Denoising Method of Interior Design Image based on Median Filtering Algorithm

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***Abstract*—Interior design image generation process is prone to the interference of many factors, resulting in the interior design image denoising effect decreases, denoising time increases, so the interior design image denoising method based on median filtering algorithm is proposed. The architecture of interior design image collection is set up, including video signal conversion module, compression coding module, programmable logic chip module and power module. The interior design image collection is realized by using sensors to collect interior design related video information and converting video signals. Based on the results of image acquisition, the median filtering algorithm based on rough set theory is used to realize the denoising of interior design images. Experimental results show that the denoising effect of the proposed method is better, the average signal-to-noise ratio of interior design images is 54.6dB, and the denoising time is always lower than 0.3s, which can be widely used in practice.**

Keywords—Median filtering algorithm; interior design; image denoising; image acquisition architecture; the rough set

I. Introduction

Interior design is a comprehensive discipline that studies the artificial environment. It is “a rational creative activity that takes science as the functional basis and art as the form of expression in order to shape an indoor environment where spiritual wealth and material wealth coexist” [1]. With the application of computer image digital interior decoration design technology, the design drawing is no longer an abstract design drawing, but can fully and truly present the design effect and improve the design quality. Before the formal start of interior design, designers should make full preparations. First of all, the designer should build a complete interior design layout in his mind. Based on this layout, the framework should be gradually enriched by collecting data and understanding customer needs [2]. According to the information provided by the customer, the decoration design concept map is sorted out and used as the design framework, which is constantly modified and optimized to form an interior design image. Therefore, the rise of computer image digitization technology has provided great help for interior design. This technology makes designers say goodbye to the traditional manual drawing method and improves the efficiency of drawing work [3]. On the other hand, each detail of interior space can be expressed in a dynamic way, which improves the expressiveness of design drawings. Therefore, the digital work of design drawings has gradually become the mainstream direction of the development of the industry, with high market potential. However, due to the influence of many factors in the process of interior design digitalization, interior design images include noise, resulting in the deterioration of interior design quality, so it is urgent to study a method of interior design image denoising.

Research for indoor design class image denoising is not much, much more to the rest of the research achievements in the field of migration to the interior design in the image denoising to reference [4], for example on at night, such as indoor under low illumination scene image sensor collected video images are widespread low signal-to-noise ratio and poor visual effect, In order to improve the de-noising effect, a video de-noising method based on time-space frequency(TSF) domain set is proposed. First, a digital gain low illumination image noise model is established, and then, according to the theory of the original video before and after two adjacent frames, finish the image registration based on the optical flow method, get the displacement map, in time-space domain to high frequency image denoising and reconstruction, and then realize the infinite impulse response combined with subsequent noise image processing, at the same time in the airspace for noise reduction, the output after a frame denoising image. However, this method has low signal-to-noise ratio and poor image quality for interior design images, so the practical application effect is not good. In reference [5], an image denoising method based on deep learning is proposed in order to make the noise image clear and obvious, as the image will be polluted by noise due to imperfect equipment and lose the details of the original image. The structure of image denoising network based on convolutional neural network is constructed, and the back propagation algorithm in convolutional neural network is optimized, so as to accelerate the training speed of the model and improve the denoising effect effectively. In order to solve the problem of poor image denoising and rendering in interior design system and consider data rendering, a research method of interior design system combining digital processing technology and image processing technology is proposed, which transmits the image after data processing to the logic layer, by digital processing module using the new threshold function of image denoising algorithm of energy distribution into consideration, Image denoising is realized by multiplying the denoising factors with the same wavelet coefficients. In the image processing module, the bidirectional reflection distribution function model is used to simulate the diffuse reflection of objects, and the Torrance-Sparrow microplane model is used to simulate the specular reflection of objects to achieve image rendering. The logic layer transfers the processed interior design image to the application layer, and displays the interior design result through PC or browser interface, so as to improve the image denoising effect [6]. However, this method is too complicated and has the problem of long denoising time for interior design images.

In order to solve the problems of the above methods, this paper proposes a denoising method of interior design image based on median filtering algorithm, and verifies the effectiveness of the proposed method through experiments.

