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MS-split and Analysis of the Comparison It with another Three Image Fusion Approaches

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Abstract

Remote sensing images fusion is able to combine the spectral information of multispectral images and the spatial Information of panchromatic images in order to obtaining images with both higher spectral resolution and spatial resolution, which plays an essential role in remote sensing image processing. This paper introduces a new image fusion approach, temporarily we call it MS-split. The new innovative method was first proposed by Zhang Hong-wei et al. We choose Brovey transform, HPF transform, PANSHARP and MS-split approaches to operate an image fusion experiment using the panchromatic images and multispectral images that come from the IKONOS, SPOT6, WordView-2, Resource 3 satellites and aerial images. Through the comparative analysis of visual interpretation and numerical quality evaluation of the experiment results, it demonstrated that the fused images by the new approach are better than the others.

Keywords: Images fusion; HPF; Brovey; PANSHARP; MS-split; Fusion result assessment

1. Introduction

Nowadays, with the rapidly development of computer technology, remote sensing and image processing technology, multisource remote sensing image has become an indispensable way for people to obtain the required geospatial information. Subsequently the study of image fusion becomes a hot issue. The advantage of multispectral image is its rich color information, in favor of feature classification and interpretation, but its spatial resolution is not high; whereas the spatial resolution of panchromatic data is higher than multispectral data, but its lower spectral resolution makes it not easily to be interpreted. The objective of image fusion is integrating the advantages of multispectral data and panchromatic data, to improve the interpretation capabilities and prove a more reliable result.

Since many earth observation satellites are launched, data with variety of spectral, spatial and temporal resolution from different sensors are provided for us. The images in experiment are chosen from the source we commonly used: the IKONOS, SPOT6, WordView-2, Resource 3 satellites as well as aerial images. There are several image fusion approaches, the ones we always used such as HIS transform [1.2], PCA transform [3], HPF transform, wavelet transform [4.5.14], Brovey transform and so on. Methods we have selected are HPF transform，Brovey transform, and PANSHARP which gets a higher evaluation. Based on the fusion of the five kinds of image from different sources, we aim to evaluate the new method through visual interpretation and numerical quality evaluation by contrast with the other three ones.

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2. Method

2.1 Introduction of the Three Fusion Methods

High Pass Filtering (HPF), offers a high pass filter to filter the high spatial resolution image, then adds the high frequency components acquired by the filter to each low resolution part of multispectral image in accordance with the pixel based directly, thereby obtains multispectral images with enhanced spatial resolution. [6] To some extent, HPF method can extract the details of panchromatic images. The details are retained and directly superimposed on multispectral images. Nevertheless while the spatial details being enhanced, it is also easy to increase the noise, which may affect visual effects. [7]

Brovey transformation is simple and calculating faster relatively, it is a typical kind of ratio calculation methods to enhance multispectral images. Equation (1) expresses its mathematical context:

$$\mathrm{I}_{\mathrm{i}} = (XS_{\mathrm{i}} \times PAN) / \sum_{k=1}^{\mathrm{n}} XS_k \tag{1}$$

I_{i} means band *i* of the synthetic image; XS_{i} represents band i of the multispectral image; PAN stands for the high resolution panchromatic image. The algorithm based on Brovey transform is easy and efficient, and can effectively improve the contrast of light and shade of the target's multispectral reflectivity illuminated by sun light in the pictures, but sometimes it may cause color distortion. [8] However, it is necessary to preprocess the image by some experienced operators as preparations before we take this method.

