COMPARISON OF DIFFERENT DATA FUSION APPROACHES FOR SURFACE FEATURES EXTRACTION USING QUICKBIRD IMAGES

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ABSTRACT

In the present study, efforts are made to fuse QuickBird multispectral and panchromatic data to enhance the visual quality of the data. Different merging techniques like, principal component analysis (PCA), multiplicative, Brovery transformation and wavelet analysis approach have been used. Statistical and numerical comparisons have been made to evaluate the effect of different merging approaches on distortion of spectral characteristics of higher spectral resolution. It is found that the wavelet based method is the most effective in preserving the spectral information contained in the original multispectral image. The fused images can be very useful for large scale urban map updating.

1. INTRODUCTION

Image fusion is the process of combining several images or some of their features, acquired by two or more sensors at the same time or different times, together to form a single image to enhance the information. The fusion process can be carried out at different levels of information representation-pixel level, feature level and decision level (Parcharidis and Kazi-Tani, 2000). In the last two decades the rapid advancement in the field of multisensors and multitemporal remote sensing data highlighted the need for a meaningful combination of all the available imaging sources. Different methods have been developed and utilized to merge complementary digital data of the same area (Taxt and Solberg, 1997; Rajan and Chaudhuri, 2002; Simone, et al., 2002; Ahmad and Singh, 2002; Oguro et al., 2003).

Many studies have attempted successfully to fuse multiresolution image utilizing different methods in order to find which one is the best. Chavez et al. (1991) compared three different methods, namely, Intensity Hue Saturation (IHS) method, principal component analysis (PCA) method and high pass filter (HPF) method for multispectral TM and SPOT panchromatic images. The comparison was carried out by using statistical, visual and graphical tools. Ahmad and Singh (2002) merged IRS-1C LISS-III multispectral data and panchromatic data using HPF, Price, IHS and P+Xs methods. The effect of merging using Otsu thresholding technique was discussed. Then mapping of surface features was carried out using Sobel, Laplacian, and high pass filter. The extensive use of the fusion techniques has not been made for high resolution satellite data, especially, QuickBird satellite images which may produce fused images comparable with an aerial photograph.

In this paper fusion at pixel level is focused. This study has been carried out using QuickBird Panchromatic and QuickBird multispectral data to compare four different fusion techniques. To evaluate the effects of different techniques the comparison has been made using statistical parameters- mean and standard deviation.

2. BRIEF LITERATURE REVIEW

To improve the information contents of images for visual interpretation and to improve the spatial resolution, several merging techniques have been developed to merge multi-sensor and multi-resolution data. Welch and Ehler (1987) used the IHS method to merge TM and PAN data. Teoh et al. (2001) merged SPOT panchromatic 10-m resolution image with Landsat TM 30-m resolution multi-spectral channel image using IHS method. The resultant image had high resolution and spectral characteristics. The image was then subjected to the process of thresholding, Gaussian filtering using a low pass filter and the Iterative Self-Organizing Data Analysis (ISODATA) unsupervised classification to derive the feature classes. Ahmad and Singh (2002) carried out a study on merging IRS-1C multi-spectral data acquired on February 26, 1997 and panchromatic data of December 16, 1996 using HPF, Price, HIS and P+Xs methods. Console and Solaiman (2000) discussed the problems and perspectives in the high resolution data fusion. Fanelli et al. (2001) used wavelet transform approach for fusing remote sensing data for urban areas.

3. STUDY AREA AND DATA CHARACTERISTICS

The study area for this analysis is taken around the Batu Kawan stadium in Seberang Perai Selatan, Pinang Malaysia. Figures 1 and 2 present the high resolution panchromatic and multispectral images of the area. These images show the presence of a stadium with car parks, Junjung River, shrubs and palm oil plantation with some scattered residences. The details of the satellite images used in the study area are given in Table1.

