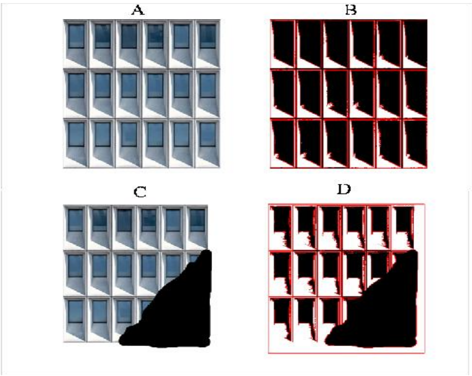

Figure 5: Outline extraction of building facade images.

A: Original building image
B: Contour extraction image of the original building image
C: Original building missing image
D: Contour extraction image of the original building missing image

In Figure 5, A is the original building image, and B is the contour extraction image of the original building image. C is the missing image of the original building, and D is the contour extraction image of the original building's missing image. It can be seen that under contour extraction, the contour extraction of the complete building facade image is more in line with the original image, while the missing image does not extract the shadow part in the image contour during contour extraction.

3.3 Algorithms for Extracting Plane Boundary of Building Point Cloud

The basic idea of a building point cloud plane boundary line extraction algorithm based on depth images is first to segment the point cloud coordinate data into targets and then convert it into a two-dimensional depth image, including establishing reference planes and interpolating depth values. The boundaries of depth images are detected, and the correspondence between depth values and point cloud coordinates is utilized to extract building point cloud boundaries.

Building plane segmentation is a complex task, as point cloud data does not carry any connection information or provide any semantic features of the underlying scanned surface [19]. Threshold segmentation is performed based on the distance from the point to the building wall, and a dataset is set on the building wall. The wall plane formula and vector are obtained using the orthogonal global least squares method.

$$m(a-\bar{a})+n(b-\bar{b})+z(c-\bar{c})=0 \tag{1}$$

In the formula, m, z are the parameters to be solved for the fitting plane.

$$\bar{a}=\frac{1}{k}\sum_{i=1}^{k}a_i,\bar{b}=\frac{1}{k}\sum_{i=1}^{k}b_i,\bar{c}=\frac{1}{k}\sum_{i=1}^{k}c_i \tag{2}$$

The sum of squares of the distances from each point to the fitting plane is:

$$W(m,n,z,\bar{m},\bar{n},\bar{z})=\sum_{i=1}^{k}\frac{[m(a-\bar{a})+n(b-\bar{b})+z(c-\bar{c})]^2}{m^2+n^2+z^2} \tag{3}$$

The overall least squares fitting considers minimizing $k(m,n,z,\bar{m},\bar{n},\bar{z})$, and the matrix is assumed:

$$M=\begin{bmatrix} a_1-\bar{a},b_1-\bar{b},c_1-\bar{c} \\ a_2-\bar{a},b_2-\bar{b},c_2-\bar{c} \\ \ldots,\ldots,\ldots \\ a_n-\bar{a},b_n-\bar{b},c_n-\bar{c} \end{bmatrix} \tag{4}$$

M is decomposed into features, and when the eigenvector corresponding to the minimum eigenvalue of the matrix M $\vec{n}=(a,b,c)$ is, $W(m,n,z,\bar{m},\bar{n},\bar{z})$ is substituted to obtain the wall plane formula, and then the distance n from the cloud dataset to the fitting plane is calculated.

$$w_i=\frac{\left|m(a_i-\bar{a})+n(b_i-\bar{b})+z(c_i-\bar{c})\right|}{\sqrt{m^2+n^2+z^2}} \tag{5}$$

According to w_i, histograms and building photos, point clouds are segmented based on different object thresholds δ to obtain building wall, accessory surface data, and other noise data, respectively.

