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IMAGE FUSION ALGORITHM BASED ON BIORTHOGONAL WAVELET

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Abstract— Image fusion could process and utilize the source images, with complementing different image information, to achieve the more objective and essential understanding of the identical object. A novel image fusion scheme based on biorthogonal wavelet decomposition is presented in this paper. As for wavelet transform algorithm, due to the virtue of its multi-resolution, wavelet transform has been applied in image processing successfully. So the image fusion algorithm based on biorthogonal wavelet transform is proposed, in which two images i.e. high and low resolution images to be processed are firstly decomposed into sub-images with different frequency, and then the information fusion is performed using these images under the certain criterion, and finally these sub-images are reconstructed into the result image with plentiful information. Another advantage of wavelet transform is that it can be much more easily realized in hardware because its data format is very simple. This could save a lot of resources, besides, to some extent, it can solve the real-time problem of huge-data image fusion. However, as the orthogonal filter of wavelet transform doesn't have the characteristics of linear phase, the phase distortion will lead to distortions of the image edge. To make up for this shortcoming, the biorthogonal wavelet is introduced here. Image fusion is studied for detecting weapons or other objects hidden underneath a person's clothing. Here the fusion of visible image and a corresponding IR image is done for such a concealed weapon detection application. The fused image obtained by the proposed algorithm will maintain the high resolution of the visible image, incorporate any concealed weapons detected by the IR sensor, and keep the natural color of the visible image. The feasibility of the proposed fusion technique is demonstrated by some experimental results.

***Keywords*— biorthogonal wavelet transform, image fusion, low SNR, multi-resolution, resolution,**

I. INTRODUCTION

Images of the same scene from sensors with different characteristics and different resolution at different time may provide complementary information about the scene. Image fusion is an advanced image processing technology, which could produce a new integrated image while retaining the important feature of these images. In the past years, the technique of image fusion has been applied widely in the field of remote sensing, medical image processing and intelligent robot.

Currently, the primary image sensors are including Visible, IR (infrared), MMW (millimeter wave), UV (ultraviolet) and x-ray sensors. When the images from different types of sensors are fused, the SNR (signal noise- rate) of these images is always different. The SNR of visible image is often higher than others. If an algorithm is improper, the part of visible image sometimes will be polluted and the quality of fused image will be degraded, or the partial information of low SNR image will be abandoned and lost.

In this paper, the image fusion algorithm based on biorthogonal wavelet transform is proposed to improve the resolution of the images to be processed are firstly decomposed into sub-images with the same resolution of the images, in which two images to be processed are firstly decomposed into sub-images with the same resolution at the same levels and different resolution among different levels, and then the information fusion is performed using high-frequency sub-images, where these sub-images are reconstructed into the result image with plentiful information. [1].

II. IMAGE FUSION TECHNOLOGY

With taking the image as research object, image fusion in general is to use images as redundant or complementary sources to extract information from them with higher accuracy or reliability as in Fig1. Image fusion technology is intended to extract the information of corresponding channel and finally form a composite image in system output based on certain image processing of multiband information, which is caught by the single sensor or many images under same scene acquiring from image sensor of many different models in an effort to observe or integrate different image information for further processing. In the last two decades, a great deal of model and algorithm researches are made on image fusions at different levels and various fusion systems are given around the world [4].

Image caught by the sensor is generally with the noise and the subsequent processing requires for a limitation of the noise, image fusion thus can be for reduction of the

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noise and improvement of the SNR and is also used for resolution improvement, because the infrared image transmitted from the satellite is sometimes with low resolution, image fusion can be adopted to improve the resolution by fusing the image caught by other sensors (including optical image, synthetic aperture image).

