ANALYSIS OF SPOT-6 DATA FUSION USING GRAM-SCHMIDT SPECTRAL SHARPENING ON RURAL AREAS

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Abstract. Image fusion is a process to generate higher spatial resolution multispectral images by fusion of lower resolution multispectral images and higher resolution panchromatic images. It is used to generate not only visually appealing images but also provide detailed images to support applications in remote sensing field, including rural area. The aim of this study was to evaluate the performance of SPOT-6 data fusion using Gram-Schmidt Spectral Sharpening (GS) method on rural areas. GS method was compared with Principle Component Spectral Sharpening (PC) method to evaluate the reliability of GS method. In this study, the performance of GS was presented based on multispectral and panchromatic of SPOT-6 images. The spatial resolution of the multispectral (MS) image was enhanced by merging the high resolution Panchromatic (Pan) image in GS method. The fused image of GS and PC were assessed visually and statistically. Relative Mean Difference (RMD), Relative Variation Difference (RVD), and Peak Signal to Noise Ratio (PSNR) Index were used to assess the fused image statistically. The test sites of rural areas were devided into four main areas i.e., whole area, rice field area, forest area, and settlement. Based on the results, the visual quality of the fused image using GS method was better than using PC method. The color of the fused image using GS was better and more natural than using PC. In the statistical assessment, the RMD results of both methods were similar. In the RVD results, GS method was better then PC method especially in band 1 and band 3. GS method was better than PC method in PSNR result for each test site. It was observed that the Gram-Schmidt method provides the best performance for each band and test site. Thus, GS was a robust method for SPOT-6 data fusion especially on rural areas.

Keywords: *Data fusion, SPOT-6, Gram-Schmidt, PSNR, rural area*

1 INTRODUCTION

Image fusion is a technique to generate a new image by integrating different spatial and spectral characteristics of the images. It is used to generate not only visually appealing images but also provide detailed input to the later image analyses like image classification, change detection etc (Kim *et al*., 2011). Pansharpening is one of technique in image fusion. The major concern in the quality evaluation of pansharpened images need to be considered as important because it affects subsequent applications such as the land-cover classification, change detection, and the extraction of physical properties (Matsuoka, 2012).

Several studies of image fusion has been widely applied in remote sensing field such as (Zhang, 2004; Alparone, 2007; Aiazzi *et al*., 2007; Khan, 2009; Santurri *et al*., 2010; Ozdarici and Akyurek , 2011; Matsuoka, 2012; Maurer, 2013; and Palubinskas 2013). Ozdarici and Akyurek (2011) evaluated four different image fusion methods i.e., Gram-Schmidt, Least Square Fusion, Principle Component Spectral Sharpening, and Wavelet-integrated Principle Component Analysis in an agricultural land. They used QuickBird MS image and evaluated in a statistical and visual manner. In visual evaluations, the method of Gram-Schmidt and LSF had better performance than other methods. In statistical evaluation, the Gram-Schmidt method had better statistical evaluation than others. A similar study was conducted by Matsuoka (2012). The study used PRISM and AVNIR-2 data from ALOS. In the quantitative assessment using correlation coefficients, ERGAS values and the Q index indicated that spectral information was preserved better in bands 2 and 3 than in the other two bands. The land cover significantly affected the spectral quality of the band 4 image. The Gram–

Schmidt spectral sharpening (GS), additive wavelet intensity (AWI), and additive wavelet principal component (AWPC) methods resulted in a relatively higher image quality on the whole bands.

The appropriate of Area of Interest (AoI) is needed to evaluate the performance of image fusion methods. It has to be a representation of many objects in the earth. Rural area is a representation of many objects in the in the earth such as forest, settlement, rice field, plantation and water body. SPOT-6 satellite imagery was used in this study because it can be used to support for many applications like land planning, agriculture, environmental protection and natural resources exploration (Astrium, 2013).

Many methods of data fusion have been applied to pansharp the high resolution remote sensing data. One of the most widespread and performing MS+Pan fusion method is the Gram-Schmidt (GS) spectral sharpening (Aiazzi *et al*., 2007). Some methods such as Principal Component Analysis and IHS are highly sensitive to bands misalignment, as it happens for some very high resolution such as IKONOS (Zhang, 2004). Principal Component Analysis and IHS. The hypothesis of this study was that GS can be used to provide a good pansharping in SPOT-6 data. .

In this study, the performance of GS was presented based on multispectral and pancromatic of SPOT-6 image. The aim of this study was to evaluate the performance of SPOT-6 data fusion using GS method on rural areas. The visual and statistical evaluation performance was performed in a rural area. To evaluate the reliability of GS method, we performed the comparison of GS method with Principle Component Spectral Sharpening (PC) method.

2 MATERIALS AND METHOD

2.1 Study area and data

The study area was selected in region of noth Kluet, South Aceh (Figure 1). It was a representative region of rural area and it was characterized by crop land, forest and settlement. The test site includes rice filed, forest, and settlement.

