Retraction Notice

The Editor-in-Chief and the publisher have retracted this article, which was submitted as part of a guest-edited special section. An investigation uncovered evidence of systematic manipulation of the publication process, including compromised peer review. The Editor and publisher no longer have confidence in the results and conclusions of the article.

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Infrared image filtering and enhancement processing method based upon image processing technology

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Abstract. Due to the processing method used in many existing image enhancement algorithms, some inherent noise in the image is amplified when the image is enhanced globally or locally. The quality of infrared images directly affects the wide application of infrared imaging technology, yet the quality of infrared image depends largely on the advanced nature and correct application of infrared image processing technology (IPT). This research mainly discusses the infrared image filtering enhancement processing method based on IPT. We briefly summarize the research significance, application fields and research status of the image registration and enhancement. We summarize the commonly used methods. We use a contrast saliency filter to obtain the region of interest and perform statistical segmentation on the region to make it more suitable for observation and subsequent processing. No matter what the background environment is, the image detail enhancement algorithm enhances all the details in the image in a balanced manner. Therefore, we adopt the scheme of separating the background and the details to avoid the influence of the background difference on the detail display effect in other enhancement methods. Objective experiments have also proved that it is difficult to achieve consistency between subjective and objective evaluation of image quality. Therefore, the evaluation of processed image quality still needs to combine subjective visual effects and objective evaluation. We use optimized hierarchical differential expression theory to solve the acquired saliency region and obtain the differential vector that realizes the gray difference amplification of this region. The dynamic range of the original image is very narrow, roughly concentrated in [0, 50]. The gray range of the image processed by the enhancement algorithm has been well expanded, basically covering [0, 255]. The proposed infrared image enhancement method achieves a better visual enhancement effect. © *2022 SPIE and IS&T* [DOI: 10.1117/1.JEI.31.5.051408]

Keywords: image processing technology; infrared image filtering enhancement; infrared imaging technology; image denoising.

Paper 210979SS received Dec. 27, 2021; accepted for publication Mar. 17, 2022; published online Apr. 5, 2022.

1 Introduction

The arrival of the infrared technology era has opened the door to a variety of applications. With the rapid development of infrared imaging technology, infrared images have been used extensively in scientific research, medical and health, military, and other fields, as well as in people's daily life. At home and abroad, a lot of manpower and financial resources have been invested in the research of infrared image processing technology (IPT). Although many new theories and algorithms have come out, they cannot meet the requirements of advanced weapon systems used in modern changeable tactics and natural environment. Therefore, the research on infrared IPT and the proposal of new and more effective algorithms are very important.

At present, most of the infrared image processing methods mainly used are concentrated in the spatial or frequency domain. As the wavelet transform has the characteristics of analyzing "time-frequency" at the same time, it can decompose the two-dimensional (2D) signal into different resolution scales, so it is particularly suitable for performing image analysis. Infrared technology is conducive to realizing the tracking and information collection of small and weak

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targets and is widely used in different fields in today's information age. The proposed algorithm solves these problems of infrared images. The processing effect of the algorithm is better and the processing process is relatively simple. Finally, it has been successfully implemented on both the software platform and the hardware platform, and it has better real-time performance.

The infrared image processing object can be divided into point target image, weak target image, and imaging target image according to the distance of the image target and the strength of the signal. With the rapid development of image processing, its integration, scale, reliability, etc. are gradually improving, and the functions it can achieve are also continuously enhanced. Mehrabani proposed a new type of inaccurate full adder based on carbon nanotube field effect transistor. It is used for approximate calculations, especially in image processing applications and has been widely used. The design he proposed generates error-free output carry. Therefore, the propagation of error values to higher bits is avoided. His actual simulation using MATLAB shows that for motion detector image processing applications, the peak signal-to-noise ratio (SNR) and image quality are higher. HSPICE simulation also confirmed the effectiveness of the design. In addition, he also used power tools to investigate the area occupancy. Power consumption, delay, area, and extra-low dispersion are important evaluation factors of the subject.[1] Walczak believes that the most commonly used fluorescence detection method in chip gel electrophoresis is to use a high-sensitivity photodiode or a cooled scientific camera as the end point detection in the fluorescence configuration. His purpose is to confirm the simple optical configuration based on a limited number of components and make low cost possible. The location and size of the software-defined detection area (the so-called uncooled charge-coupled device matrix detector of interest is combined with software image processing to make the high-resolution fluorescence detection area of the chip gel electrophoresis) have been identified as the main factors affecting detection performance. He studied several parameters (including SNR and peak full width at half maximum) that characterize electrophoretic patterns. Finally, the detection device he developed was used to separate DNA in separation plates with a theoretical number of more than 600,000 gradients.[2] Hosseininia believes that IPT can be used to evaluate the quality of food and beverage products. Therefore, he focused on studying the relationship between different concentrations of sunset yellow in Miranda soft drinks and IPT colorimetric parameters. He used high-performance liquid chromatography to evaluate the sunset yellow content of Miranda soft drinks. The image processing results show that as the sunset yellow concentration increases, all chromaticity values change. The results show that digital IPT can successfully predict the concentration of sunset yellow in beverages. Therefore, IPT can be used as a potential predictive tool to determine the content of synthetic pigments in food and beverage products.[3] Kong believes that adaptive cross-region guided image filtering (ACR-GIF) is a commonly used cost aggregation method. However, the weights in the ACR points are usually not considered, which affects the accuracy of the parallax results. He proposed an improved the cost aggregation method to solve this problem. First, the orthogonal weight is proposed according to the structural characteristics of ACR, and then he calculates the orthogonal weight of each point in the ACR. Second, he used ACR-GIF (ACR-GIF-orthogonal weights) with orthogonal weights to filter the amount of matching costs. In order to reduce the calculation time of this method, he proposed an efficient weighted aggregation calculation method based on orthogonal weights. He also proposed a local stereo matching algorithm. The results of the Middlebury evaluation platform show that compared with ACR-GIF, the proposed cost aggregation method can significantly improve the parallax accuracy with less additional time overhead. And the performance of the stereo matching algorithm proposed by him is better than other state-of-the-art local and non-local algorithms.[4] To improve the image processing accuracy and speed of the laser three-dimensional imaging system, effectively filter the noise in the image and optimize the processing speed and image accuracy, Wei proposed an improved adaptive meanshift image filtering algorithm based on the traditional meanshift filtering algorithm. He first introduced the traditional mean shift filtering algorithm and improved it on the basis of the traditional algorithm. He chose a small number of pixels to participate in the average calculation, which can increase the speed of the algorithm. According to the size of the broadband matrix h, he selects the appropriate pixel value to participate in the calculation process of the average value, thereby improving the accuracy of the result. Finally, he verified the improved algorithm through comparative experiments. Experimental results show that the improved algorithm can effectively filter out the noise in the image and improve the clarity of the image.[5] The infrared image is the temperature distribution map of the scene, and the temperature range of the real scene may be very large. Therefore, if the infrared thermal imager is to be widely used in various occasions, it must meet the high gray-level dynamic range, that is, high data quantization and storage methods are required. The higher the temperature of the object, the stronger the infrared thermal radiation energy. Objects with very cold surfaces, such as ice cubes, can also emit infrared light.

