Comparative Study on Pansharpening Methods for Satellite Images

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Abstract - ***Pansharpening combines a low-resolution color multispectral image with a high-resolution grayscale panchromatic image to create a high-resolution fused color image. A pansharpened image represents a sensor fusion between the multispectral and panchromatic images which gives the best of two image types, high spectral resolution and high spatial resolution. There are a number of applications in remote sensing that require images with both high spatial and spectral resolutions. The fusion or pansharpening, provides a solution to this by combining the clear geometric features of the panchromatic image and the color information of the multispectral image. One type of pansharpening method are based on injection of details from PAN image into MS image and another method is based on decomposing the MS image into different color space or principal components. In this paper, we conduct a study on six different pansharpening methods.***

Key Words: ***Pansharpening, Spectral resolution, Spatial resolution, Multispectral image.***

1. INTRODUCTION

The launch of high-resolution satellites used for remote sensing has created a need for the development of efficient and accurate image fusion methods. These satellites are commonly capable of producing two different types of images: a low-resolution multispectral image and a high-resolution panchromatic image. The multispectral sensor provides multi-band images with accurate color data with low spatial resolution. Conversely, the panchromatic sensor yields grayscale images with high spatial resolution but imprecise color data. There are a number of applications in remote sensing that require images with both high spatial and spectral resolutions. The fusion of the multispectral and panchromatic images, or pan-sharpening, provides a solution to this by combining the clear geometric features of the panchromatic image and the color information of the multispectral image. The problem with the images provided by modern satellites is that they have either high spatial resolution, i.e., panchromatic (PAN) image or high spectral resolution, i.e., multispectral (MS) images.

Pan Sharpening is shorthand for panchromatic sharpening. It means using a panchromatic (single band) image to “sharpen” a multispectral image. In this sense, to “sharpen” means to increase the spatial resolution of a multispectral image. A multispectral image contains a higher degree of spectral resolution than a panchromatic image, while often a panchromatic image will have a higher spatial resolution than a multispectral image. A pan sharpened image represents a sensor fusion between the multispectral and panchromatic images which gives the best of image types, high spectral resolution and high spatial resolution.

A multispectral image is an image that contains more than one spectral band. It is formed by a sensor which is capable of separating light reflected from the earth into discrete spectral bands. A color image is a very simple example of a multispectral image that contains three bands. Multispectral images are designed to take advantage of the different spectral properties of materials on the earth’s surface. The most common example is for detection of healthy vegetation. Since healthy vegetation reflects much more near infrared light than visible light, a sensor which combines visible and near-infrared bands can be used to detect health and less healthy vegetation.

In contrast to the multispectral image, a panchromatic image contains only one wide band of reflectance data. The data is usually representative of a range of bands and wavelengths, such as visible or thermal infrared, that is, it combines many colors so it is “pan” chromatic. A panchromatic image of the visible bands is more or less a combination of red, green and blue data into a single measure of reflectance. Modern multispectral scanners also generally include some radiation at slightly longer wavelengths than red light, called "near infrared" radiation. Panchromatic images can generally be collected with higher spatial resolution than a multispectral image because the broad spectral range allows smaller detectors to be used while maintaining a high signal to noise ratio. For example, 4-band multispectral data is available from QuickBird and GeoEye. For each of these, the panchromatic spatial resolution is about four times better than the multispectral data. Panchromatic imagery from QuickBird-3 has a spatial resolution of about 0.6 meters. The same sensor collects the nearly the multispectral data at about 2.4 meters resolution. For GeoEye's Ikonos, the panchromatic and multispectral spatial resolutions are about 1.0 meters and 4.0 meters respectively. Both sensors can collect co registered panchromatic and four-band (red, green, blue and near-infrared) multispectral images.

Pan-sharpening can be referred to as a special case of image fusion. Since then, further research in the image fusion area is mostly focused on improving fusion quality and reducing color distortion. Among the existing hundreds of various pan-sharpening methods, the most popular ones are intensity hue saturation technique (IHS), principal component analysis (PCA), Brovey transform [2], and wavelet-based fusion.

Fig -1: QuickBird panchromatic image, 0.6 meter ground resolution.

A QuickBird multispectral image of the same area at about 2.4 meter resolution is shown below.

Fig- 2: QuickBird multispectral image, 2.4 meter ground resolution showing the same areas shown in the panchromatic image above.

The impact of both the multiple of four decreases in spatial resolution and the enhanced color information available in the multispectral image are readily apparent in these two images. Using Remote View's projective pan sharpening algorithm to sharpen the multispectral image produces the result shown below.

