Infrared and visible image fusion based on edge detail enhancement and wavelet transform

Ranran Wei [1, a], Zhongyuan Wang [2, b] and Meng Liu [1, c]

[1] National Demonstration Center for Experimental Electrical and electronic technology, Chanchun University of Science and Techonlgy, ChangChun, JiLin;

[2] National Demonstration Center for Experimental Electrical and electronic technology, Chanchun University of Science and Techonlgy, ChangChun, JiLin.

[a]1603409002@qq.com, [b]17808050776@163.com, [c]869218104@qq.com

Abstract

Aiming at the problem that the image after traditional wavelet transform has blurred edge details and insufficient image information retention, an infrared and visible image fusion algorithm based on edge detail enhancement and wavelet transform is proposed. First, edge enhancement processing is performed on infrared and visible images. Then, the best wavelet base is selected, and the processed infrared and visible images are respectively subjected to multi-scale wavelet decomposition by wavelet transform to obtain high-frequency components as well as low-frequency components of infrared and visible images respectively, after that the rule of large absolute value are adopted for high-frequency components fusion, and the rules for regional energy are used for the low-frequency components fusion. Finally, the fused image is obtained by inverse wavelet transforming the fused high-frequency component and low-frequency component. The experimental results show that compared with the traditional fusion algorithm, the proposed algorithm can obtain fused images with rich edge detail information and high definition.

Keywords

Image fusion, infrared image,visible light image, wavelet transform, edge.

1. Introduction

Image fusion is to fuse the information of multiple images into one image. The fused image contains more abundant information, which is conducive to people's observation or processing. The advantage of image fusion is that it can increase the time-domain and frequency-domain information contained in the image, and at the same time increase the reliability and certainty of the image. Infrared and visible image fusion can effectively combine the target preservation characteristics of infrared image and the scene detail preservation characteristics of visible image, and enhance people's ability of scene perception and target recognition under adverse conditions such as smoke, occlusion and insufficient light [1]. Therefore, the research of infrared and visible image fusion has attracted wide attention.

Wavelet transform is a transform method based on short-time Fourier transform. This method overcomes the limitation of Fourier transform on analysising local information and non-stationary signal. It highlights the local features of image through transform, and realizes multi-scale decomposition of information through scaling and translation method [2]. Although the image processed by traditional wavelet transform can get a clear edge contour, there are some problems such as blurred edge details and insufficient information preservation. To solve this problem, this paper proposes an infrared and visible image fusion algorithm based on edge detail enhancement and wavelet transform. Compared with the traditional fusion algorithm, the fusion image obtained by this algorithm has the characteristics of good fusion effect, high clarity and rich edge details.

2. Principle of wavelet transform for image fusion

2.1 Wavelet transform principle

Wavelet transform is a new transform analysis method based on short-time Fourier transform. It overcomes the shortcoming of STFT and provides a window that can change with the frequency, and can analyze and process signals in time and frequency domain. Wavelet transform includes continuous wavelet transform and discrete wavelet transform. Mallat fast algorithm is a signal decomposition algorithm on orthogonal wavelet basis and a discrete sequence of wavelet transform. Through this discrete sequence of wavelet transform method, the application of image wavelet transform becomes reality.

The process of image wavelet decomposition and reconstruction is shown in Figure 1 below.

