THE FUSION OF SPOT PANCHROMATIC AND TM MULITSPECTRAL IMAGE BASED ON MULTI-BAND BIORTHOGONAL WAVELET

LIANG Shouzhen[a, b, *], LI Lanyong[a]

[a] School of Geomatics, Liaoning Technical university , Fuxin - Lilanyong@sohu.com1
[b] Yantai Institute of Coastal Zone Research for Sustainable Development, Yantai - Liangshzh0816@163.com

Comission VII,WG VII/6

KEY WORDS: Fusion, Multi-band,Biorthogonal ,Wavelet,TM,SPOT

ABSTRACT:

Remote sensing image fusion aims at integrating the information conveyed by data acquired with different spatial and spectral resolution from satellite and aerial platforms. Image fusion is a very important issue in remote sensing and mapping applications such as features extraction, image classification because the fused image can provide more comprehensive information than single image. At present there are various methods developed to fuse or merge images from different sources, acquired at different time or having different characteristics, particularly low-resolution multi-spectral and high-resolution panchromatic images. Some fusion techniques or methods, such as PCA(principle component analysis), IHS (Intensity-Hue-Saturation) and Brovey transform ,can provide superior visual high resolution multi-spectral images but ignore the requirement of high quality synthesis of spectral information .In other words, there are some distortion of spectral characteristics in comparison with original multi-spectral images.This paper develop a nesw method which integrate multi-band wavelet and biorthogonal wavelt to merge remote sensing images. Multi-band wavelet transform can deal with arbitrary integer ratio of images resolution, while biorthogonal wavelet transform can reduce the ambiguity on the edge of image because it is symmetric and smooth. A example of fusion based on three-band and biorthogonal wavelet transform is experimented with SPOT panchromatic image and Landsat TM image and the fused image is compared with fused images based on orthogonal wavelet ,PCA,HIS and Brovey transform respectively in this paper. Some parameters including mean gradient, combination entropy, standard deviation and correlation coefficient are adopted to appraise the fused images.

1. INTRUDUCTION

Image fusion refers to a process that extracts redundant and complementary information from a set of input images and fuses it into a single and more complete image. The fused image should have more useful information content. The fusion of the two images can take place at the signal, pixel, or feature level. Presently many image fusion methods have been proposed for combining remote sensing data .A detailed review on this issue was given by Pohl and Van Genderen (Pohl et al,1998).The well-known methods are, for example, the HIS (Intensity, Hue, Saturation) (Edwards et al,1994), PCA (Principal components Analysis) (Zhou,1998; Chavez,1989), Brovey Transform (Gillespie et al,1987) .These methods are conventional methods which have been studied widely. But these fusion methods have some deficiencies. At least in comparison with the ideal output of the fusion,these fusion techniques can often produce poor results.The most obvious problem is that it leads to some distortion of spectral characteristics. Recently developments in wavelet analysis provide a potential solution to these drawbacks. For example, Nunez developed an approach to fuse a high-resolution panchromatic image with a low-resolution multi-spectral image based on wavelet decomposition (Nunez et al,1999). Ranchin and Wald designed the ARSIS concept for fusing high spatial and spectral resolution images based on the multi-resolution analysis of two-band wavelet transformation (Ranchin et al,2000).

However, the fusion method based on well-known two-band wavelet, which have been successful for the fusion of SPOT panchromatic and other multispectral images, is not very efficient for the fusion of images whose ratio of spatial resolutions is not 2^n (n = 1, 2, 3, ...), e.g., for fusing a 10-m resolution

panchromatic SPOT image and with 30-m resolution multispectral TM images .Moreover, the two-band orthogonal wavelet lacks symmetry ,which makes the color of fused image not been smoothly integrated into the spatial features.Namely it produces some distortion of spectral characteristics in the original multispectral images.But biorthogonal wavelet is symmetric and multi-band wavelet can effectively fuse diffent ratio of spatial resolution .So these problems can be solved if integrating multi-band wavelet with biorthogonal wavelet to fuse remotely sensed data. So in this paper, we adopt the new fusion technique to merge SPOT panchromatic images with multispectral TM images.This technique can effectively fuse differet or arbitrary ratio of spatial resolution such as 30m-resolution TM images and 10m-resolution SPOT panchromatic images ,and in this approach the color distortion can be reduced to a certain extent.