Figure 1. QuickBird High Resolution (0.61 m) Panchromatic Image

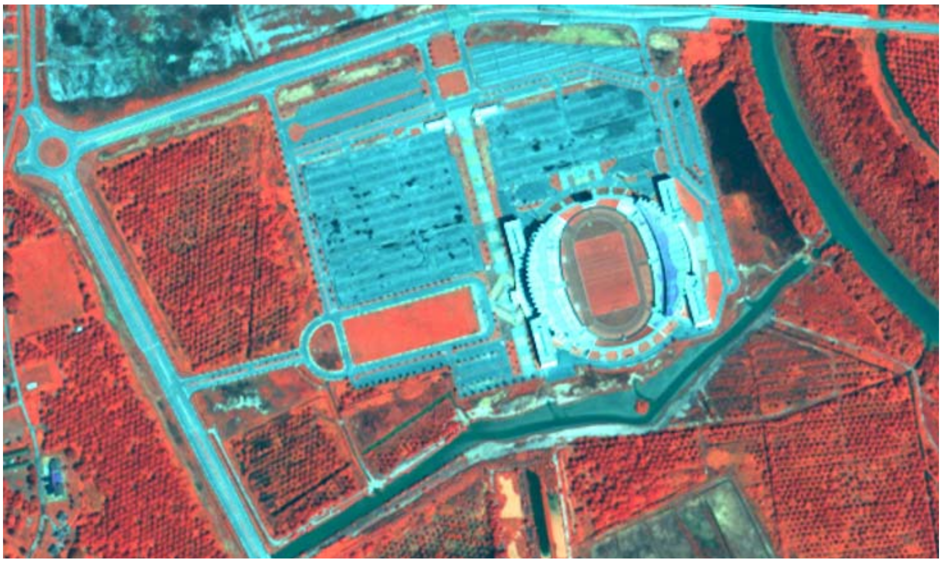

Figure2. QuickBird multispectral image (Resolution 2.44 m)

Table: Details of QuickBird satellite data used in the study

Type of Sensor	Band	Resolution (m)	Image Size (pixels)	Wavelength (µm)
Multispectral	1	2.44	616 x 390	0.45-0.52
	2	2.44	616 x 390	0.52-0.60
	3	2.44	616 x 390	0.63-0.69
	4	2.44	616 x 390	0.76-0.90
Panchromatic	-	0.61	2462 x 1556	0.45-0.99

4. Image Fusion Techniques

This study attempted to evaluate statistically four up-to-date data merging techniques namely principle component analysis (PCA), multiplicative, Brovery transform and wavelet transform. The preprocessing and mainly geometric correction is most important to any level of data fusion. The images should be co-registered at the sub-pixel accuracy. The pixel fusion is advantageous as the images can use the most original information (Pohl and Genderen, 1998). In such studies, all the output images are evaluated and compared with the original images. It has been emphasized that statistical evaluation is the most and the first approach applied for such comparisons, visual/graphical comparison comes at the later stage (Parcharidis and Kazi-Tani, 2000; Pohl and Genderen, 1998). The statistical parameters like means and standard deviations are used to assess the quality of any fused image.

4.1 Fusion method based on Principal Component (PC) Analysis

Principal component analysis uses a linear transformation of multispectral data to translate and rotate data into a new coordinate system that maximizes the variance of the original data. The first principal component is replaced by high resolution image after PCA transformation has been achieved. Then the inverse transformation is carried out from PCA back to multispectral original data.

4.2 Fusion method based on Multiplicative approach

Multiplicative approach is based on the following simple arithmetic integration of the two raster sets:

$DN_{B1} \times DN_{high\ res.\ Image} = DN_{B1\_new}$

$DN_{B2} \times DN_{high\ res.\ Image} = DN_{B2\_new}$

$DN_{B3} \times DN_{high\ res.\ Image} = DN_{B3\_new}$

Where, DN = digital number

B = band

$DN_{high\ res.\ image}$ = Digital number of high resolution image
DN_{B1_new} = Digital number of band 1 merged image
For all the three bands the digital number of merged image can be determined.

