

A NOVEL IMAGE FUSION METHOD FOR MULTI-SPECTRAL AND HIGH-RESOLUTION PANCHROMATIC IMAGES

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KEY WORDS: Image Fusion, Multi-Source Images, Spectral Distortion, Spectral Preservation, Spatial Resolution, SAO

ABSTRACT:

How to greatly benefit from a variety of remote sensing data has become a bottle-neck problem in application of remote sensing. As an image has high spectral resolution, but relatively lower spatial resolution. Image fusion technology emerged as the times required, can highly enhance image quality by distilling and integrating information of several images, overcoming the limitations and differences of the single one in the geometry, spectrum and spatial resolution, etc. Lots of fusion methods were posed, but they more or less change the spectral information. To ameliorate this problem, this paper addresses a simple, fast, and efficient method SAO (Simple Arithmetic Operation). It just needs to take the multi-spectral and high-resolution panchromatic images carry out a simple arithmetic operation. SPOT5 XS+P images are used to assess the effectiveness of SAO method in comparison to IHS transform, Brovey transform, SSVR methods. Compared to other fusion methods, the images generated by SAO method have high spatial resolution while preserving the basic spectral characters of the original multi-spectral image.

1. INTRODUCTION

With the rapid development of remote sensing technique, the instruments and tools, used to obtain remote sensing data, are more and more, and multi-source remote sensing images are richer and richer. Remote sensors carried by different platforms can retrieve images in the same area with different resolution, as well as the same platform can obtain images in this area with different spatial and spectral resolution. So, the use of remote sensing data to research the ground surface has change to synthetical use of multi-source data from single data analysis, that is, to dynamic monitoring instead of static analysis (Gao, 2007). As an image generated by the same remote sensor have high spectral resolution but relatively lower spatial resolution, most resource satellites, such as Landsat7, SPOT, QuickBird, IKONOS, supply panchromatic image with high spatial resolution as well as multi-spectral image with lower spatial resolution. How to fuse multi-source images to integrate their advantages and reduce the redundancy has become a key problem remote sensing workers need to resolve, also an important problem remote sensing has been faced with.

Image Fusion as a tool to improve spatial resolution, is often used to fuse the images with different spatial resolution. The most typical application is the fusion of panchromatic image with high spatial resolution and multi-spectral image with lower spatial resolution, which requires retaining not only the spectral characters of original multi-spectral image, but also the spatial details of original panchromatic image, in order to improve the spectral and spatial resolution, displaying image in more detail (Zhao, etc. 2003). Presently the main image fusion methods used widely are IHS transform, principal components analysis and wavelet transform. The IHS transform method is to firstly transform the RGB colour image to intensity (I), hue (H), and saturation (S) three components, secondly process the panchromatic image and replace the intensity component, lastly

carry through inverse transform, switching the IHS components to a RGB colour image. This method improves the spatial resolution at the cost of losing spectral information. The principal components analysis is to make the multi-spectral image implement a K-L transform, and then replace the first component by panchromatic image, finally carry through an inverse transform. As a result, the fused image holds both high resolution and spectral information, but the spectral information has changed much. The wavelet transform is to make the multi-spectral image and high resolution panchromatic image carry through a wavelet transform, and replace the corresponding components of multi-spectral image after the wavelet transform by the high frequency component generated by the wavelet transform on the high resolution panchromatic image. After that, carry an inverse transform to produce a new fused image. The wavelet transform method can to a certainty reduce the spectral distortion produced by the first two methods.

To ameliorate the problem of spectral distortion, this paper presents a more efficient fusion method, which just need take the multi-spectral and panchromatic images carry out simple arithmetic operation. Its fusion result has higher spatial resolution while preserving the spectral characters of original multi-spectral image. Taking the spectral preservation of fusion result into account, the fused image can be used to quantificational analysis.

2. SAO FUSION METHOD

Most fusion methods skip the spectral characters to get high spatial resolution, resulting in spectral distortion, which affects the quantificational analysis. To improve this problem, this paper introduces a more efficient fusion method SAO (Simple Arithmetic Operation). Though it just needs to take simple

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arithmetic operation, its fused result preserves better spectral characters and more spatial details.

SAO method, a simple arithmetic operation method, is similar to SSVR method posed by Pang, etc. (Pang Xinhua, etc. 2008). But the core idea of SSVR method is to simulate and compose panchromatic image from multi-spectral image, while the SAO method is to simulate and compose multi-spectral image from panchromatic image. And the object of SSVR method is radiance, while SAO method is DN value, radiance, reflectivity, etc.

The algorithm of SAO method can be written as

$$E_{fi} = E_{pan} \times \frac{E_{msi}}{E_{pan\ max}} \quad (1)$$

Where E_{fi} = the value of the fused image in band i

E_{pan} = the value of original panchromatic image

E_{msi} = the value of the image resampled to the same resolution of panchromatic from original multi-spectral image in band i

$E_{pan\ max}$ = the maximal value of original panchromatic image

In formula (1), E_{pan} reflects the spatial details of fused image,

and $\frac{E_{msi}}{E_{pan\ max}}$ the spectral characters. Therefore, SAO method

improves the spatial resolution, at the same time preserving the spectral characters.

