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AN ADAPTIVE FUSION METHOD BASED ON REGIONAL FEATURE FOR ALOS IMAGE

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Abstract:

Most Earth observation satellites provide both panchromatic images with a higher spatial resolution and multispectral images with a lower spatial resolution. Image fusion techniques can integrate the spatial detail of the panchromatic image and the spectral characteristics of the multispectral image into one image Exiting image fusion techniques such as the Intensity-Hue-Saturation (IHS) transform method, Brovey transform method and High Pass Filter (HPF) method may not be optimization while fusing the new generation commercial satellite image such as ALOS. The most serious problem is that the fused image usually has a notable deviation in visual appearance and spectral values from the original image. In this paper, we proposed a new fusion method for ALOS images, when adding the detail information of panchromatic image to the intensity component of multispectral image, the weight coefficients are determined adaptively based on the structural similarity(SSIM) between the panchromatic image and the intensity component of the multispectral image. Experimental results indicate that this method is effective when fusing ALOS image.

Keywords:

Image fusion; IHS transform; SSIM; ALOS

1. Introduction

In recent years, more and more high-resolution satellites, such as SPOT5, IKONOS, QuickBird, ALOS, have been launched. Most of them can provide both panchromatic image with high spatial resolution and multispectral image with rich spectral information. A recent research focus on for remote sensing is the development of methods for applying these high-resolution images in various fields. To effectively utilize such images, image fusion techniques that can combine the high-resolution panchromatic and low-resolution multispectral images into one color image are urgently needed.

A variety of image fusion methods have been developed in the past two decades. Cliche et al. presented a fusion method to integrate the SPOT panchromatic information into multispectral image for image sharpness enhancement[1]. Ehlers discussed data fusion techniques that have proved successful for synergistic merging of SPOT HRV, LandSat TM and SIR-B images[2]. Li et al. proposed a pixel level image fusion algorithm for merging LandSat TM images and SPOT panchromatic images using the discrete wavelet frame transform[3]. Chen et al. provided to integrate the high spectral resolution (Airborne Visible Infrared Imaging Spectrometer, AVIRIS), and the surface texture information, derived from radar data (Topographic Synthetic Aperture Radar, TOPSAR), into a single image of an urban area[4]. Zhang et al. presented a fusion approach that integrates the advantages of both the IHS and the wavelet techniques to reduce the color distortion of IKONOS and QuickBird[5]. Most of them have received ideal results for the special remote sensing image (such as TM, AVIRIS, IKONOS,QuickBird,et al). But as new image data, few fusion techniques for ALOS images have been discussed.

ALOS(Advanced Land Observing Satellite) is a new land observing satellite, which was launched in Jan,2006. It carries three sensors: PRISM(panchromatic remote-sensing instrument for stereo mapping, with spatial resolution 2.5m), AVNIR(advanced visible and near infrared radiometer type-2,with spatial resolution 10m),and PALSAR(phased array type L-band synthetic aperture radar). In this paper, we propose a fusion scheme for ALOS images. To effectively decrease the color distortion, the weight coefficients are determined adaptively based on the regional feature of the original image when combining the panchromatic image and the intensity component of multispectral image. The experiment results show that it is an ideal fusion scheme for ALOS image.

2. Common image fusion methods

2.1. Brovey transform fusion scheme

The brovey transform was developed to increase visually contrast in the low and high ends of an image's histogram (i.e. to provide contrast in shadows, water and high

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reflectance areas such as urban features). This method uses a ratio algorithm as (1) to combine the images. Since the brovey transform is intended to produce RGB images, only three bands at a time should be merged from the input multispectral scene.

$$\begin{cases} R_{new} = R/(R+G+B) * PAN \\ G_{new} = G/(R+G+B) * PAN \\ B_{new} = B/(R+G+B) * PAN \end{cases} \quad (1)$$

Where R, G, B are the bands of original multispectral images respectively, PAN is the panchromatic image, $R_{new}, G_{new}, B_{new}$ are the bands of fused images.

2.2. Standard IHS fusion scheme

The common color space includes RGB(Red, Green, and Blue) and IHS(Intensity, Hue, and Saturation). The former is usually used by computer monitors to display a color image; and the later is another color space which is more consistent to human's visual system. In IHS color space, the intensity component represents the total amount of the light, the hue is the property of the color determined by its wavelength, and the saturation is the purity of the color. When a multispectral image is transformed to IHS color space from RGB color space, the intensity component image is usually appears like a panchromatic image. This characteristic is utilized in image fusion to fuse a high-resolution panchromatic image into a low-resolution color image[6]. The basic idea is to replace the intensity component of multispectral image with the panchromatic image.