II. Standard Image Acquisition

A. *Interior Design Image Collection*

In order to improve the quality of interior design class image acquisition, this paper designed image acquisition architecture interior design class, including video signal conversion module, compression module, a programmable logic chip module, power supply module, mainly through the use of sensors to collect interior design related video information, and transformed the video signal processing, image acquisition in interior design class.

1) Video signal conversion module: DMD sensor is used to collect interior design related video information, and the video signal is converted. The conversion of video signals is realized by a dedicated video processing chip [7]. This paper uses special video processing chip SAA7113, is a powerful and simple operation of the bit video input processing chip, the chip adopts technology, through the bus and or microcontroller connected to form an application system. It contains two analog processing channels, which can realize video signal source selection, anti-aliasing filtering, conversion, automatic box position, automatic gain control, clock generation, multi-standard decoding, brightness contrast saturation control and multi-standard data decoding.

After the SAA7113 is turned on, the chip does not immediately collect analog video signals for A/D conversion processing and output digital signals. It must be initialized by the front-end processor through the serial bus to set up its internal register before it can operate normally. LLC is the output of line locking clock, which is twice the frequency of pixel clock, and 27MHz is used to synchronize the whole interior design image acquisition architecture. One CYCLE of LLC generates one byte of image data, and the rising edge of LLC can be used as the write signal of frame storage after being inverted in CPLD [8-9]. The function of RTS0 and RTS1 is determined by programming the internal register. RTS0 and RTS1 are thresholds for different routers. The interface is set RTS0 as the horizontal output reference signal line effective signal, and RTS1 as the vertical output reference signal and parity field signal. RTS0: high level means a row of valid pixels, low level means field blanking signal. The rising edge of RTS0 represents the beginning of the effective singular field image, and it is also used to represent the beginning signal of the frame image. The falling edge of RTS1 indicates the start of output of a valid even field image. SAA7113 and its peripheral circuits are shown in Fig. 1.

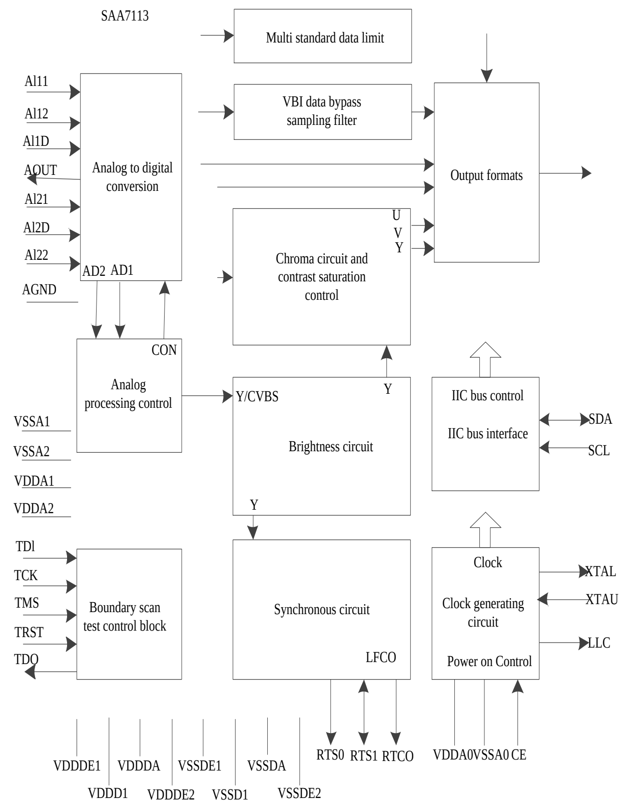

Fig. 1. SAA7113 and its peripheral circuit

2) Compression coding module: The JPEG compression and coding part adopts THE JPEG special codec chip ZR36060, which can realize the image compression and decoding function. In this paper, only its compression and coding function is used [10-11]. ZR36060 is specially designed for computer video acquisition and editing applications, which can easily realize real-time compression and decompression of video signals. During compression, ZR36060 receives digital video signal and encodes it as JPEG stream period; during decompression, it receives a JPEG stream and decodes it into digital video output. The internal structure of ZR36060 is shown in Fig. 2.