PANSHARP is a method based on statistical principles, according to the principle of least squares approximation to calculate the relationship between the original multispectral image and the grey scale value of panchromatic image. Comprise the following characteristics: Using the minimum variance technique to make sure that the gray values of the band involved in fusion have been the best match; Based on least squares principle to adjust the distribution of gray values of every single band in order to reduce color deviation of fusion results; Additionally a series of statistical computing is taken for all input bands, which can eliminate the dependence of data preprocessing and improve the degree of automation in the integration process. [9]

2.2 MS-split

Since in many current fusion methods, the first step is mathematical transformation, like PCA, wavelet, HIS and some others we previously mentioned, respectively through orthogonal linear transformation, wavelet transform, space color registration and so on. Then replace one component with the panchromatic band, in most cases, it is the intensity channel that be substituted. Finally the fusion image is obtained after inverse transformation. But it's worth noting that the panchromatic band is not exactly the same as one component, that's the reason why color distortion may happen in the result. Whereas the MS-split approach is based on the spectral reflection principle of the target's surface on the ground, by it we can calculate the relationship between the panchromatic and multispectral images by inversion. The optimal solution of the model parameters can be calculated by principle of least squares. The algorithm is shown in equation (2):

$$\begin{aligned} \hat{V}_p &= \sum_{i=1}^{n} a_i \times V_{mi} \\ \varepsilon_i &= \hat{V}_p - V_p \\ \sum \varepsilon_i^{\,2} &= \min \end{aligned} \tag{2}$$

V_p represents reflectivity of the panchromatic bands of sensor; n relates to the size of the image; a_i means fusion model coefficients; V_{mi} is reflectivity of the multispectral bands; ε_i means deviation between reflectivity of the multispectral bands and panchromatic bands.

3. Result and Analysis

3.1 Information about Experimental Data

Resolution of the panchromatic images and multispectral images in the experiment is displayed in table 1:

Table 1. Resolution of Experimental Data

Images		Resource 3	SPOT6	IKONOS	WordView-2	Aerial
Resolution	PAN	2.5 m	1.5 m	1 m	0.5 m	0.2 m
	MS	6 m	6 m	4m	1.8m	1 m

3.2 Original and Synthetic Images

3.2.1. The Original Panchromatic, Multispectral Images of Resource 3and the Refused Images by all Methods are shown:

Figure 1. Original Panchromatic Picture

Figure 2. Original Multispectral

Figure 3. Result by HPF

Figure 4. Result by Brovey

Result by

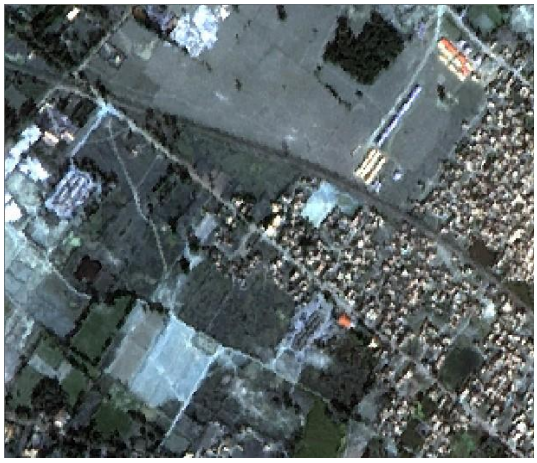

Figure 5. Result by PANSHARP

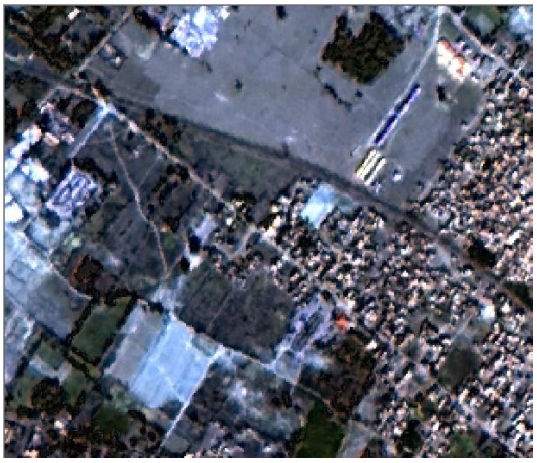

Figure 6. Result by MS-split

3.2.2: The Original Images of SPOT 6and the Results Refused by all Methods as follows:

Figure 7. Original Panchromatic Picture

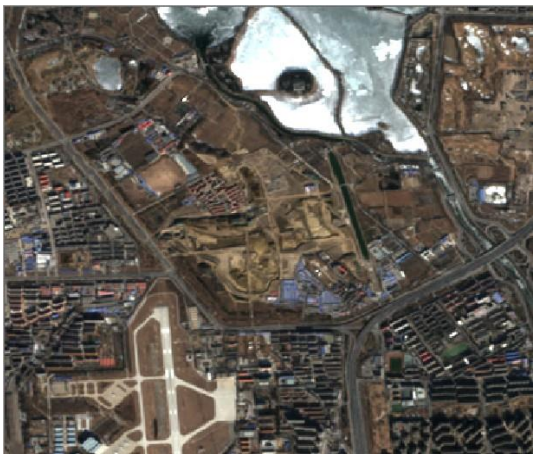

Figure 8. Original Multispectral Picture

Figure 9. Result by HPF

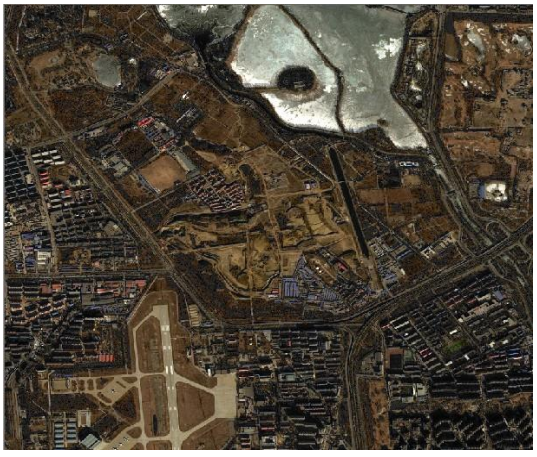

Figure 10. Result by Brovey

Figure 11. Result by PANSHARP

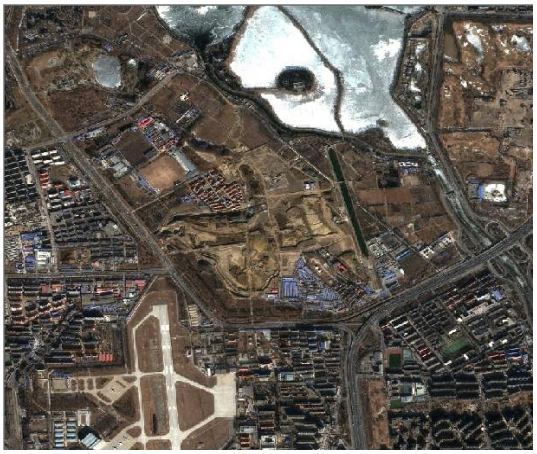

Figure 12. Result by MS-split

3.2.3: The Original Panchromatic, Multispectral Images of IKONOS and the Refused Images by all Methods are Displayed:

Figure 13. Original Panchromatic Picture

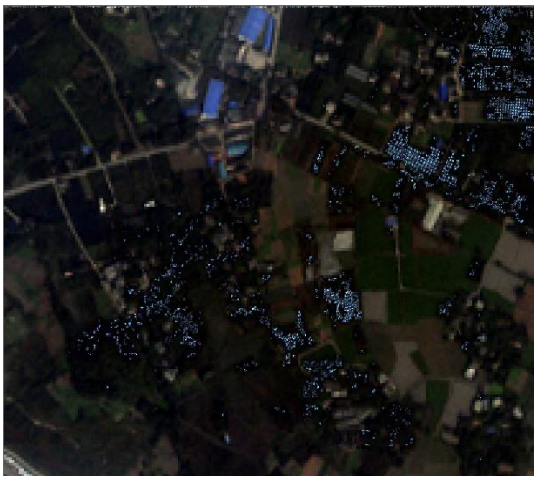

Figure 14. Original Multispectral Picture

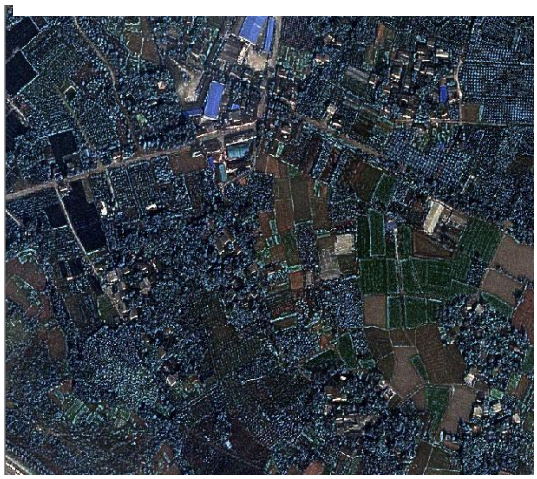

Figure 15. Result by HPF

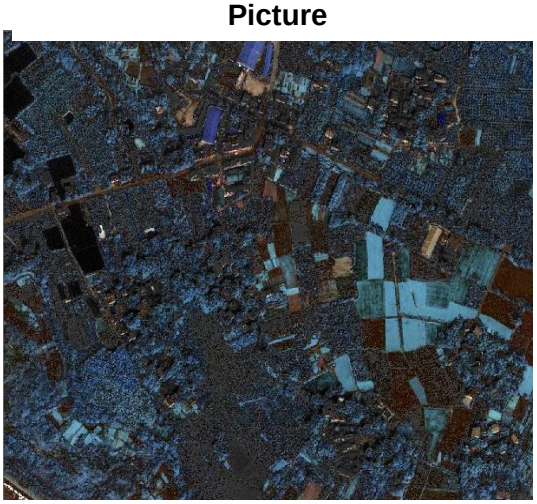

Figure 16. Result by Brovey

Figure 17. Result by PANSHARP

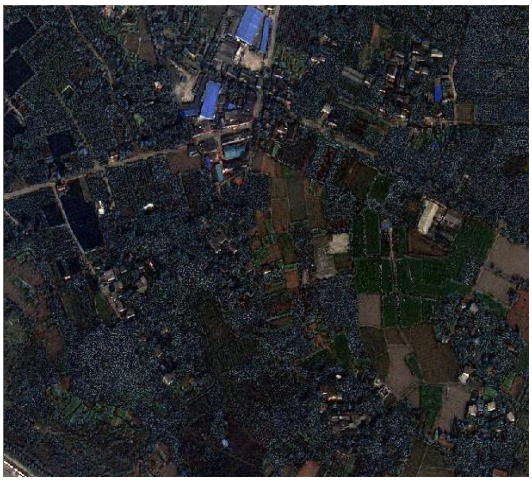

Figure 18. Result by MS-split

3.2.4: The Original Panchromatic, Multispectral Images of WorldView-2 and the Refused Ones are Demonstrated:

Figure 19. Original Panchromatic Picture

Figure 20. Original Multispectral Picture

Figure 21. Result by HPF

Figure 22. Result by Brovey

Figure 23. Result by PANSHARP

Figure 24. Result by MS-split

3.2.5: The Original Images of Aerial Images and the Refused Images are Illustrated as follows:

Figure 25. Original Panchromatic Picture

Figure 26. Original Multispectral Picture

Figure 27. Result by HPF

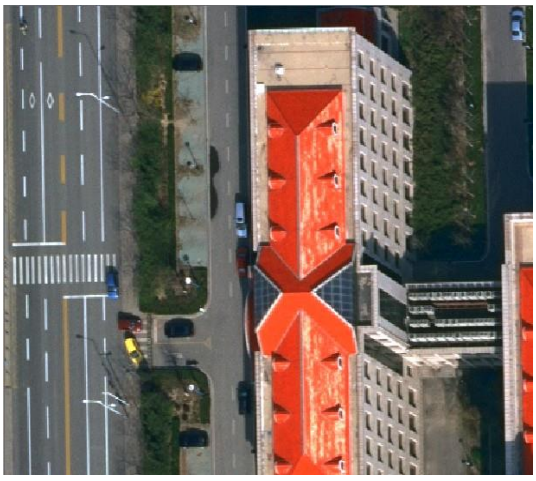

Figure 28. Result by Brovey

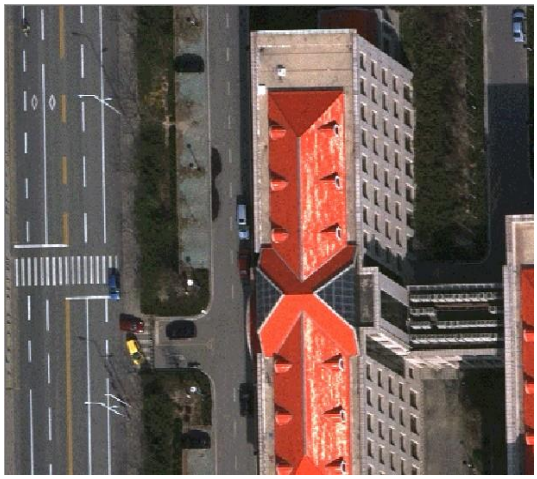

Figure 29. Result by PANSHARP

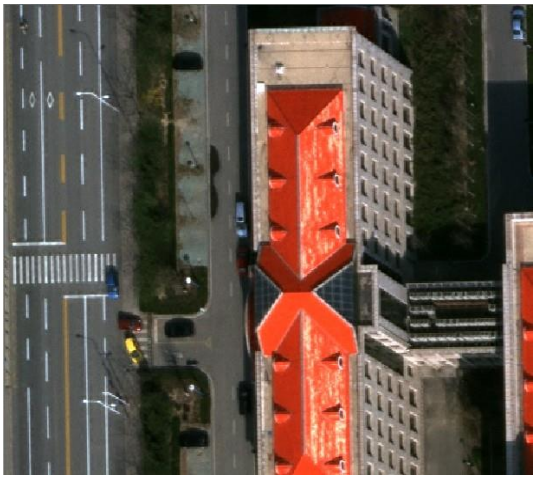

Figure 30. Result by MS-split

3.3 Visual Interpretation

From the point of visual interpretation of the integrate results: For HPF method, in the IKONOS, SPOT6 image fusion results, boundaries of roads, vegetation buildings and others are clear, from the fused images it can be seen that the special characteristics are sharpened; but in the Resource 3 and Aerial image fusion results, compared with original multispectral images, color distortion is very serious and salt and pepper noise appeared. For Brovey approach, in the IKONOS image fusion result, texture features of targets become less clear; to the Resource 3 and SPOT 6, after enlarge the merged pictures and compared with original panchromatic images, part of spatial information has been distorted; moreover in the result of Resource 3 there still exist color distortion. As for PANSHARP and MS-split approaches: In the three lower resolution images, details of special features by MS-split are more obvious than PANSHARP; In terms of the color of results, these two approaches are closer to original multispectral images, but the difference between them is inconspicuous, so we can't draw an exact conclusion about which one is better than another.

3.4 Numerical Quality Assessment

3.4.1: Evaluation Criteria. Mean grey value: Average gray value of pixels, which performs the brightness reflected into our eyes. Most commonly we consider that the fewer the discrepancies of all the corresponding bands, the better spectral characteristics are kept before and after the experiment. [10].Its formula is showed in equation (3):

$$\overline{D} = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} D(i, j)}{M \times N} \tag{3}$$

D (i, j) relates to gray value of pixels; M, N means the number of rows and columns of the image pixels.