The concept of weighted gradient histogram has a wide range of applications in image processing, such as the vector statistics of the local descriptor in the famous scale-invariant feature transform operator, some image segmentation and denoising based on partial differential equations, the histogram of oriented gradient operator for human detection and recognition, etc. This article mainly introduces some traditional methods of infrared image detail enhancement, and introduces the advantages and disadvantages of these algorithms. The enhancement algorithm proposed in this paper first separates the background image and the detail image through mean filtering, and then performs the weighted histogram equalization on the detail image. The weight of each pixel in the image is the difference between the expansion filter and the erosion filter, and then a series of transformations. The algorithm highlights the detailed information of the infrared image to a large extent, so that the image can provide more useful information. The result of software simulation is of great help to the subsequent hardware realization. Professional image processing software includes Adobe's photoshop series; application-based processing management and processing software picasa, etc., as well as domestic very practical popular software Color Shadow, non-mainstream software such as Meitu Xiuxiu and dynamic image processing software such as Ulead GIF Animator, gif movie gear, etc.

2 Infrared Image Filtering and Enhancement Processing Method

2.1 *Image Processing Technology*

The overall nature of the image can be seen through the image histogram. For example, on the histogram, if the pixels are mainly distributed in low gray levels, it means that the overall image is dark. If the pixels are mainly distributed in high gray levels, it means that the overall image is brighter. If the pixel occupies most or even the entire grayscale range, and the grayscale values are evenly distributed at all levels, the dynamic range of the image is appropriate for the selected grayscale bits. The image contrast is higher and the gray level is better. If the pixel distribution is only concentrated in the middle, and the gray range occupied is very narrow, the image contrast will be low. Many details in the image cannot be clearly distinguished.[6]

The definition of the bilateral filter is stated as

$$f(x,y)=\frac{\sum_{i=1}^{l} s(x,y)\cdot g[f(x,y)-f'(x,y)]^2 * [f(x,y)+f'(x,y)]^2}{\sum_{i=1}^{l} k(x,y)}. \tag{1}$$

Among them, (x,y) is the pixel coordinate of the center point of the filter window, (x',y') is the coordinate position adjacent to (x,y).[7]

The specific forms of $s((x-x\prime),(y-y\prime))$ and $g(f(x-x\prime),f(y-y\prime))$ are the standardized Gaussian functions of the spatial domain and the gray domain respectively, and the expressions of the two can be stated as[8]

$$s((x-x\prime),(y-y\prime))=\exp\left\{-\frac{(x'-x)^2+(y'-y)^2}{2\beta}\right\}, \tag{2}$$

$$g(f(x-x\prime),f(y-y\prime))=\exp\left\{-\frac{f(x'-x)^2-f(y'-y)^2}{2\beta}\right\}. \tag{3}$$

To match it to the grayscale range of $[m,n]$, the image after the mapping transformation is represented by $g(x,y)$, and the transformation process is expressed as[9]

$$g(x, y) = \frac{(2^n - 1)}{b - a} \cdot [f(x, y) - a]^2 + m. \tag{4}$$

For the input image $f(x, y)$ with the M-bit gray level range of [0, 2M − 1], if it wants to map to the output image $g(x, y)$ with the N-bit gray level range of [0, 2N − 1], the γ transformation expression used is given by[10]

$$g(x, y) = (2^n - 1) \cdot \left[\frac{f(x, y)}{2^m - 1}\right]^2. \tag{5}$$

2.2 *Image Quality Evaluation*

The standard deviation of an image reflects the uniformity of the grayscale distribution of pixels, and describes the dispersion of each point of the image relative to the average grayscale value, which is specifically defined as[11]

$$\delta = \sqrt{\frac{1}{M \times N} \sum_{\mathrm{i}=1}^{m} \sum_{j=1}^{n} (f - u)^2}. \tag{6}$$

Divide the image into several sub-blocks, usually selected as the size of the image block, and calculate each sub-block. After getting the contrast of all blocks, average it, which is the contrast of the entire image. Its expression is given by[12]

$$C_i = \frac{f_{\max} - f_{\min}}{f_{\max} + f_{\min}}. \tag{7}$$

Information entropy characterizes the richness of the information in the image. The larger the entropy, the wider the distribution range of the image gray value, and the larger the amount of corresponding image information. The smaller the entropy, the more concentrated the image gray value distribution, and the smaller the amount of information contained. If the probabilities of all gray-level pixels of the image are approximately equal, the amount of image information tends to be the largest. If all the gray values of the image are almost concentrated in one gray level, the image information volume tends to 0.[13] Its expression is stated as

$$H = -\sum_{\mathrm{k}=0}^{255} p(k) \log_2 p(k), \tag{8}$$

$$P(K) = \frac{A}{M \times N}. \tag{9}$$

The average gradient of the image, as the name implies, is the average representation of the overall gradient of the image. It is a measure of the clarity of the image and the equation for calculation is expressed as[14]

$$G = \frac{1}{(M - 1)(N - 1)} \sum_{i=1}^{m} \sum_{i=1}^{n} \sqrt{\frac{[f(i, j) - f(i + 1, j)]^2 + [f(i, j) + f(i + 1, j)]^2}{2}}. \tag{10}$$

Among them, $f(i, j)$ is the gray value of the pixel at the corresponding coordinate position.

