Infrared and Vsible Image Fusion Method Based on Wavelet Transform*

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Abstract - According to the feature of infrared and visible image , a method of image fusion based on wavelet transform is proposed in this paper . Firstly, we make wavelet transform for the infrared and visible image after Preprocessing and regist-ration, so we get the different frequency wavelet coefficients of source images , then we separately do image fusion for different frequency domain after decomposition according to the rules: The low frequency wavelet coefficients are weighted and on high frequency wavelet coefficient we select large. Meanwhile we com-pare it with Space domain fusion algorithm according to the rules :The pixel are weighted and selected large. The simulation experiment result shows that using wavelet second fusion method has a good effect on the infrared and visible image fusion.

Index Terms - Image fusion, Wavelet transform, Infrared image and visible image, Simulation experiment

I. Introduction

Image fusion [1] is a method which can merge multiple feature images from different imaging devices or sensors to one image. This image or scene is more complete. Based on different stages of image fusion, we usually dispose it on three levels : The pixel level fusion, the feature level fusion and the decision level fusion. On different level of image fusion we use different method. There is lots of methods on pixel level fusion, including: The simple method of weighted average to get fusion image; Laplace Pyramid [2][3] method proposed by Burt; Ratio low pass Pyramid method, contrast Pyramid meth-od, gradient Pyramid method [3] etc.

In the 90's , with the theory of wavelet transform [4] widely used in image processing , the technique of wavelet transform also has been successfully used in image fusion. The processing based on different resolution ratio of wavelet transform turn to be hot issue in signal and image processing research field in recent years.

Method of wavelet transform in this paper belongs to the pixel level fusion, which is fundamental and frequented-used. It has the advantages of holding original information of fusion image, meanwhile the fusion accuracy is at a high level and the loss of information less than the other level fusion. This paper is based on the multi-resolution of wavelet decompose-tion, and use the method according to the rules: The low frequency wavelet coefficients are weighted and on high frequency wavelet coefficient we select large. Then we simulate algorithm by using Matlab and analyzed the result.

Fusion method researched in this paper is aiming at the infrared image and visible image, with the same objects at the same distance with different sensors to capture the image, which can compensate for a single infrared sensor or a CCD sensor imaging defects, and it meet the specific needs of the image scene. Using this method we can make full use of the same scene complementary and redundant information of different images. Accordingly we achieve a more detailed , more specific explanation of the scene, meanwhile it provid the conditions for target recognition and tracking further. In this paper, the following image processing experiments we use: the image after pretreatment and registration, which is the same size.

II. Common image fusion algorithm

A. Space domain fusion method

Pixel level image fusion technology [5] mainly includes the method based on space domain and frequency domain. Fusion method in space domain is a selection processing directly to the source image pixel value. This paper adopt two algorithm: pixel value weighted average fusion method and the pixel value selected large (small) fusion method.

1). The pixel value weighted method

The basic principle of the pixel value weighted average fusion method is that the source image without any conversion and processing, and directly to the corresponding pixel in the image gray value to be the weighted average process, thus generating new image. This method is one of the most direct method.

Assuming the source images is A, B, the final fused image is F. The two images are weighted average fusion process can be expressed as follows:

$$F(i, j) = \omega_1 * A(i, j) + \omega_2 * B(i, j) \quad (1)$$

Where i represents the number of rows of image pixels, j represents the number of columns of image pixels, w_1,w_2 respectively represent image A, B weighted value of the information of the fusion image.

2). The pixel value selected large(small) method

The basic principle of the pixel value selected large (small) fusion method is that the source image without any conversion and processing, and directly to the corresponding

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pixel in the image gray value to select large (small) process, thus generating new image. The two images are selected large (small) fusion process can be expressed as follows:

$$F(i,j)=\max(A(i,j),B(i,j))$$
$$F(i,j)=\min(A(i,j),B(i,j)) \quad (2)$$

B. Frequency domain fusion method

Fusion method in frequency domain is the first in a certain way to separate the high and low resolution information of image effectively, and on different frequency bands by using different fusion rules to process, finally the fused image is obtained. Generally frequency domain fusion methods are: the Pyramid decomposition method, wavelet transform method etc.