VCLK and VCLK×2 are the external clock input. External clock input is connected to the machine terminal by using external oscillation pulse. VCLK×2 is the video clock. For CCIR digital video format, it is connected to the 27MHz clock. VCLK is half the frequency of VCLK×2 and requires synchronization with VCLK×2. SATRT and FRAME are external control signals. The interface of ZR36060 can be divided into video interface, host interface and code interface. The video signal is input and output by the video terminal, the control word of the chip is written and read by the host interface, and the JPEG code is input and output by the code in the activation mode.

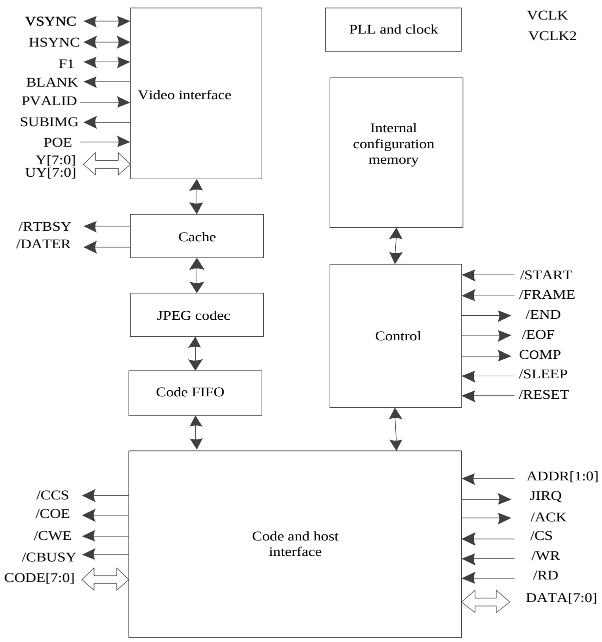

Fig. 2. ZR36060 internal structure

3) Programmable logic chip module: The microcontroller AT89S52 is the transaction control core of this paper [12]. It will enter the working state after power-on and will run continuously. Therefore, the reset circuit of the microcontroller part adopts power-on reset. Interior design image acquisition architecture does not have high requirements for the running speed of the microcontroller. The clock circuit of the microcontroller is composed of 12mb external crystal and grounding capacitor. Reset circuit and clock circuit are shown in Fig. 3.

The communication between the microcontroller and GPRS network is realized through the universal asynchronous serial interface (UART), and its level standard is RS-232, which is a serial physical interface standard developed by the American Electronics Industry Association. The RS-232 has the fastest transmission speed and the maximum transmission distance of 30m. The serial port adopts MAX232 level conversion chip and DB9 interface. The interface circuit is shown in Fig. 4.

4) Power module: The front-end circuit of interior design image acquisition architecture includes digital part and analog part. The interface level of each chip consist of 5 volts and 3.3 volts. To reduce the interference of digital signals with analog circuits, the digital and analog power circuits need to be separated and connected to a point on the circuit board. Considering the power consumption of image acquisition, a three-terminal voltage stabilizer power supply of 5V to 3.3V is utilized. The circuit of the power supply is shown in Fig. 5.

