DISTINCT IMAGE FUSION METHODS FOR LANDSLIDE INFORMATION ENHANCEMENT

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ABSTRACT:

Image fusion is a basic tool for combining low spatial resolution multi-spectral and high spatial resolution panchromatic images using advanced image processing techniques. Study on efficient image fusion method for specific application is on of the most important problems in current remote sensing community and the comparison of distinct Image fusion methods is prevalent. However, not much work has been reported about fusion for landslide feature enhancement. The present work is focused on the intensity-hue-saturation (IHS) merger, Brovey transform (BT) merger, principal component analysis(PCA) merger and the proposed new merger based on shift invariant discrete wavelet transform(SIDWT) theory using maximum value selection rule of approximation coefficents for landslide characteristic enhancement. Here we use the panchromatic (PAN) band and multi-spectral(MS) bands of the LANDSAT-7 ETM+ at the spatial resolutions of 15m and 30m for experiment. Visual interpretation of specific landslide body show the validity of the new method and shannon entropy and standard deviation indexes for synthetically quantitative evaluation of the test imagery also show the advantage of the new scheme on image fusion.

1. INTRODUCTION

1.1 General Instructions

Remote sensing is a fundamental tool providing a relatively lower cost for the detection, classification and monitoring of landslide phenomena. There are several means that permit the improvement of image quality by fusing panchromatic(PAN) band and multispectral(MS) bands. Probably the most popular image fusion methods are those based on the intensity-hue-saturation transformation(IHS), principal component analsysis (PCA) and brovey transform (BT). In this paper, we present a improved merger based on shift invariant discrete wavelet transform theory(I-SIDWT) using maximum value selection rule of approximation coefficients, which is fit for landslide information enhancemnt. We have determined the validity of each fusion method by quantity evaluation of the test imagery and visual comparison of landside body enhancement.

2. THE POPULAR IMAGE MERGERS

2.1 Standard IHS Merger

To get the fused image, red, green, and blue (RGB) bands are firstly converted to intensity, hue, and saturation (IHS) bands. Then intensity band which contain most spatial structures of MS bands is substituted by the PAN band. Before doing this, and in order to minimize the modification of the spectral information of the fused MS bands with respect to the original MS bands, the histogram of the PAN band is matched with that of the intensity band. Applying the inverse transform, we obtain the fused RGB image (Carper,et al.,1990; Maria, et al.,2004).

2.2 Standard Brovey Merger

The Brovey transform merger uses a mathematical combination of the MS bands and PAN band. Each MS band is multiplied by a ratio of the PAN band divided by the sum of the MS bands. The fused R_{new},G_{new},B_{new} bands are as follows(Vrabel,1990):

$$R_{new} = \frac{R}{R+G+B} \times PAN \tag{1}$$

$$G_{new} = \frac{G}{R+G+B} \times PAN \tag{2}$$

$$B_{new} = \frac{B}{R+G+B} \times PAN \tag{3}$$

2.3 PCA Merger

The PCA merger is based on the fact that the first principal component contains the main spatial information of the MS bands, while the spectral information with respect to each band is picked up in the other principal components. A principal components transformation is performed on the MS bands. The first principal component is substituted by the PAN band whose histogram has previously been matched with that of the first principal component, which is much similar to the IHS method. Finally, an inverse transform is performed obtaining the fused image(Welch,et al.,1987).

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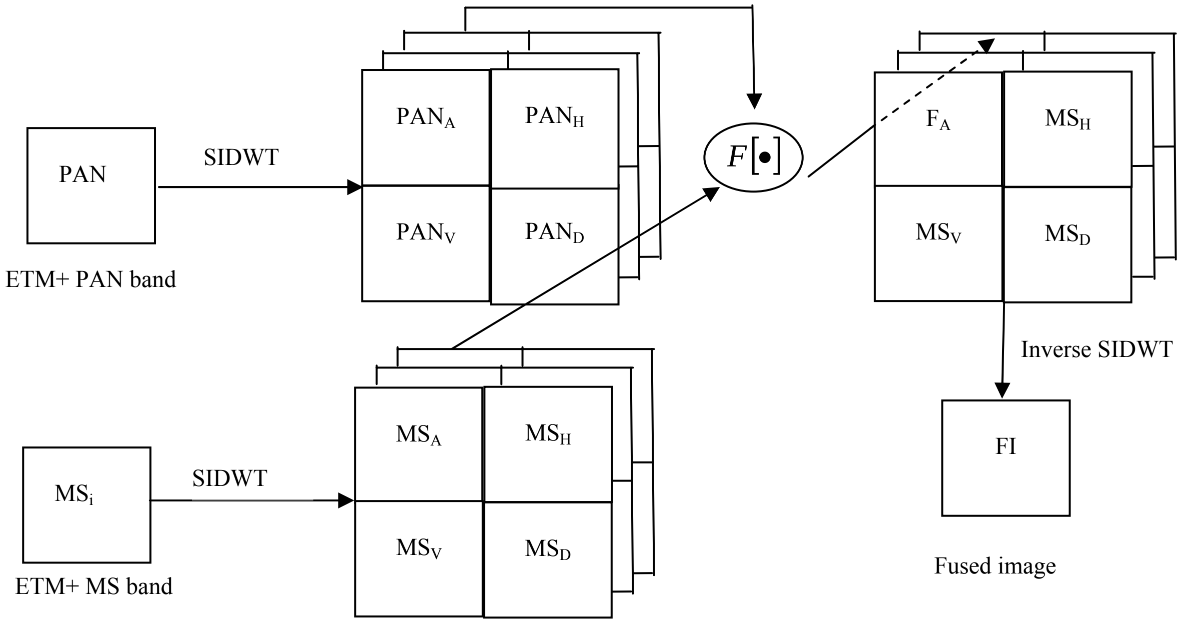