The mean square error can be used to evaluate the fidelity of the image enhancement processing. The smaller the value, the better the fidelity of the image. Its expression is given by the equation [15]

$$\mathrm{MSE} = \frac{1}{M \times N} \sum_{i=1}^{m} \sum_{i=1}^{n} (f - f_i)^2. \tag{11}$$

Among $f_{i,j}$ them, is the gray value of the corresponding point of the original image, $f_{i,j'}$ is the gray value of the corresponding point of the processed image, (i, j) represents the coordinate position of the pixel in the image, and $M \times N$ represents the image size.[16]

The general steps of the absolute evaluation method are: first, the observer will watch the image to be evaluated, and then the quality of the image will be evaluated according to the pre-defined evaluation standard and its grade will be determined. Finally, we have to find the average grade J of this image. J is the result of evaluating this image, and the average grade J is given by[17]

$$J = \sum_{i=1}^{k} nj / \sum_{i=1}^{k} n. \tag{12}$$

In the equation, K is the total number of pre-defined levels.[18]

The correlation distribution of the gray-scale transformation coefficients is given by

$$s_k = T(r_k) = \frac{\sum_{j=0}^{k} p(r)}{\sum_{j=0}^{l-1} p(r)} \qquad (k = 0, 1, 2, \ldots, l-1). \tag{13}$$

Define other weight matrix elements except $w(j,k)$ as[19]

$$w(j+m, k+n) = \frac{g(j,k;m,n)}{2\sum_{m=-1}^{1}\sum_{n=-1}^{1} F(j,k;m,n)}, \tag{14}$$

$$g(j,k;m,n) = \frac{1}{|F(j+m,k+n) - F(j,k)|}. \tag{15}$$

The basic framework of layered processing is shown in Fig. 1. Although bilateral filtering can obtain better performance when extracting image details and protecting strong edges. However, near the strong edges of the image, the difference in pixel values is large, which makes the Gaussian weighting coefficient unstable, resulting in an obvious gradient flip effect. The weighted least squares filter introduces a matrix related to the gradient, and obtains the output smooth image by solving the inverse matrix of the input image. The filter can effectively control the halo and gradient flip effects. With the increase of the coefficient, the smoothing effect becomes more obvious, and the larger the scale of the extracted details. Compared with the bilateral filter, its detail extraction ability is stronger, and the protection ability to strong edges is stronger. Different parameter selections can extract detailed information of different scales, while the edge information of other scales can be well preserved and will not be destroyed. This makes the weighted least squares filter often used for multi-scale detail enhancement.[20,21]

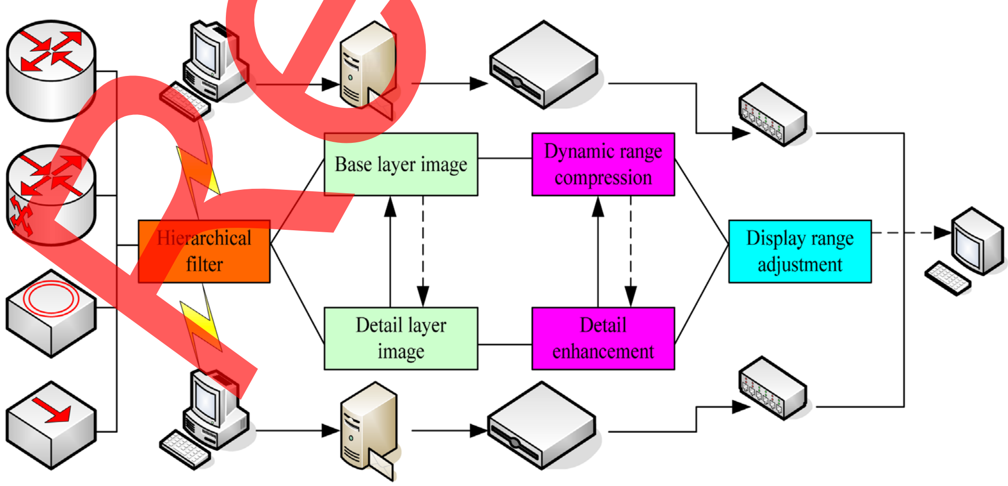

Fig. 1 The basic framework of layered processing.

The multiscale decomposition of the image by the 2D discrete wavelet transform decomposes the image into a simple multilevel frame, that is, the multiresolution representation of the image. Each component of the frame has unique frequency characteristics and spatial orientation characteristics, which provide a good basis for image analysis and processing.

2.3 *Filter Enhancement*

The guided filter is a filter based on linear transformation. For the input image I_m, its output I_{gif} can be expressed as

$$I_{\text{gif}}(i,j)=\frac{1}{|w|}\sum_{(i',j')\in w_{i,j}}(a(i',j')I_{\text{in}}(i',j')+b(i',j')), \tag{16}$$

$$a(i,j)=\frac{\frac{1}{|w|}\sum_{(i',j')\in w_{i,j}}G(i',j')(I_{\text{in}}(i',j'))-\mu_{i,j}\overline{I_{\text{in}}(i',j')}}{\sigma_{i,j}^2+\varepsilon}, \tag{17}$$

$$b(i,j)=\overline{I_{\text{in}}(i',j')}-a(i,j)\mu_{i,j}. \tag{18}$$

The one-dimensional signal is roughly divided into three intervals, labeled as I, II, and III. Interval I belongs to a flat area. Although there is less detailed information, the three filters can extract these tiny fluctuations into the detail layer. In this interval, the detailed information of the bilateral filter and the guided filter fluctuates around 0, which meets the filtering requirements. However, the weighted least squares filter will have undesirable performance in areas with obvious gradient changes, such as the image frame and strong edges. At the border, the pixel value of the smoothed image exceeds the pixel value of the input image, resulting in a drop in the detail layer signal. The over-sharpening near the strong edge also shows the down-suppression of the detail information. The weighted least squares filter does not closely approximate the original image in the area with obvious gradient changes.[22] Interval II is mainly a strong edge, and the three kinds of filters have different degrees of gradient flipping in this interval. This also shows that there is no ideal filter. No matter how good the filter is, it cannot absolutely approximate the original information at all edges. In this interval, the bilateral filter and the guided filter smooth the strong edges to varying degrees, which makes the detail layer flip. The weighted least squares filter over-sharpened the strong edges, which also caused the detail layer to flip. Interval III is the area with rich details, which is the main area for extracting details. It can be seen from the figure that the performance of the three filters in this interval is basically the same, and these detailed fluctuations can be extracted better. On the whole, although the performance of the three filters at some edges has some deficiencies, they all have strong detail extraction capabilities.[23]