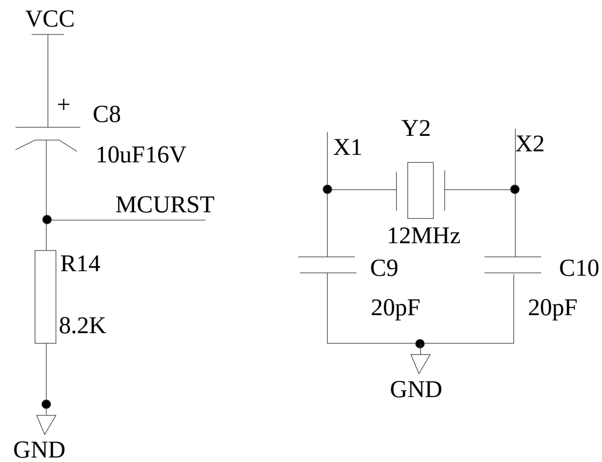

Fig. 3. Reset and crystal oscillator circuit

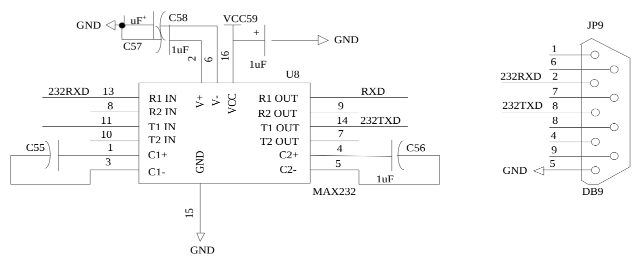

Fig. 4. UART interface circuit

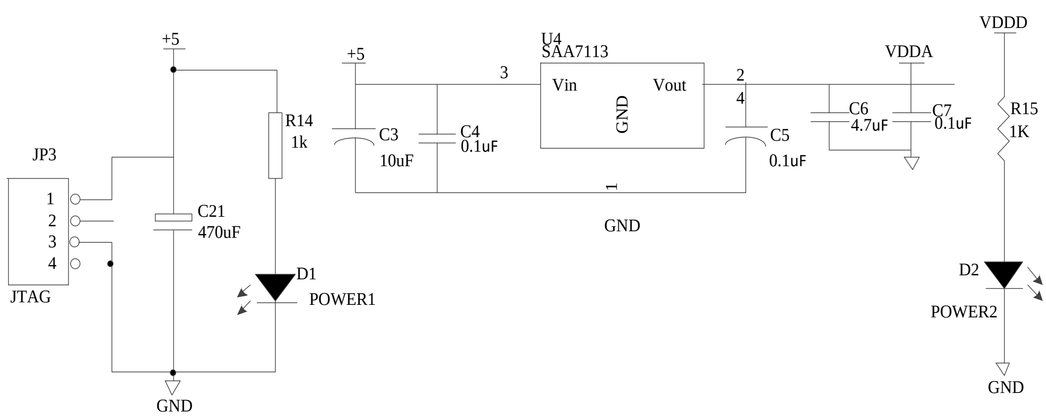

Fig. 5. Power supply circuit

III. Interior Design Image Denoising Method

A. Image Denoising based on Median Filtering Algorithm

As a representative of nonlinear filtering methods, standard median filtering technology can protect image edges while reducing noise, but it only considers the sorting information of data in the filtering window, not the timing information of data, so it will produce edge jitter in image processing. It is possible to remove important image details such as points, corners, and thin lines [13-14]. Considering the problems existing in the standard median filtering, national and international scholars have improved it from many aspects, and produced many improved median filtering algorithms, which make full use of the sorting and timing information of data and improve the filtering quality. Therefore, this paper applies it to interior design image denoising process to improve the effect of denoising.

The basic idea of median filtering is to replace the value of a point in interior design images or digital sequences with the median value of each point in a neighborhood of the point [15]. The median is defined as follows:

For a group of numbers $x_1, x_2, ..., x_n$, which are expressed as $x_{t1}, x_{t2}, ..., x_{tn}$ in order of size, then:

$$y = Med\{x_1, x_2, ..., x_n\} = \begin{cases} x_{t[(n+1)/2]}, n \in 2n+1 \\ \left[x_{t[(n)/2]} + x_{t(n/2+1)}\right]/2, n \in 2n \end{cases} \quad (1)$$

y is called the median of sequence $x_1, x_2, ..., x_n$.

A neighborhood of a particular size or shape of a point is called a window. In the one-dimensional case, the median filter is a sliding window with an odd number of pixels. The value of the center pixel of the window is replaced by the median value of each pixel in the window [16-17] for filtering. Suppose $\{x_{i,j}, (i,j) \in I^2\}$ represents the gray value of each pixel of interior design images, then the two-dimensional median filtering with a filtering window of A can be defined as:

$$y_{i,j} = Med\{x_{i,j}\} = Med\{x_{i+r,j+r}, (r,s) \in A(i, j \in I^2)\} \quad (2)$$

Median filtering also has the following main features:

1) The output of median filter is related to the density distribution of noise, and it has obvious effect on the interference of narrow pulses with small pulse width and long distance.