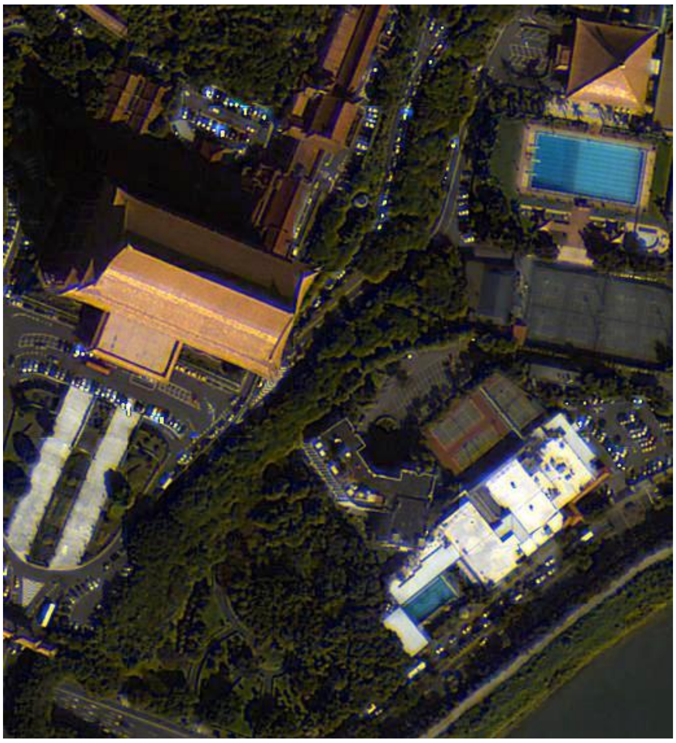

Fig- 3: Pan sharpening example based on the two images shown above. Result has 0.6 meter spatial resolution and 4 multispectral bands.

There have been many studies on pan sharpening and many, many algorithms have been developed. Some are slightly better than others at preserving either spatial or spectral information, but there is generally always a loss of one or the other or both. All of the methods depend on the panchromatic and the multispectral image being very closely coregistered. When images are co registered, you can think of overlaying one on top of the other and examining any pixel in the top image. The pixel in the image below that should be the exact same feature on the ground. Pan sharpening algorithms depend on the input images being co registered because they all perform operations on corresponding pixels in both images. They all do something with the multispectral pixel and the panchromatic pixels to create new pixels. If the images are not co registered, the processing will use the wrong pixels, not the corresponding ones and the result will not look natural.

By increasing the spatial resolution of the high spectral resolution multispectral image, many other image processing tasks which are performed on the multispectral image are enhanced. This includes simple visual image interpretation and visual exploitation, as well as product generation and advanced methods such as Orthorectification and orthomosaic.

2. DIFFERENT PANSHARPENING METHODS

2.1 IHS (Intensity Hue Saturation)

This is the most basic and popular image fusion technique. First the multispectral image must be resized and the images must be registered. In this technique, first a color image transformed to IHS color space and the intensity band is replaced by the panchromatic image and then the fused image is converted back to RGB space. IHS is very fast and can quickly process large volumes of data and generate sharp images.IHS fused images experience spectral distortion from the original multispectral image. There have been many modifications of IHS in an attempt to help this spectral distortion problem [3].

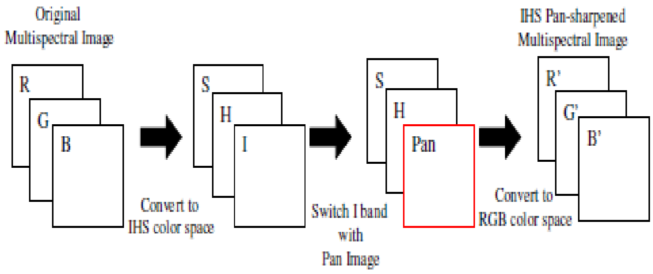

Fig -4: IHS Method.

2.2 PCA (Principal Component Analysis)

The PCA converts intercorrelated multispectral bands into a set of uncorrelated components. The first band, which has the highest variance, is replaced by the panchromatic image. They are fused together by inverse PCA to obtain high-resolution pansharpened image [4].

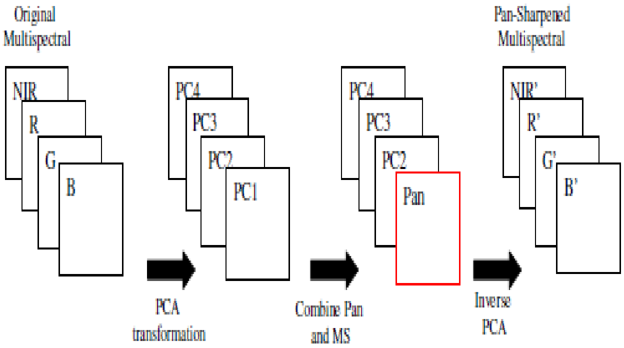

Fig -5: PCA Method

2.3 Wavelet Method

The Wavelet method uses Discrete Wavelet Transforms (DWT) to decompose the original MS and Pan image and combines them to construct the pan-sharpened image.DWT transforms the original image into components. One component contains low-resolution information, and the others contain more detailed local spatial information. The Pan and MS image are decomposed. The low-resolution component of the Pan is replaced by the low-resolution MS component. The final image is created by performing an inverse wavelet transformation [5].