In the study, SPOT-6 MS (6.2 m) and Pan (1.55 m) were used to test the image fusion methods. The images were acquired on January 25th, 2013. The spectral range of SPOT-6 image lied between 0.45 μm - 0.89 μm. The multispectral image consisted of four channels including blue (0.450 - 0.520 μm), green (0.530 - 0.590 μm), red (0.625 - 0.695 μm), and near-infrared (0.760 - 0.890 μm). The images used in the study had radiometric and ortho rectified imageries.

Figure 1. SPOT-6 image (MS – left, Pan – right) in north Kluet, South Aceh.

2.2 Image fusion and quality assessment methods

The spatial resolution of the multispectral (MS) image was enhanced by merging the high resolution Panchromatic (Pan) image in GS method. The steps of GS method given by Laben and Brower (2000); Ozdarici and Akyurek (2011); and Aiazzi *et al*. (2007). Firts, a lower spatial resolution Pan image was simulated. In the process, the high resolution Pan image was interpolated up to an appropriate scale. Second, the GS transformation was performed on the simulated lower spatial resolution of Pan image and the plurality of lower spatial resolution spectral band images. The simulated lower spatial resolution Pan image was employed as the first band in the GS transformation. Third, the statistics of the higher spatial resolution Pan image was adjusted to match the statistics of the first transform band resulting from the Gram-Schmidt transformation to produce a modified higher spatial resolution Pan image. Fourth, the modified higher spatial resolution Pan image was substituted for the first transform band resulting from the GS transformation to produce a new set of transformed bands. Fifth, the inverse GS transformation was performed on the new set of transform bands to produce the enhanced spatial resolution MS image.

Image fusion result was needed to be assessed to understand its quality. The assessment can be done by visual and statistic assessment. The assessment criterion was based on preserving the spectral quality of the multispectral data for the fused products. Based on the results, if spectral quality of the multispectral and fused images was similar to each other, it can be stated that their global statistical parameters should be very similar (Zhang, 2002).

In the study, several statistic assessment methods were used i.e., Relative Mean Difference (RMD), Relative Variation Difference (RVD), and Peak Signal to Noise Ratio (PSNR) Index.

The RMD refers to the difference of means between the fused products and the low resolution image as formulated as follows (Ozdarici and Akyurek (2011):

$$\text{RMD}=(F - LR) / LR \quad \text{.....} \quad (1)$$

where F refers to the mean value of the fused image, LR is the mean value of the low resolution image.

The RVD refers to the variation difference between the fused product and the low spatial resolution image as formualted as follows (Ozdarici and Akyurek (2011):

$$\text{RVD}= \frac{(\partial_F^2 - \partial_{LR}^2)}{\partial_{LR}^2} \quad \text{.....} \quad (2)$$

where ∂_F^2 is the fused image variation and ∂_{LR}^2 is the low resolution image variation.

The PSNR index is used to reveal radiometric distortions of the final product after applying an image fusion method as formulated as follows (Ozdarici and Akyurek (2011):

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(F_i - LR_i)^2 \quad \text{.....} \quad (3)$$

and

$$PSNR = 20log_{10}\frac{Peak}{\sqrt{MSE}} \quad \text{.....} \quad (4)$$

where F_i is the pixel value i of the fused image, LR_i is the pixel value i of the low resolution image, N refers to the number of non-null image pixels, Peak is the maximum pixel value.

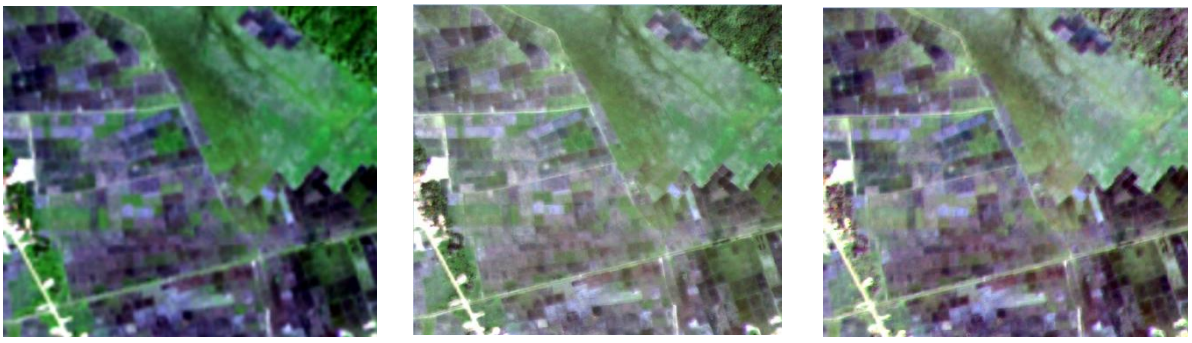
3 RESULTS AND DISCUSSION

The results of image fusion using GS and PC were assessed visually and stastically. The visual quality of the fused image using GS was better than the fused image using PC. It can be seen clearly in Figure 2. The color of the fused image using GS was more natural than the fused image using PC. Visually, the fused image using GS more similar to the MS image than the fused image using PC.