2) Through the observation of the overall test, it is found that the spectrum characteristics of the median filter have little fluctuation and the mean value is relatively stable. Therefore, it can be considered that the spectrum of the signal after the median filter is basically unchanged [18].

3) Some specific input signals can remain unchanged after median filtering, such as monotonically decreasing or monotonically increasing sequences.

For interior design image processing, standard median filtering mainly has the following deficiencies:

1) From the perspective of signal estimation theory, because the standard median filter is a non-parametric estimation, it does not make full use of the statistical knowledge of the observation model available in practice during processing, so it is quite blind and conservative.

2) Although median filtering has a good suppression effect on long trailing probability distribution noise, such as impulse noise, it has a less ideal suppression effect on short trailing distribution noise and medium trailing distribution noise, such as uniform distribution noise and Gaussian distribution noise.

3) When the number of interference samples in the filtering window is larger than half of the window length, median filtering has no effect. In this case, increasing the size of the filtering window can improve the noise filtering ability, but will destroy the image details.

4) After the median filtering of the image, some thin lines or sharp edges and corners may be eliminated, which destroy the geometric structure of the image.

5) Edge jitter will occur after median filtering for nonconstant signals disturbed by pulse. Even in low noise area, edge displacement still exists.

In order to further improve the filtering effect of standard median filter, rough set theory is used. For noisy interior design images, the effect and quality of early processing often determine the quality of subsequent processing (such as feature extraction, image segmentation, etc.) [19-20]. The complexity and strong correlation of image information cause incompleteness and uncertainty in image processing. Rough set theory has been successfully applied to image processing, among which image filtering is a key research direction in the future. Its basic idea is to treat the information expressed in each image as a knowledge system, and to detect and process the noise pixels in the image by using the approximate set concept of rough set. In this paper, a median filtering algorithm based on rough set theory is proposed to denoise interior design images.

An interior design image can be regarded as a knowledge system. Image I and equivalence relation R constitute an approximate space of interior design image, which is represented by $K = (I, R)$. For a filtering window, an approximate space is formed by the pixels in the window(W) and equivalence relation R, and is represented by $K = (W, R)$.

Rough set theory includes conditional and decision attribute. The conditional attribute set $C = \{c_1, c_2\}$, where c_1 is the extreme value attribute and c_2 is the region attribute of the pixel (hereinafter referred to as the region attribute).

Let the extreme value attribute $c_1 = \{0,1\}$, where 0 represents that the current pixel is the extreme point, that is, its gray value is greater than or equal to the maximum or less than or equal to the minimum gray value of the neighborhood pixel, and 1 represents that the current pixel is not the extreme point. Generally, it is assumed that the gray image to be processed consists of flat region and detail region. If the gray value of the current pixel is close to that of most neighboring pixels, it indicates that the pixel is located in a flat region. Otherwise, it indicates that it is in the detail area. Let the region attribute be $c_2=\{0,1\}$, where 0 means that the current pixel is in the flat region and 1 means that the current pixel is in the detail region. According to the equivalent concept of the irresolvable relation, draw the molecular diagram, classified by attribute C.

1) Drawing the molecular diagram according to c_1: Let x represent image pixel, and the equivalence relation R_{c_1} is defined as the following:

If the gray values of the two pixels are greater than or equal to the maximum or less than or equal to the minimum gray values of the neighboring pixels, then the two pixels are related, that is, they belong to the equivalence class and can be described by the following formula:

$$R_{c_1}(x)=\left\{x \middle| f_{ij} \geq \max(f_w) \quad or \quad f_{ij} \leq \min(f_w)\right\} \tag{3}$$

Where, f_{ij} is the gray value of the corresponding pixel, $\max(f_w)$ represents the maximum gray value of pixel in neighborhood x, and $\min(f_w)$ represents the minimum gray value of pixel in neighborhood x. $R_{c_1}(x)$ represents the set composed of all pixels with extreme gray value, and the complement of R_{c_1} represents the set composed of all pixels with non-extreme gray value.

