Filtering and Enhancement Method of Ancient Architectural Decoration Image based on Neural Network

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***Abstract*—Due to poor ambient light or uneven lighting, the old decoration image acquisition methods are easy to cause the image blur. To solve this problem, this paper proposes a neural network-based filtering enhancement method for ancient architectural decoration images, which preserves image details by enhancing contrast, smoothing noise reduction and edge sharpening. Based on the convolutional neural network which is composed of encoder, decoder and layer hop connection, the residual network and hole convolution are introduced, and the hole U-Net neural network is constructed to fuse the pixel feature blocks of different levels. This method enhanced the image contrast according to the gray level and frequency histogram, and aiming at the gray value of the pixel to be processed in the image. And the middle value of the gray value of the neighborhood pixel is used to filter the noise of the ancient building decoration image. The paper also analyzes the joint strength of beams and columns in ancient buildings, and calculates the elastic constants of beams and columns and the stress at the joint of them, considering the image texture characteristics of the wood in ancient buildings with the mortise and tenon connection of beams and columns. Experimental results show that the proposed method has good noise suppression performance, can effectively obtain image detail features, and significantly improve the subjective visual effect of ancient architectural decoration images.**

Keywords*—Neural network; decorative images of ancient buildings; filter enhancement method; encoder; decoder; pixel gray value

I. INTRODUCTION

Ancient buildings are one of the most important cultural heritages left over by the history of various countries, marking the national civilization, the pride of various countries and the wealth of all mankind [1-2]. The comprehensive protection of ancient buildings is conducive to the promotion of national traditional culture and can benefit future generations of mankind. On the vast land, there are many distinctive ancient villages and residential buildings, as well as many magnificent royal ancient buildings, which can be said to be countless. These buildings integrate ancient folk culture and architectural art, and are the witness of history and the crystallization of culture [3-4]. Its existence not only leaves exquisite evidence for the development of architectural history and human civilization history, but also provides diversified development reference for contemporary architectural art [5]. With the substantial improvement of people’s living standards and cultural level, tourism has developed very rapidly around the world, in which the visit of ancient buildings has become more and more popular, and more places of interest have begun to be open to the public and for the public to visit. More and more developers began to explore the cultural connotation and historical value of ancient buildings, followed by the birth of a series of antique buildings, trying to restore the ancient architectural style in terms of layout and building materials. In recent years, people pay more and more attention to the protection of ancient buildings [6], especially China, which has a long history and many ancient buildings. But after years of erosion, most China ancient buildings have been weathered, corroded and even man-made damage to varying degrees. How to reconstruct the damaged ancient buildings and ensure the high degree of restoration after reconstruction has become the main research problem in the field of ancient building restoration [7]. Image filtering and enhancement processing is an enhancement strategy to improve the decorative features of ancient buildings. It can improve the overall image quality from the aspects of pixel definition, contrast and brightness. However, in daily life, because of the photographer’s photography level and surrounding environment, the initial image quality is usually poor. Therefore, it is imperative to design a reasonable and complete image filtering and enhancement processing method.

The body of the study consists of six parts. In Section III, the convolutional neural network is introduced and modified into U-Net neural network, which establishes the basic framework for the proposed method. In Section IV, the beams and columns of ancient buildings are introduced, and their properties such as handover strength, elastic constant and connection stress are calculated. The characteristics of the application objects of the proposed method are investigated to make the method more suitable for this kind of image. In Section V, the image filtering enhancement method based on neural network is introduced in detail. The validity of the proposed method is verified by experimental analysis in the Section VI. Conclusion and prospect are described in Section VII.

II. Related Works

There are many research types in the field of filtering and enhancement of ancient architectural images. The study [8] proposes a quantitative evaluation of the architectural style of Agora, an ancient Greek city in Athens based on image correlation and fractal dimension analysis. Agoras is the center of Western European life and can be called the starting point of western European civilization. In previous studies, image processing technology was used to restore the initial shape of buildings and cities. Then, each building in the three-dimensional model of the square is built around the formation of the square. In this study, the 3D model of temple focuses on temple buildings and corridor extracts the facade of each building, quantitatively evaluates the similarity by performing fractal dimension analysis and image analysis, and considers the correlation of the two analysis results. The research [9] pointed out the evolution of Vladivostok's spatial structure and architectural image, and the problems and contradictions existing in the modern stage of the development of Far East maritime cities, which is the result of insufficient consideration of the basic principles of its formation and development. The solution to these problems is to analyze their spatial structure and architectural image from the perspective of evolution. This method can reveal all the existing shortcomings and contradictions, and formulate the main direction, principles and means of urban environmental construction, so as to improve and humanize the urban environment. From the perspective of evolutionary method and complex analysis method proposed by the author, the development of Vladivostok urban spatial structure and architectural image is considered. In the latest research, the performance of machine learning has been further optimized. The authors [10] proposed a new NA-DE hybrid neural network algorithm. It incorporates NNA and differential evolution algorithms. In the experiment, the controller optimized by this algorithm has better performance. In addition, it shows better robustness to the uncertainty of parameters in the system. The literature [11] proposes a trainable network framework based on attention mechanism. The framework combines model training, feature extraction and band selection. The experimental results show that the model constructed based on this framework has higher regression R^2 value and classification accuracy, and the original spectral space information can be used to effectively select the band while training the model.