Based on the vector obtained by plane fitting and the rotated vector being $n_2=(0,0,-1)$, the rotation matrix $w(\theta)$ is calculated. The solution process is as follows:

According to n and $n_2=(0,0,-1)$, the rotation angle θ is determined:

$$\theta=\arccos\left(\frac{n\cdot n_2}{|n|\cdot|n_2|}\right) \tag{6}$$

The unit rotation axis is determined from n and $n_2=(0,0,-1)$:

$$w=\frac{(n_2\cdot n)}{|(n_2\cdot n)|} \tag{7}$$

According to the weight formula of the scanning points, by setting different values and using a weighting method, the depth value of the building facade image can be calculated:

$$W_i=\left(\sum_{k=1}^{n_{ij}}m_{ik}\cdot n_{ik}^{k}\right)/\sum_{k=1}^{n_{ij}}w_{ik} \tag{8}$$

By normalizing the grid depth values to the grayscale space, the pixel values of the point cloud depth image corresponding to the grid can be obtained, thereby obtaining the point cloud depth image of the entire scanning area. This article investigates the depth values of facade images under cloud images for 20 buildings, as well as the depth values of facade images under traditional images, and analyzes their errors. A total of two days of investigation are conducted and the results are analyzed, with depth values ranging from 0 to 1. The higher the depth value, the higher the quality of the image. The specific survey results are shown in Table 1.

Building facade image	Traditional image depth value		Cloud image depth value		Building facade image	Traditional image depth value		Cloud image depth value	
	The first day	The second day	The first day	The second day		The first day	The second day	The first day	The second day
1	0.51	0.54	0.79	0.9	11	0.52	0.6	0.75	0.91
2	0.45	0.55	0.72	0.87	12	0.53	0.55	0.66	0.82
3	0.51	0.61	0.77	0.88	13	0.55	0.58	0.68	0.91
4	0.51	0.56	0.76	0.94	14	0.5	0.54	0.67	0.87
5	0.51	0.62	0.76	0.84	15	0.52	0.59	0.72	0.82
6	0.55	0.58	0.72	0.86	16	0.58	0.63	0.79	0.89
7	0.56	0.61	0.77	0.86	17	0.56	0.59	0.71	0.83
8	0.55	0.68	0.78	0.81	18	0.63	0.67	0.72	0.9
9	0.59	0.69	0.73	0.89	19	0.47	0.52	0.79	0.84
10	0.58	0.7	0.64	0.81	20	0.5	0.64	0.61	0.83

Table 1: Analysis of depth values of building facade images using different methods.

According to Table 1, in the analysis of traditional image depth values, the average depth value of the building facade image on the first day is 0.534, with a standard deviation of 0.042. However, the average depth value of the building facade image on the second day is 0.603, an increase of 0.069 compared to the first day. In the analysis of cloud image depth values, the depth values of the building facade images on the first day are lower than those on the second day, and the depth values of the building facade images on the second day increase by 0.137 compared to the first day, while the standard deviation on the second day decreases by 0.014 compared to the first day. It can be seen that the depth value of building facade images based on digital technology and cloud images has significantly improved compared to traditional images. In addition, the depth value of building facade images under cloud images also continuously increases over time. This article extracts and repairs the facades of two buildings through edge detection and morphological operations, with morphological, structural elements [2,2] and a line width of 0.8. The facades of the two buildings are extracted and repaired. The specific extraction and repair process is shown in Figure 6.

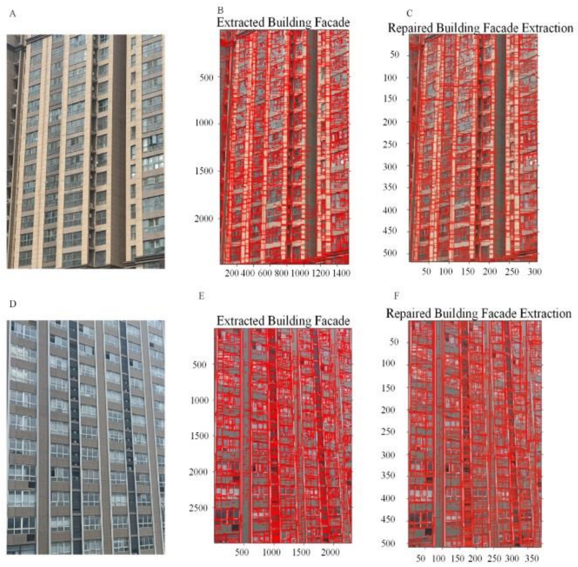

Figure 6: Extraction and restoration of the exterior facades of two buildings.