2) Drawing the molecular diagram according to c_1: R_{c_2} is defined as a small difference between the gray value of a pixel and its adjacent pixels. $R_{c_2}(x)$ represents the set of pixels in all plane areas, and R_{c_2} is complement represents a group of pixels in all detail areas. The difference of gray values is measured by introducing fuzzy membership degree. For a certain pixel point x, the following fuzzy membership function is defined as its degree of belonging to surrounding points:

$$u_z(x)=\left[1+\frac{\left(f_{ij}-f_z\right)^2}{f_z+\lambda}\right]^{-1} \tag{4}$$

Where, z represents the point in the neighborhood of x, f_z represents the gray value of the neighborhood pixel of pixel x, and λ is a constant, which is the square of the mean gray value of the image. According to the definition of membership function, the larger $u_z(x)$ is, the more similar x and z are, and the more likely x and z are to be classified into the same category. Therefore, we can use fuzzy membership function to judge the similarity of gray values between pixels.

The flatness pixel area to be processed for the current pixel () is determined based on the above analysis, can choose the current pixel as elements to be processed, calculate the fuzzy membership degree, on the other a pixel the sum of membership degree, the greater the means of each pixel gray value are more close to, on the basis of pixel gray similarity to measure area, To judge the flatness of the region. Therefore, for any point in the image, the following conditions can be used to determine whether it is located in the detail region or flat region: If the sum of the membership degree of the point to be processed relative to all neighborhood points is greater than or equal to a threshold value, the point is considered to be located in the flat region; otherwise, it is considered to be located in the detail region.

To sum up, it can be concluded that:

$$R_{c_2}(x)=\left\{x \middle| \sum_{x\in Z} u_z(x) \geq T\right\} \tag{5}$$

Where, W represents the selected window centered on the current pixel, that is, a neighborhood of the current pixel, and T represents the preset threshold.

After combining the subgraphs, we can get:

$$W=R_{c_1}(x)-R_{c_2}(x) \tag{6}$$

The pixel in A is median filtered, while the gray values of the other pixels remain unchanged.

In the interior design noisy image, the pixel at position (i,j) is represented by x, and its gray value is f_z. A_{ij} is the filtering window for median filtering of pixel point x, the neighborhood pixel of x is represented by z, and the gray value of pixel z is set as A_{ij}. T is the preset threshold.

The denoising process of interior design images based on median filtering algorithm is as follows:

Step 1: Determine the gray maximum value $\max(f_w)$ and minimum value $\min(f_w)$ of the neighborhood pixel of pixel x in the filtering window A_{ij};

Step 2: Judge the extreme value attribute of pixel point x. If $\min(f_w) \leq f_{ij} \leq \max(f_w)$, When the pixel point x is a signal point, directly output f_{ij}, and execute step 6; Otherwise, when the pixel x is an extreme point, the fuzzy membership function is used to further judge its regional attributes.

Step 3: Calculate the fuzzy membership of pixel x with respect to its neighbor pixel z according to the fuzzy membership function $u_z(x)$, and sum it.

Step 4: Compare the summation result $\sum_{x\in Z} u_z(x)$ with threshold T. If $\sum_{x\in Z} u_z(x) \geq T$, pixel point x is located in the flat area and is the signal point. Output f_{ij} directly and go to step 6. If $\sum_{x\in Z} u_z(x) < T$, pixel x is a noise point, and median filtering is performed on it.

Step 5: According to the standard median filtering principle, replace the gray value f_{ij} of pixel x with the gray median of pixel in the filtering window;

Step 6: If all pixels in the image are processed, complete the process; otherwise, go to the first step to continue to process with the next pixel, so as to achieve interior design image denoising.

IV. Experimental Design

In order to verify the effectiveness of the interior design image denoising method based on median filtering algorithm designed in this paper, experimental tests were carried out. The proposed test parameters are shown in Table I.

In order to verify the application effect of different methods, LYX's method, HCX's method, LYF's method and the method designed in this paper are selected as experimental methods. By selecting multiple interior design scenes, collecting interior design images with sensors, and taking the collected data as experimental sample data, by comparing the denoising effect of interior design images of different methods. The signal-to-noise ratio of interior design images and the denoising time of interior design images are used to verify the practical application effects of different methods.