Although the above research has made some progress, because only the feature information is enhanced and the enhanced information is not matched, the visual effect of image filtering and enhancement is poor, and it is easy to lose the local detail information of the image. Therefore, this study proposed a neural network-based filtering and enhancement method for ancient architectural decoration images. In this method, residual network and hole convolution are introduced to build hole U-Net neural network, which can fuse pixel feature blocks of different levels, enhance the contrast of decorative images of ancient buildings, and filter the noise of decorative images of ancient buildings.

III. Neural Network

Using cavity convolution with different convolution rates, a neural network [12] is constructed to obtain more and more detailed image information of ancient architectural decoration, provide as perfect a visual image as possible for image filtering and enhancement, and further improve the image enhancement effect.

The neural network composed of encoder, decoder and layer hopping connection is shown in Fig. 1. The encoder is similar to the feature extraction layer, while the decoder mainly carries out an operation similar to deconvolution. In the process of decoding, image features extracted during encoding are also added. Jump joins can bridge the semantic gap between the encoder and the decoder, and it can also recover fine-grained details of the target object. The image is first down-sampled by the encoder to obtain the high-level semantic feature map, and then up-sampled by the decoder to restore the feature map to the resolution of the original image. Each time the decoder is upsampled, the jump connection will fuse the feature maps corresponding to the same resolution in the decoder and the encoder in a splicing way to help the decoder recover the details of the target better.

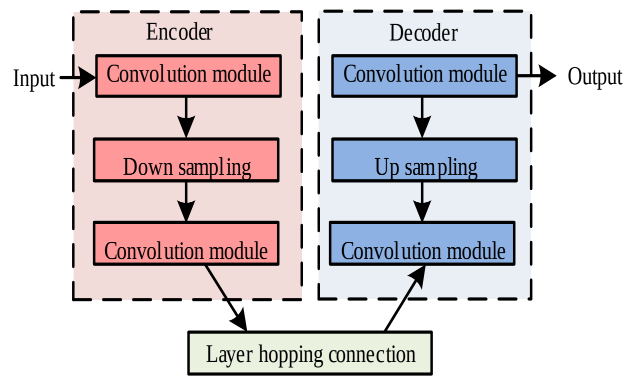


Fig. 1. Neural network architecture

As can be seen from Fig. 1, the encoder and decoder have symmetry, and the number of ancient building decoration image channels and resolution and other parameters correspond one by one. They are respectively composed of two convolution modules. Each convolution module contains two convolution stages, and its functions are to extract the deep features of ancient building decoration image and repair the details of ancient building decoration image; The function of layer hopping connection is to associate the image feature blocks between codec and decoder, and further optimize the image restoration effect of ancient architectural decoration of decoder by using the deep features extracted by encoder feature blocks.

The process of using neural network filtering to enhance the image of ancient architectural decoration is described as follows:

1) Based on the gray level and single channel initial ancient building decoration image, the encoder uses the maximum pool of two steps for down sampling processing, so that the ancient building decoration image channel is multiplied by 2 and the resolution is divided by 2;

2) After the decoder uses the same step deconvolution of 2*2 convolution kernel for up sampling, it also performs the same processing on the ancient building decoration image and resolution. Finally, the number of compression channels is the number of types to be output, and the segmentation result of the ancient building decoration image is obtained.

3) Layer hopping connection integrates the semantic information and orientation information contained in different levels of features through splicing, so that the number of feature channels is one fourth of the input, and accurately segment the ancient building decoration image.

The semantic information and orientation information of ancient architectural decoration image have certain randomness, so the deep and shallow feature weights change constantly with the image content; Moreover, the decoration image of ancient buildings will change with the passage of time, which increases the probability of problems such as blurred boundary, uneven illumination and high noise in the visual image [13], which brings great difficulty to the subsequent processing and application of the image. Therefore, in order to balance the feature weights of different levels of neural network and improve the image quality of ancient architectural decoration, the residual network and cavity convolution are integrated into the neural network to construct the cavity neural network, so as to remove the network gradient and fully extract the multi-scale features of the image.

Assuming that based on the neural network with convolution layers of n, the following formula is used to derive the gradient of the network whose first layer weight is w_1, and the calculation formula is:

$$\frac{\partial Q}{\partial e_1}=\frac{\partial Q}{\partial q_n}\cdot\ldots\cdot\frac{\partial q_3}{\partial q_2}\cdot\frac{\partial q_2}{\partial q_1}\cdot\frac{\partial q_1}{\partial e_1} \quad (1)$$

In formula (1): Q represents the loss function, $Q(y,f(x))=|y-f(x)|$. $q_i\left(i=1,2,\ldots,n\right)$ represents the activation function output with the number of layers of i, and ∂ represents the sign of partial derivative. When the partial derivative of $\frac{\partial Q}{\partial q_n}$ satisfies $\frac{\partial Q}{\partial q_n}<1$, the more network layers, the faster the network gradient decreases, and infinitely approaches 0.