A: Building 1 image
B: Extraction of the exterior facade of Building 1 image
C: Restoration of the exterior facade extraction of Building 1 image
D: Building 2 image
E: Extraction of the exterior facade of Building 2 image
F: Restoration of the exterior facade extraction of Building 2 image

Figure 6A shows the image of Building 1; Figure 6B shows the extraction of the exterior facade of Building 1 image; Figure 6C shows the restoration of the exterior facade extraction of Building 1 image. Figure 6D shows the image of Building 2; Figure 6E shows the extraction of the exterior facade of Building 2 image; Figure 6F shows the restoration of the exterior facade extraction of Building 2 image. Under edge detection and morphological operations, the facade of building images is clearer, but there are some overlapping edges that affect the extraction of the facade. However, by performing noise removal, edge connection, and morphological operations on the extracted image, the facade image becomes clearer, which can reduce the interference caused by external elements [20].

4. EXPERIMENT WITH OBTAINING AND REPAIRING BUILDING FACADES

4.1 Errors in Obtaining and Repairing Building Facades under Cloud Images

The main purpose of obtaining and repairing building facades under cloud images is to generate images with small errors compared to the original image. Therefore, evaluating their accuracy can measure the application effect of digital technology and cloud images in building facade restoration. This article first analyzed the data errors of real building facades and building facades detected under cloud images and analyzed their point cloud alignment errors and area errors. A total of ten building facades were surveyed and compared with the data errors obtained from traditional building facades. The peak point cloud alignment error was 7, and the peak area error was 25. The specific investigation results are shown in Figure 7.

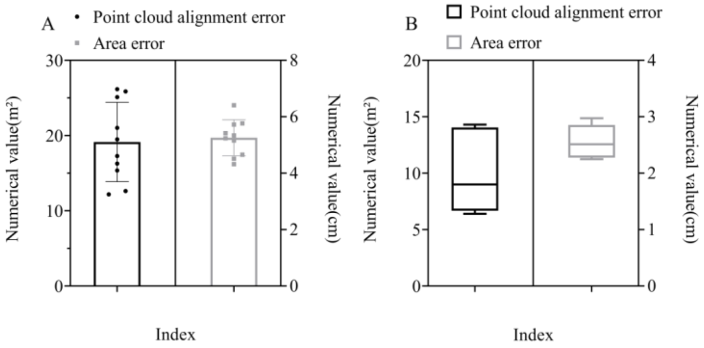

Figure 7: Error analysis of data obtained from building facades under different technologies.

A: Analysis of data error in obtaining traditional building facades
B: Analysis of data error in obtaining building facades based on digital technology and cloud images

Figure 7A shows the error analysis of data obtained from traditional building facades, while Figure 7B shows the error analysis of data obtained from building facades using digital technology and cloud images. Among them, the x-axis is an indicator, and the y-axis is a numerical value. In the data error analysis of traditional building facade acquisition, the point cloud alignment error range was 3.25-6.98cm, with a mean of 5.106cm, an area error range of 16.2-24.04m², and a mean of 19.707m². In the data errors obtained from building facades using digital technology and cloud images, the average point cloud alignment error was 1.994cm, which was 3.112cm lower than the traditional building facades. The average area error was 12.794m², which was 6.913m² lower than the traditional building facades. Digital technology and cloud images have high accuracy in obtaining data on the area of building facades and point cloud alignment, which can reflect the accuracy of the alignment between the original image and the detection image of the building facade. The smaller the difference, the closer it is to the real image.

4.2 Structural Similarity Indicators Obtained from Building Facades

In the acquisition of building facades, the structural similarity between the image and the original image is also particularly important. The higher the structural similarity, the higher the quality. Typically, the value of structural similarity is between [-1, 1] [21]. Therefore, this article investigated the structural similarity between building facade images and original images under cloud images, as well as the structural similarity between traditional building facade images and original images, and compared them to analyze the quality of building facade acquisition under cloud images. A total of 20 buildings were surveyed. The specific investigation results are shown in Figure 8.

