IMAGE FUSION AND IMAGE QUALITY ASSESSMENT OF FUSED IMAGES

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ABSTRACT:

It is of great value to fuse a high-resolution panchromatic image and low-resolution multi-spectral images for object recognition. In the paper, tow frames of remotely sensed imagery, including ZY03 and SPOT05, are selected as the source data. Four fusion methods, including Brovey, PCA, Pansharp, and SFIM, are used to fuse the images of multispectral bands and panchromatic band. Three quantitative indicators were calculated and analyzed, that is, gradient, correlation coefficient and deviation. According to comprehensive evaluation and comparison, the best effect is SFIM transformation, combined with fusion image through four transformation methods.

1. INTRODUCTION

In recent years, the launch of high-resolution satellites has opened a new era for remote sensing. With these remote sensors, images of various spatial and spectral characteristic can be obtained. For example, from the ZY03 sensor, 2.1 m resolution panchromatic and 5.6 m resolution multispectral and 3.5 m resolution front-facing, rear-facing images are available. With the development of remote technique and the launch of new satellites, remote image have great promoted at spatial resolution and spectral resolution (Wang, 2003). Fusion of two images from different sources can provide information that cannot be obtained when the images are processed individually. Image fusion can improve the accuracy when we extract useful information from image (Jia, 2000). To data, various fusion algorithms have been developed (Chavez, 1991, Siddiqui, 2003, Hallada, 1983, Vrabel, 2002). As Zhang combined DWT and IHS algorithms and apply to image fusion of the IKONOS and Quick Bird (Zhang, 2005). Yang combined NSCT and HIS and apply to image fusion of the SPOT and TM (Yang, 2008). In the paper, we tested Brovey，PCA，Pansharp and SFIM. And we assessed the quality of fusion image with indices of gradient, correlation coefficient and deviation.

2. IMAGE FUSION METHODS AND QUALITY INDICATORS

2.1 Image fusion methods

In this section, we analyze image fusion method that can be used for high-resolution satellite image fusion, such as those for fusion of panchromatic and multi-spectral images. Four categories of image fusion methods are addressed: Brovey, PCA, Pansharp, and SFIM.

1) Brovey Algorithm

The Brovey Algorithm is a ratio method that normalizes multispectral bands used for a RGB display(GILLESPIE, 1987). The result is then multiplied by a high-resolution band to add high spatial frequency information. The Brovey Algorithm can only allow a limited number of bands to be fused. The Brovey Algorithm can be defined as follows:

$$B_{i\_NEW} = \frac{B_{i\_m}}{B_{r\_m} + B_{g\_m} + B_{b\_m}} \times B_{\mathrm{h}} \quad (1)$$

Where B_{i_NEW} is the i th band of fused high-resolution image, B_{i_m} is one of the bands, that is red band, green band or blue band. $B_{r\_m}, B_{g\_m}, B_{b\_m}$ stand the pixel value of red band, green band and blue band. B_{h} is the high-resolution image.

2) PCA Algorithm

PCA transform is created based on the statistical characteristics dimensional linear transformation, the mathematical transformation is called K-L(Sun, 2002). The PCA transform converts intercorrelated MS bands into a new set of uncorrelated components. The first component also resembles a PAN image. It is, therefore, replaced by a high-resolution PAN for the fusion. The PAN image is fused into the low-resolution MS bands by performing a reverse PCA transform.

3) Pansharp Algorithm

The PANSHARP algorithm is based on the least number of squares to an approximate

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gray-value relationship between the original multispectral image, panchromatic image,
and fused image. This method also statistics all bands of the input and fusion results in order to eliminate the dependence of the data set(Tan,2008).

4) SFIM Algorithm

The SFIM is a ratio method that the high-resolution image is divided by a simulated low-resolution image and the result is then multiplied by the low-resolution image. The algorithm was defined by LIU (2000a) as below:

$$B_{SFIM_i} = \frac{B_{low_i} \times B_{high}}{B_{mean}} \qquad (2)$$

Where B_{SFIM_i} is the i th band of fused high-resolution image, B_{low_i} is a pixel in the i th band of a low-resolution input image, co-registered to a high-resolution input image B_{high}, and B_{mean} is a corresponding pixel in a simulated low-resolution image derived from B_{high} using an average filter for a neighborhood equivalent to the resolution of B_{high}.