Figure 1 The block diagram of the SIDWT image fusion scheme

3. IMPROVED SIDWT MERGER

It is well known that the DWT yields a shift variant signal representation resulting in a shift dependent fusion scheme while SIDWT image fusion scheme overcoming the disadvantages. SIDWT, related to the concept of wavelet frames, was proposed by Unser(Unser,1995). Considering some characteristic of the approximation wavelet coefficients of SIDWT, An approximation scale based wavelet coefficient maximum selection rule for image fusion was presented. For convenience, We firstly summarize the SIDWT for the case of 1D input signals, then the actual improved image fusion methodology(Yocky,1996).

The fast SIDWT was realized by so-called ὰ trous algorithm by means of upsampling and downsampling filters. Each stage of the SIDWT splits the input signal into the detail coefficient $d_i(n)$,and the approximation coefficient $c_i(n)$ which serve as input for the next decomposition level:

$$d_{i+1}(n) = \sum_k g(2^i \cdot k) \cdot c_i(n-k) \qquad (4)$$

$$c_{i+1}(n) = \sum_k h(2^i \cdot k) \cdot c_i(n-k) \qquad (5)$$

The decomposition start with $c_0(n)=f(n)$. The filter $g(2^i \cdot k)$ and $h(2^i \cdot k)$ at level i are obtained by inserting appropriate number of zeros between the filter taps of the prototype filters g(k) and h(k).

The reconstruction of the input signal is performed by the inverse SIDWT

$$c_i(k) = \sum_n \tilde{h}(2^i \cdot k - n) \cdot c_{i+1}(k) + \sum_n \tilde{g}(2^i \cdot k - n) \cdot d_{i+1}(k) \qquad (6)$$

Where $\tilde{g}(2^i \cdot k)$ and $\tilde{h}(2^i \cdot k)$ denote reconstruction filters. An extension of the decomposition scheme to 2d images follows by the usual tensor product formulation.

The actual improved image fusion methodology can be developed: In the first step a SIDWT decomposition is applied on each MS bands and PAN band with specific levels. Salient spatial information is included in detail components and spatial information in approximation components. Since larger absolute transform coefficient correspond to sharper brightness change, it is a good rule to select the coefficients whose absolute values are higher. Fiugre 1. shows the schematic diagram of the basic structure of the proposed image fusion scheme. Fusion operator F[•] denotes that wavelet coefficient maximum selection of MS bands and PAN band of the corresponding approximation scale.

4. EXPERIMENTAL RESULTS

LANDSAT-7 ETM+ and SPOT images are now available for the landslide information interpretation in our study. According to Jian(Liu,2000), the 15-m resolution LANDSAT-7 ETM+ PAN band is more suitable than 10-m resolution SPOT PAN band for fusion with color composites of ETM+ MS bands. So we start with ETM+ PAN and ETM+ MS bands fusion for testifying the proposed applicable merger. ETM+ image (127/39) taken on 31 July 2000 was used for the study and 1024*1024 pixels including dadiping landslide body,located in wan county, three gorge area, china, is selected as test site. The composition of band4(R)5(G)3(B) is chose as MS bands for landslide information indentification (Figure.2) according to Emerson(Emerson,2003).