To decrease the color distortion effectively, the panchromatic image is usually stretched to match mean and standard deviation of the intensity image, and then replace the intensity image with the stretched panchromatic image. We called this fusion method as modified IHS transform method.

2.3. HPF fusion scheme

In fusion experiment, we need the detail information of the panchromatic image but not the total image. From HPF fusion, the detail information of the panchromatic image is extracted and added to each band of multispectral image.

2.4. DWT fusion scheme

In recent years, discrete wavelet transform (DWT) has also been used in image fusion [8]. However, because of an underlying down-sampling process in DWT, its multiresolution decompositions and consequently the fusion results are shift variant. This is particularly undesirable when the source images cannot be perfectly registered.

3. A fusion method based on regional feature for ALOS image

With the standard IHS transform fusion, the intensity component of multispectral image is totally replaced by the high-resolution panchromatic image, if the intensity component has a high correlation to the panchromatic image, it will produce a satisfactory fusion result. The higher the correlation is, the less color distortion the fusion results have.

For ALOS data, the spectral range of panchromatic image is 0.52-0.77um, and there are 4 bands in multispectral image: band1(0.42-0.50um), band2(0.52-0.60um), band3(0.61-0.69um), and band4(0.76-0.89um). Because the difference of the spectral range between the panchromatic image and the random three bands of multispectral image, the correlation between the panchromatic image and the intensity image is very low, so the color distortion is significant when IHS fusion is performed. However, despite of color distortion, IHS fusion image usually shows plentiful color in the fusion results and was used popularly.

The basic idea of this method is to modify the high-resolution panchromatic image so it looks more like the intensity component of the multispectral image. Instead of using a total replacement of the intensity component, this method makes an adaptive partial replacement based on SSIM.

The procedure of the adaptive fusion method based on regional feature for ALOS Image is as follows:

1) Register the multispectral image to the panchromatic image.
2) Resample the registered multispectral image to the same spatial resolution as that of the panchromatic image.
3) Transform the resample multispetral image from RGB to IHS color space to obtain the intensity(I), hue(H), and saturation(S) components.
4) Appling histogram matching to match the histogram of the panchromatic image to that of the intensity component(I), and obtaining a new panchromatic image(P_{new})
5) Calculating the SSIM index between the P_{new} and I within a local square window as the central pixel value of the window, then moving pixel-by-pixel over the entire image, we can obtain a SSIM metric. In the

region where the SSIM index is higher than threshold T, I will be replaced by P_{new}; otherwise, I will be preserved. We called the new intensity component as I_{new}. The SSIM index introduced by Wang and Bovik[9] for the corresponding regions between I and P is defined as(2)

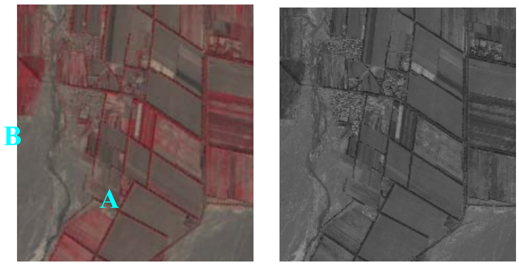
$$SSIM(I,P)=\frac{(2\mu_I\mu_P+C_1)(2\sigma_{IP}+C_2)}{(\mu_I^2+\mu_P^2+C_1)(\sigma_I^2+\sigma_P^2+C_2)} \qquad (2)$$

Where μ_I, μ_P are the mean of I and P, σ_I^2 and σ_P^2 are the variance of I and P, σ_{IP} is the covariance of I and P C_1 and C_2 are small constants.

6) Perform an IHS to RGB transform on I_{new}, together with the original hue(H) and saturation(S) components, to create the fused image.

4. Experiment and result

The study area is located in Qinghai province, China. We cut a subset image which size is 1024*1024. There are crops, bare soil, roads, and populated subdivision with houses. In the image, the area of crops and bare soil is smooth(as area A in figure1 (a)), the populated subdivision with houses(as area B in figure1(a)) is with plentiful detail information.



(a) (b)

Figure1. The original multispectral and panchromatic image

When calculating the SSIM index between I and P_{new}, we use the window with size 7*7. We define In the experiment, we define the threshold T as the mean SSIM index. Figure2 shows the SSIM matric. From Figure2 we can see that the SSIM is higher in the region where it is smooth. On the country, the SSIM is lower. That is because that in the smooth region, both I and P_{new} do not have much detail information, while in the detail region, there are much more detail information in P_{new} the in I.