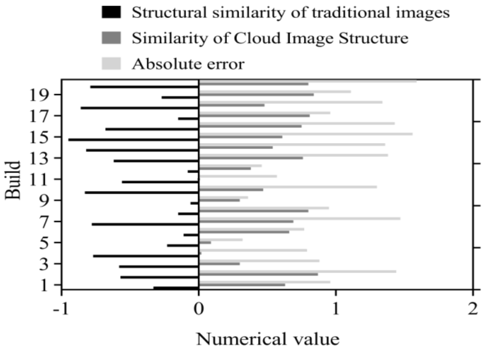

Figure 8: Structural similarity and absolute error analysis of building facade images under different methods

In Figure 8, the x-axis represents numerical values, and the y-axis represents buildings. In traditional facade images, the structural similarity between the obtained image and the original image was negative, ranging from -0.95 to -0.060, with an average of -0.510. In the cloud image, the structural similarity between the obtained elevation image and the original image was positive, ranging from 0.01 to 0.870, with an average of 0.541. In contrast, the structure of the building facade image in the cloud image was very similar to the original image, indicating that the brightness, contrast, and structural information of the image are also more in line with the original image. In the absolute error analysis of structural similarity between traditional facade images and cloud images, the average absolute error was 1.050. The information acquisition of building facade images under cloud images is more comprehensive and more in line with the original building, which facilitates relevant personnel to conduct structural analysis based on their facade images to enhance the structural performance of the building.

4.3 Efficiency of Obtaining and Repairing Building Structural Facades

The efficiency of building facade acquisition under digital technology and cloud images is an important indicator for measuring its methods, and a good image facade acquisition must have efficient acquisition efficiency. This article investigated 10 building facade images and analyzed the efficiency of building facade acquisition and restoration under cloud images [22-23]. A total of two days were surveyed, and 10 building facade images were processed every day. The peak efficiency was 1, with 0.81-1 being excellent and 0.6-0.8 being average. The specific survey results are shown in Figure 9.

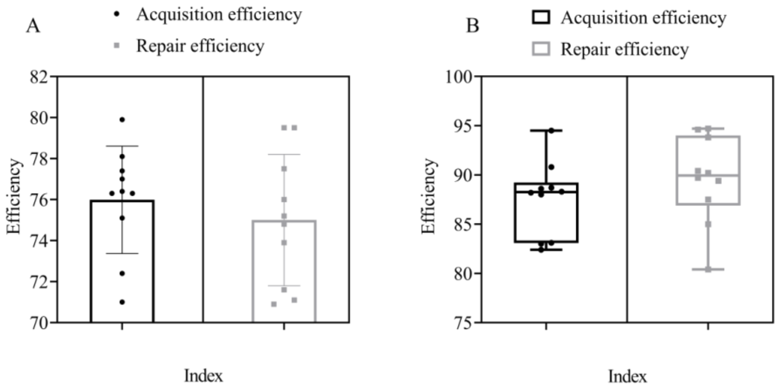

Figure 9: Efficiency of obtaining and repairing building facades within two days.

A: Efficiency in obtaining and repairing building facades on the first day
B: Efficiency in obtaining and repairing building facades on the second day

Figure 9A shows the efficiency of building facade acquisition and restoration on the first day, while Figure 9B shows the efficiency of building facade acquisition and restoration on the second day. Among them, the x-axis is the indicator, and the y-axis is the efficiency.

In the analysis of building facade acquisition and restoration efficiency on the first day, the efficiency of building facade acquisition under cloud images was 75.99%, with a standard deviation of 0.0248, a restoration efficiency of 75.00%, and a standard deviation of 0.0304. The efficiency of obtaining and repairing building facades was average. On the second day of building facade acquisition and restoration efficiency, the efficiency of building facade acquisition under cloud images was 82.40%-94.50%, with an average of 87.56%, an increase of 11.57% compared to the first day. The efficiency of facade image restoration was 80.40%-94.70%, with an average of 89.57%, an increase of 14.57% compared to the first day. This indicates that the acquisition and restoration of building facades in cloud images can improve over time, and the efficiency of both acquisition and restoration is excellent. The acquisition and restoration of building facades are also related to the acquisition of facade image information and the analysis of facade structures. The improvement of acquisition and restoration efficiency can accelerate the analysis of the performance of building facade structures.

