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A Study for the Adaptive wavelet-based Image Merging method

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ABSTRACT

The goal of image merging techniques are to enhance the resolution of low-resolution images using the detail information of the high-resolution images.

Among the several image merging methods, wavelet-based image merging techniques have the advantages of efficient decorrelation of image bands and time-scale analysis. However, they have no regard for spatial information between the bands. In other words, multiresolution data merging methods merge the same information-the detail information of panchromatic image-with other band images, without considering specific characteristics.

Therefore, a merged image contains much unnecessary information.

In this paper, we discussed this "mixing" effect and, proposed a method to classify the detail information of the panchromatic image according to the spatial and spectral characteristics, and to minimize distortion of the merged image.

Keywords: Image Merge, Wavelet Transform, MWD

I. Introduction

In recent years, as it has been possible to obtain the variable low or high resolution satellite images and the variable images of sensor systems, several image merging/ fusion techniques have been proposed. In particular, in image merging/fusion techniques, it is very important not only to increase the image quality but also to minimize the distortion of an image after merging/fusion.

Therefore, in order to improve the quality of observation, many approaches have been developed to combine the information coming from multiple images to create a new image where the informative content is more suitable for human perception.

In recent years, a MWD (Multiresolution Wavelet Decomposition) method[1]~[3] has been proposed as a new technique. A MWD method is based on wavelet transform that is helpful for analyzing time-scale analysis [4],[5] ,and has the advantages of efficient decorrelation of image bands.

A multiresolution data merging method, however, merges the same information - the detail information of the panchromatic image -with other band images, without considering

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specific band characteristics. A merged image, therefore, contains much unnecessary information. This paper proposes an efficient method for considering spatial and spectral characteristics. We first classify the parts that correct to merge one band with the panchromatic band, and then merge only the correct parts. In this way, we minimize the distortion of the original image.

This paper is organized as follows: Section 2 provides previous MWD methods. In Section 3, the proposed algorithm is detailed. The simulation results are provided in Section.4, which is followed by conclusions in Section.5.

II. MWD Method

Image merging techniques are applied to increase the resolution of color band images to that of the panchromatic band. Among several image-merging techniques, a MWD method merges high-resolution parts of the panchromatic image with low-resolution parts of the color band to increase the resolution of color band image.

2.1. Procedure

A. Resampling

Resample the color band image to the resolution of the panchromatic band image.

B. Histogram matching

Match the histogram of color band images with that of the panchromatic band image

C. DWT(Discrete Wavelet Transform)

Transform each band image to wavelet domain.

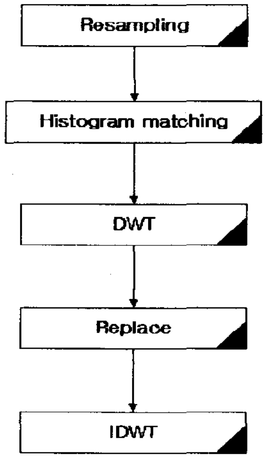

Fig. 1 The Block Diagram of MWD

D. Replace the information

Replace the coarsest band of color band images into that of the panchromatic band image.

E. IDWT (Inverse Discrete Wavelet Transform)

Reconstruct the replaced color band images.

This method is well known and proven to show good performance, but it ignores the correlation between bands, and has unnecessary parts.

III. Proposed Method

The goal of image merging techniques is to enhance the resolution of low-resolution images using detail information of the high-resolution image. This technique has to preserve the characteristic of original images, and not to distort the original band characteristic.

For example, the bandwidth of SPOT panchromatic-image is 0.51~0.73μm, that of multispectral mode 1 is 0.50~0.59μm, that of multispectral mode 2 is 0.61~0.68μm, and that