The structure of this paper is as follows. The first section is introduction .In this section mainly introduce the study and development on image fusion and the structure of the whole

* Corresponding author :Liang Shouzhen, E-mail:,liangshzh0816@163.com

paper. The second section discusses the theoretical basis and transformation characteristics of multi-band and biorthgonal wavelet. Then the fusion method based on multi-band and biorthgonal wavelet is implemented to fuse 10-m SPOT panchromatic and 30-m multispectral TM images Next, the experimental result is compared with previous methods developed for image fusion, such as IHS ,PCA and two-band wavelet

2. BIORTHOGONAL AND MULTI-BAND WAVELET

2.1 Mltiresolution Analysis

Wavelets are functions in $L^2 R$ determined from a basic wavelet function by dilations and translations.They are used for representing the local frequency content of functions. The basic wavelet should be well localized in general, and the wavelet should have zero mean(Daubechics, I.,1992.). The basic method to construct a wavelet is Multiresolution Analysis.A Multiresolution Analysi*s (MRA)* is defined by a sequence of closed subspaces (V_j) $j \in Z$,which approximates $L^2 R$, and a function $\Phi \in L^2 R$ s an orthonormal basis for V_0.

$$\{0\} \cdots \subset V_{-1} \subset V_0 \subset V_1 \subset \cdots L^2(R)$$
$$\{\Phi_{0,n} ; \Phi_{0,n}(x) = \Phi(x-n), n \in Z \}$$

Where $\Phi(x)$ is a scaling function

2.2 Multi-band wavelet

Generally, a wavelet family is described in terms of its mother wavelet, denoted as $\psi(x)$. A daughter wavelet $\psi_{a,b}(x)$ is defined by the equation

$$\psi_{a,b}(x) = \frac{1}{\sqrt{a}} \psi((x-b)/a) \qquad (1)$$

where a, b∈R and a≠0;

a is called the scaling or dilation factor and b is called the translation factor.

A common choice is $a=2^j$ and $b=2^j k$, where j and k are integers. The resulting equation is

$$\psi_{j,k}(x) = \frac{1}{\sqrt{2^j}} \psi(2^{-j} x - k) \qquad (2)$$

$$WT_f(j,k) = \langle f(t), \Psi_{j,k}(t) \rangle = \frac{1}{\sqrt{2^j}} \int_R f(t) \psi^*(2^{-j} x - k) dx \qquad (3)$$

This equation(2) is two-band orthogonal wavelet. Accordingly the wavelet transform of function f(x) is (3)

After 2-band discrete wavelet transform, an image yields four images: one low-pass image and three high-pass images. Namely, approximation coefficients (labeled LL), horizontal coefficients HL (variations along the columns), vertical coefficients LH (variations along the rows), diagonal coefficients LL (variations along the diagonals) (Gonzalez and Woods, 2001). The three high frequency image is called detail image, which contain information of local details.

When $a = n^j$ and $b= n^j k$,the resulting equation is

$$\psi_{j,k}(x) = \frac{1}{\sqrt{n^j}} \psi(n^{-j} x - k) \qquad (4)$$

$$WT_f(j,k) = \langle f(x), \Psi_{j,k}(t) \rangle = \frac{1}{\sqrt{n^j}} \int_R f(x) \psi^*(n^{-xj} - k) dx \qquad (5)$$

We denoted it as n-band wavelet. After n-band discrete wavelet transform, an image yields n2 images: one low-pass image and n2-1 high-pass The high frequency image is called detail image, which contain information of local details and low frequency is approximate.image.

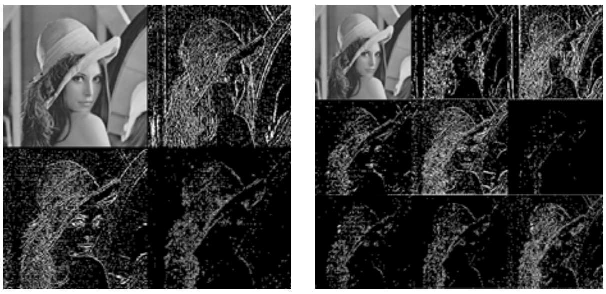

Figure1 two-band wavelet and three-band wavelet transform

2.3 Biorthogonal wavelet

Generally a function f(x) can be decomposed as a superposition of the orthogonal basis$\psi_{j,k}(x)$, But to biorthogonal wavelet, a function f(x) can be written (7)

$$f(x) = \langle WT_f, \varphi_{j,k}(x) \rangle = \int \langle f(x), \varphi_{j,k}(x) \rangle \varphi_{j,k}(x) dx \qquad (6)$$

$$f(x) = \langle WT_f, \varphi_{j,k}(x) \rangle = \int \langle f(x), \varphi^*_{j,k}(x) \rangle \varphi_{j,k}(x) dx \qquad (7)$$