III. Fusion method based on Wavelet Transform

A. The image wavelet decomposition

Mallat[6] proposed a wavelet transform decomposition and reconstruction fast algorithm, he used two one-dimensional wavelet image decomposition of [7] the decomposition filter, and used two dimensional reconstruction filter realization of two-dimensional image to complete wavelet reconstruction [8]. If the H (low) and G (high) is two one-dimensional Mallat algorithm of a mirror image of filter operator , according to the following formula:

$$\begin{cases} C_{j+1}=HC_jH' \\ D^h_{j+1}=GC_jH' \\ D^v_{j+1}=HC_jG' \\ D^d_{j+1}=GC_jG' \end{cases} \quad \text{j=0,1, ... ,J-1} \quad (3)$$

While the corresponding reconstruction formula can be expressed as follows:

$$C_j=H'C_{j+1}H+G'D^h_{j+1}H+H'D^v_{j+1}G+G'D^d_{j+1}G$$
$$\text{j=J-1,J-2,.....,0} \quad (4)$$

In the formula, C_{j+1}、D^h_{j+1}、D^v_{j+1}、D^d_{j+1} respectively correspond to the low frequency component, horizontal high frequency component, vertical high frequency component and the diagonal high frequency component of the image C_j. H',G' respectively represent Conjugate transpose matrix of H ,G.

B. Fusion process based on wavelet transform method

The basic steps of image fusion Based on wavelet transform can be expressed as follows:

1) Firstly we conduct wavelet transform of infrared image and visible light image A, B, and establish the image wavelet decomposition ;
2) Then the high frequency decomposition layer and low frequency decomposition layers of infrared and visible light image are respectively processed. The decomposition of different frequency wavelet coefficients of the layer according to the fusion rules[9], so we get the wavelet coefficients fused;
3) Finally we conduct wavelet inverse transform for wavelet coefficients fused , F is the fused image. The figure below shows the fusion process [11] with wavelet transform:

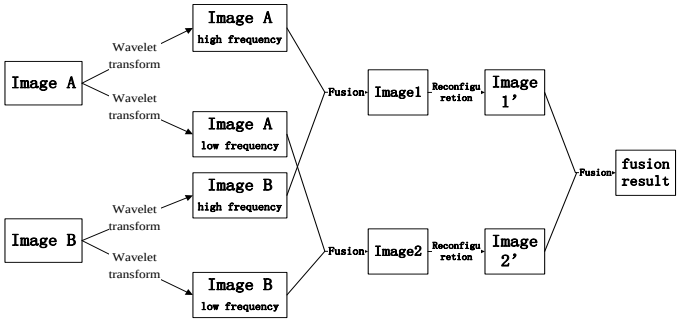

Fig. 1 image fusion process based on wavelet transform

C. Fusion rules based on wavelet transform method

1). The low frequency fusion method

On the process of the wavelet transform image fusion, the low frequency components not only mainly include the contours and original information of image ,but also affects the image edge details. Based on the low frequency part of the wavelet coefficients we use weighted average fusion strategy.

Set the source images A, B , fusion results for F. For the low frequency wavelet coefficient matrix of fusion image:

$$C_n(F)=\alpha C_n(A)+\beta C_n(B) \quad (5)$$

Among them, there are three cases:

If the purpose is to improve the image fusion effect of A, we can choose $\alpha>\beta$;

If the purpose is to improve the image fusion effect of B, we can choose $\alpha<\beta$;

If the two source images of the same scene is from the same imaging model in image collected at different time, we can choose $\alpha=\beta=0.5$.

2) The high frequency fusion method

The high-frequency part of the image determines the image details and important information. Based on the high frequency part of the wavelet coefficients with larger absolute value as the fusion strategy.

The basic idea is: first in the high frequency sub image corresponding to the source image respectively select a region of a window for the fusion pixel as the center, its size is optional for 3*3, 5*5 or 7*7 and processed according to the following rules:

If $|D_i(A)(i,j)|=|D_i(B)(i,j)|$

Then $N_A=N_A+1$, And $N_B=N_B+1$

Else if $|D_i(A)(i,j)|>|D_i(B)(i,j)|$

Then $N_A=N_A+2$, And $N_B=N_B+2$

$$i \in [m-r/2, m+r/2],\ j \in [n-r/2, n+r/2] \qquad (6)$$

In this scenario , r refers to the width of the window, (m,n) is regional center , N_A and N_B is counter respectively correspond to the two window,the initial value is 0.