2.2 Quality indicators for assessing image fusion

The purpose of image fusion is to enhance the spatial and spectral resolution from several low-resolution images. Several indices have been proposed for assessing image quality, which can also be applied to assessing the quality of a fusing image. In this section, we select three indices to assess the quality of fusion image. Those includes: gradient, correlation coefficient and deviation.

1) Gradient:

$$\bar{g} = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} \sqrt{(\Delta F_x^2 + \Delta F_y^2)/2} \qquad (3)$$

The gray-scale variation of the image in a direction. Tiny detail and texture changes can be reflected with this index.

2) Deviation:

$$wi^k = \frac{1}{n} \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{\left| \overline{DN_{i,j}^k} - DN_{i,j}^k \right|}{DN_{i,j}^k} \qquad (4)$$

where wi^k is the deviation index of the k th band, $\overline{DN_{i,j}^k}$ denotes the original image gray level of a pixel with coordinate (i, j). $DN_{i,j}^k$ denotes the fusion image gray level of a pixel with coordinate (i, j). Deviation index used to compare the degree of deviation of fusion images and low-resolution multispectral images.

3) Correlation:

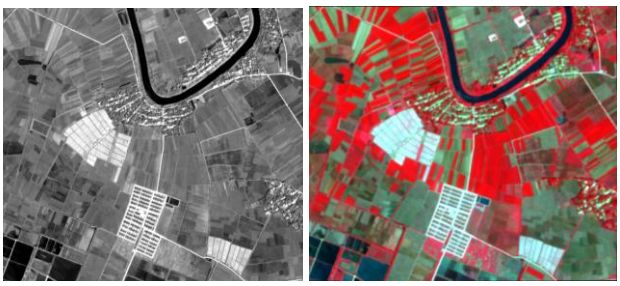
$$C(F,R) = \frac{\sum_{i=1}^{M} \sum_{j=1}^{M} \left[R(i,j) - \bar{R}\right]\left[F(i,j) - \bar{F}\right]}{\sqrt{\sum_{i=1}^{M} \sum_{j=1}^{M} \left[R(i,j) - \bar{R}\right]^2 \sum_{i=1}^{M} \sum_{j=1}^{M} \left[F(i,j) - \bar{F}\right]^2}} \qquad (5)$$

where F and R are two images, $R(i, j)$ and $F(i, j)$ the elements of the image R and the image F, respectively. $\bar{R}$ and $\bar{F}$ stand for their mean values. If C (F, R) is closer to 1, which means that the two images are more similar and the better the fusion image fidelity.

3. RESULT AND ANALYSIS

3.1 Result

In the paper, four fusion methods, including Brovey, PCA, Pansharp, and SFIM, are used to fuse the images of multispectral bands and panchromatic band. Three quantitative indicators were calculated and analyzed, that is, gradient, correlation coefficient and deviation. Figure.1 is the original image of ZY03, Figure.2 is the fusion image of ZY03, Figure.3 is the original image of SPOT05, Figure.4 is the fusion image of SPOT05.