According to the correlation between the output value of the simultaneous loss function and the number of network layers, the residual network structure composed of convolution layer and curve is used to remove the network gradient. The input items reach the network output through the curve and convolution layer respectively, so the definition formula of residual network structure is as follows:

$$W_a=D\left(n\right)+n\times Q \quad (2)$$

In formula (2): W_a represents the network output part, $D\left(n\right)$ represents the residual network part, and n represents the input item or direct mapping structure.

Neural network hole convolution is to increase the convolution rate index in the convolution core of convolution layer, expand the field of view of convolution layer and prevent the loss of down sampling information. Based on the 3*3 cavity convolution with the expansion rate of 1, when the expansion rate increases to two, insert a zero between the two adjacent points of the convolution core to make it 7*7; when the expansion rate increases to four, insert three 0 between the two adjacent points of the convolution core to make it 15*15, and so on. Thus, a positive correlation between the field of view of cavity convolution and the expansion rate is established.

After the convolution of residual network and hole, the neural network is improved into hole U-Net neural network, as shown in Fig. 2.

According to Fig. 2, the operation process of U-NET is shaped like "U", which can be divided into two parts: code and decode, including input and output layer, convolution layer and pooling layer, but not full connection layer. Through the network structure, pixel feature blocks of different levels in the decoration images of ancient buildings are fully integrated. Published in 2015, U-Net is a variant of FCN. Its original intention is to solve the problem of biomedical images. Due to its good effect, it has been widely applied in various directions of semantic segmentation, such as satellite image segmentation, industrial defect detection, etc [14]. Its structure is simple but effective, and it can recognize multi-scale features of image features. Therefore, it is selected in this study to expand the neural network.

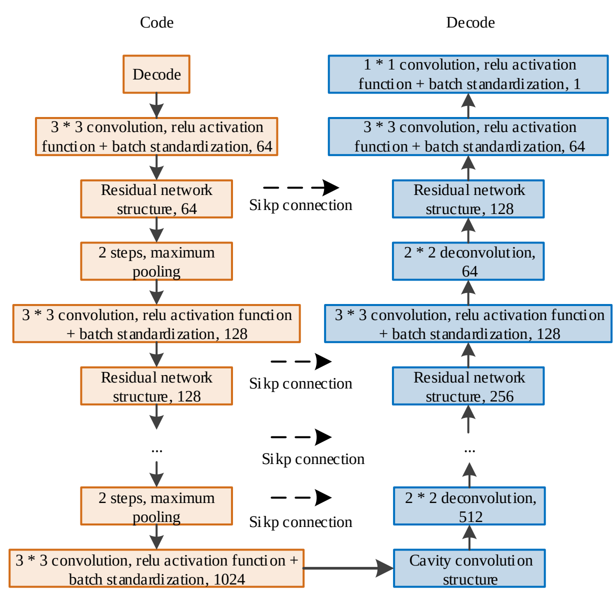


Fig. 2. U-Net neural network architecture

IV. Basic Characteristics of Beams and Columns in Ancient Buildings

A. Orthotropic

In general, wood is constructed according to cells with different shapes, sizes and arrangement order. This construction characteristic also determines the anisotropy of wood. The anisotropy of wood elasticity is obtained by applying the principle of orthogonal symmetry to wood. When wood materials in ancient buildings are cut from different directions, they will show inconsistent texture characteristics. Specifically, they can be divided into four characteristics: along grain direction, chord direction, radial direction and tangent direction. The longitudinal cutting of wood refers to the direction parallel to the wood fiber in the process of actual operation, that is, the cutting direction of the trunk from the bottom line, which becomes the direction along the grain; Chord direction and radial direction refer to the direction perpendicular to wood fiber, which can be called transverse grain direction; In general, after the wood is cut, the center of the trunk will show an annual ring like a concentric circle, while the radial cutting and chord cutting are perpendicular to the annual ring. The only difference is that the radial direction passes through the tangent direction of the tree center, and the chord direction does not pass through the tangent direction.

B. Mechanical Properties of Beams and Columns in Ancient Buildings

1) Flexural strength: Since the bending strength of wood is higher than the strength under external force, in general, the external force strength and bending strength along the grain of wood can be improved respectively, and on this basis, it conforms to the following formula:

$$W_{sd}=\left(3\frac{\sigma_l}{\sigma_y}-1\right)/\left(\frac{\sigma_l}{\sigma_y}+1\right) \quad (3)$$

In formula (3), σ_l and σ_y represent the external force strength and bending strength of wood samples respectively.

When the wood in ancient buildings is damaged by bending, the wood fiber under external force on the cross section of the material will be unstable and wrinkled. With the strength of cyclic load, the position of fiber instability will develop to the neutral axis of the section, and finally the wood will break.