For the guided filter, because there are more operations to calculate the image mean and variance in the intermediate calculations, the functions that characterize the details can be designed with the help of these intermediate calculations, which are given by[24]

$$W(i,j)=\frac{1}{|w|}\sum_{(i',j')\in w_{i,j}}\left(\text{abs}\left(\frac{(I(i,j)-\mu_{i,j})*(I(i',j')-\mu_{i,j})}{\sigma_{i,j}^2+\varepsilon}\right)\right), \tag{19}$$

$$g(i,j)=g_L+(1-k(i,j))*(g_H-g_L). \tag{20}$$

With the continuous improvement of the demand for processing power in the fields of signal processing and communication, the parallel development technology of digital signal process (DSP) has also been developed rapidly. The method of multi-device parallelism and on-chip multicore can effectively improve the processing performance. Compared with traditional single-core DSP, multicore parallel processing requires multitask parallel design, which makes the system design more complicated. The common mode of multicore DSP parallel processing is shown in Fig. 2. Each core in the system is cascaded and equal, and data flows through each core in turn. The whole algorithm is divided into independent small blocks, each block is executed by

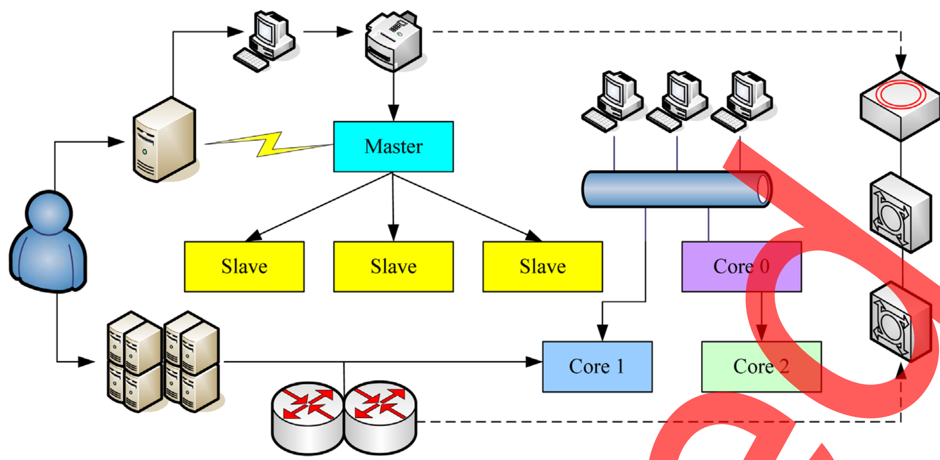

Fig. 2 Common modes of multicore DSP parallel processing.

a single processing core, and the output of one core becomes the input of the next core. The use of data flow mode requires a reasonable segmentation algorithm to make the load of each core almost uniform, so as to achieve the best performance. Typical applications of data stream mode include: high-performance video codec, video transcoding, long term evolution (LTE) physical layer implementation, etc. The algorithm design in this paper uses a combination of two modes. It needs to use four DSP cores in processing, among them core 0 is regarded as the main core, used for the transmission of DSP and external data. It mainly realizes the startup configuration of DSP system, network configuration, board resource configuration and so on. After the program is executed, core 0 receives the data sent by the upper computer and distributes it to the processing core; receives the data processed by the processing core and packs it back to the upper computer. The DSP core uses native development kit for network configuration, and the data are sent and received using the UDP protocol, and its principle is the same as that of the host computer.[25]

2.4 *Experimental Platform*

To evaluate the processing performance of the algorithm proposed in this paper, the comparison algorithms selected in the experimental link include the dual-platform histogram equalization algorithm and the infrared image detail enhancement algorithm based on the guided filter. In addition, in order to reflect the best results of each algorithm as much as possible, taking into account the differences between infrared image data, this paper strictly follows the relevant guidance of the paper itself in the selection of parameters. In the selection of infrared image data, in view of the characteristics of the image will change with the change of external factors such as the type of the detector and the target scene. In order to reflect the typicality and completeness of the experimental data, the image data sources of this experiment include refrigerated detectors (resolution of 320×256) and uncooled detectors (resolution of 384×288). In the selection of experimental scenes, this article refers to the selection criteria of FrancescoBranchitta, requiring scenes to contain one or more of the four features, namely: large dynamic range, smooth areas, strong edges, and rich details. In addition, in order to reflect the processing performance of this algorithm in a small dynamic range, the experimental data also includes uncooled image data of one scene in indoor and outdoor environments. At this time, the data of the refrigerated detector is not collected because the temperature of the refrigerated detector is relatively high. Only under extreme test conditions (such as collecting black body radiation scenes under uniform ambient temperature) can the small dynamic range conditions be met, so this extreme scene is not included in this experiment.[26]

Spatial domain processing can be defined by the following equations

$$g(x, y) = T[f(x, y)], \tag{21}$$

$$s = T(r), \tag{22}$$

where $f(x, y)$ is the input image and $g(x, y)$ is the processed r image. and s are defined variables. After linear transformation, it is given by

$$s_1 = \frac{W_2 - W_1}{R_2 - R_1} \times (r_2 - r_1) + s_1. \tag{23}$$

The basic form of logarithmic transformation is given by

$$s_2 = \log(r) + \beta + \delta, \tag{24}$$

$$s_3 = C\ \ln(r + 1), \tag{25}$$

Among C them, is the scale ratio coefficient.