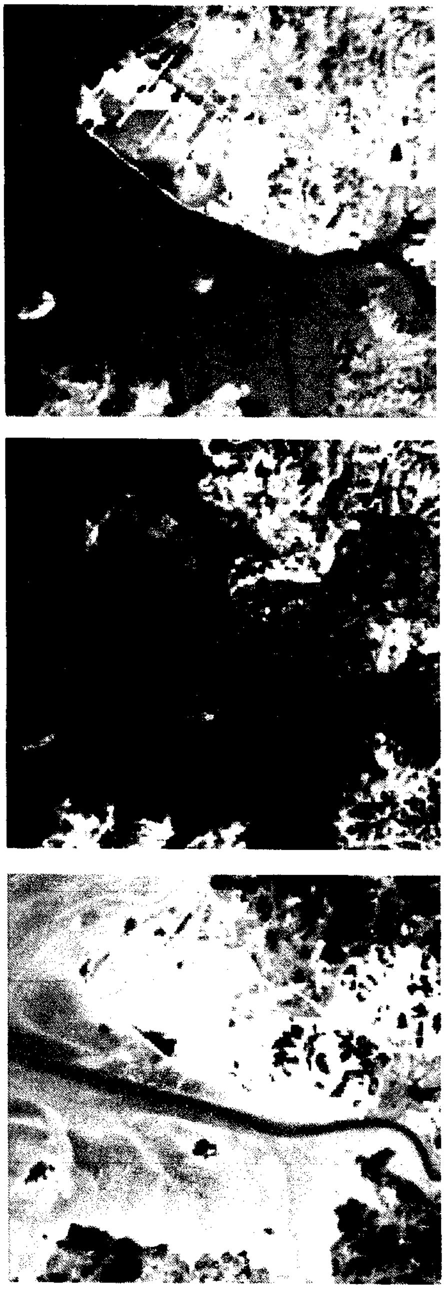

Fig. 2. The example of low-resolution Image (Landsat Image)

of multispectral mode 3 is 0.79~0.89μm.
This fact means that those images contain the different spectral and detail information, even though they are depicting the same the same region.(Fig. 2).

Therefore, if this method were to merge these images by the general MWD technique, which enhances the resolution of 'different' low frequency bands using the detail information of the 'same' panchromatic image without considering the spectral characteristics, this method would just be "MIXING" between the bands. Therefore, there are probabilities of changing the spectral characteristics of the original band images as well as enhancing the resolution of that by just "mixing".

In this paper, we discuss this "mixing" effect and, propose the method to classify the detail-information of the panchromatic image according to spatial and spectral characteristics, and to minimize distortion of the merged image.

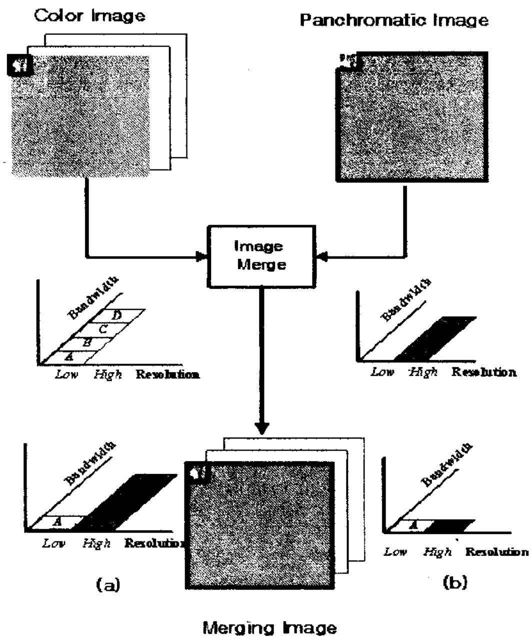

Fig. 3. Multiresolution Wavelet Decomposition method.(a) general MWD pattern, (b) desired pattern

General MWD methodsmerged all high resolution parts of the panchromatic image with the low resolution parts of the color bands. To be precise, because this method enhances the resolution of 'different' low frequency bands using the detail information (A`,B`,C`,D`) of the 'same' panchromatic image without considering the spectral characteristics, a merged image causes much distortion, and then is not trustworthy.

In fig.3, an x-axis describes the resolution of the satellite image in the same area, and a y-axis describesthe frequency domain of the satellite image.(= band)

If there are 4-color band images (S_x^A, S_x^B, S_x^C, S_x^D) and 1 panchromatic band image(S_x^P) of high resolution, each band image can be described by the following equation.(Eq 1~6)

$$S_l^A = A,\ S_l^B = B,\ S_l^C = C,\ S_l^D = D \quad (1)$$

$$S_h^P = A + B + C + D + A' + B' + C' + D' \quad (2)$$

$$S_h^A = A + A' \quad (3)$$

$$S_h^B = B + B' \quad (4)$$

$$S_h^C = C + C' \quad (5)$$

$$S_h^D = D + D' \quad (6)$$

where S_x^m x = h : high resolution
x = l : low resolution
m : band

However, in the general MWD method, each band image can be described by the following equation (Eq 7~10)

$$S_h^A = A + A' + B' + C' + D' \quad (7)$$

$$S_h^B = B + A' + B' + C' + D' \quad (8)$$

$$S_h^C = C + A' + B' + C' + D' \quad (9)$$

$$S_h^D = D + A' + B' + C' + D' \quad (10)$$

For that reason, it is positively necessary to separate the unnecessary parts from the parts of all high resolution.

3.1. Classification Rule

We first need to determine the threshold to separate the parts to merge in the color band imagewithin the detail level of the panchromatic image.