2) Bearing strength: In ancient buildings, wood bearing pressure refers to the performance of transmitting load on the cross section of the intersection of beams and columns when they intersect into nodes. The intersection point of force is called bearing stress on this cross section, and the corresponding resistance is called bearing strength. However, because the actual intersecting section is unstable, the bearing capacity along the grain of wood is lower than that along the grain.

When the cross grain of the whole surface is under pressure, the appropriate maximum proportion will be selected as the measurement standard of the bearing strength. The bearing pressure of part of the cross grain is consistent with that of the whole surface. However, due to the bearing pressure of the cross grain on the length of some wood, it is necessary to consider the improvement of the strength caused by the fiber action of the wood on both sides of the bearing pressure point.

In general, the elastic characteristic constants of wood include: elastic modulus E_i, Poisson's ratio μ_{ij} and shear elastic modulus G_{ij}. The elastic modulus of longitudinal L, radial R and chord T of wood cutting is the elastic modulus in the main direction. Assuming $E_L=E_1$, $E_R=E_2$ and $E_T=E_3$. E_L、E_R and E_T represents the elastic modulus of wood cut longitudinally, radially and vertically, respectively. And it is determined that there is only one normal stress in the main direction, the ratio of normal stress to linear strain in the corresponding direction can be written as:

$$E_i=\sigma_i/\varepsilon_i \qquad (i=L,R,T \quad \text{or } i=1,2,3) \quad (4)$$

According to the ratio of formula (4), Poisson's ratio μ_{ij} is the normal stress, and σ_i acts alone in the L direction; when the corresponding bearing stress is zero, the opposite number of the ratio of stress in L direction to strain in R direction is:

$$\begin{aligned}&\mu_{i,j}=-\varepsilon_j/\varepsilon_i\\&(i=L,R,T \quad \text{or } i=1,2,3,\ j=1,2,...,3)\end{aligned} \quad (5)$$

According to formula (5), $G_{L,R}$, G_{RT} and G_{TL} can be described as shear elastic modulus in bearing plane LR, RT and TL respectively.

C. Characteristic Analysis of Beam Column Joints

1) Characteristic points of mortise and tenon structure: Mortise and tenon connection is a semi-rigid connection between rigid connection and hinge connection. Because most ancient building structures adopt straight mortise connection, the straight mortise is mainly analyzed, and the finite element numerical simulation analysis of mortise and tenon connection of building structure is carried out [15]. According to the unique characteristics of the building structure in this technology, the virtual spring element will be used to simulate the semi-rigid structure. In practical application, this spring element has no substantial mass and element.

2) Analysis of tenon joint intersection: In order to calculate and solve the stress effectively and simply, assuming that the shear capacity of wood along the x axis and y axis is the same, and the bending and torsion capacity in different directions is the same, the simplified $k_x=k_1$, $k_y=k_z=k_2$ and $k_{\theta x}=k_{\theta y}=k_{\theta z}=k_3$ can be obtained. Only these three unknown variables need to be solved, and there are:

$$k_x = \frac{F_x}{\Delta_x} \qquad (6)$$

According to formula (6), similarly, the load F_z treatment along the z axis can be carried out on the model to obtain the shrinkage strength of the mortise joint along the z axis:

$$k_z = \frac{F_z}{\left|\Delta_z^4 - \Delta_z^5\right|} \qquad (7)$$

In formula (7), Δ_z^4 and Δ_z^5 are respectively described as the average value of all nodes on section A_4 and section A_5 moving along the z axis.

According to the calculation result of formula (7), the torque M_y rotating around the y axis is applied to the surface A_3 of the mortise joint, and the state is determined after multiple iterative calculations, the moving distance of i node in the upper surface A_1 along the x axis is solved, where Δ_z^4 and Δ_z^5 are expressed as the average value of multiple nodes on FF and A_4 moving along the A_5 axis respectively. According to the simplified expression of formula (7), the value of stress in each direction of mortise and tenon joint can be obtained.

V. Filtering and Enhancement of Ancient Architectural Decoration Image based on Neural Network

A. Filtering and Enhancement of Ancient Architectural Decoration Image

Using the hollow U-Net neural network, after fusing the different levels of features in the ancient building decoration image, the image is transformed into a mode more convenient for automatic analysis and visual observation through the stages of enhancing contrast, smoothing and noise reduction and edge sharpening, so as to realize the filtering enhancement of the ancient building decoration image and improve the visual effect.

1) Contrast enhancement: The pixel gray variable θ of the ancient building decoration image is any integer between 0 and 255. When processing the image, the gray variable is normalized to the interval of 0 to 1. If the gray variable is continuous, the initial gray distribution of the image can be described by using the probability density function $S(\theta)$. The decoration image of ancient buildings is usually discrete, and the discrete gray level can be expressed by Z_x. The corresponding gray level distribution is A_{qw}, and the calculation formula is:

$$A_{qw} = S(\theta) \times Z_x \times R_{as} \times V_{av} \qquad (8)$$

In formula (7): R_{as} represents the total number of image pixels, and V_{av} represents the number of gray pixels. Randomly select a normalized gray variable θ and convert the gray value using the following expression:

$$H_{dz} = M(\theta) \times S_{ab} \times A_{qw} \qquad (9)$$

In formula (8): H_{dz} represents the new gray value after conversion, $M(\theta)$ represents the monotonically increasing conversion function, and S_{ab} represents the probability of occurrence of the converted gray value.