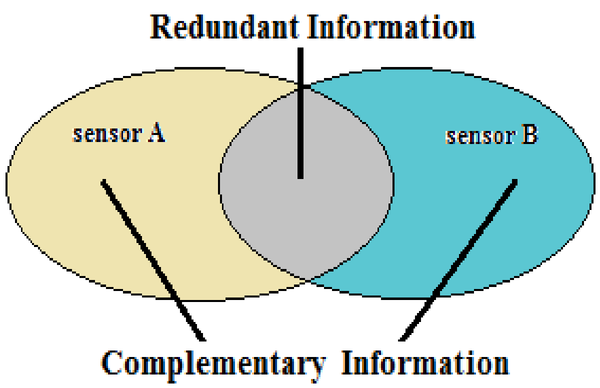

Fig. 1 Fusion of two images

In the course of image processing, it always requires to improve the image quality, highlight the details and texture feature, as well as preserve the edge details and energy of the image on the basis of reserving the original information, image fusion can get these effect despite it is difficult for some general image enhancement.

To compensate the loss/failure messages in a sensor image with the images from other sensors. Obviously, the image fusion technology is not the image enhancement in the general sense, but a new technology in the computer vision and image understanding field. In 1997, Hall and Llinas gave a general introduction to multi-sensor data fusion.

Another in-depth review paper on multiple sensors data fusion techniques was published in 1998 [11]. This paper explained the concepts, methods and applications of image fusion as a contribution to multi-sensor integration oriented data processing. Since then, image fusion has received increasing attention. Further scientific papers on image fusion have been published with an emphasis on improving fusion quality and finding more application areas. As a case in point, Simone describe three typical applications of data fusion in remote sensing, such as obtaining elevation maps from synthetic aperture radar (SAR) interferometers, the fusion of multi-sensor and multi-temporal images, and the fusion of multi-frequency, multi-polarization and multi-resolution SAR images. Vijay raj provided the concepts of image fusion in remote sensing applications.

Quite a few survey papers have been published recently, providing overviews of the history, developments, and the current state of the art of image fusion in the image-based application fields but recent development of multi-sensor data fusion in remote sensing fields has not been discussed in detail. As the orthogonal filter of wavelet transform doesn't have the characteristics of linear phase. The phase distortion will lead to distortions of the image edge. To make up for this shortcoming, the Biorthogonal wavelet is introduced here.

III. WAVELET USED IN THE IMAGE FUSION

A. Image fusion algorithm based on wavelet transform

With wavelet multi-resolution analysis and fast Mallet transform, the algorithm first decomposes an image to get a approximate image and a detail image, which respectively represent different structures of the original image. [5] Then targets for all floors of the image feature domain and processes them with special fusion algorithm, so the effect of fusion will be much better i.e. the source images A and B are decomposed into discrete wavelet decomposition coefficients: LL (approximations), LH, HL and HH (details) at each level before fusion rules are applied. The decision map is formulated based on the fusion rules. The resulting fused transform is reconstructed to fused image by inverse wavelet transformation and is as shown in Fig.2.

Wavelet transform has the ability of reconstructing, so there is no information loss and redundancy in the process of decomposition and reconstruction. The fast Mallet transform largely decreased the time of operation and made its application possible in image processing.[6] However, as the orthogonal filter of wavelet transform doesn't have the characteristics of linear phase, the phase distortion will lead to the distortion of the image edge. To make up for this shortcoming, the biorthogonal wavelet is introduced here. The wavelet reconstruction is needed in the image fusion and only the filters with linear phase could ensure to avoid the distortion of image. Unlike the conventional orthogonal wavelet, within biorthogonal wavelet, reconstruction and decomposition filter is different.

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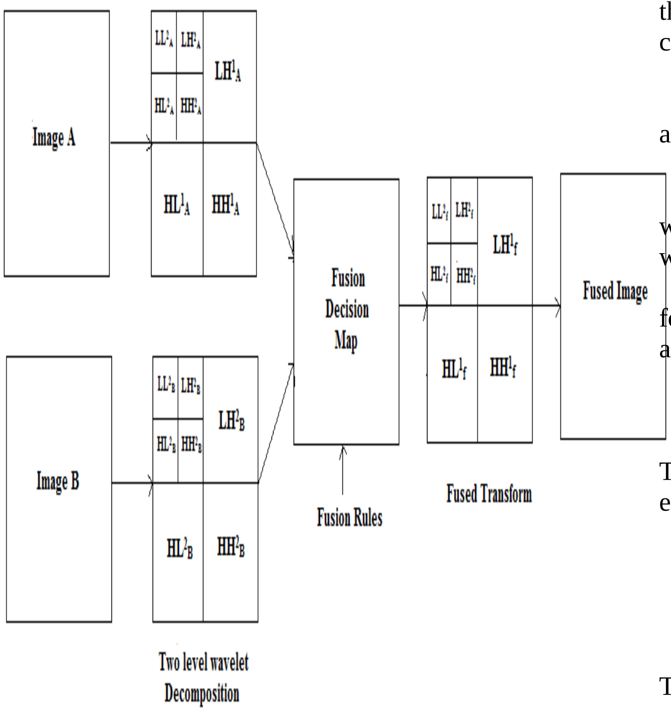