4.4 Square Equalization of Building Facade Images

In the acquisition and restoration of building facade images, it is also necessary to perform histogram equalization on the facade image. By redistributing the pixel values of the image, the pixel values in the image can be improved to ensure uniform distribution throughout the entire range, thereby increasing the contrast of the image. This article conducted histogram equalization processing on building facades and occluded images. The specific processing results are shown in Figure 10.

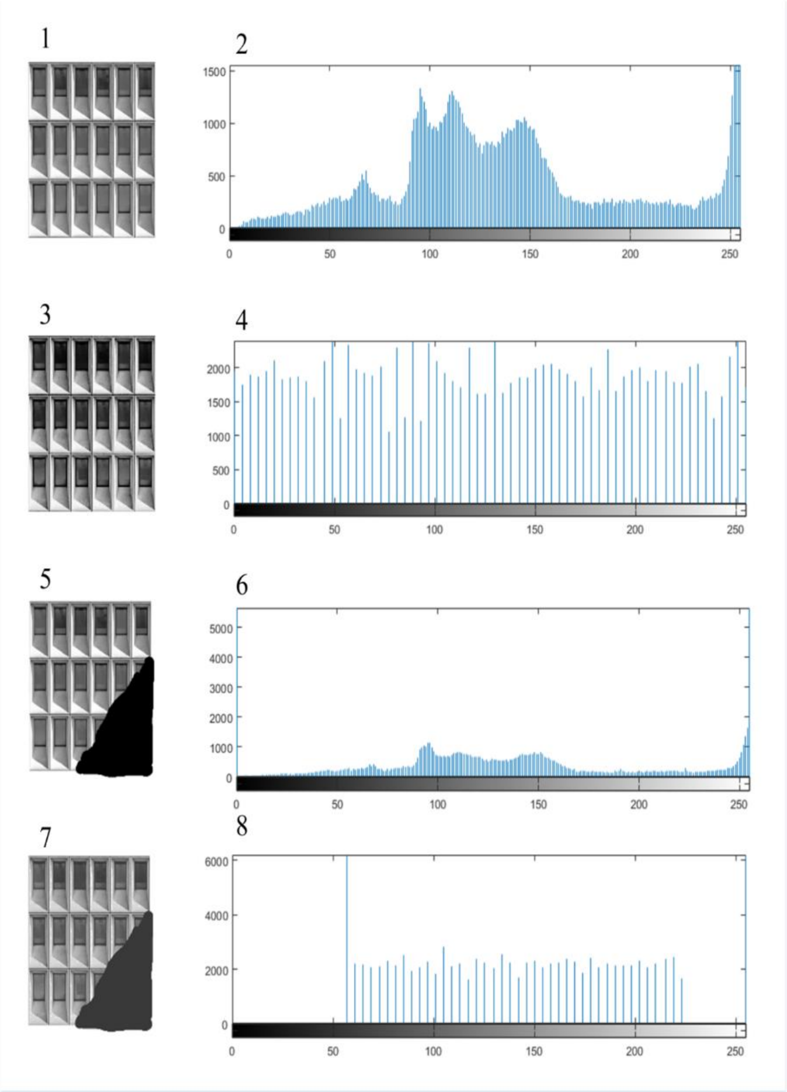

Figure 10: Square equalization processing of building facade images.

In Figure 10, 1 is the original building image, and 2 is the histogram of the original building image. 3 is the original building image after histogram equalization, and 4 is the histogram of the original building image after equalization. 5 is the original building occlusion image, and 6 is the histogram of the original building occlusion image. 7 is the original building occlusion image after histogram equalization, and 8 is the histogram of the original building occlusion image after equalization. The original building image and the original building occlusion image have clearer texture details and stronger contrast after equalization.

