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A Comparison of Image Fusion Methods for IKONOS Imagery

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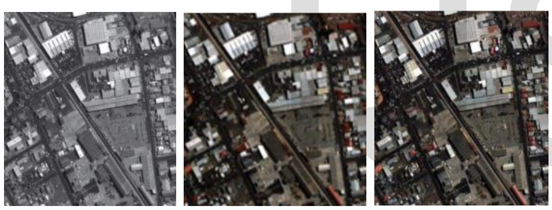
Abstract- Image fusion technique is used to integrate a high-resolution panchromatic (PAN) image and a low-resolution multispectral (MS) image to generate a multispectral image which have higher spatial resolution than original MS while preserving spectral information. There are several methods exist such as Intensity-Hue-Saturation(IHS), Generalized IHS, Brovey transform and PCA. This paper presents a comparative analysis of several image fusion methods.

Index terms- Bias, CC, Multispectral, Panchromatic, sCC, SD, VAR.

1 Introduction

THE purpose of image fusion is to combine information from multiple images of the same scene into a single image that ideally contains all the important features from each of the original images. The resulting fused image will be thus more suitable for human and machine perception or for further image processing tasks [1]. Many image fusion schemes have been developed in the past.



(a) (b) (c)

Fig.1 (a) PAN (b) MS (c) Fused image

Because of the trade-off between spatial and spectral resolutions, spatial enhancement of poor-resolution multispectral (MS) data is desirable.

2 IMAGE FUSION METHODS

There are several methods existed for fusing images, some of them are described here.

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2.1 IHS METHOD

A typology of simple and fast well established algorithms is known as component substitution (CS)[2]. When exactly three multispectral (MS) bands are concerned, the most straightforward CS fusion approach is to resort to an intensity–hue–saturation (IHS) transformation [3]. The Intensity component I is then substituted by the Pan image before the inverse IHS transform is applied.

RGB-IHS conversion

$$\begin{bmatrix} I \\ v1 \\ v2 \end{bmatrix} = \begin{bmatrix} 1/3 & 1/3 & 1/3 \\ -\sqrt{2}/6 & -\sqrt{2}/6 & 2\sqrt{2}/6 \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

And

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} I \\ v1 \\ v2 \end{bmatrix} \quad (2)$$

$$H = \tan\text{-}1\left(\frac{v2}{v1}\right) \text{ and } S = \sqrt{v1^2 + v2^2} \quad (3)$$

Equation for IHS fusion is

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} 1 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} Pan \\ v1 \\ v2 \end{bmatrix} \quad (4)$$

Where R, G, B, I, v1 and v2 represent the corresponding value for the resized original multispectral image. R′, G′, and B′ are corresponding values of the fused images. A computationally efficient method Fast IHS (FIHS) as

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} R + \delta \\ G + \delta \\ B + \delta \end{bmatrix} \quad (5)$$

Where $\delta = Pan - I$ and $I = \frac{R+G+B}{3}$

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2.2 GIHS METHOD

It is a unifying image fusion method called Generalized HIS [3][5]. If more than three bands are available, a viable solution is to define a generalized IHS (GIHS) transform by including the response of the near-infrared (NIR) band into the intensity component.

$$\begin{bmatrix} R' \\ G' \\ B' \\ NIR' \end{bmatrix} = \begin{bmatrix} R + \delta' \\ G + \delta' \\ B + \delta' \\ NIR + \delta' \end{bmatrix} \qquad (6)$$

Where δ'=Pan – I′ and $I' = \frac{R+G+B+NIR}{4}$

2.3 BROVEY METHOD

The BT is a simple image fusion method that preserves the relative spectral contribution of each pixel but replaces its overall brightness with the high resolution PAN image [5]. It is defined as

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \gamma . \begin{bmatrix} R \\ G \\ B \end{bmatrix} = \frac{Pan}{I} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (7)$$

Where $\gamma = \frac{Pan}{I}$

2.4 PRINCIPAL COMPONENT ANALYSIS (PCA) METHOD

An alternative to IHS-based techniques is Principal Component Analysis (PCA) [5] [6]. Analogously to the IHS scheme, the Pan image is substituted to the first principal component (PC1). Histogram-matching of Pan to PC1 is mandatory before substitution, because the mean and variance of PC1 are generally far greater than those of Pan.