Fig .2 Wavelet based Image fusion

In order to achieve symmetry and compactness, the biorthogonal wavelet makes concession in orthogonality, and can be accurately reconstructed with the FIR filter. [9] Compared with the orthogonal wavelet transform, the shape of biorthogonal wavelet could have a broader range of options, which bring greater design flexibility [4].

In wavelet transformation, the basic functions are a set of dilated and translated scaling functions:

and a set of dilated and translated wavelet functions:

Where (*n*) and (*n*) are the scaling function and the mother wavelet function respectively. One property that the basis function must satisfy is that both the scaling function and the wavelet function at level j can be expressed as a linear combination of the scaling functions at the next level j+1:

and

where h (m) and g (m) are called the scaling filter and the wavelet filter respectively.

For any continuous function, it can be represented by the following expansion, defined in a given scaling function and its wavelet derivatives (Burrus, et.al.1998):

The fast Discrete Wavelet Transform (DWT) can be expressed as follows:

The scaling filter $h^*(n)$ is a low pass filter extracting the approximate coefficients, with , while the wavelet filter $g^*(n)$ is a high-pass filter extracting the detail coefficients . The coefficients are down sampled (i.e. only every other coefficient is taken).

The reconstruction formulas are given by:

Generally, discrete wavelet is introduced by multi-resolution analysis. Let (R) be the Hilbert space of functions, a multi-resolution analysis (MRA) of (R) is a sequence of closed sub spaces , j Z (Z is the set of integers), of (R) satisfying the following six properties (Mallat, 1989):

- The subspaces are nested: *j* Z
- Separation: = {0}
- The union of the subspaces generate (R): = (*R*)
- Scale invariance: *f* (*t*) *j* Z

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- Shift invariance:
  $f(t)$ Z
- , scaling function, so that {(- k} is a Riesz basis of .

There is also a related sequence of wavelet subspaces of (R), Z, where is the orthogonal complement of in Then, = , where is the direct sum.

The above applies to about one-dimension situation; for two-dimension situation, the scaling function is defined as:

Vertical wavelet:

Horizontal wavelet:

Diagonal wavelet

(x, y) can be thought of as a 2-D scaling function, are the three 2-D wavelet functions.
For the two-dimension image, the transform can be expressed by the follows:

(13)

(14)

(15)

(16)
Here, corresponds to the j-1 level approximate image, and are the horizontal, vertical, and diagonal sub images, respectively

B. Biorthogonal wavelet

If the orthogonality condition is relaxed to biorthogonality conditions, wavelets with some special properties that are not possible with orthogonal wavelets can be obtained. In the biorthogonal transform, there are two multi-resolution analyses, a primal and a dual:

Primal:

Dual:

The dilations and translations of the scaling function {} constitute a basis for and, similarly, { for ; the biorthogonality conditions imply:

For the biorthogonal transform, perfect reconstruction is available. [8]

C. Fusion Rules

In the process of image fusion, the fusion quality always lies on the rules and the choice of fusion operator. [10] As the human eyes are highly sensitive to the dramatic changes in a local part of an image, like the edge and corner, the multi-resolution fusion method is based on this idea. In addition, the local characteristics of an image often don't be presented by a single pixel, but a lot of neighboring pixels from a local region. Here the test images are decomposed using discrete wavelet transform. The approximations are subjected to pixel based maximum election rule. A 3X3 square mask and odd order rectangular averaging mask (5X7) are each applied to detail images. The new sets of coefficients from each source image are added to get new approximations and details. Final fused coefficient matrix is obtained by concatenation of new approximations and details

1) Perform independent wavelet decomposition of the two images until level L to get approximation () and detail ( ) coefficients for l=1,2,..., L.