2.5 *Design of the Camera*

The camera is powerful and provides high-quality images for the back-end processing program. Regarding the selection of the infrared camera, after comprehensive consideration, it was decided to adopt the long-wave uncooled focal plane infrared thermal imaging core TC384. This movement makes the design of complex infrared imaging systems simple and fast. TC384 can meet the requirements of industrial temperature measurements, medical diagnosis, and safety vision. It is widely used in industrial temperature measurements, scientific research, monitoring, night vision, construction, and other industries. The technical parameters of the TC384 infrared imaging component are shown in Table 1. The combination of high spatial resolution and large dynamic range of the battlefield is suitable for detecting weak target signals and identifying multiple targets. Under various complex human and background interferences, it can realize automatic identification and selection of targets, and has strong anti-photoelectric interference ability.

2.6 *Optimization of Image Fusion Algorithm*

The detail layer processing method based on the weight coefficients of the guided filter can effectively preserve the image boundary while suppressing a large amount of noise in the detail layer. But the filter weight parameter is only used in the adaptive gain correction algorithm. Increase the calculation amount of the algorithm, and each pixel must be operated in the window. Even if the data required for the calculation already exists before, it will still bring additional calculations. From the perspective of the realizability of the algorithm, this article believes that it

Table 1 Technical parameters of TC384 infrared imaging module.

Project		TC384
Detector performance	Pixel	384 × 288
	Pixel size	25 μm
	NETD	<80 mk
	Spectral range	8 to 14 μm
Image performance	Spatial resolution	1-25 mm
	Electronic zoom	50/60 Hz
	Image filtering	4×
	Image enhancement function	Have
	Correction function	Have
	External power supply	Automatic or manual function

is necessary to reduce the amount of calculation brought by this processing method. Because the gray level of the basic layer image changes slowly, and the detail layer, as the difference between the original image and the basic layer, is positive or negative. Therefore, when the basic layer is directly superimposed on the detail layer with larger absolute value, many noise-like interference points will be generated in the original smoother basic layer image. In either case, it will greatly interfere with the quality of the final image. Therefore, before completing the weighted summation of the basic layer image and the detail layer image, this paper also performed the gray level overflow correction operation in the high temperature and low temperature areas.

3 Infrared Image Filtering and Enhancement Results

The short-wave window is between 1 and 5 μm, and the long-wave window is between 8 and 14 μm. The general infrared thermal imaging camera uses the bands: short wave (3 to 5 μm); long wave (8 to 14 μm), as shown in Fig. 3:

Median filtering is a nonlinear digital filter technique often used to remove noise from images or other signals. The design idea is to check the samples in the input signal and determine whether it is representative of the signal, and use the observation window composed of an odd number of samples to achieve this function. The method adopted in this paper is to add different degrees of salt and pepper noise, speckle noise, and Gaussian noise to the original image. Then carry out general median filtering and improved median filtering on the image respectively, and then compare the changes of SNR before and after filtering to draw an analysis conclusion. It can be seen that for salt and pepper noise, the improved median filter algorithm has advantages over the general median filter algorithm in terms of improving the SNR. For speckle noise and Gaussian noise processing, the improved median filter algorithm is not as effective as the general median filter. The comparison of median filtering and improved median filtering is shown in Fig. 4. It can be seen that the improved median filter algorithm can better retain the details of points, lines, and sharp features than the general median filter algorithm.

Compared with the traditional flat-outside histogram method and the histogram equalization method, the effect of the platform histogram enhancement method in this paper has been improved by 10.68% and 79.97%, respectively. In terms of evaluation parameters, the method in this section is also 10.57% higher than the method of histogram equalization, which is similar to the effect of traditional platform histogram on evaluation parameters. However, the complexity of the algorithm in this paper is less than that of the traditional method, and it can achieve image enhancement adaptively, so it is an effective enhancement method. Table 2 shows the effect of the platform histogram enhancement method in this paper and the traditional flat outside histogram method.

The enhancement effect obtained by quantitatively comparing the genetic algorithm and histogram equalization is shown in Table 3. It can be seen from Table 3 that the enhancement effect of using genetic algorithm in contrast is 9.4% higher than that of the latter. In the detailed

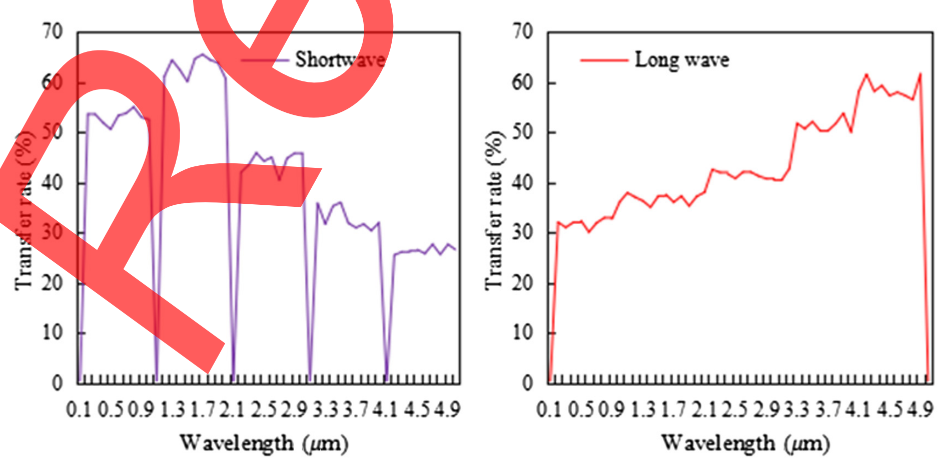

Fig. 3 Wave bands used by infrared thermal imaging cameras.