Figure 2. The result of SPOT-6 image fusion using GS (left) and PC (right) methods in north Kluet, South Aceh.

Table 1. Statistical result of image fusion in whole area

Methods	RMD			RVD			PSNR
	Band 1	Band 2	Band 3	Band 1	Band 2	Band 3	
Gram-Schidt	-0.0034	-0.0016	-0.0024	0.0303	0.5756	0.2612	45.8240
PC	-0.0041	0.0000	0.0000	-0.5774	0.0103	-0.4815	37.1545



(a) (b) (c)

Figure 3. Rice filed: (a) SPOT-6 MS, (b) Gram-Schimdt and (c) PC in Kluet Utara, South Aceh

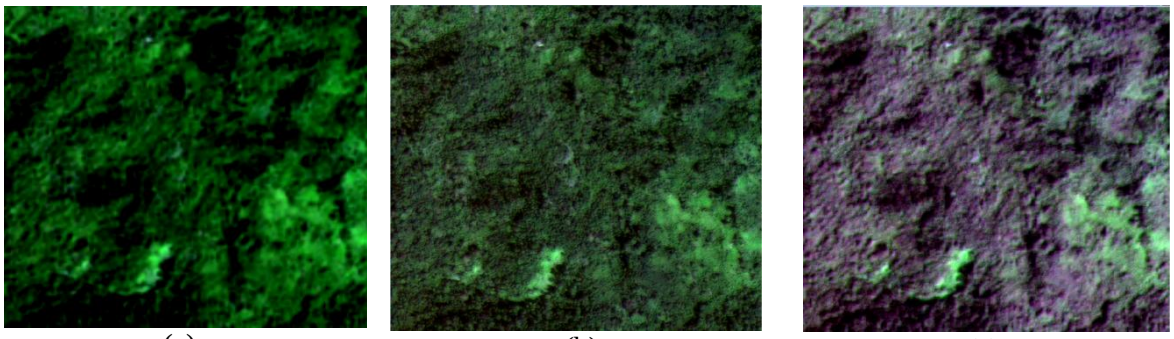
The statistical assessment was done by RMD, RVD and PSNR. The fused image was assessed in several sites i.e., whole area, rice field area, forest area, and settlement area. In the whole area, the results of RMD and RVD of the GS and PC methods were almost similar. But the GS method was better that PC method in PSNR result (Table 1).

In the rice field area, the fused image using GS method was almost similar than the fused image using PC. It can be seen clearly in Figure 3. In the statistical assessment, the RMD and RVD results of both methods were similar. GS method was better that PC method in PSNR result.

In the forest area, the fused image using GS method is better than the fused image using PC. The color of the of the fused image using GS is more natural than the fused image using PC. It can be seen clearly in Figure 4. In the statistical

assessment, the RMD results of both methods were similar. In the RVD, GS method was better then PC result especially in band 1 and band 3. GS method was better than PC method in PSNR result.

In the settelement area, the fused image using GS method is almost similar than the fused image using PC. It can be seen clearly in Figure 5. In the statistical assessment, the RMD and RVD results of both methods are similar. GS method is better than PC method in PSNR result (Table 2).



(a) (b) (c)

Figure 4. Forest: (a) SPOT-6 MS, (b) Gram-Schimdt and PC in north Kluet, South Aceh.

(a) (b) (c)

Figure 5. Settlement: (a) SPOT-6 MS, (b) Gram-Schimdt and PC in north Kluet, South Aceh.

Table 2. Statistical result of image fusion area of rice field, forest, and settlement.

Methods	Fields	RMD			RVD			PSNR
		Band 1	Band 2	Band 3	Band 1	Band 2	Band 3	
Gram-Schidt	Rice Field	-0.5576	-0.6489	-0.7124	-0.6220	-0.5141	0.6305	44.3627
PC		-0.5653	-0.6815	-0.7097	-0.5462	-0.1838	0.8753	35.6933
Gram-Schidt	Forest	-0.9008	-0.8198	-0.7884	0.1656	-0.5044	-0.4318	44.6430
PC		-0.7945	-0.7860	-0.5063	6.2530	-0.1112	2.6412	35.9735
Gram-Schidt	Settlement	-0.6907	-0.6455	-0.5565	-0.5434	-0.6762	-0.7005	45.6121
PC		-0.6706	-0.6481	-0.5366	-0.5768	-0.6248	-0.7340	36.9426

4 CONCLUSION

The Gram-Schmidt method provided the best performance for each band and test site. The visual quality of the fused image using GS method was better than using PC method. The color of the fused image using GS was better and more natural than using PC. Therefore, GS can be used to provide a good pansharping in SPOT-6 data and can support for many applications on rural areas.

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