4.3 Fusion method based on Brovery Transformation

Brovery transformation is a simple numerical method to merge different source data. It is based on the assumption that the spectral range of the panchromatic image is same as that covered by multispectral bands. The transformation is defined by the following relation

$$Y_k(i,j) = \frac{X_k(i,j)X_p(m,n)}{\sum_{k=2}^{4} X_k(i,j)}$$

where $X_k(i,j)$ and $Y_k(i,j)$ are the k^{th} original multispectral band and fused multispectral band data, i and j are the pixel number and line number of the kth multispectral bands, respectively. Whereas, X_p (m,n) is the original panchromatic band data; m and n are the pixel and line numbers of panchromatic band data, respectively. In case of QuickBird data, the image fusion by Brovery transformation can be carried out as follows: (i) Choose three bands (2, 3 and 4), (ii) Resample them to 0.61 m spatial resolution, and (iii) perform Brovery transformation for resample new image data.

The resulting image consists of a combination of three bands of multispectral image and the panchromatic image

4.4 Fusion method based on Wavelet Transform

Wavelets are derived waveforms that have a lot of mathematically useful characteristics that is why they are preferred to simple sine or cosine functions. Wavelets are discrete and have a finite length unlike sine waves which are continuous and infinite in length. The wavelets are applied to the input image recursively via a pyramid algorithm. According to the basic theory wavelet decomposition, an image can be separated into high frequency and low frequency components.

The fusion method based on the multi-resolution wavelet decomposition (MWD) consists in decomposing the panchromatic image and each band of the resampled multispectral image to a chosen wavelet approximation level. The fused image may be obtained by replacing the approximation images arising from pyramidal decomposition of the multispectral bands for each band of multispectral data and to applying inverse wavelet transform on these fused pyramidal sets. Another method to fuse different image information is based on the observation that in an IHS colors space geometric and thematic features are already well separated. So, only the intensity (I) and panchromatic image can be fused with DWS. The final fused image will be obtained by performing an inverse wavelet transform followed by an IHS to RGB colors space back transform. In the same way, DWS method can be applied to the fusion of panchromatic image with the first principal component of a PC decomposition, and then by performing the inverse PC transform.

4. RESULT

The resulting images obtained using PC analysis, multiplicative approach, Brovery transformation and wavelet transform with single band, intensity hue saturation (IHS) and PC are shown in Figures 3-8. The statistical parameters (means and standard deviations) of fused images obtained from each approach are presented in Table 2. In case of principal component analysis (PC) approach the fusion of panchromatic band has reduced the numerical values of the average and the standard deviation of the original multispectral band data. For Brovery transformation, it is found that the statistical parameters of fused multi spectral bands are different from that of the original one because the new information is derived from the ratio of panchromatic band. These parameters of the fused image by multiplicative approach are very much different as the new pixel values are computed simply by multiplication of pixel values of the original multispectral band data and the panchromatic band. The statistical comparison of spectral characteristics of data indicates that the results generated with the wavelet (single band) and wavelet (PC) approaches are almost similar, and less distorted than the principal component, multiplicative and the wavelet (IHS) approaches.

The visual comparison of the images revealed that all the methods improved the resolution and features present in the multispectral images. The fused QuickBird images are a powerful basis for the generation of large scale landuse maps (Volpe, 2003). The map updating is often required, especially, in the outskirts where the urban environment is fast growing. For a small to medium area the fused images are extremely competitive when compared to aerial photographs. The 0.61 m resolution fused image is capable for mapping approximately at scales from 1: 2,500 to 1: 5,000.

The high information content in the fused images enabled the identification of single buildings, space between buildings, green areas, distance from the roads and small approach roads. This information can be helpful for planning of new residence or hotel. The fused image content can also be useful to aid for detection of legal violation such as use of unauthorized sidewalks for commercial activities, unauthorized coverage of a building, illegal building construction etc.