Seeing formula (1), SAO method is also similar to Brovey transform. Only in Brovey transform, $E_{pan\ max}$ is the sum of the corresponding value of three bands of original multi-spectral image. This makes it be enslaved to the condition the spectral range of multi-spectral image has to be coincident with panchromatic image. But SAO method has not. It is simple, and its steps are described as follow: Firstly resample the multi-spectral image to the same spatial resolution with panchromatic image. Secondly rectify the images to make them match. Then calculate E_{fi} according to formula (1). Lastly analyze the quality of fused result.

3. FUSION EXPERIMENT AND ANALYSIS

3.1 Study Area and Data

The fusion methods commonly require the spectral range of multi-spectral image to be coincident with panchromatic image as a basic hypothesis, while SAO algorithm does not. To highlight the advantage of SAO algorithm, SPOT5 data is used to access the efficiency. The characteristics of SPOT5 data can be seen in Table 1. Only the spectral range of Band1 and Band2 is coincident with panchromatic image. So, multi-images combining band3, 2, 1 or band4, 3, 2 are used to carry out SAO algorithm, to validate its availability.

SPOT5 MS	band1 0.50~0.59	10m	0.09
	band2 0.61~0.68		0.07
	band3 0.78~0.89		0.11
SPOT5 PAN	band4 1.58~1.75	20m	0.17
	0.49~0.69	2.5m	0.20

Table 1. The spectral range and spatial resolution of SPOT5 image

The study area is the neighborhood of Feilaixia Hydro Project, Qingyuan city, and the remote sensing image was produced on October 23, 2007 (see Figure1). There are complicated features, including buildings, roads, farmlands, rivers, ponds, etc., which have different shapes and colors. Remote sensing, in a narrow sense, may be defined as a method for retrieving the physical properties of objects, thus the diversity of the surface, results in the diversity of remote sensing data. So the fusion result can show the merits of the fusion algorithm.

3.2 Result and Analysis

To verify the SAO algorithm, the traditional IHS transform, Brovey transform, SSVR algorithm and SAO algorithm are used (see Figure 2.). The fused results tell different fusion method can get different fused results, and the same fusion method used to fuse different images can get different fused results. So how to evaluate the fusion effect is a very important part in the image fusion. A simplest and the most direct method is visual evaluation, which can evaluate the fusion effect directly according the images before and after fusion, but it is just a qualitative method and more subjective. So the quantitative evaluation, the physical method of different evaluation index, is needed, too.

3.2.1 Qualitative evaluation: The fused images show the spatial resolution and definition are all improved, especially the results by IHS transform and SAO algorithm, in which the small roads and the borders of buildings are clearer. While the fused image by SSVR algorithm is the worst. However, in the side of spectral preservation, SAO algorithm is the best, while Brovey transform and IHS transform is the worst. Namely the spectral characters of the fused image by Brovey transform or IHS transform have changed the most. From the results with different combination of bands, except that the fused image by SAO has higher spatial resolution and completer spectral characteristic, other fused images comprising band4, band3, 2 have more spatial details, but less spectral characters. This qualitatively explains that the fused image by SAO algorithm has higher spatial resolution while maintaining the spectral characters of original multi-spectral image.

Data	Spectral Range	Spatial Resolution	Band Width
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(a) The original panchromatic image



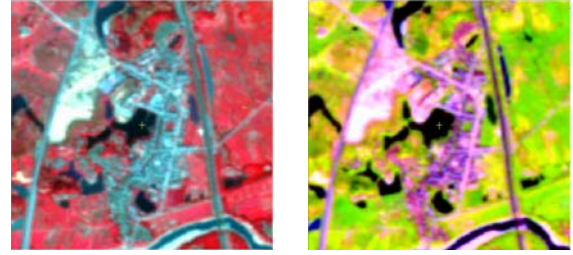
(b) The original multi-spectral image combined by band3, 2, 1



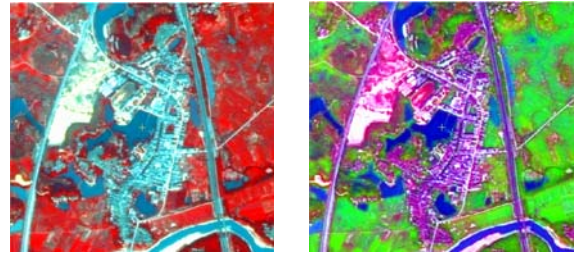
(c) The original multi-spectral image combined by band4, 3, 2