1) Comparison of denoising effects of interior design images: The indoor design image denoising effects of LYX's method, HCX's method, LYF's method and proposed method in this study are compared in 50 experimental scenes. The comparison results are shown in Fig. 6-7.

TABLE I. Experimental Environment Parameters

Runtime environment	Parameter	Explanation
Hardware environment	CPU	Intel(R) Core (TM)i5-9400
	Frequency	2.90GHz
	RAM	16.0GB
Software environment	Operating system	Windows 10
	Version	18362.1082 pro
	Digits	64bit
	Analog software language	APDL
	Simulation software	Matlab 7.0

By analyzing the results of Fig. 6 and Fig. 7, it can be seen that the image denoising effect of HCX's method is the worst of the four methods, and the image denoising effect of LYX's method and LYF's method is better than that of HCX's method. Compared with the three experimental comparison methods, the image denoising effect of this method is better.

(a) Reference [4] method

(b) Reference [5] method

(c) Reference [6] method

(d) Paper method

Fig. 6. Scene 1 image denoising effect

(a) LYX's method

(b) HCX's method

(c) LYF's method

(d) Proposed method

Fig. 7. Scene 2 image denoising effect

2) Comparison of signal-to-noise ratio of interior design images: The signal-to-noise ratio of interior design images of LYX's method, HCX's method, LYF's method and this proposed method are compared. The results are shown in Table II.

By analyzing the data in Table II, it can be seen that the maximum signal-to-noise ratio of interior design images in LYX's method is 39.7dB, the minimum value is 32.7dB, and the average value is 35.9dB; The maximum signal-to-noise ratio of interior design image in HCX's method is 28.9dB, the minimum value is 23.1dB, and the average value is 26.4dB; The maximum signal-to-noise ratio of interior design image in LYF's method is 39.6dB, the minimum value is 29.7dB, and the average value is 33.1dB; Compared with these methods, the maximum signal-to-noise ratio of interior design image in this method is 58.4dB, the minimum value is 50.6dB, and the average value is 54.6dB, which shows that the signal-to-noise ratio of interior design image processed by this method is higher, the image is clearer, and the practical application effect is better.

TABLE II. SIGNAL TO NOISE RATIO OF INTERIOR DESIGN IMAGES

Number of experiments	Image signal-to-noise ratio/dB			
	LYX's method	HCX's method	LYF's method	Paper method
10	35.1	25.6	30.6	50.6
20	34.2	28.9	31.2	51.4
30	36.9	27.6	35.6	52.3
40	39.7	24.7	30.7	56.4
50	36.4	25.6	35.4	58.4
60	35.6	28.7	29.8	53.2
70	34.1	23.1	29.7	56.7
80	32.7	25.8	32.8	58.2
90	38.5	26.7	35.7	53.6
100	35.7	27.5	39.6	54.7
average value	35.9	26.4	33.1	54.6