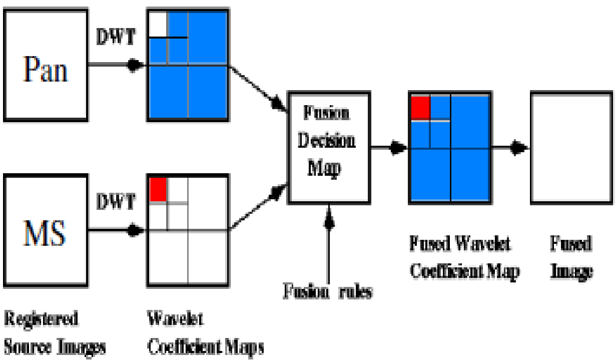

Fig -6: Wavelet Method

2.4 P+XS Method

This is a variational method, which calculates the pansharpened image by minimizing energy functional. It obtains the edge information of the panchromatic image, using the gradient. The spectral information is obtained by approximating the panchromatic image as a linear combination of the multispectral bands [6].

2.5 VWP Method

VWP combines the Wavelet method with P+XS.VWP uses the geometry matching term from P+XS. It uses wavelet decomposition to obtain spectral information. It explicitly preserves spectral quality better [7].

2.6 With Matting Model

In this method, a simple yet powerful matting model-based pansharpening is used. First, the spectral foreground and background of the MS image are estimated with a local linear assumption. Then, the alpha channel of the MS image is substituted by the PAN image, and a composition operation is used to reconstruct the high-resolution MS image. The proposed method does not rely on the image formation assumption which has been used by most of pansharpening methods. The advantages of this method are high performance and ability to obtain a pan sharpened image that looks closest to the reference high-resolution MS image. This method includes many steps as shown below:

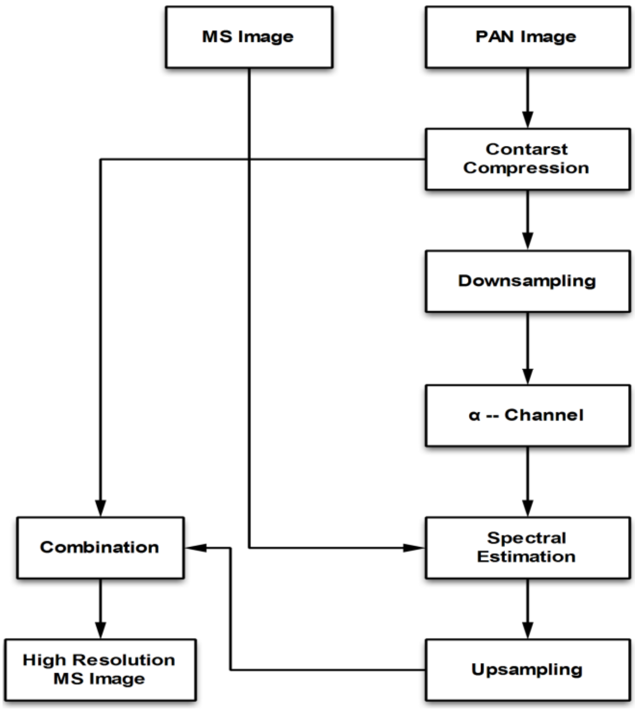

Fig -7: Block Diagram of proposed system

At first,contrast compression is performed on the high-resolution PAN image (HP).This step aims at compressing the pixel values of the PAN image into a relatively small range, which ensures that the edge features of the PAN image are to be processed equally in the following spectral estimation process.

Next,the contrast compressed PAN image is downsampled to the resolution of the MS image.With the alpha channel and the low-resolution MS image, the corresponding low-resolution spectral foreground LF and background LB can be estimated based on two assumptions. One is that the alpha channel, spectral foreground, and background should be able to reconstruct the low-resolution MS image. The other is that the spectral foreground and background should be spatially smooth. Once the spectral foreground LF and background LB are obtained, the high-resolution spectral foreground HF, background HB can be approximately estimated by upsampling LF and LB, respectively.

Next, the pansharpened MS image is obtained by combining the high-resolution spectral foreground HF, background HB, and the high-resolution alpha channel together.

3. CONCLUSION

In this paper, we can conclude that it is advantageous to use a matting model based pansharpening method. By substituting the alpha channel of the MS image with the PAN image, an ideal high-resolution MS image is expected to be reconstructed nearly perfectly. Compared to the widely used pansharpening methods, the proposed method produces images that look much closer to the ideal reference high-resolution MS image. Therefore, it is considered that this proposed method can be used for analysis of remote sensing images such as remote sensing image classification and change detection.

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