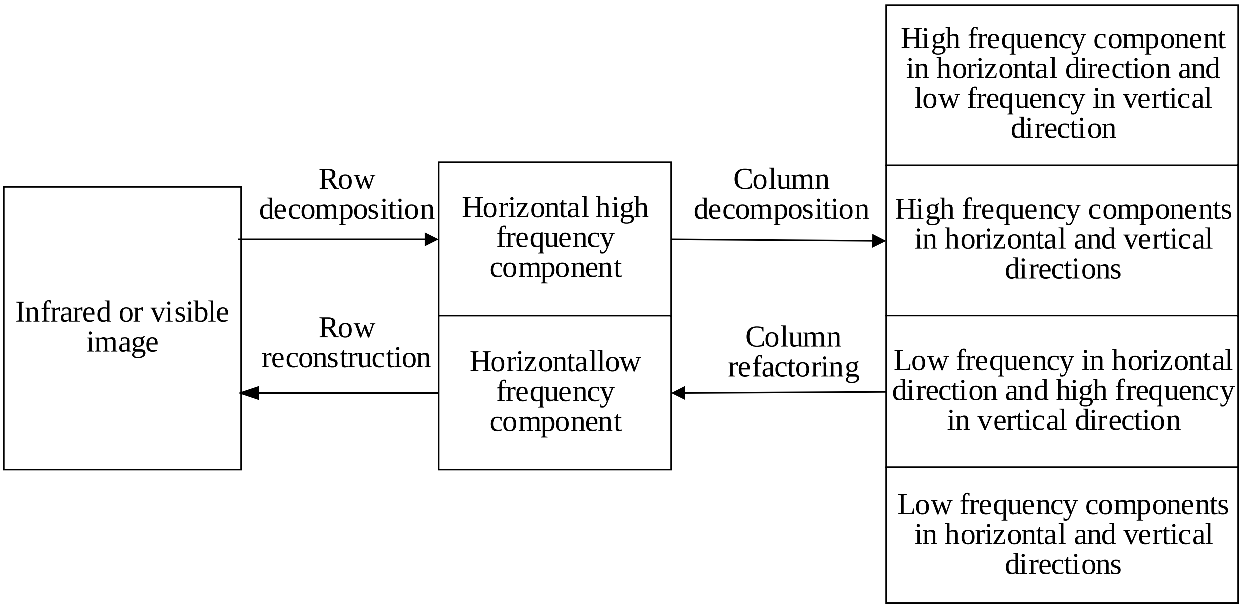

Figure 1 Image wavelet decomposition and reconstruction process

2.2 Edge enhancement principle

The edge of an image often contains most of the information of an image. The edge exists at the mutation point of the image signal. These points constitute the image contour. These contours are the important feature conditions for edge detection. That is to say, we can detect and extract the edge of an image when we enhance the edge. Edge enhancement can improve the contrast of specific areas of the image and make the overall effect of the image clearer. In this paper, Roberts operator edge detection method is used to enhance the edge details of infrared and visible image processing. The basic steps of edge detection are as follows:

◆ Firstly, infrared and visible images are smoothed;

◆The mutation points in each image are extracted as candidate points for edge points;

◆Find out the real edge points from the candidate points and connect them;

3. Image fusion based on wavelet transform

3.1 Low-frequency component image fusion rules

The low-frequency component decomposed by the wavelet transform determines the brightness and edge information of the image, including rich texture and background information, which affects the restoration of image quality. In this paper, the low-frequency component is fused by the rule of regional energy [3]:

$$P_F(i,j)=\begin{cases}P_A(i,j),E_A(i,j)\geq E_B(i,j)\\P_B(i,j),E_A(i,j)<E_B(i,j)\end{cases} \tag{1}$$

Where E(i,j) represents the regional energy value, and the formula is as follows [4]:

$$E(i,j)=\sum_{p=-\frac{P+1}{2}}^{\frac{P+1}{2}}\sum_{q=-\frac{Q+1}{2}}^{\frac{Q+1}{2}}\omega*[P(i+p,j+q)]^2 \tag{2}$$

Where

$$\omega=\frac{1}{16}\begin{bmatrix}1&2&1\\2&4&2\\1&2&1\end{bmatrix} \tag{3}$$

The size of the area is generally taken as an odd number, such as 3 × 3 or 5 × 5, etc., this paper takes 3 × 3.

3.2 High-frequency component image fusion rules

The high-frequency components decomposed by wavelet transform can reflect the edge features and texture information of the image. In this paper, the high-frequency components adopt the fusion rule of absolute value, which is not only simple but also effective to highlight infrared and visible light. Detail and texture information in the image [5]:

$$C_{mn}^A=\begin{cases}C_{mn}^H,\left|C_{mn}^H\right|\geq\left|C_{mn}^L\right|\\C_{mn}^H,\left|C_{mn}^H\right|<\left|C_{mn}^L\right|\end{cases} \tag{4}$$

C_{mn}^A represents the high-frequency component coefficient of the fused image, C_{mn}^H and C_{mn}^L represent the high-frequency and low-frequency component coefficients obtained by the wavelet transform, and Cmn represents the coefficient of the n-th direction of the m-th layer of the high-frequency.