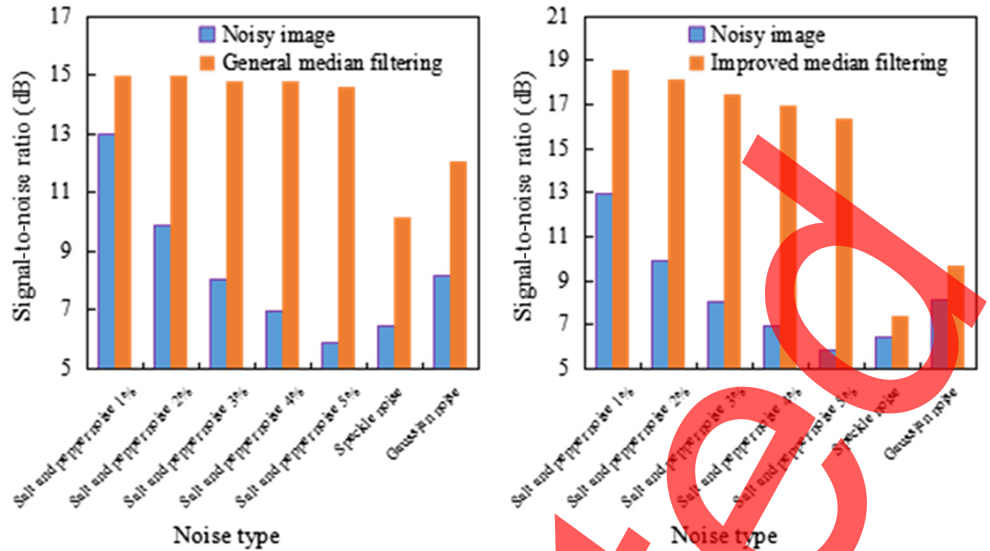

Fig. 4 Comparison of median filtering and improved median filtering.

Table 2 The effect of the platform histogram enhancement method in this paper is compared with the traditional flat outside histogram method.

-	Original image	Traditional platform histogram enhancement	This article platform histogram enhancement	Histogram equalization
Contrast	0.1244	0.3052	0.3378	0.1877
Detailed evaluation parameters	0.0265	0.0309	0.0293	0.0265
Precise	0.93	0.95	0.94	0.96

Table 3 Quantitative comparison of the enhancement effect obtained by genetic algorithm and histogram equalization.

Enhancement	Original image	Genetic algorithm enhancement effect	Histogram equalization
Contrast	0.3763	0.4586	0.4152
Detailed evaluation parameters	0.0059	0.0073	0.0068
Precise	0.88	0.93	0.92

evaluation, the enhancement effect of using the genetic algorithm is also about 6.8% higher than the latter. Therefore, it can be considered that the use of genetic algorithm for image enhancement is a feasible and effective enhancement method than traditional histogram equalization methods. The results are better than the results obtained by the histogram equalization method in terms of preservation of image details and improvement of target and background contrast.

From the statistical results in Table 4, compared with the direct gray-scale linear stretching of the original 14-bit infrared image, the average gray value of the image is reduced. This is to better balance the overall brightness and contrast of the image to fundamentally improve the visual effect. Table 4 shows the comparison between the algorithm in this paper and the direct gray-scale linear stretching of the original 14-bits infrared image.

The quantitative representation of the fidelity of color images is a very complex problem, so the quantitative representation of the fidelity of black-and-white images is currently used more.

Table 4 Comparison between the algorithm in this paper and the direct gray-scale linear stretching of the original 14 bits infrared image.

Infrared scene	Algorithm	Average gray value	Information entropy
Scene 1	Grayscale linear stretch	121.3376	4.3827
	Local grayscale linear stretch	60.4890	6.5999
	Algorithm	73.1660	6.6361
Scene 2	Grayscale linear stretch	130.4653	3.9147
	Local grayscale linear stretch	118.3599	6.5382
	Algorithm	123.3980	6.6139
Scene 3	Grayscale linear stretch	114.5038	4.2066
	Local grayscale linear stretch	39.0298	6.3878
	Algorithm in this paper	75.1715	7.2984

Table 5 Absolute evaluation scale standards.

Quality scale	Hinder the scale	Score
No picture quality deterioration at all	Very good	5 points
It can be seen that the image quality has deteriorated, but it does not hinder viewing	Good	4 points
It is clear that the image quality has deteriorated, which is a slight hindrance to viewing	Generally	3 points
Hinder viewing	Difference	2 points
Very serious obstruction to viewing	Very bad	1 point

Absolute evaluation refers to a qualitative analysis method of image quality in which the observer directly evaluates the image to be evaluated (i.e., the enhancement result of the algorithm) according to his visual experience. The five-level absolute scale commonly used internationally mainly includes quality scale and obstruction scale. Among them, the quality scale is suitable for ordinary personnel, and the obstruction scale is suitable for professionals. The absolute evaluation scale standards are shown in Table 5.

The unprocessed original infrared image is shown in Fig. 5(a), where it can be found that the image is dark, and the sense of hierarchy of objects in the image is not obvious. The image processed by the weighted histogram enhancement algorithm is shown in Fig. 5(b). The contrast of the image has been greatly improved, and the different sceneries in the image can be better recognized.

Since infrared images have the characteristics of narrow grayscale dynamic range, it is essential to increase the dynamic range of the image to enhance the infrared image. Therefore, whether the dynamic range of the image can be effectively increased is one of the important indicators to evaluate the pros and cons of the enhancement algorithm. The result after processing with this algorithm is shown in Fig. 6.

Relative evaluation means that the observer first classifies a certain batch of images to be evaluated (i.e., the enhancement result of the algorithm) according to their visual perception, and then compares and ranks all the images in each specific category with each other. Finally, scores are based on the ranking results, and the relative evaluation scale standards are shown in Table 6.

The dynamic range of the original image is very narrow, roughly concentrated in [0, 50]; the grayscale range of the image processed by the enhancement algorithm in this paper has been well

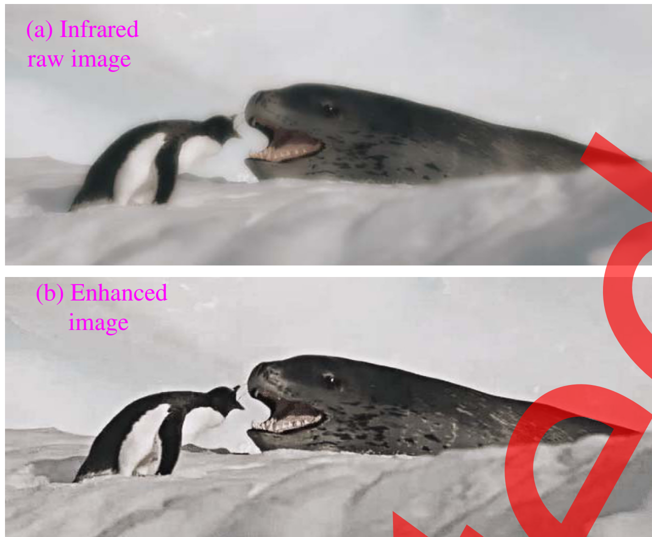

Fig. 5 Infrared image processing. (a) Unprocessed infrared raw image and (b) the image processed by the weighted histogram enhancement algorithm.