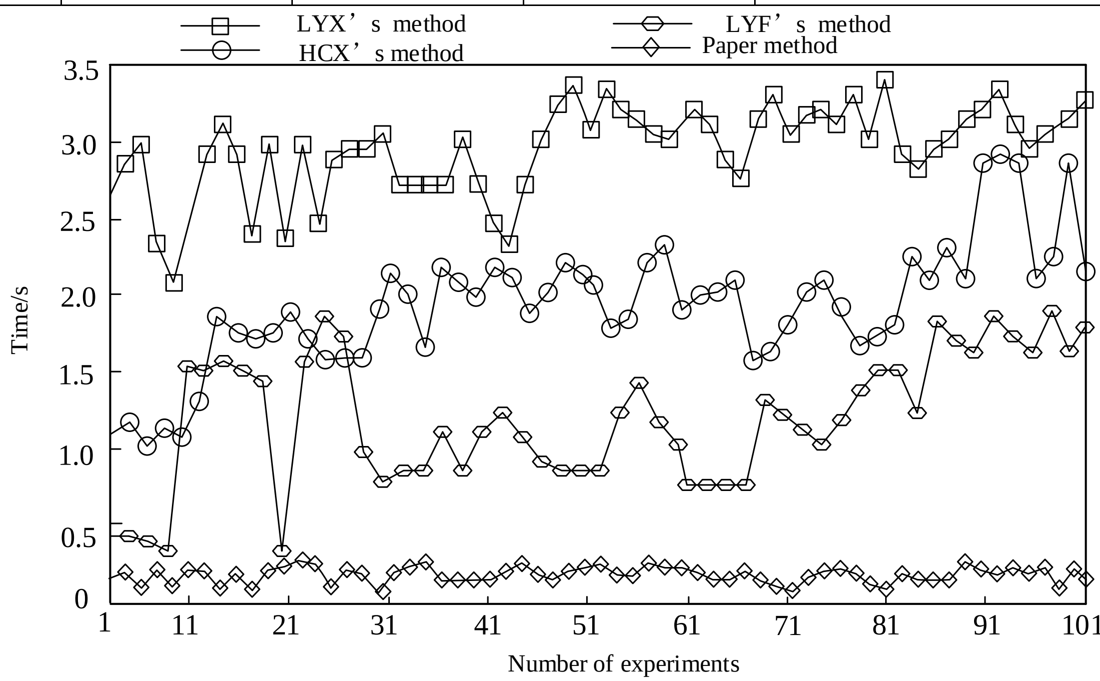

Fig. 8. Comparison of denoising time of interior design images

3) Comparison of denoising time of interior design images: The denoising time of interior design images of LYX's method, HCX's method, LYF's method and proposed method in this study are compared. The results are shown in Fig. 8.

By analyzing the data in Fig. 8, it can be seen that the denoising time of interior design image of LYX's method is between 2.1s and 3.4s, the denoising time of interior design image of HCX's method is between 1.0s and 2.9s, the denoising time of interior design image of LYF's method is between 0.3s and 1.8s, The denoising time of this method for interior design images is always less than 0.3s, which shows that the denoising time of this method for interior design images is shorter and more effective.

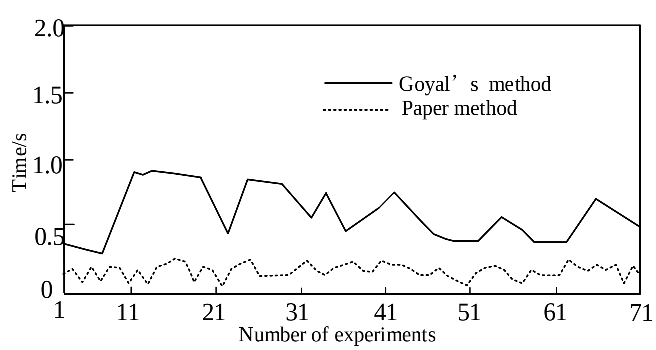

Fig. 9. Comparison of denoising time of interior design images

4) Comparison of image denoising time with the latest method: The method proposed in this paper and Goyal's method are used to denoise the interior design image. The results are shown in Fig. 9.

By analyzing the data in Fig. 8, it can be seen that the denoising time of Goyal's method for the design image is between 0.35s and 0.98s, and the overall time required is still greater than that of the research method. This shows that the method has shorter and more effective noise reduction time for interior design images.

V. Conclusion

With the development of computer technology, the functions provided by digital interior design software have become more and more abundant. The application of relevant software can completely replace the traditional manual design method. Digital room design software can quickly and conveniently complete sketch design. In short, it is to process the two-dimensional plane image through computer software, so that it can be presented in a digital way, so that people can understand the content of the image in a more intuitive way. However, in the process of interior design image generation, interior images are easily interfered by various external factors, resulting in the rise of image noise. Therefore, this paper proposes an interior design image denoising method based on median filter algorithm. The experimental results show that the image denoising effect of this method is better. The average signal-to-noise ratio of interior design image is 54.6dB, and the denoising time of interior design image is always less than 0.3s. It can realize accurate and rapid denoising of interior design image and improve image quality.

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