Here, we assume that the mean and standard variation of a difference image are an important key in dividing the two images. Under thisassumption, we calculated the difference between the two band images (color and panchromatic), in pixel by pixel. Then we determined the threshold value "Th" as shown in Fig. 4.

$$Th = M + 2*SV$$

3.2. Procedure

A. Resampling

: Resample the color band images to the resolution of the panchromatic band image.

B. Histogram matching

: Match the histogram of color band images to that of the panchromatic band image

C. Determine threshold(Th) & make the Difference Plane

Step 1. calculate the difference($D_l^{P-m} = S_h^P - S_l^m$) between the two image($S_h^P$, S_l^m)

Step 2. calculate mean(M), standard variation (SV) of D_l^{P-m}

Step 3. determine Th.

$$Th = M + 2*SV \quad (11)$$

: Match the histogram of color band images to that of the panchromatic band image

D. DWT(Discrete Wavelet Transform)

: Transform each band image to wavelet domain.

E. Replace the information.

if D_l^{P-m} (x,y) < Th,

then scale to the high resolution parts of S_h^P and replace them.

else if D_l^{P-m} (x,y) > Th,

then scale to the high resolution parts of S_l^m and replace them.

F. IDWT(Inverse Discrete Wavelet Transform)

: Reconstruct the replaced color band images.

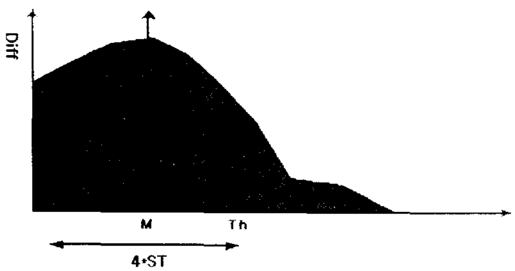

Fig.4. Pattern of selecting the threshold

Ⅳ. Simulation and Results

To test the performance of this approach, simulation was run on the IKONOS 1m panchromatic image, 4m color band images.

The proposal of this research is to compare the original image with the merged image. Therefore, we first defined the "true image set," and "test image set".

We defined that the "true image set" as a 4m color band image. We determined that the simulated test image was as followings.

A. True Image set : a 4m color image set.

B. Test image set :

① Panchromatic Test image : a 4m-resolutionimage resampling a 1m panchromatic image.

② Color Test Image : a 16m-resolution image resampling 4m color image.

Then, we merged the test image by the MWD method, and the proposed method, and compared the True Image set.

We had used the Daubechies-8 Tab wavelet, which provides good performance.[4] The peak signal-to-ratio(PSNR), which was defined as

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \tag{12}$$

(*WhereMSE is the mean square error between the target/reference images*).

was employed as a measure of the quality of the merged images.

As shown in the figures, the proposed method showed good performance.

It is true that the NDVI (Normalized Difference Vegetation Index) method doesn't fit the high resolution satellite image, but, the proper NDVI method about the high resolution satellite image has yet to be created. Simply, we used the NDVI method for the comparison of the results on the objective side.

In the Fig 5, we can see that the MWD method has much distortion in the mountain area compared with the true image. Actually, we could see so many distortions looking like the black points in the mountain area.