If $N_A > N_B$,then $D_i(F)(m,n) = D_i(A)(m,n)$

If $N_A < N_B$,then $D_i(F)(m,n) = D_i(B)(m,n)$

If $N_A = N_B$,then

$$\begin{cases} D_i(F)(m,n) = D_i(A)(m,n), if \left|D_i(A)(m,n)\right| \geq \left|D_i(B)(m,n)\right| \\ D_i(F)(m,n) = D_i(B)(m,n), if \left|D_i(A)(m,n)\right| < \left|D_i(B)(m,n)\right| \end{cases} \qquad (7)$$

So we complete the high frequency part of the fusion, finally on the fusion of low frequency and high frequency coefficients of the wavelet transform we get the fusion image.

D. Wavelet transform second fusion method

In order to make a better visual effect after fusion, important information and complementary information more comprehensive and contains the original image fusion, the improved method of wavelet transform are proposed: the image of infrared image and visible light image by wavelet transform fusion are once again with the fusion of visible image, two times the fusion image is obtained. Steps is as below:

1) The infrared image A and visible light image B is proceeded by using wavelet transform, fusion rule for the wavelet coefficient absolute large (the rules of image information entropy, image contrast is most obvious, but the details of the image is not clear), the fused coefficients by inverse wavelet transform fusion image F1 is obtained.
2) Image fusion F1 and visible image B is proceeded by using wavelet transform, fusion rule for the low frequency wavelet coefficient (weight ratio is 0.35:0.65) and the high frequency wavelet coefficient absolute large (the rules of important information and complementary information of the original image, the image is clear, the best), the fused coefficients by inverse wavelet transform to obtain F for image fusion ,F is the fusion result.

IV. Simulation experiment

In order to compare the fusion effect, respectively, using pixel weighted average and absolute large wavelet coefficients fusion method, weighted average and absolute and fusion method, wavelet transform fusion method, wavelet transform two fusion method of image fusion of source images. Fusion of infrared and visible light image fusion using various methods, obtained the result is shown in figure 2.

Among figure 2, Figure 2 (a) and 2 (b) respectively refer to infrared and visible light images to be fused;Figure 2 (c) refers to pixel weighted average fusion result; Figure 2 (d) refers to The pixel value selected large method result; Figure 2 (e) refers to the wavelet coefficients weighted average fusion result; Figure 2 (f) refers to wavelet coefficient absolute selected large fusion result; Figure 2 (g) represents the hybrid algorithm fusion result based on wavelet transform; Figure 2 (h) represents the improved wavelet second fusion method result.