Most ancient architectural decoration images have fixed shapes, so histogram regularization processing needs to be carried out on the basis of equalization processing to further enhance the image contrast [16-17]. For the converted gray value function H_{dz}, the equalization result is T_k. After replacing the inverse gray u with uniform gray s, the calculation formula for contrast enhancement of ancient building decoration image is as follows:

$$D_{bd} = H_{dz} \times T_k \times T(\theta) \times u \times s \qquad (10)$$

If there is $T(\theta) = T^{-1}\left(\frac{1}{\theta}\right)$, the histogram regularization completes the contrast enhancement of ancient architectural decoration image.

2) Smooth noise reduction: In the process of collecting, transmitting and quantifying the ancient building decoration image, the noise of fuzzy image information will be formed. Therefore, the median filter method is used to remove the noise of the ancient building decoration image on the premise that the image edge contour and line can be well preserved.

For the gray value of the pixel to be processed in the image, the intermediate value of the gray value of the pixel in its neighborhood is used to complete the replacement. The implementation form is as follows:

$$Z_{JZ} = med\left\{M(\alpha_1, \beta_1), M(\alpha_2, \beta_2), ..., M(\alpha_n, \beta_n)\right\} \qquad (11)$$

In formula (10): Z_{JZ} represents the intermediate value of the neighborhood gray of the pixel to be processed, med represents the median value, $M(\alpha_n, \beta_n)$ represents the pixel whose coordinate is (α_n, β_n), α represents any integer, and β represents the number of rows and columns of the pixel.

3) Edge sharpening: A gradient method is designed to sharpen the pixels with significant changes in image edge and gray level. Based on the field theory, set a vector field as $t = t(\alpha, \beta, \gamma)$, and obtain the vector field gradient according to the extreme value of directional derivative at any point, as shown below:

$$A_{grad}(t) = \frac{\partial O}{\partial \alpha} a + \frac{\partial O}{\partial \beta} b + \frac{\partial O}{\partial \gamma} c \qquad (12)$$

In formula (11): a, b and c represent arbitrary constants.

Given the pixel $O(\alpha, \beta, \gamma)$, the following vector formula is used to define the corresponding gradient of the coordinate (α, β, γ):

$$B_{grad}\left[O(\alpha, \beta, \gamma)\right]^{\mathrm{T}} = \begin{bmatrix} \frac{\partial O}{\partial \alpha} \\ \frac{\partial O}{\partial \beta} \\ \frac{\partial O}{\partial \gamma} \end{bmatrix} \qquad (13)$$

The amplitude of the vector is $G\left[O(\alpha, \beta, \gamma)\right]$, and the following absolute value operation method is used for approximate calculation:

$$\begin{aligned} G\left[O(\alpha, \beta, \gamma)\right] &= \left|O(\alpha, \beta, \gamma) - O(\alpha+1, \beta, \gamma)\right| \\ &+ \left|O(\alpha, \beta, \gamma) - O(\alpha, \beta+1, \gamma)\right| \end{aligned} \qquad (14)$$

In order to simplify the complexity of edge sharpening, the obtained gradient $G\left[O(\alpha, \beta, \gamma)\right]$ is used to describe the pixel $O(\alpha, \beta, \gamma)$ and obtain the gradient image.

B. *Filtering and Enhancement of Ancient Architectural Decoration Image*

Before realizing the filtering and enhancement of ancient building decoration image, obtain the ancient building decoration image data through tilt photography technology and preprocess it. Obtain the ancient building decoration image data through three-dimensional laser scanning system and preprocess it [18]; Then, based on the preprocessed tilt image data and point cloud data, ICP algorithm is used to register the tilt image data and point cloud data; Finally, according to the registration results, the filtering and enhancement of ancient architectural decoration image is realized by using CGA rules.

1) Image preprocessing of ancient architectural decoration: The acquisition of ancient building decoration image needs to determine the UAV aerial photographing area, route and time according to the target ancient building and UAV elevation information, set the UAV flight take-off and landing points, and obtain the ancient building decoration image by controlling the UAV. In tilt photography, the vertical ground shooting method is adopted, also known as central projection. In order to ensure the accurate expression of the target ancient architecture, the central projection image is converted into the map projection mode of Orthophoto projection, and the conversion formula is as follows:

$$\begin{cases} x = -j\dfrac{a_1(X - X_g) + b_1(Y - Y_g) + c_1(Z - Z_g)}{a_3(X - X_g) + b_3(Y - Y_g) + c_3(Z - Z_g)} \\ y = -j\dfrac{a_2(X - X_g) + b_2(Y - Y_g) + c_2(Z - Z_g)}{a_3(X - X_g) + b_3(Y - Y_g) + c_3(Z - Z_g)} \end{cases} \qquad (15)$$

In formula (14), j represents focal length, a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2 and c_3 represent the parameters of external orientation element matrix, (X, Y, Z) represents point cloud data coordinate information, g represents ranging observation value, and (X_g, Y_g, Z_g) represents the coordinate information of a point of the target building in the ground coordinate system.