The histograms of the original building image and the original occluded image were concentrated between 100 and 150, and the frequency of their data was mostly between 0 and 1500. The histogram after histogram equalization was relatively scattered. The frequency of the histogram after equalization of the original building image was mostly 0-3000, while the frequency of the histogram after equalization of the original building occlusion image was mostly 0-5000. This indicates that histogram equalization can map the grayscale levels in the original image to a more uniform range, making the details in the image clearer and more visible. The frequency of the building facade image after equalization has significantly increased, indicating an increase in the number of pixels in the building facade image. Among them, the originally darker or brighter pixels are worth a significant improvement, increasing the contrast of the image.

4.5 Histogram for Extracting and Repairing Building Facades

This article conducted histogram equalization processing on the images extracted and repaired from the exterior facade of buildings to analyze the specific effects of their extraction and repair. Firstly, the grayscale processing was performed, and then the grayscale histogram was calculated and drawn. The specific results are shown in Figure 11.

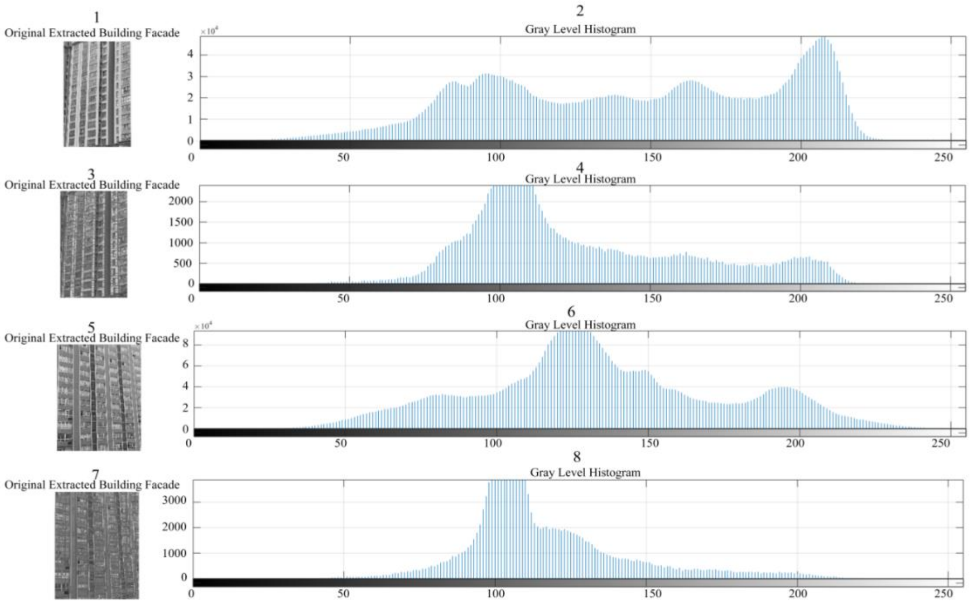

Figure 11: Restoration image and histogram of building façade.

1: Building 1 facade image
2: Histogram of Building 1 facade image
3: Restoration grayscale image of Building 1 facade
4: Histogram of restoration grayscale image of Building 1 facade
5: Building 2 facade image
6: Histogram of Building 2 facade image
7: Restoration grayscale image of Building 2 facade
8: Histogram of restoration grayscale image of Building 2 facade

In Figure 11, 1 represents the Building 1 facade image, and 2 represents the histogram of the Building 1 facade image. 3 is the restoration grayscale image of the Building 1 facade, and 4 is the histogram of the restoration grayscale image of the Building 1 facade. 5 represents the Building 2 facade image, and 6 represents the histogram of the Building 2 facade image. 7 is the restoration grayscale image of the Building 2 facade, and 8 is the histogram of the restoration grayscale image of the Building 2 facade. In the histogram, the grayscale image of the exterior facade of Building 1 reached its maximum value after the grayscale value of 200, while the grayscale image of the exterior facade of Building 2 reached its maximum value between the grayscale values of

100-150. The grayscale values of the exterior restoration image of Building 1 were concentrated in the range of 50-220, while the grayscale values of the exterior restoration image of Building 2 were concentrated in the range of 50-210, and the grayscale values of Building 1 were more concentrated.