4. Image fusion experiment results analysis

In order to verify the effect of the method on the fusion of infrared and visible images, four sets of typical infrared and visible images were tested respectively, and the objective evaluation results of subjective visual evaluation and quantitative indicators were compared with the traditional methods as shown in Figure 2 and Table 1. Show:

A1 B1 C1 D1

A2 B2 C2 D2

A3 B3 C3 D3

A1-A3 is an infrared image; B1-B3 is a visible image; C1-C3 is a traditional method fusion image; D1-D3 is a fusion image of the method; the visible light image used in this experiment is a grayscale image, and the infrared image is a black and white image.

Figure 2 for infrared and visible images and fused images for testing

As shown in Fig. 2, the fusion image obtained by the test can be seen from the subjective visual evaluation of the human eye. The fusion image obtained by the traditional method (C1) has low brightness, low contrast, and obvious distortion of the spectrum, which makes the image quality not too good. the method fusion image (D1) has high brightness, high contrast and clear edge texture. The fusion image obtained by the traditional method (C2) has low definition between rivers and branches, and the fusion image (D2) of this method has improved. The fusion image obtained by the traditional method (C3) pedestrians, vehicles and other facilities are not clear, the contrast is not high, the edge contour is not prominent, the method fusion image (D3) contrast is improved, the edge contour is clearer, and the facilities such as people and vehicles are more Layering. In summary, from the direct observation of the human eye, the edge details of the fusion image of the method are clearer, the brightness is higher, the contrast is higher, and the visual characteristics of the human eye are more suitable.

In order to improve the rigor of the experiment and make it more convincing, the fusion image effect of the method is further verified. This paper continues to use objective quantitative indicators to evaluate the effect, that is, select five kinds of objective evaluation indicators [6]: standard deviation, information entropy, sharpness, edge intensity, and average gradient. As shown in Table 1 below:

Table 1 Objective evaluation indicators of fusion images

Evaluation index	C1	D1	C2	D2	C3	D3
Standard deviation	82.3969	97.0916	76.6909	81.1719	86.1993	91.2165
Information entropy	4.8211	5.0788	4.6908	5.3530	4.7030	4.9398
Sharpness	3.1085	4.8760	2.1175	2.9037	2.9891	4.0032
Edge strength	32.6225	44.2340	18.9725	23.7987	38.982	45.2565
Average gradient	3.2977	4.0378	2.3564	3.6753	2.0292	3.0982

From table 1, using five objective evaluation indicators [6]: standard deviation, information entropy, sharpness, edge intensity, and average gradient to evaluate the fused image in Figure 2. The objective evaluation indicators in the above table: the larger the standard deviation, the information entropy, the sharpness, the edge intensity, and the average gradient, the better. The data from Table 1 can be objectively obtained: compared with the fusion image obtained by the traditional method, the standard deviation of each evaluation index is increased by 9.38% on average, the information entropy is increased by 8.17% on average, and the average resolution is improved by 42.64%. The edge strength increased by an average of 26.05%, and the average gradient increased by an average of 42.17%. In summary, the standard deviation, information entropy, sharpness, edge intensity, and average gradient of the fused image obtained by the method of the present invention are improved. The target object in the fused image is easier to identify, the amount of information is richer, the edge details are clearer, and the fused image is better.

5. Conclusion

Based on the weakness of the traditional wavelet transform image, an infrared and visible image fusion algorithm based on edge detail enhancement and wavelet transform is proposed. The problems of fuzzy edge details and insufficient image information retention in the traditional wavelet transform are further improved. The experimental results show that the proposed method has great advantages for infrared and visible image fusion. The resulting fused image has a better fusion effect, higher definition, and richer edge detail information.

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