The obtained target ancient architecture decoration image has multiple perspectives, such as left perspective, right perspective, front perspective, rear perspective and positive perspective. The inclined image of each perspective contains rich geographic information of the target ancient architecture. The definition of the target ancient architectural decoration image plays an important role in image filtering and enhancement. Tilt images from different perspectives will produce large overlapping areas, resulting in some deviation between tilt image data and real data, which will affect the accuracy of filtering and enhancement of ancient architectural decoration images. Therefore, it is necessary to preprocess the target ancient building decoration image data to improve the filtering and enhancement accuracy.

Tilt image preprocessing is mainly divided into two stages, as follows:

Stage 1: Configure relevant information, such as sensor pixel information and parameter information, so as to reduce the displacement deviation during filtering and enhancement of ancient building decoration image;

Stage 2: uniform light and color processing, so as to ensure the filtering of ancient architectural decoration image and enhance the consistency of hue. The hierarchical diagram of point cloud data of ancient building decoration image preprocessing is shown in Fig. 3.

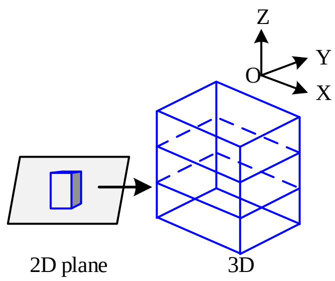


Fig. 3. Hierarchical diagram of point cloud data of ancient building decoration image preprocessing

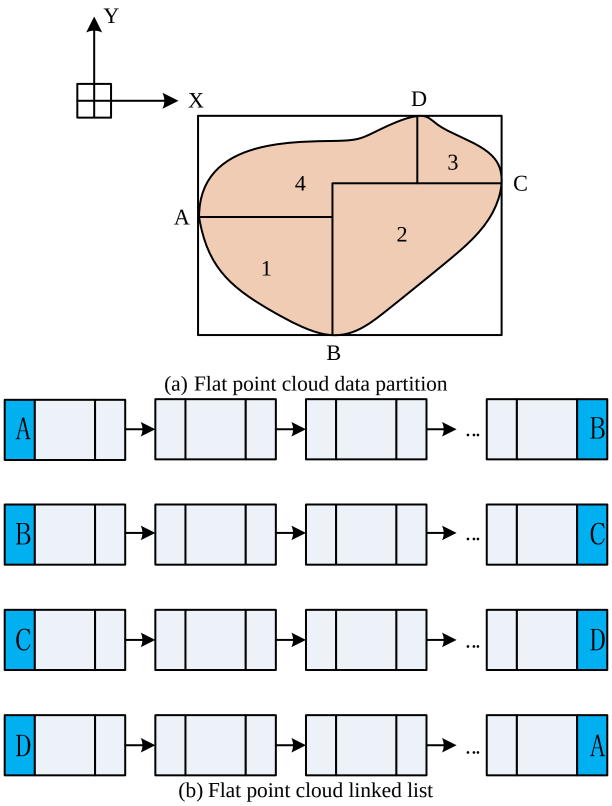


Fig. 4. Image preprocessing point cloud data partition storage graph

As shown in Fig. 3, the image preprocessing point cloud data in each sub cube is still stored hierarchically with the Z axis coordinate value from small to large. The maximum and minimum values of coordinates X and Y are used as the point cloud data segmentation points, the plane data is divided into four parts and stored as a point cloud data linked list. The above point cloud data preprocessing process is shown in Fig. 4.

According to Fig. 4, calculate the cube space containing all point cloud data, and the calculation formula is:

$$\begin{cases} L_{abc} = roundup\left(X_{\max} - X_{\min}\right) \\ W_{abc} = roundup\left(Y_{\max} - Y_{\min}\right) \\ H_{abc} = roundup\left(Z_{\max} - Z_{\min}\right) \end{cases} \quad (16)$$

In formula (15), L_{abc} represents the length of the cube and W_{abc} represents the width of the cube; H_{abc} represents the height of the cube; $roundup(\cdot)$ represents the upward rounding function; $\left(X_{\max}, Y_{\max}, Z_{\max}\right)$ represents the maximum coordinate of cube space; $\left(X_{\min}, Y_{\min}, Z_{\min}\right)$ represents the minimum coordinate of cube space.