Fig. 6 The result of processing using the algorithm.

Table 6 Relative evaluation scale standards.

Relative measurement scale	Hinder the scale	Score
The best of the group	Very good	5 points
Better than the average in the group	Good	4 points
Average in the group	Generally	3 points
Worse than the average in the group	Difference	2 points
Worst in the group	Very bad	1 point

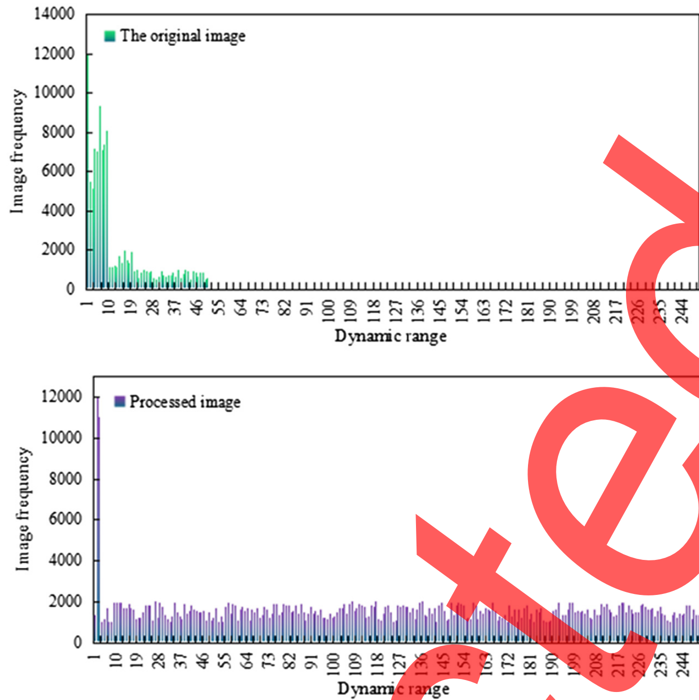

Fig. 7 The grayscale of the image processed by the enhanced algorithm in this paper.

expanded, basically covering [0, 255]. The grayscale of the image processed by the enhancement algorithm in this paper is shown in Fig. 7.

The comparison of the edge information image of the unprocessed original image group and the edge information image of the image group after the enhancement processing of the algorithm is shown in Fig. 8. After image edge detection is performed on the original image and the image processed by this algorithm, it can be found that the edge information of the detected image is significantly more than that of the original image. This shows that it is easier to find small objects in the image by processing the image with this algorithm, and it has laid a good foundation for the subsequent image processing (such as effectively detecting the image target).

The comparison of the simulation results is shown in Fig. 9, and the following conclusions can be drawn: the histogram equalization method reduces the gray level in exchange for the

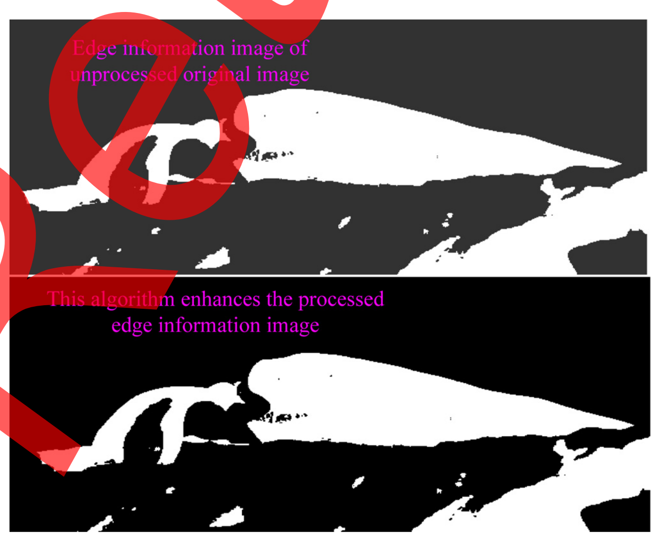

Fig. 8 Comparison of the edge information image of the unprocessed original image group and the edge information image of the image group after the enhancement of the algorithm in this paper.

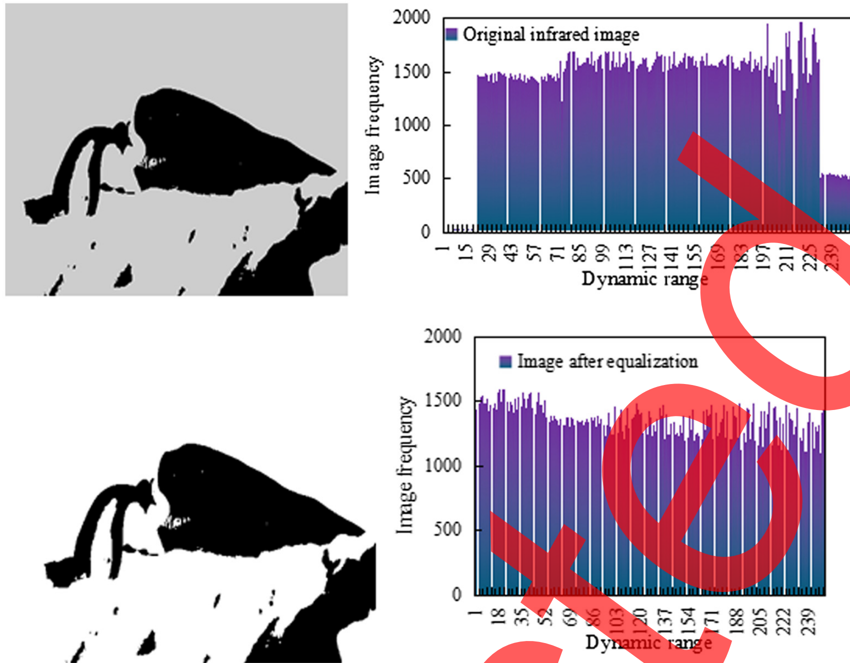

Fig. 9 Comparison of simulation results.

increase of the contrast. Although the histogram equalization method increases the contrast of the image, it often makes the visual effect of the processed image stiff and not soft enough. In addition, because the signal and noise are not distinguished during the equalization process, the noise after equalization is more obvious than before.