2) Select pixel based algorithm for approximations () which involves fusion based on taking the maximum

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valued pixels from approximations of source images A and B.

maximum (

Here, is the fused and are the inputs approximations, *i* and *j* represent the pixel positions of the sub images.

3) A binary decision map is formulated based on the maximum valued pixels between the approximations. The decision rule for fusion of approximation coefficients in the two source images A and B is thus given by (20).

(20)

4) A small window of size 3X3 or 5X7 is selected from the detail sub bands based on whether the type of filter mask used is square or rectangular. Perform region level fusion of details by applying 3X3 square and 5X7 averaging filter mask to detail coefficients. The resultant coefficients are added from each sub band.

are vertical high frequencies, are horizontal high frequencies, are diagonal high frequencies of the fused and input detail sub bands respectively.

5) We obtain the final fused transformcorresponding to approximations through pixel rules and the vertical, horizontal and diagonal details by mask based fusion where *l* =1,2,..., *L*.

6) The new coefficient matrix is obtained by concatenating fused approximations and details. Fused image is reconstructed using inverse wavelet transform and displayed.

IV. THE EXPECTED RESULTS

The original images Visible and IR are illustrated in Fig.3 and Fig.4 respectively, and the fusion image is illustrated in Fig.5. According to the results, the hidden weapon could be detected in the IR image, but the figure of people couldn't be seen vividly in the IR image (Fig.4). As in visible image (Fig.3) the figure of people can be recognized but the hidden weapon couldn't be detected. After the fusion process, the hidden weapon matches the figure of corresponding suspicious person in Fig.5. Here the biorthogonal wavelet helps to finds out the hidden weapon which can we can see more clearly in fig as compared with the other previous method in finding out the hidden weapon.

Fig. 3 High resolution (visible image)

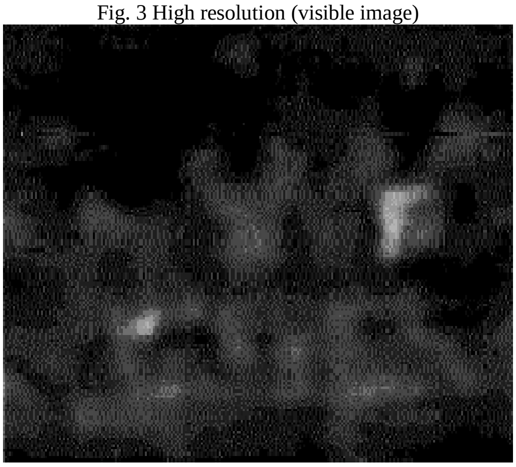

Fig. 4 Low resolution (IR image)

Fig.5 Fused Image

V. CONCLUSION

In this paper, image fusion method was proposed where we fused Visual and IR images to provide a fused image that provides a detailed description of the people in the scene and any hidden weapons detected by the IR image. The utility of the proposed method is demonstrated in the experiment tests. Here a newly developed method based on the biorthogonal wavelet transformations for fusing images is done.

Theoretically, one of the main reasons to choose biorthogonal wavelets is the fact that biorthogonal filters are symmetric and smoother. This is the reason why the biorthogonal wavelets based image fusion method is very efficient for fusing images. According to the results of fusion, the biorthogonal wavelet is greater and more applicable, and can better maintain and pick up image information. When different SNR (signal-noise-ratio) images are fused, the choice of fusion rules should be cautious, as the pixels from low SNR image are always less active. The fusion of images with different resolutions should be researched further. It should be noted that the small dim target pixels and noise singularities are hard to distinguish in this experiment. So, the noise singularity pixels should be eliminated and the small dim target pixels should be enhanced through image preprocessing in future experiment.

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