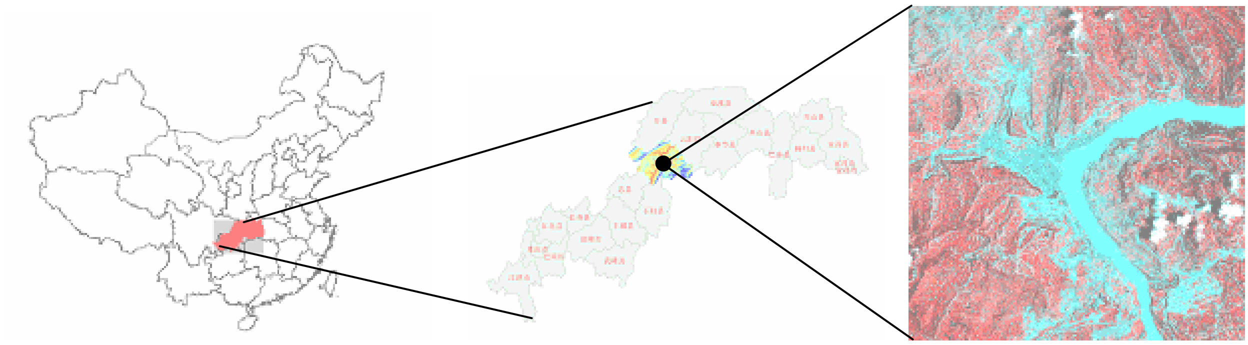

Figure 2. Location of the study area and test imagery (color composite of bands4(red),5(green),3(blue))

Approximate symmetry Daubechies3 wavelet function with support block of 5, filter length of 6 and moment vanish of 3 is chose because of its strong detail description ability. Scale function ,wavelet function and corresponding filters are shown in figure 2. The MS bands and PAN band were decomposed into three levels with maximum value selection of approximation on level 3(Figure 3.).Figure 6. give the selection result of MS band3 and PAN band on approximation component.

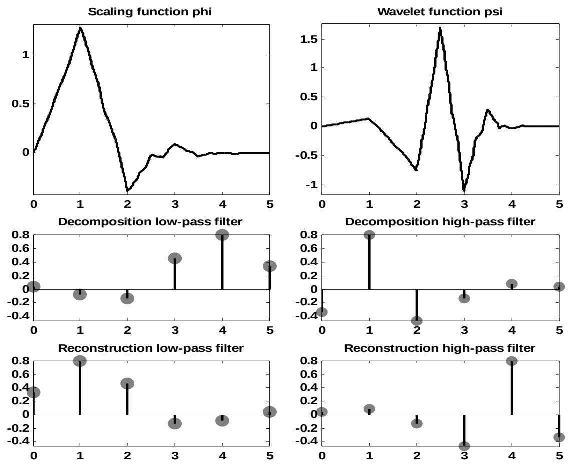

Figure 3. scale function ,wavelet function and corresponding filters

4.1 Visually Evaluation for Landslide Information Enhancement

Four fusion results all give more daliping landslide information compared with the original MS bands composition image(figure 4.) visually. The I-SIDWT fusion method give the best visual effect than other three fusion methods referring to the highlighted dadiping landslide body information and There is a greater contrast between the body and the about area. PCA merger give the worst result. IHS and BT method almost give the same visual effect.

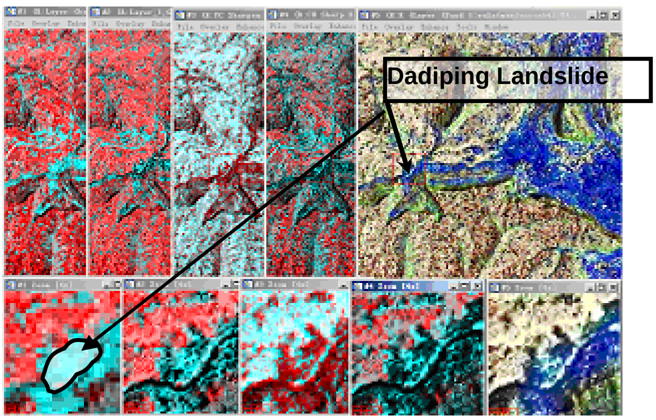

Figure 4. Visual analysis of the color compositions for dadiping landslide(from left to right are TM4-5-3, IHS, PCA, BT, Improved SIDWT)

4.2 Quantity Evaluation of Distinct Megers

In order to give a quantity evaluation of the test imagery, two indexes are considered here(Hu,2002):

- *Shannon Entropy*

Entropy is a synthetic index for imagery information contents. Probing to a 8-bits image, Shannon Entropy is defined as:

$$H(x) = -\sum_{i=0}^{255} p_i \log_2 p_i \qquad (7)$$

where, p_i is the probability of graylevel i in the evaluated region approximately given by:

$$p_i = \frac{f_i}{N} \qquad (8)$$

f_i is the frequency of graylevel i; N denote the total pixels of the image.
The higher the value of Shannon entropy, the more textural information of the fused images, which indicate the better merger.