Figure 1. The original images in study area

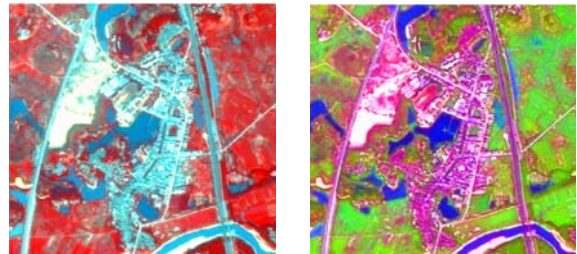
3.2.2 Quantitative evaluation: Visual evaluation is indispensable, but it can't evaluate the quality of fused image quantitatively. So, to be more objective, 4 kinds of index are introduced: entropy (EN), average gradient (G), deviation index (D), correlated coefficient (C). Entropy is an index measuring the amount of information; the greater the value is, the more information the fused image contains. Average gradient responds to the image relative definition; usually, the greater the value, the clearer the image. Deviation index is used to compare the deviation of images before and after fusion; the smallest the value, the little the spectral distortion. Correlation coefficient responds to the relative degree of two images, by comparing the correlation coefficient of images fused before and after, to know the changing extent of spectrum. By analyzing the four indexes, the quality of fused image can be evaluated quantitatively from spatial details, definition and spectrum.



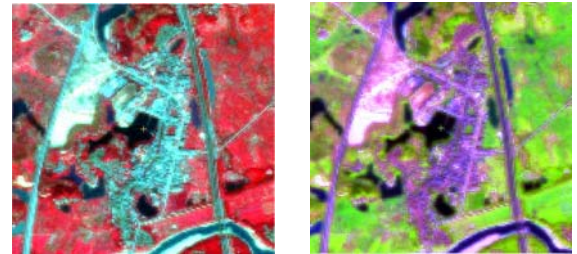
(a) The original multi-spectral images



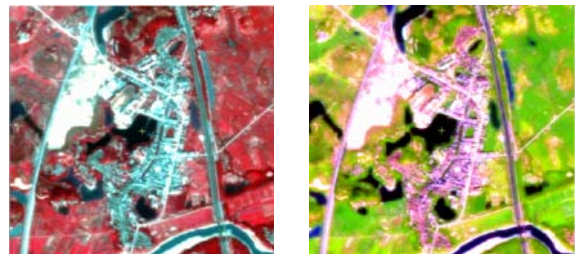
(b) Results of IHS transform



(c) Results of Brovey transform



(d) Results of SSVR algorithm



(f) Results of SAO method

Figure 2. Fusion results in local study area Where the left images were combined by band3, 2, 1, and the right ones were combined by band4, 3, 2.

Combination of bands	Fusion method	EN	W	G	C
Band3,2,1	IHS	18.488	0.832	2.498	0.836
	Brovey	13.617	0.664	0.907	0.871
	SSVR	10.107	0.549	0.609	0.972
	SAO	16.776	0.467	1.758	0.864
Band4,3,2	IHS	19.024	0.600	2.568	0.782
	Brovey	14.168	0.672	0.936	0.813
	SSVR	10.394	0.450	0.497	0.966
	SAO	18.135	0.467	2.044	0.911

Annotation: EN is the sum of the value of three bands, and G, W, C all are the average value.

Table 2. Quantitative evaluation indexes of fusion results

As can be seen from Table 2., from the amount of spatial information and the degree of clarity, the fused images by IHS transform or SAO algorithm are better, which contain more spatial details and be clearer; from the spectral preservation, SAO and SSVR algorithms have lower G value and higher C value, that is, their fused images have maintained spectral characters better; from the combination of bands, on the one hand, the fused image constituted by band4, 3, 2 with higher EN value and G value have more spatial information and be clearer, on the other hand, they have higher W value, namely, their spectral characters have change more. However, the W values of SAO algorithm with different combination of bands are similar, which prove that the algorithm gets rid of the bondage of the hypothesis of the consistency of spectral range of multi-spectral and panchromatic images in other fusion methods. From the analysis above, quantitative evaluation is coincident with qualitative evaluation. Therefore, for synthetical capability, SAO algorithm, which improves the spatial resolution of multi-spectral image while preserving its spectral characteristic, is a better fusion method.

4. CONCLUSIONS

To solve the problem of spectral distortion in fusing, this paper addresses a new simple algorithm (SAO). The core idea of this method is to synthesize a multi-spectral image with high spectral resolution from panchromatic image by simulating original multi-spectral image, namely, giving the spectral information of original multi-spectral image to the panchromatic image with high spatial resolution. Thus, this method will be not affected by the spectral responding range. SAO algorithm, which improves spatial resolution while maintaining the spectral characters, is a better fusion method. It is simple and can be applied in radiation, DN value or reflectivity. SAO method presented in this paper, can maintain the spectral characters more perfectly, but the spatial information of the fused image is not the richest. So, it needs to be improved further.

ACKNOWLEDGEMENTS

Thank Lei Chen, Dan Xu, Wei Wang, Hui Lin, Zhixin Zhang for providing discussions and help.

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