According to the above calculation results, the point cloud data of ancient buildings are simplified, and the specific steps are as follows:

Step 1: Combine the point cloud data to segment points, and cluster and sort the point cloud data of each layer;

Step 2: Set an appropriate reduction step according to the filtering and enhancement requirements of ancient architectural decoration images;

Step 3: Based on the point cloud data reduction standard, retain the point cloud data that meets the reduction standard, and delete the point cloud data that does not meet the reduction standard;

Step 4: If the point cloud data is in the layer, return to step 1; If the point cloud data is not in the layer, proceed to step 5;

Step 5: If the point cloud data is in the cube, update the point cloud data segmentation points; if the point cloud data is not in the cube, the point cloud data reduction is completed and the reduced point cloud data is output.

2) Filtering and enhancement of ancient architectural decoration image: According to the above preprocessing results of ancient building decoration image, the filtering and enhancement of ancient building decoration image is realized under the neural network by applying CGA rules. The specific process is as follows:

CGA rule is a computer language that can automatically build models and has the characteristics of target description and visual observation. The basic idea of the rule is to replace a shape symbol with a certain number of new shapes. By inserting extruded taper and scatter, rendering texture and so on, the decorative details of ancient buildings can be modeled [19]. Nowadays, CGA rules have been integrated into the CE platform, and the rule programming has been completed in collaboration with C++ language to realize the filtering and enhancement of ancient architectural decoration images with numbering programs. The CGA rule commands are shown in Table I.

Based on the registration results of the ancient building decoration image and the point cloud data, execute the CGA rule command shown in Fig. 1, and finally complete the filtering and enhancement of the ancient building decoration image through the conversion operation. The expression is:

$$V_{fg} = \left(X_g, Y_g, Z_g\right) \times R_s + H_t \times Y_r \quad (17)$$

TABLE I. CGA RULE COMMAND TABLE

Operation Category	Function Name	Command
Addition operation	I(insert)	Insert
	Extrude taper	Pull up
	RoofGable;roof Hip;Roof Pyramid;roof Shed	Roof lifting
	Scatter	Scatter
Subtraction operation	InnerRect	Inner rectangle
	Shape L;shape U;shape O	Deformation
	Convexity	De convexity
	Setback	Back off
	Offset	Deviation
	Comp split	Decompose
Conversion operation	Mirror;mirrorScope；Reverse Normals	Image
	Texture	Mapping
	T(scope translate) translateUV	Move
	AlignScope ToAxes center	Alignment
	R(scope rotate) rotateUV	Rotate
	S(scope size) sizeUV	Zoom
	Set	Set up
	Color	To color

In equation (16), R_s represents the image scaling coefficient, H_t represents the image motion vector, and Y_r represents the rotation coefficient. Through the above conversion operation, the research on the filtering and enhancement method of ancient building decoration image under neural network is realized, which not only provides a means to solve the contradiction between opening and protection of ancient building decoration image, but also provides accurate and complete data support for ancient building management and repair.

VI. EXPERIMENTAL ANALYSIS

In order to verify the performance of the filtering and enhancement method of ancient architectural decoration image based on neural network in practical application, an experiment is designed. The specific experimental process is as follows:

A. Selection of Experimental Objects

A Hutong in Beijing, China is selected as the experimental object of ancient architectural decoration image, which is a quadrangle in the Ming and Qing Dynasties. The South and east of the ancient building are qilinbei Hutong and scissors Lane Hutong respectively. Opposite is Fuxue primary school. It can be seen that the experimental object has a strong flavor of old Beijing life. The experimental object covers an area of about 15000 square meters and is now a key unit of cultural relics protection in Beijing. With the change of history, the owner of the experimental object has changed for several generations, but the shape and architectural layout of the main house have not changed significantly, and the original appearance of ancient buildings in the Ming and Qing Dynasties is basically retained. The schematic diagram of experimental objects of various ancient architectural decoration images is shown in Fig. 5.

Fig. 5. Schematic diagram of experimental object

B. Experimental Instrument Setting

The experiment is carried on Matlab 7.1 platform and runs on the microcomputer platform configured with Genuine Intel(R) CPUT1600 1.66 GHZ and 1GB RAM. The effects of the decorative image filtering and enhancement methods of this method, literature [8] method、literature [9] method and literature [10] method are compared. In the experiment, the UAV camera and three-dimensional laser scanner are mainly used to obtain the information data of the experimental object. In order to ensure the accuracy of the obtained information, the parameters of the experimental instrument are reasonably set, as shown in Table II and Table III. In addition, the superparameter of the neural network as shown in Table IV is set, so that the maximum iteration of the network is 1000 times, and the training will stop when the set accuracy is reached.

TABLE II. CAMERA PARAMETER SETTING

Camera Parameters	Numerical Value	Image Parameters	Numerical Value
Camera model	ILCE-QX1	Image size	5462 * 3632 pixels
Time of exposure	1/1000 秒	Ground resolution	5cm
Aperture value	F/5.6	Horizontal resolution	350dpi
Focal length	16mm	Vertical resolution	350dpi
Maximum Aperture	2.96875	Image overlap	80%-90%
ISO speed	ISO-200	Image bit depth	24

TABLE III. PARAMETER SETTING OF 3D LASER SCANNER

Parameter Name	Numerical Value	Company
Scanning principle	Pulse	-
Field of view range	360×270	Degree
Ranging range	1-350	m
Angle measurement accuracy	±60	mrad
Single point ranging accuracy	±6(50)	mm
Maximum scan rate	5000	Spot/s

There are about 30 courtyards and 60 houses, including rockeries, shrubs, gardens, etc.