- *Standard deviation*

Standard deviation indicators: a performance measure σ is defined as the standard deviation of the difference image between the fused image and the low spatial resolution MS bands:

$$\sigma = \sqrt{\left(\frac{\sum_{i=1}^{N} \sum_{j=1}^{N} [F(i,j) - L(i,j)]^2}{MN} \right)} \qquad (9)$$

where, M, N is the dimensions of the imagery; F(i,j) and L(i,j) denote the gray value of the fused and the low spatial resolution image respectively.

In Table 1., We show the values of quantitative evaluation indexes of the merged images for different fusion methods described and the original ETM+ MS bands.

The lower the value of this parameter, the better the spectral quality of the merged image. They should be as close to 0 as possible.

The high information quantity of the merged images obtained using I-SIDWT is obvious because of the highest shannon entropy. At the same time, I-SIDWT merger keep better spectral quality than other three mergers except IHS merger at MS band5 indicated by standard deviation. however, the false color composition of the merged image(Figure 5.) with IHS merger visually compared with I-SIDWT shows poor quality.

	ETM+	I-SIDWT	IHS	BROVEY	PCA
TM Band3					
Standard deviation		0.06	0.0788	0.7176	0.12
Shannon Entropy	3.94	4.80	3.89	2.76	4.15
TM Band4					
Standard deviation		0.077	0.0795	0.7157	0.3162
Shannon Entropy	4.29	4.82	4.40	3.21	4.07
TM Band5					
Standard deviation		0.087	0.0790	0.7162	0.3830
Shannon Entropy	4.19	4.82	4.18	2.98	4.31

Table 1. The values of quantitative evaluation indicators of the merged images for different fusion methods and the original ETM+ bands

5. CONCLUSION

The improved SIDWT fusion method presented in this paper allow to obtain higher quality probing to the test imagery than those obtained applying the IHS, BT and PCA merger. This can be explained by the preservation of more spatial information of PAN band and spectral information of MS bands.

It is necessary to develop appropriate merger in aid of landslide information interpretation. Different fusion methods show different improvement on landslide information. The improved SIDWT fusion method showed significant improvement for the landslide body indentification than other methodological approaches. The presented method can also be applied to other imagery from other sensors for different application objective.

6. AKNOWLEDGEMENT

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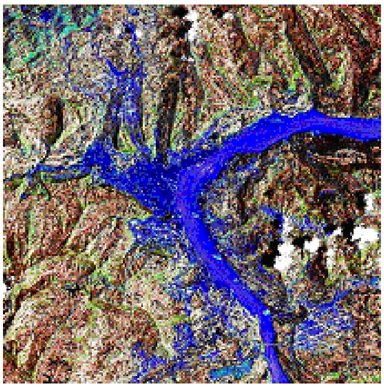
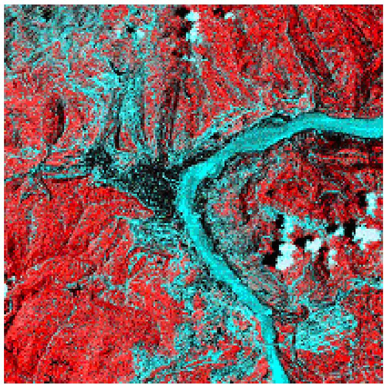
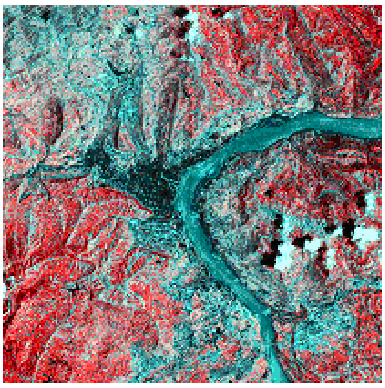


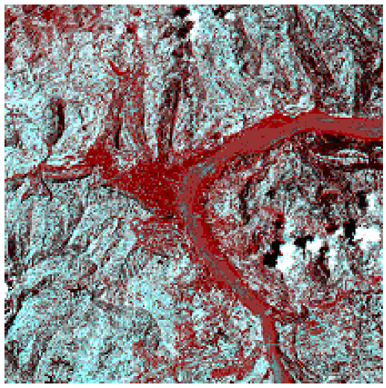
(a) The improved SIDWT merger



(b) The IHS merger



(c) The BT merger



(d) The PCA merger

Figure 5. Colour composite images of merged TM bands4,5,3 and TM PAN band

(a)

(b)

Figure 5. (a) Approximation of SIDWT decomposition of MS band3 on level 3 (b)Approximation wavelet coefficient on level 3 after maximum value selection rule between MS band 3 and PAN band