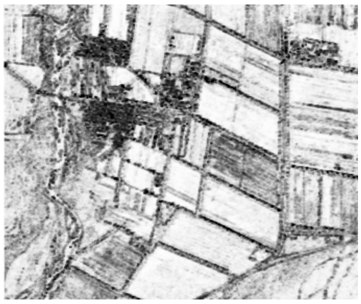
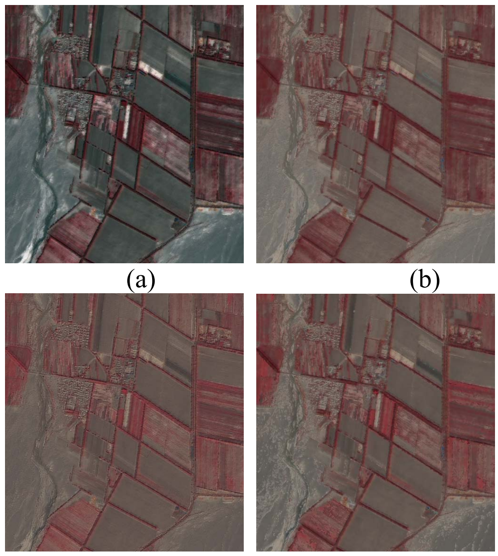


Figure2. The SSIM between I and P_{new}

We compare the fusion method proposed in this paper to Brovey fusion, modified IHS transform fusion, and HPF fusion. Figure3 shows the fusion results.



(a) (b)

(c) (d)

Figure3. (a) the fused image from modified IHS transform method (b) the fused image from Brovey transform method (c) the fused image from the HPF method (d) the fused image from the adaptive fusion method based on regional feature

To assess the quality of the fusion image, fusion results from different techniques should be evaluated visually, spectrally and spatially[10]. Visual comparison reveals that all the fused images inherited high spatial information from the panchromatic image, but the color distortion is different. The fused images (b), (c), and(d) have much higher color distortion. The crops and trees in the original multispectral image is red, but in the fused image (b), (c), and(d), they appeared dark red.

To assess the quality of the fused images quantitatively, we choose the following factor:

4.1. Discrepancy

The band discrepancy is computed based on (3)

$$D=\frac{1}{M*N}\sum_i\sum_j|I'(i,j)-I(i,j)| \qquad (3)$$

Where M,N is the size of the image, I' is the fused image, and I is the original multispectral image.

Higher discrepancy between the fused image band and the corresponding original multispectral image band indicates that more color distortion at that band. A smaller discrepancy between the fused image and the corresponding original multispectral image is desired.

4.2. Correlation coefficient

The correlation coefficient between the fused image and corresponding original multispectral image are also calculated to assess the spectral quality of the fused image.

4.3. Peak Signal to Noise Ratio(PSNR)

The PSNR between the fused image and the original image id defined as (4)

$$PSNR = 10\lg\frac{255\times 255}{RMSE^2} \qquad (4)$$

where RMSE is the root mean square error.

4.4. Entropy

Entropy is a factor to assess the spatial quality of the fused image. It was defined as (5)

$$H=-\sum_{i=0}^{L-1}p_i\ln p_i \qquad (5)$$

Where L is the grey level of the image, p_i is the probability of pixel grey value to be i. The computed entropies of fused image are as table6.

From Table 1, we can see that the adaptive fusion method based on regional feature produce better result with higher correlation coefficient , higher PSNR and less band spectral discrepancy . At the same time, the entropy of the adaptive fusion method based on regional feature is not obvious different from the other fusion methods.

5. Conclusions

Many fusion methods have been experimented for ALOS images in our study. The results show that all the fused images inherit high spatial information from the panchromatic image, but the color distortion is different. The adaptive fusion method based on regional feature presented in this paper is suitable to ALOS image. It can preserve the spectral characteristics of the multispectral image, while inheriting the spatial integrity from the panchromatic image. The weight coefficient is adjusted adaptively depended on the regional features. Further improvement of adaptive fusion method based on regional feature is to automate the best design of filters and the window size according to the image to be fused. Similarly, other approaches for quality assessment of the fused image should be investigated in future.

TABLE1 THE CONTRAST BETWEEN DIFFERENT FUSION RESULTS

		Spectral discrepancy	Correlation coefficient	PSNR	Shanon
Brovey transform method	R	28.7485	0.6730	17.8106	4.5748
	G	13.4875	0.9063	23.5704	4.6634
	B	12.9569	0.8973	23.6046	4.6441
modified IHS transform method	R	13.3760	0.3015	23.7612	3.8311
	G	10.1037	0.8707	26.4046	4.4961
	B	9.5964	0.8481	26.8389	4.3547
the HPF method	R	6.6107	0.7436	28.1703	3.9741
	G	6.7700	0.7853	27.9049	4.1076
	B	6.4046	0.7290	28.4991	3.9233
the adaptive fusion method based on regional feature	R	6.0512	0.6468	26.4929	3.9975
	G	4.4469	0.8879	29.2426	4.3283
	B	4.2104	0.8636	29.7046	4.1773

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