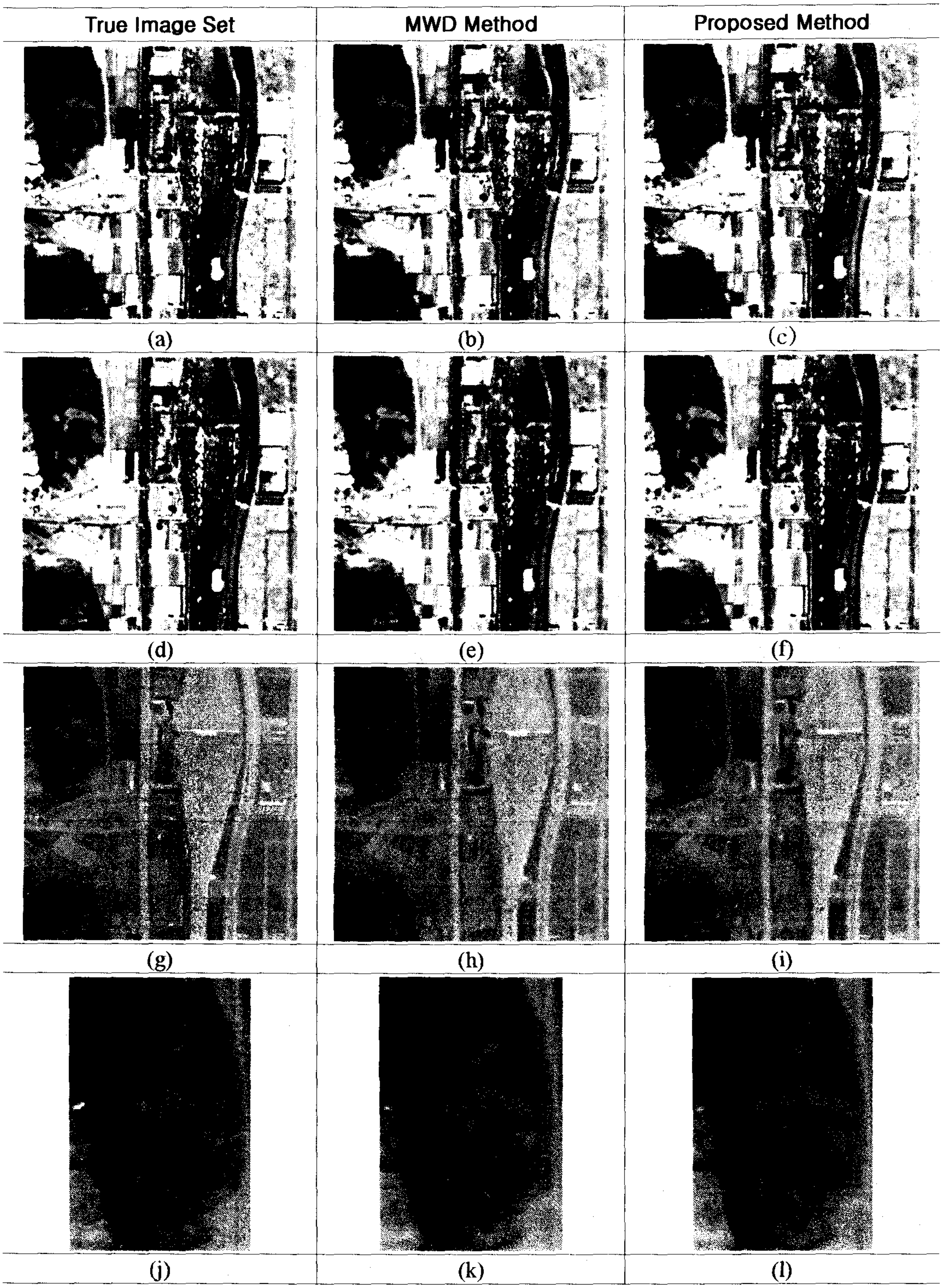

Fig.5 Result Images : Red band Image (a)~(c), RGB Image (d)~(f), NDVI (g)~(i), and Zoom in (j)~(l)

However, the proposed method results were similar to those of the true image set. On the visual performance side, that was good performance, too.

Also, although the proposed method merged the high-resolution information of panchromatic image by selective replacement, there were no differences between the true RGB color band and the merged RGB color band.

Table 1 is the PSNR table that compared true image set with the result image of the other method.

Table 1. PSNR Result.

	Band			
	Red	NIR	Green	Blue
Proposed	26.13	25.56	26.13	25.53
MWD	25.96	25.32	25.85	25.37

Also, as shown in table 1, in quality performance, the proposed method is better than the MWD method.

V. Conclusion

In this paper, we discussed this "mixing" effect and, proposed a method to classify the detail information of the panchromatic image according to the spatial and spectral characteristics, and to minimize distortion of the merged image.

As shown in result, the PSNR of our method was better than the MWD method. Also, from an objective and visual point of view, our method reduced distortion of theMWD method by selective replacement.

But, it is necessary that we study much to determine the threshold of selective basis that classify the only parts of color band information.

References

1. Garguet-Duport B., J. Girel, J.M. Chassery, and G. P autou 1996, "The Use of Multiresolution Analysis and Wavelet Transform for Mergign SPOT Panchromatic and multispectral Image Data," *Photogrammetric Engineering and Remote Sensing*, Vol. 62 , No. 9, pp 1057-1066.
2. H. Li Manjunath, B.S, and Mitra, S.K., 1995, "Multisensor Image Fusion Using the Wavelet Transform," *Graphical Model and Image Processing*, Vol. 57, No.3,pp 235-245.
3. D. A. Yocky, 1996, Multiresolution wavelet decomposition image merger of landsat thematic mapper and SPOT panchromatic Data, *Photogrammetric Engineering and Remote Sensing*, Vol. 62, No 9, pp 1067-1074.
4. I. Daubechies, 1992, *Ten Lectures on Wavelets*,Society for Industrial and Applied Mathematics.
5. G. Strang, and Nguyen, T., 1997, *Wavelet and Filter Banks*,Wellesley-Cambridge Press.