4.6 Operation Time and Computational Complexity of Obtaining and Repairing Building Facade Images

The acquisition and restoration of building facade images require extremely high technical runtime and computational complexity. Therefore, this article analyzed the operation time and computational complexity of obtaining and repairing building facade images. A total of 10 buildings were surveyed, and the peak computational complexity was 1. The reasonable range of computational complexity was 0.2-0.6, and the reasonable range of running time was 5-10 seconds. The specific investigation results are shown in Figure 12.

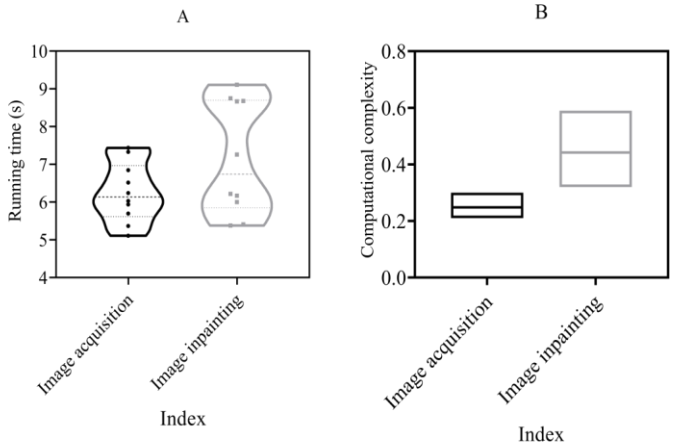

Figure 12: Analysis of operation time and computational complexity for obtaining and repairing building facade images.

A: Operation time analysis of building facade image acquisition and restoration
B: Analysis of computational complexity for obtaining and repairing building facade images

Figure 12A shows the analysis of the operation time for obtaining and repairing building facade images, with the x-axis as the indicator and the y-axis as the running time. Figure 12B shows the computational complexity analysis of obtaining and repairing building facade images, with the x-axis as the indicator and the y-axis as the computational complexity.

In the analysis of operation time, the operation time for image acquisition ranged from 5.11 to 7.44 seconds, with an average of 6.25 seconds; the operation time for image restoration was 5.38 to 9.11 seconds, with an average of 7.17 seconds. Through the comparison of their mean values, it was found that the operation time of image acquisition and restoration was within a reasonable range, and the operation time of image restoration was 0.91 longer than that of image acquisition. The main reason is that the acquisition process of building facade images under cloud images can rely on powerful digital technology to improve information acquisition speed. However, in the process of image restoration, the time required for image restoration is often longer due to issues such as severe image occlusion or unclear contrast.

In the analysis of computational complexity, the average computational complexity for image acquisition was 0.25, and the average computational complexity for image restoration was 0.44, which was 0.19 higher than that for image acquisition. Moreover, the computational complexity for image acquisition and restoration was within a reasonable range. With the support of cloud imaging and digital technology, image acquisition has a fast information acquisition speed, and the repair process is relatively cumbersome. It needs to be repaired according to the degree of image damage, so the complexity of image repair is relatively high.

4.7 Integrity and Clarity of Building Facade Image Acquisition and Restoration under Cloud Images

Obtaining and repairing images of building facades under cloud images is an important indicator for evaluating image acquisition, and the fidelity and smoothness of image restoration are also very important analysis indicators in image restoration. Therefore, this article analyzed the application effect of cloud images and digital technology in building facade images by testing the specific changes in indicators for obtaining and repairing facades of 20 buildings under cloud images. The peak values of these four indicators are all 1, with 0.8-1 being excellent and 0.6-0.8 being average. The specific investigation results are shown in Table 2.