Where $\langle \varphi_{j,k}(x), \varphi^*_{j',l}(x) \rangle = \delta_{jj'} \delta_{kl}$ (8)

When applying the biorthogonal wavelet to decompose function or images, the function $\varphi^*_{j,k}(x)$ is used, while the function $\varphi_{j,k}(x)$ is applied to reconstrut function f(x) The biorthogonal wavelet systems generalize the classical orthogonal wavelet systems. They are more flexible and generally easy to design. One of the main reasons to choose biorthogonal wavelets over the orthogonal ones is symmetric. Symmetric wavelets and scaling functions are possible in the framework of biorthogonal wavelets. However, the orthogonality no longer holds in biorthogonal wavelet systems. However,that is the near orthogonal system.

3. IMAGE FUSION AND QULITY APPRAISAL

3.1 Image fusion

Wavelet-based fusion technique integrates the high-frequency components of the higher resolution data with the low-frequency components of the lower resolution data (or the lower resolution data) in a Multi-Resolution Analysis (MRA). Currently wavelet-based image fusion methods used are mostly based on two computation algorithms: the Mallat algorithm (Mallat,1989; Ranchin et al,2000) and the à trous algorithm (Aiazzi et al,2002; Shensa,1992).In this paper the Mallat algorithm is used. The fusion process has been well described (Yocky,1996; Aiazzi et al,2002). The first step is to co-register two images precisely. It is generally preferable to register the lower resolution image to the higher resolution image. In other words the high resolution image is used as reference image. However if the lower resolution image has georeference that is to be retained, it may be desirable to use it as the reference image. the process includes two sides:locality transform and resampling. Secondly it is to calculate the ratio of spatial resolution between different resolution images. If the result is integer w,the value would be adopted as dimension of muti-band wavelet transform .The high-resolution image would be decomposed based on w-band biorthogonal wavelet transform. Accordingly if the w is not integer ,the Lease common multiple of the resolution of two images must be calculated.Then interpolation of high-resolution image is carried on based on lease common multiple Following this ,the decomposition of new high-resolution is processed based on multi-band biorthogonal wavelet transform.A low frequency image and w^2 -1 high frequency images are accquired.Then the low frequency image of the higher resolution image is replaced by the low resolution image . Finally, an inverse wavelet transform is applied. The result is an image which merges the high-resolution image and the low-resolution image.

3.2 Quality analysis and appraisal

In this paper several parameters including combination entropy ,correlation coefficient ,mean gradient and standard deviation , as used in other studies such as Wald et al.(1997), Sun et al.(1998), and Li et al.(1998),are adopted to value quality of the fusion image. Standard deviation and correlation coefficient are parameter we are familiar with, so combination entropy and mean gradient are only presented in this paper.According to Shannon information theory，the larger the entropy of image is , the richer the information and the better quality of a image is .

$$H(x) = -\sum_{i=0}^{n} P_i \log_2 P_i \qquad (9)$$

where $H(x)$ = the entropy of image

i = *the* grey value of pixel

. n = the number of pixel of image

P_i =the probability of *i*

$$\bar{g} = \frac{1}{(N_x - 1)(N_y - 1)} \sum \sqrt{\left(\Delta I_x^2 + \Delta I_y^2\right)/2} \qquad (10)$$

Where $\bar{g}$ is mean gradient

N_x, N_y is the number of colums and lines respectively

$\Delta I_x^2, \Delta I_y^2$ is the square sum of difference of adjacent pixel

4. EXAMPLE AND FUSED IMAGE ANALYSIS

As an experimental study, the multi-band biorthogonal wavelets-based image fusion method was applied to the10m resolution Spot panchromatic image and three 30m resolution Landsat multispectral images.Because the ratio of spatial resolution is three,we adopt three-band biorthogonal wavelet to merge two images.Menwhile ,this paper also fuses two images based on PCA,IHS and Brovey in order to appraise the fused image based on three-band biorthogonal wavelet.