$$\begin{bmatrix} PC1 \\ PC2 \\ PC3 \end{bmatrix} = \begin{bmatrix} \emptyset 11 & \emptyset 12 & \emptyset 13 \\ \emptyset 21 & \emptyset 22 & \emptyset 23 \\ \emptyset 31 & \emptyset 32 & \emptyset 33 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (8)$$

$$H = \tan\text{-}1\left(\frac{PC3}{PC2}\right) \quad \text{and} \quad S = \sqrt{PC2^2 + PC1^2} \qquad (9)$$

The first component PC1 of PCA space is replaced by Pan image and retransformed back into original RGB space.

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} \emptyset 11 & \emptyset 12 & \emptyset 13 \\ \emptyset 21 & \emptyset 22 & \emptyset 23 \\ \emptyset 31 & \emptyset 32 & \emptyset 33 \end{bmatrix} \begin{bmatrix} Pan \\ PC2 \\ PC3 \end{bmatrix} \qquad (10)$$

3. SIMULATION RESULTS:

These Methods are applied to the IKONOS-2 data set available at [7]. An IHS method gives greater spectral distortion while preserving spatial information. This problem is somehow solved by GIHS method which includes another fourth NIR band. A problem the GIHS method is that the color of the image still changed during fusion. The color distortion problem is the worst resulted by the BT and slightly better by the IHS method. This changes are clearly noticeable in fig.(2) and fig.(3) and here we compare different results using quality parameter like bias[8], SD[8], VAR[8], CC(cross-correlation)[9], spatial CC[9]. This results are shown in Table I and Table II.