The comprehensive processing method of weak infrared image proposed in this paper can denoise and enhance infrared image is very obvious. The noise of the image is reduced, the contrast of the image is enhanced, the clarity of the image is improved, and the edges, contours and details of the original image are better maintained. Compared with other methods, it can be seen that the method proposed in this paper can effectively improve the large noise of infrared images, and solve the problems of low contrast and blurring.

4 Discussion

The performance and working environment of infrared imaging equipment will change with time, and the non-uniformity of infrared images will also change accordingly. When imaging equipment works for a long time, the performance of imaging equipment components will change. Therefore, the non-uniformity of infrared images will become more and more serious. But in the process of adjusting the imaging system, there will be a correction residual problem, which is related to the adjustment method and the working environment of the system.

The sharpness of the image is an important indicator for evaluating the quality of the image. This index is used to evaluate the degree of image degradation after compression, transmission or algorithm processing, and it can better express human visual perception. When the sharpness of an image is relatively low, it means that the image is fuzzy and the visual effect is poor. The gradient information of the image can better express the clarity of the image, but the gradient information is more sensitive to noise, which makes the results unsatisfactory when measuring images with noise. The structural similarity evaluation algorithm can better evaluate the quality of the image. This method is a full-reference image quality evaluation method. When the original image cannot be obtained as reference information, this method cannot be used to evaluate the image quality. Images are displayed to people in the form of transforming information into graphics, so this way of providing people with information is more intuitive and richer in content. The process of image acquisition, transmission, compression, and storage may cause problems in image quality degradation. Therefore, the use of images to convey information is easily affected by image quality. At the same time, it also brings trouble to the post-processing of the image, such as image recognition, target tracking, and so on. Therefore, image quality evaluation can guide the improvement of imaging equipment and the setting of algorithm parameters in order to obtain high-quality images to lay a solid foundation for image post-processing.

The display quality of an image is a strong evidence to measure the pros and cons of an algorithm, and the primary consideration in the design of an algorithm is also the image display quality. In general, image quality includes two aspects: the fidelity of the image and the intelligibility of the image. Fidelity describes the degree of deviation of the assessed image from the standard image. Generally speaking, people pay more attention to the fidelity of natural images, because they are used to compare it with the scene in memory in the subconscious. Intelligibility describes the ability of images to provide information to people or machines.

Generally speaking, China's infrared image registration and enhancement technology started late compared with foreign countries, and its maturity and application fields are obviously lagging behind. Therefore, no matter from scientific research or engineering, it is necessary to increase research intensity and input cost. Feature-based enhancement technology has broad application prospects, and image enhancement technology should be improved on the basis of traditional theoretical framework in the future. It should be further strengthened to improve the accuracy, speed, and real-time performance of the algorithm. It is believed that with the rapid economic development and continuous advancement of technology, the application fields of image enhancement will become more extensive, and it will have more brilliant and brilliant prospects.

The visual model is the mathematical basis for machine vision to simulate the human eye and is used to realize the visual function of the human eye. In many applications, the human eye is the receiving terminal of infrared image information. Therefore, the research of infrared image processing based on vision model has important theoretical and application significance. However, due to the continuous improvement of real-time requirements in applications, the rapid development of microelectronics technology, and the inherent defects of infrared imaging devices, the processing of infrared image enhancement is particularly important. In general, infrared images have defects such as low contrast, high noise, and high ambiguity. This brings certain difficulties to the next step of feature extraction, target recognition and tracking of infrared images. Therefore, how to effectively improve image contrast, suppress image noise, and enhance image edges and lines have become very important tasks in infrared image processing. By comparing the pictures before and after processing, it can be found that the infrared image has been significantly enhanced. Moreover, the hardware implementation process of the algorithm is not complicated, and the hardware resources consumed and the processing time of the algorithm are in a controllable range.

The human visual system is very sensitive to the edge of the target object. By observing the edge information, the shape of the target object can be obtained, and the analysis and interpretation of the target can be achieved. However, human vision is robust and cannot distinguish the edge blur within a certain range. This ability to distinguish the edge blur is called the contrast sensitivity of the human eye. Human eye brightness and contrast sensitivity reflect the vision's ability to distinguish between light intensity and light intensity contrast, and provide a theoretical basis for the establishment of signal perception models in computational vision.

5 Conclusion

It is obviously difficult to improve these algorithms simply from enhancing the image and suppressing the noise at the same time. The next step should focus on the denoising problem of the enhanced image. The algorithm proposed in this paper combines the advantages of various algorithms and achieves a better enhancement effect. At the same time, it is fully self-adaptive, without manual intervention, and can enhance different types of infrared images. However, due to the many processes of the algorithm, logarithmic calculations are used. Therefore, the real-time performance of the algorithm is slightly lacking compared with other real-time algorithms, and the tool of sampling image histogram cannot be used to enhance the original image to improve the real-time performance of the algorithm. It can only improve real-time performance by optimizing algorithms and performing parallel calculations when hardware design is required. Aiming at the deficiencies of the algorithm, it is necessary to improve the real-time performance of the algorithm, and to verify the adaptability of the algorithm by enhancing more kinds of infrared images. At the same time, it is necessary to study other better methods to replace some links in the algorithm in order to achieve better enhancement effects. The most important research direction is how to determine a unified, objective, and reasonable image quality evaluation method. It can be consistent with people's subjective feelings, which can become the basis of image enhancement methods.

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