TABLE IV. HYPERPARAMETER SETTING OF CONVOLUTIONAL NEURAL NETWORK

Parameter Name	Numerical value
Learning rate	0.001
Batch_size	128
Iterations	1000
Step size	1

C. Result Analysis

The signal-to-noise ratio is used to measure the noise suppression performance of the four methods in the process of image enhancement. Generally, the higher the signal-to-noise ratio, the smaller the noise contained in the ancient building decoration image, and the better the image quality. The calculation process of signal-to-noise ratio is as follows:

$$X_{SNR}=\sum_{i,j}^{n} x'^{2}_{ij} / \sum_{i,j}^{n} y'_{ij} - x'^{2}_{ij} \qquad (18)$$

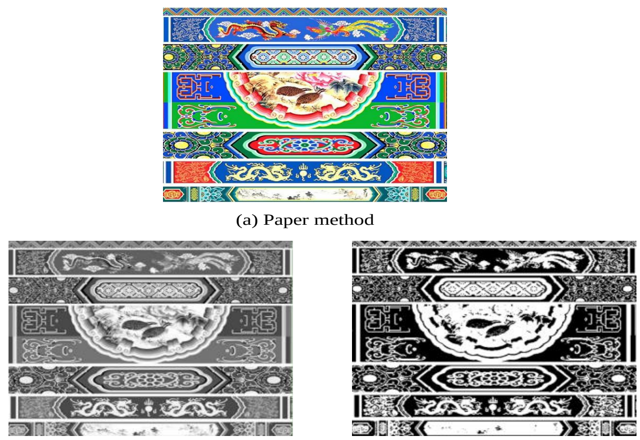
Different Gaussian white noises are introduced into the image, and four methods are used for enhancement respectively. The enhanced images' signal-to-noise ratio is compared. The results are shown in Table V.

TABLE V. COMPARISON RESULTS OF SIGNAL-TO-NOISE RATIO OF THREE METHODS

White Gaussian Noise	Reference [8] Method	Reference [9] Method	Reference [10] Method	Paper Method
1	11.15	11.44	13.12	**14.52**
2	10.20	10.43	12.20	**12.42**
3	9.73	9.91	11.33	**11.89**
4	7.82	8.99	9.96	**10.92**
5	7.57	7.82	9.69	**10.45**
6	7.18	7.54	9.10	**9.99**
7	7.11	7.43	8.84	**9.85**
8	7.07	7.24	8.52	**9.75**
9	6.92	7.04	8.13	**8.99**
10	6.76	6.94	8.21	**8.77**

It can be seen from Table V that under the same Gaussian white noise, the signal-to-noise ratio of the method in this paper is greater than that of the methods in literature [8], [9] and literature [10], which can effectively suppress the adverse impact of noise on the image. This is because this method uses the median filter method to remove the noise of ancient architectural decoration image on the premise of better preserving the image edge contour and lines. For the gray value of the pixel to be processed in the image, the intermediate value of the gray value of the adjacent pixel is used to complete the replacement, which is helpful to suppress the adverse effect of noise on the image to a certain extent.

Fig. 6 is a comparison diagram of ancient building decoration image after filtering and enhancement processing under three methods.



(a) Paper method

(b) Reference [8] method

(c) Reference [9] method

Fig. 6. Image filtering and enhancement processing effect under three methods

It can be seen from Fig. 6 that the images processed by the methods of literature [8] and literature [9] can only get gray images, and the processing of image target details is relatively rough, resulting in blurred image edge feature extraction. However, the filtering enhancement processing effect of ancient building decoration image under this method is very close to the original image, and the color is consistent, Visually, the image obtained by this method is clearer than that obtained by the literature method. This method can show more detailed information in the image, greatly improve the image contrast, enhance the processed image content, and has strong practicability and robustness. Mainly because most of the ancient architectural decoration images in this method have fixed shapes, histogram regularization processing is carried out on the basis of equalization processing to further enhance the image contrast.

VII. CONCLUSION AND PROSPECT

The filtering and enhancement method of ancient architectural decoration image based on neural network can effectively suppress the adverse impact of noise on the image, show more detailed information in the image, greatly improve the image contrast and enhance the processed image content. It has strong practicability and robustness. Although the work has achieved preliminary results, there are still many deficiencies, and a large number of technical problems need to be further studied and solved. Although this work has achieved preliminary results, it only has a good adaptability to the decorative images of Chinese ancient buildings, and cannot be well adapted to other types and styles of decorative images. In the following work, other types of decorative images of ancient buildings should be studied, and the information acquisition problem of some colored images that are not covered and exposed to light and wind and rain for a long time will be studied.

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