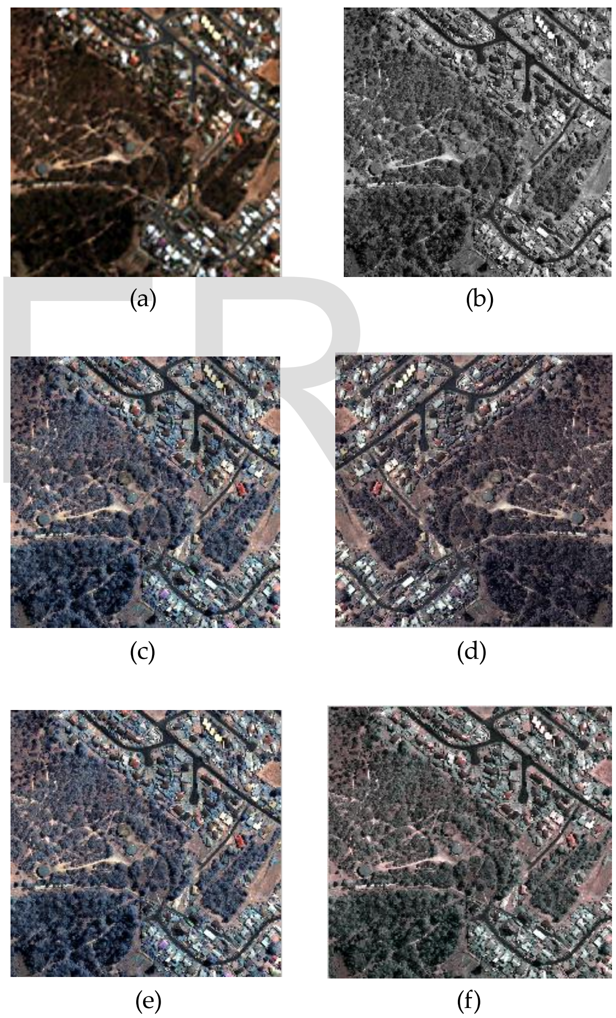

Fig.2 Fusion result of IKONOS-2 images (a)MS (c)FIHS (d)GIHS (e)Brovey (f)PCA

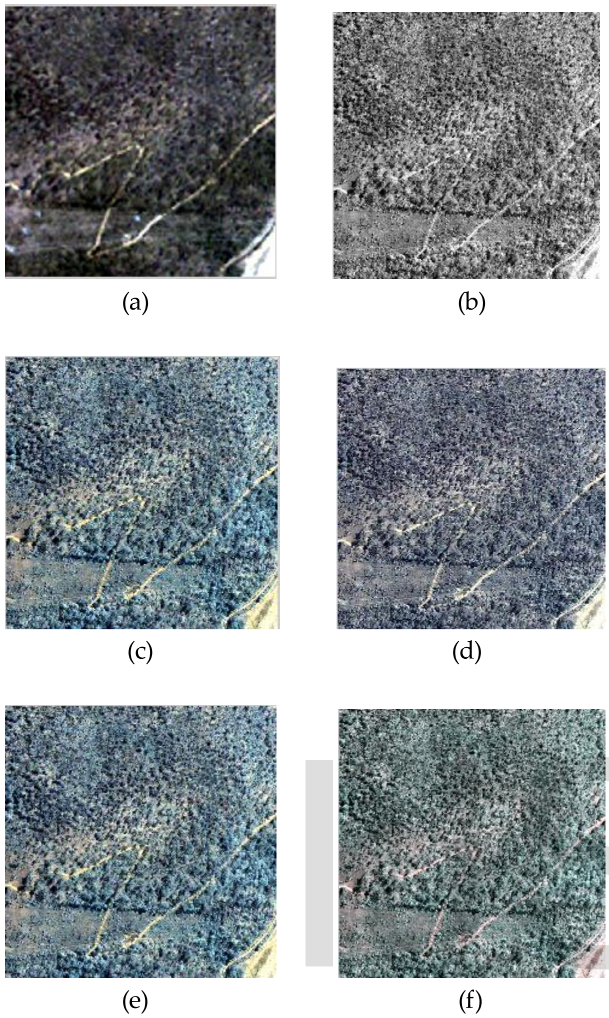

Fig.3 Fusion result of IKONOS-2 Vegetation area (a) MS (b) PAN (c) FIHS (d) GIHS (e) Brovey (f) PCA

Table I: Quality indices of IKONOS-2 image fusion result (for images shown in fig.2)

	Band	FIHS	GIHS	Brovey	PCA
BIAS	R	0.3508	0.4318	0.3508	0.5803
	G	0.3502	0.3553	0.3502	0.3939
	B	0.3510	0.3877	0.3510	0.5210
SD	R	0.3283	0.3453	0.3283	0.4028
	G	0.3567	0.3356	0.3567	0.3315
	B	0.3161	0.3100	0.3161	0.3617
VAR	R	0.9797	1.2332	0.9797	1.5743
	G	1.1021	1.2426	1.1021	0.7731
	B	1.5843	2.2864	1.5843	0.8783
CC	R	0.8072	0.8195	0.8072	0.7814
	G	0.6990	0.8035	0.6990	0.6599
	B	0.5237	0.6799	0.5237	0.6068
sCC	R	0.9919	0.9982	0.9919	0.9991
	G	0.9994	0.9991	0.9994	0.9998
	B	0.9954	0.9984	0.9954	0.9998

Table II: Quality indices of IKONOS-2 image fusion result (for images shown in fig.3)

	Band	FIHS	GIHS	Brovey	PCA
BIAS	R	0.4527	0.5306	0.4527	0.7122
	G	0.4514	0.4140	0.4514	0.5307
	B	0.4499	0.2830	0.4499	0.5699
SD	R	0.2573	0.2830	0.2573	0.3263
	G	0.2747	0.2456	0.2747	0.2546
	B	0.2480	0.2264	0.2480	0.2611
VAR	R	2.4773	2.6311	2.4773	3.5000
	G	5.0558	4.0845	5.0558	4.0247
	B	14.9324	13.2342	14.9324	17.4757
CC	R	0.7629	0.6971	0.7629	0.6776
	G	0.5838	0.6311	0.5838	0.4802
	B	0.3313	0.4409	0.3313	0.4235
sCC	R	0.9934	0.9971	0.9934	0.9988
	G	0.9994	0.9993	0.9994	0.9979
	B	0.9979	0.9987	0.9979	0.9979

4 CONCLUSION

Although selection of fusion algorithm is problem dependent but this review results that spatial domain provide high spatial resolution. But spatial domain have image blurring problem. In general case color of fused image is more distorted in FIHS than in GIHS, Brovey and PCA. But for the vegetation area images, GIHS gives better fusion results than other methods and for the urban area images, result of Brovey method is good than other methods.

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