Table 2. Statistical Results of Merging Techniques

Band	Original data		PCA		Multiplicative		Brovery transform		Wavelet transform					
									Single Band		IHS		PC	
	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.
1	247.6	72.6	150.6	66.7	97207.5	57985.3	299.8	186.7	246.6	73.5	584.0	233.5	245.4	72.7
2	352.5	124.9	204.1	121.4	140916.1	97244.0	165.9	49.2	351.2	126.4	353.5	153.4	349.0	124.7
3	212.4	117.2	61.0	110.0	86785.6	77985.6	-	-	211.7	118.1	-	-	209.3	117.2
4	546.7	196.7	867.3	55.5	219295.1	120602.8	117.0	29.7	547.9	194.2	251.9	157.2	544.3	196.6

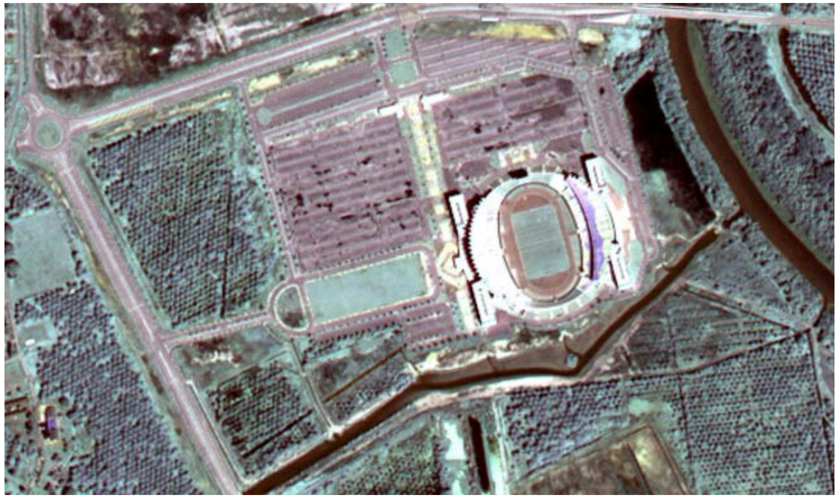

Figure 3. Fused image by principal component analysis

Figure 4. Fused image by multiplicative method

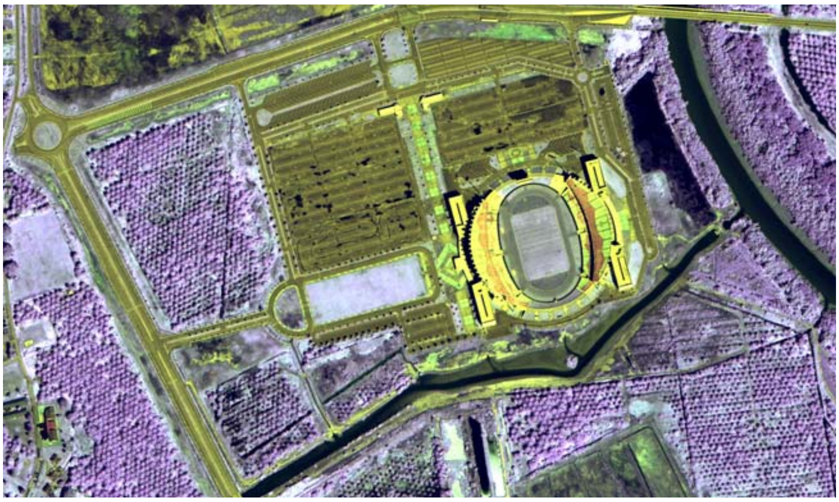

Figure 5. Fused image by Brovery transformation

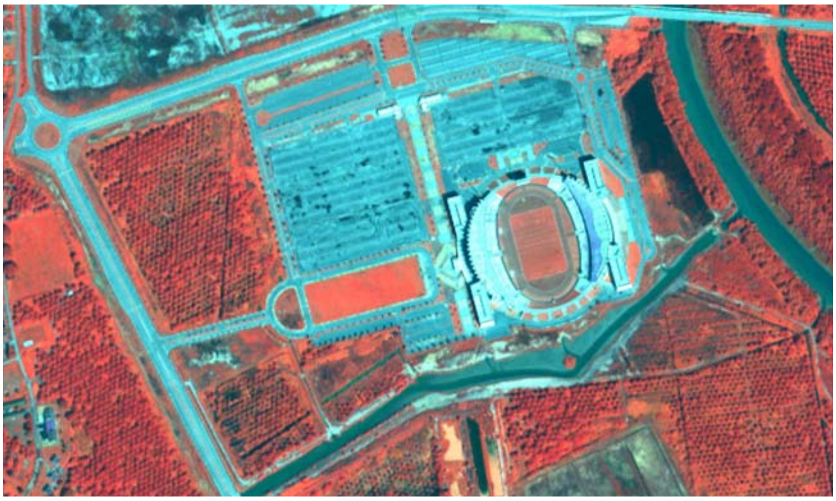

Figure 6. Fused image by wavelet Transformation (single band)

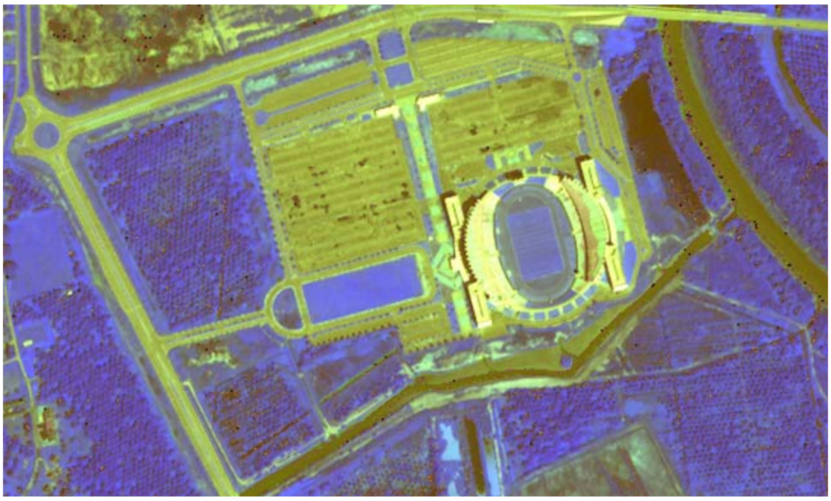