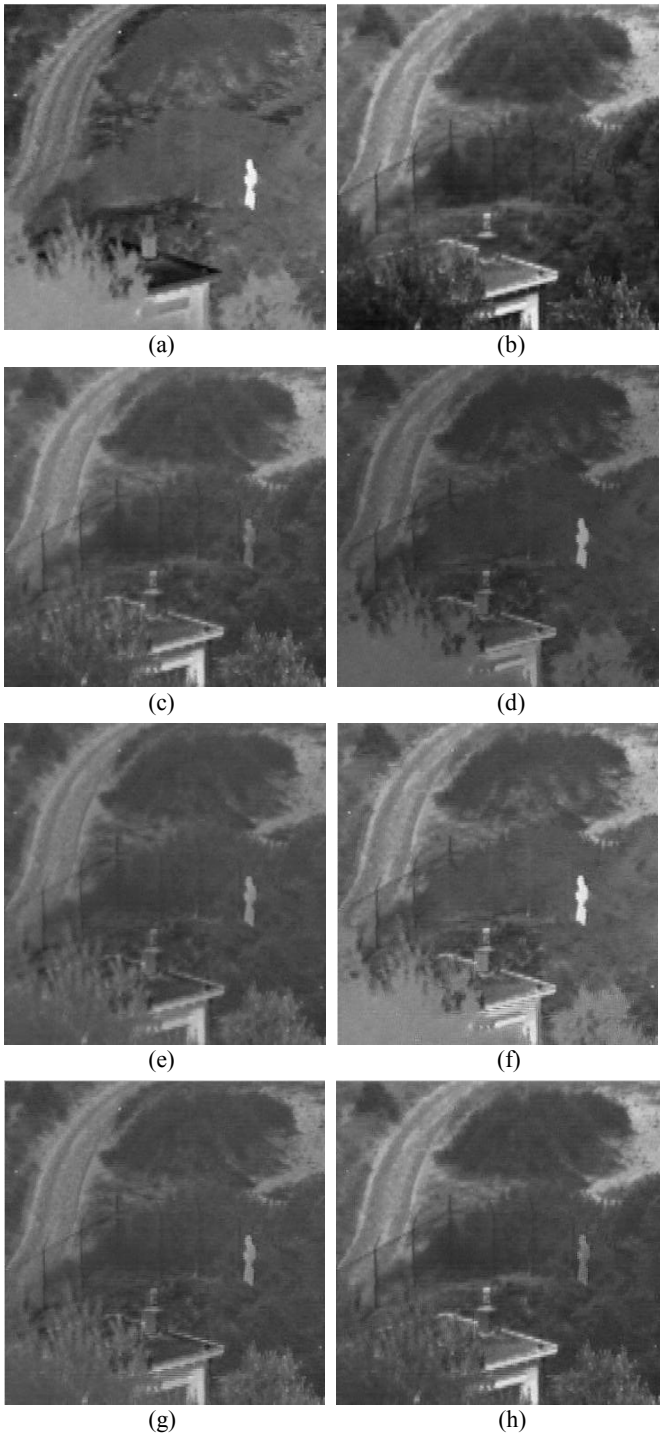

Fig. 2 experiment result of various fusion methods

According to the experimental results above, through the objective evaluation on the information entropy, standard deviation, mean error, mean grads [10] standard to evaluate, under the table is the result of objective evaluation index statistics of image fusion:

Among table 1, Method 1 refers to pixel weighted average fusion method; Method 2 refers to The pixel value selected large method; Method 3 refers to the wavelet coefficients weighted average fusion method; Method 4 refers to wavelet coefficient absolute selected large fusion method; Method 5 represents the hybrid algorithm fusion method based on wavelet transform; Method 6 represents that the improved wavelet second fusion method .

TABLE I Objective evaluation index of image fusion experiment

Index / NO.	Objective evaluation index			
	Information entropy	standard deviation	average error	average gradient
Method 1	6.4753	0.1079	0.3467	0.0197
Method 2	6.0381	0.0773	0.2910	0.0158
Method 3	6.1503	0.0844	0.3394	0.0171
Method 4	6.6564	0.1121	0.4186	0.0304
Method 5	6.2020	0.0860	0.3394	0.0251
Method 6	6.5761	0.1199	0.3509	0.0271

From the evaluation index 1, four methods based on wavelet coefficient absolute and fusion method for large image information entropy, indicate that the image contains the original information is most, but the details of the image display is not clear; the improved wavelet transform two fusion methods of information entropy method is to select only to the absolute, but the details of the image are clearly visible, and the contrast of the image clear, distinct, conducive to the observers watch. After the analysis of the experimental results, the wavelet transform fusion strategy is improved by two times after fusion than the classic strategy can more effectively improve the fusion effect.

Image fusion evaluation in addition to quantitative analysis of the objective evaluation and subjective evaluation, qualitative analysis, the following table is the image fusion subjective evaluation [11] :

TABLE II Subjective evaluation index of image fusion experiment

Index / No	score	quality index	Prevent index
1	5 points	very good	Can not see the image quality deterioration at all
2	4 points	good	Can see that the image quality is bad, but without prejudice to watch
3	3 points	general	See a deterioration of picture quality obviously, obstructing the viewing
4	2 points	bad	obstructing the viewing
5	1 points	worst	obstructing the viewing seriously

From table 2 of the subjective evaluation index, we can see the improved wavelet second fusion method image clearly in the portrait and landscape details, scores is between 4~5, near to 5,and image quality is much better than other fusion methods.

V. Conclusion

Aiming at the infrared and visible light images, this paper proposes an image fusion algorithm based on wavelet transform. The decomposed wavelet in image proceed on the high frequency and low frequency respectively by the respective fusion rules. The experimental results show that the fusion image obtained by using the fusion algorithm is beneficial to the whole scene understanding, experimental data and visual effects have demonstrated the effectiveness of the algorithm. After image fusion the image contains important information to be integrated and complementary information , and it is more suitable for human and machine vision, more conducive to further analysis and understanding of image.

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