Building	Acquisition of building facade images		Building facade Inpainting		Building	Acquisition of building facade images		Building facade Inpainting	
	Image Integrity	Image clarity	Image fidelity	Image smoothness		Image Integrity	Image clarity	Image fidelity	Image smoothness
1	0.82	0.83	0.91	0.94	11	0.88	0.97	0.98	0.98
2	0.86	0.97	0.94	0.94	12	0.93	0.83	0.84	0.98
3	0.9	0.98	0.93	0.83	13	0.96	0.83	0.88	0.83
4	0.81	0.89	0.87	0.85	14	0.92	0.95	0.88	0.99
5	0.85	0.99	0.86	0.82	15	0.93	0.93	0.84	0.89
6	0.82	0.92	0.89	0.94	16	0.97	0.98	0.84	0.94
7	0.91	0.82	0.93	0.89	17	0.95	0.85	0.89	0.96
8	0.93	0.88	0.84	0.9	18	0.91	0.9	0.84	0.94
9	0.96	0.85	0.84	0.82	19	0.92	0.94	0.99	0.91
10	0.91	0.95	0.96	0.93	20	0.82	0.97	0.95	0.88

Table 2: Analysis of indicators for obtaining and repairing building facade images under cloud images.

According to Table 2, in the analysis of building facade image acquisition, the average integrity of the image was 0.90, and the average clarity was 0.91, all of which were excellent. In the analysis of building facade image restoration, the average fidelity of the image was 0.90, and the average smoothness was 0.91, all of which were excellent. With the support of cloud images and digital technology, the image information obtained from building facade images is more comprehensive, which can provide information support for subsequent restoration of building facade images. The building facade images obtained from cloud images are clearer, which can help relevant personnel carry out image restoration in a timely manner, as blurred and distorted images can affect the quality of image restoration. In addition, under cloud images, the architectural facade image is closer to the style and appearance of the original building, which can inherit its cultural value. Moreover, with the support of digital technology, the restored facade image has almost no appearance, and the surface is flat and smooth, making it more beautiful.

4.8 User Subjective Evaluation of Building Facade Images under Cloud Images

This article also surveyed 15 experts in building image restoration to investigate their usability, authenticity, and operational interactivity in building facade image restoration under cloud images. Among them, 0.8 or above is excellent, with a peak of 1. The higher the value, the higher the evaluation. The specific investigation results are shown in Table 3.

Expert	Usability	Authenticity	Operational interactivity
1	0.99	0.95	0.92
2	0.95	0.99	0.95
3	0.89	0.99	0.97
4	0.80	0.87	0.97
5	0.89	0.87	0.90
6	0.88	0.92	0.81
7	0.93	0.86	0.98
8	0.99	0.89	0.88
9	0.91	0.94	0.93
10	0.85	0.94	0.83
11	0.85	0.93	0.96
12	0.86	0.97	0.97
13	0.93	0.90	0.81
14	0.97	0.95	0.88

15	0.90	0.97	0.93

Table 3: User subjective evaluation of building facade images.

According to Table 3, among the surveyed users, the subjective evaluations of the usability, authenticity, and operational interactivity of image restoration were excellent. The average evaluation of image usability was 0.91, the average evaluation of image authenticity was 0.93, and the average evaluation of operational interactivity was 0.91. From this, it can be seen that the information obtained from building facades under cloud images is more authentic and reliable, and its operation is also more convenient, facilitating users to extract information data in a timely manner and repair defects based on the images. In addition, with the support of digital technology, the process of extracting the contour of building facades and obtaining and repairing information is also more rapid and convenient.

5. CONCLUSIONS

The extraction and repair of building facade rules based on digital technology can fully utilize the advantages of computer processing of complex problems, making it a powerful urban construction tool. With the development of computer and digital technology, there are more and more building facade databases, and their scale is also increasing. Although the buildings in cloud images have a strong background and exhibit varying details, which increases the difficulty of extraction, the vertical boundaries of buildings are their common features. By preprocessing the image, unnecessary backgrounds were removed while maintaining high brightness on the roof. An improved point cloud plane boundary algorithm was utilized to extract edge contours from images. The research results of this article provided a new approach for texture rendering in building facade repair, greatly reducing the rendering workload during the reconstruction process, and ensuring real-time image quality while updating in real-time. Based on cloud images, only the initial texture area of the building facade is extracted, which cannot accurately segment the overall texture information of the facade, resulting in deviation in the repair effect of the facade. Therefore, if attributes such as feature descriptions can be extracted from the texture information of building facades within the original area, better reconstruction results can be obtained.

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