From the fused images Figure2 ,it should be noted that both the spatial and spectral resolution have been enchanced. The fused images contain the spatial information of high-resolution Spot panchromatic and multi-spectral information of TM image.Fused image based on three-band biorthogonal wavelet has a better visual rusult in comparison with other three fused images.Moreover this paper appraises the fused image quantitively by four parameters :standard deviation ,mean gradient , combination and correlation. The result is Table1

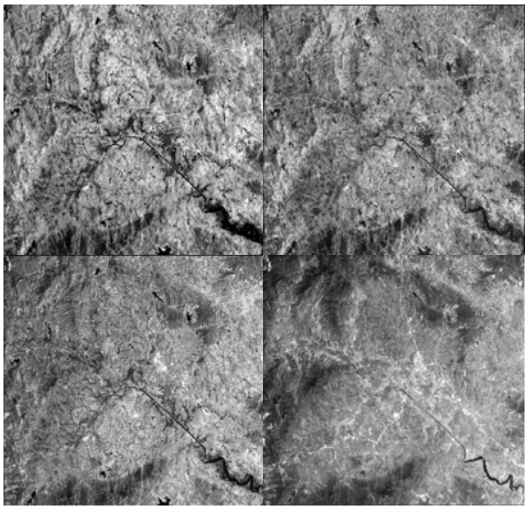

Figure2 the fused images based on,3-band biorthogonal wavelet , PCA, IHS and , Brovey

In general the standard deviation and combination entropy can reflect the information of image and deviation from original image to a certain degree. The fused image based on three-band biorthogonal wavelet transform has the most entropy among all fused images.So this technique fuses more information than other fusing techniques.In addition, the standard deviation of the biorthogonal wavelets based image fusion is more close to the standard deviation of original images than these of other methods,which indicates this method has less distortion of spectral characteristics .

The correlation coefficient reflects the redundancy degree of images. According the table1,we know the original image contains a plenty of redundant information and the correlation coefficient of fused image based on three-band biorthogonal wavelet is less than that of original image and other fused image except of fused image based on PCA, which indicates that this method has less redundant information .

The mean gradient reflects the contrast between the details variation of pattern on the image and the clarity of the image. Of all images including original TM image ,the fused image based on three-band biorthogonal wavelet transform has the most mean gradient.

According to previous statistics and analysis, we can draw a conclusion that the fusion method based on three-band biorthogonal wavelet is efficient for merging low resolution multi-spectral TM image and high resolution Spot panchromatic image.It has many advantages in comparison with other methods when the ratio of spatial resolution of original image is not two.Certainly other fusion methods have advantage in some ways.

Method	M G	S D	C C	C E
PCA	34.07	46.72	0.296	7.668
	35.73	52.38	0.389	
	26.95	53.30	-0.25	
IHS	31.77	53.14	0.647	7.661
	32.12	46.45	0.774	
	27.52	52.83	0.617	
Brovey	33.39	52.81	0.776	7.683
	34.31	46.07	0.661	
	27.68	52.99	0.463	
3-band	39.82	56.33	0.578	
Biorthogonal	44.63	52.93	0.523	7.786
Wavelet	33.95	58.83	0.00718	
Original	35.89	52.89	0.587	7.70
Image	36.81	49.40	0.533	
(TM)	29.99	55.14	0.03	

Table1 the comparison of fused image of different methods

5. CONCLUSIONS

In this paper, a new fusion method based on three-band biorthogonal wavelet was presented to merge the multi-spectral TM and high resolution Spot panchromatic image. Several parameter including mean gradient, standard deviation, correlation coefficient and combination entropy were adopted to appraise the fused products. At last the result of experiment proves that the fusion method based on three-band biorthogonal wavelet is more efficient to fuse the TM 30m-resolution image and 10m-resolution Spot panchomatic image than other fusion methods. The reason is that biorthogonal wavelet is symmetric and three-band wavelet can produce the low frequency image which has the same resolution with low-resolution image.Thus the spectral information can be reseaved to the greatest extent and the distoration of spectral characters can be resolved. Further we can draw a conclusion that n-band biorthogonal wavelet has some advantages when the ratio of spatial resolution is n. So the multi-band biorthogonal wavelet can play a impotant role in image fusion.

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