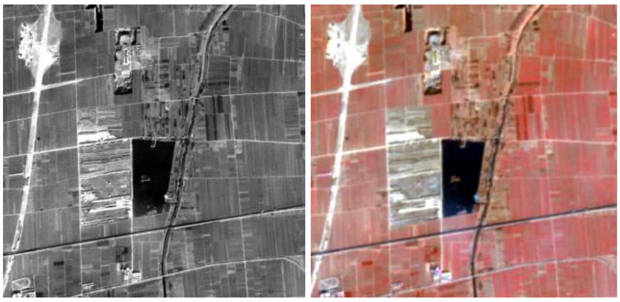
ZY03 Pan ZY03 Mul

Figure.1 Original images of ZY03

ZY03 Brovey ZY03 PCA

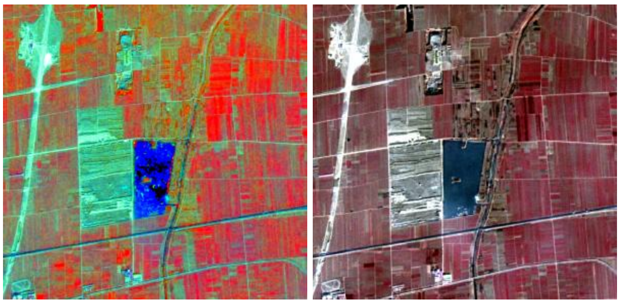
ZY03 Pansharp ZY03 SFIM

Figure.2 Fused images of ZY03

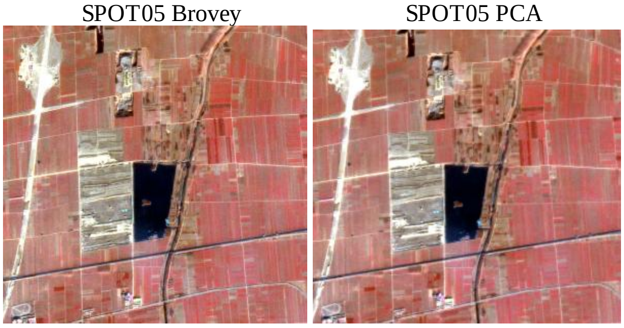


SPOT05 Pan SPOT05 Mul

Figure.3 Original images of SPOT05



SPOT05 Brovey SPOT05 PCA



SPOT05 Pansharp SPOT05 SFIM

Figure.4 Fused images of SPOT05

3.2 Quantitative analysis

Considering the drawbacks of the subjective quality assessment method, much effort has been devoted to develop objective image quality assessment methods. A good fusion approach retain the maximum spatial and spectral information from the original images and should not damage the internal relationship among the original bands. Based on these three criteria, we select gradient, correlation coefficient and deviation to assess the fusion image.

fusion methods	gradient	deviation	correlation coefficient
Brovey	8.31111	0.528676	0.432419
PCA	9.78541	0.41091	0.88355
Pansharp	13.16326	0.03310	0.93890
SFIM	13.10289	0.02274	0.96633

Table 1 Assessment results of ZY03 fused image

fusion methods	gradient	deviation	correlation coefficient
Brovey	1.61168	0.65731	0.22867
PCA	4.52237	0.05483	0.81224
Pansharp	3.31930	0.02060	0.93861
SFIM	3.44472	0.01801	0.95655

Table 2 Assessment results of SPOT05 fused image

Form Table 1,we observe that the value of gradient obtained by SFIM transformation method is almost the largest(SFIM: 13.102892 ≈ Pansharp: 13.163267), the value of deviation obtained by SFIM transformation method is minimum, and the value of correlation coefficient obtained by SFIM transformation method is the largest. From these quantitative results, we can conclude that the fusion result which is obtained by SIFM transformation method is the best.
Form Table 2,we observe that the value of gradient obtained by SFIM transformation method is the largest, the value of deviation obtained by SFIM transformation method is minimum, and the value of correlation coefficient obtained by SFIM transformation method is the largest. From these quantitative results, we can conclude that the fusion result which is obtained by SIFM transformation method is the best.

4. CONCLUSIONS

Selection of proper fusion technique depends on the specific remote image. Four fusion methods, including Brovey, PCA, Pansharp, and SFIM, are used to fuse the images of multispectral bands and panchromatic band. Three quantitative indicators were calculated and analyzed, that is, gradient, correlation coefficient and deviation. Finally, form the above analysis and comparison, we can conclude that SFIM algorithm can preserve the spectral characteristics of the source multispectral image as well as the high spatial resolution characteristics of the source panchromatic image and suited for fusion ZY03 and SPOT05 images.

5. ACKNOWLEDGEMENTS

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