Figure 7. Fused image by wavelet transform (HIS)

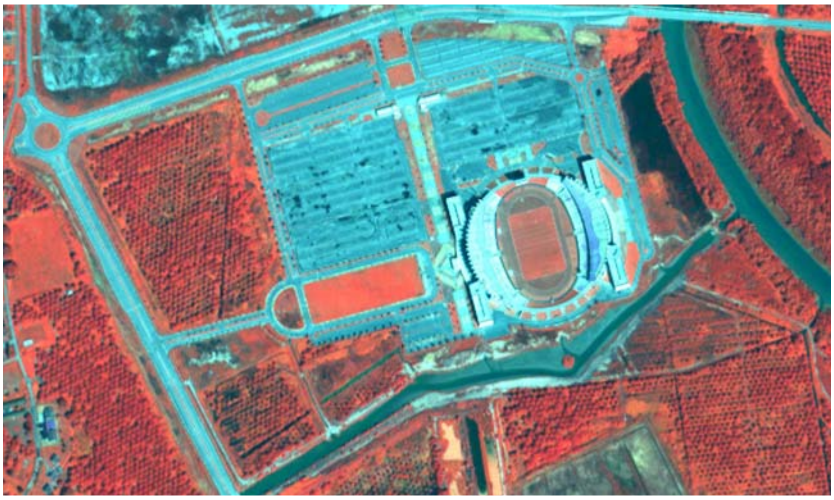

Figure 8. Fused image by wavelet transform (PC)

5. CONCLUSION

Many image fusion methods have been proposed in the literature for fusing multispectral data in order to produce multispectral images having the highest spatial resolution available within a data set. In this study a comparison of the available four methods has been carried out to fuse QuickBird panchromatic (0.61 m) resolution and QuickBird multispectral (2.44 m resolution). All the methods are found to improve resolution and the features present in the multispectral image. Wavelet transforms approach with single band and PC has best preserved the statistical parameters. The fused images are useful for urban environment mapping at large scale from 1: 2,500 to 1: 5,000 scales.

6. ACKNOWLEGEMENT

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