Standard deviation reflects dispersion degree of image intensity relative to its mean value. Generally a smaller standard deviation means a smaller contrast ratio and the hue of picture is more single and uniform, distinguish ability of surface features in the image is lower; conversely the larger standard deviation, the gray value distribution is more scattered, surface features are easier interpreted. [11] Formulas are expressed by equation (4):

$$\partial = \sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(D(i,j)-\overline{D})^2}{M \times N}} \tag{4}$$

3.4.2: Statistics and Analysis. Evaluation indexes' statistical values of each RGB band are displayed in table (2):

Table 2. Statistical Values of Each RGB Band

Index	Image	Band	Ms	HPF	Brovey	PANSHARP	MS-split
Mean Gray value	Resource 3	R	99.849	115.109	174.681	86.817	89.403
		G	101.278	107.398	149.003	91.221	91.819
		B	96.936	111.337	144.483	89.436	90.87
	SPOT6	R	52.956	62.986	34.462	73.164	52.457
		G	48.888	62.622	29.158	80.843	48.273
		B	46.25	66.925	23.255	87.655	45.522
	IKONOS	R	67.667	90.643	49.265	76.564	78.569
		G	70.099	95.623	44.162	78.589	78.241
		B	75.678	107.842	43.745	88.655	85.492
	WorldView-2	R	42.036	103.888	96.26	63.16	66.286
		G	56.034	107.117	99.406	66.703	69.24
		B	47.431	93.256	83.721	63.491	64.237
	Aerial	R	83.421	138.992	97.244	90.282	84.225
		G	83.656	140.586	98.438	86.315	83.425
		B	77.274	132.532	96.624	83.84	77.041
Standard deviation	Resource 3	R	54.942	90.527	62.384	49.736	64.163
		G	54.181	81.239	63.328	50.165	54.927
		B	53.899	79.665	65.876	51.494	54.54
	SPOT6	R	52.946	73.528	47.404	59.699	54.653
		G	49.574	75.707	42.8	62.68	52.666
		B	47.73	82.801	39.307	65.633	54.076
	IKONOS	R	44.74	57.277	50.928	42.355	43.355
		G	45.188	60.307	49.055	42.434	42.967
		B	50.573	68.114	53.051	46.238	49.419
	WorldView-2	R	44.109	51.892	70.833	40.346	53.481
		G	43.747	56.905	70.618	42.334	51.543
		B	50.84	65.787	70.079	46.183	55.281
	Aerial	R	57.135	95.989	57.02	49.807	57.56
		G	54.883	94.943	52.206	47.605	55.402
		B	54.937	94.486	49.088	47.529	55.393

From the fusion outcomes in Table 2, we can draw conclusion that, compared with statistical values of original multispectral images, images obtained by HPF and Brovey methods get the largest numerical difference. The quantitative value of consequence gotten by PANSHARP and MS-split are closer than the first two. In all the fusion results, only the indicators of WorldView-2 image obtained by PANSHARP approach are closer than MS-split, but for the other four ones Pan-split is closer than PANSHARP.

4. Conclusion and Prospect

Recently, automatic registration and fusion of multisource satellite images, target recognition of high spatial resolution images, classification of special features from hyper spectral image have become several key technologies development of photogrammetry and remote sensing science to be solved [12]. Compared with the single source of information, the fused image has a higher spectral and spatial resolution; accuracy and precision of the visual recognition and feature classification are improved [13]. Many studies have shown that image fusion improved the reliability and capabilities of interpretation, and have applied to topographic mapping, map updates, land resources survey and other areas with a wide range [14].

In this paper, a new algorithm for image fusion is proposed and a comparative experiment is performed by fusing images of different resolution, sensor and source. From subjective judgment and quantitative evaluation we draw a conclusion that MS-split method is better than the other ones, so it could be widely used in image fusion in the future.

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