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Pan-sharpening Effect in Spatial Feature Extraction

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Abstract : A suitable pan-sharpening method has to be chosen with respect to the used spectral characteristic of the multispectral bands and the intended application. The research on pan-sharpening algorithm in improving the accuracy of image classification has been reported. For a classification, preserving the spectral information is important. Other applications such as road detection depend on a sharp and detailed display of the scene. Various criteria applied to scenes with different characteristics should be used to compare the pan-sharpening methods. The pan-sharpening methods in our research comprise rather common techniques like Brovey, IHS(Intensity Hue Saturation) transform, and PCA(Principal Component Analysis), and more complex approaches, including wavelet transformation. The extraction of matching pairs was performed through SIFT descriptor and Canny edge detector. The experiments showed that pan-sharpening techniques for spatial enhancement were effective for extracting point and linear features. As a result of the validation it clearly emphasized that a suitable pan-sharpening method has to be chosen with respect to the used spectral characteristic of the multispectral bands and the intended application. In future it is necessary to design hybrid pan-sharpening for the updating of features and land-use class of a map.

Key Words : Pan-sharpening, Feature Extraction, SIFT, Segmentation, Edge

1. Introduction

High resolution satellite data include a commonly panchromatic image and four multispectral band color images. The image pan-sharpening is generally applied using high spatial detail and low spatial color information together for application. Various pan-sharpening methods, such as high-pass filtering, principal component, IHS, and wavelet have been used (Choi *et al.*, 2007; Kalpoma *et al.*, 2007; Kim *et al.*, 2010). In this way, research related to a pan-sharpened image in land use classification was performed.

There are several studies comparing these techniques such as; IHS, PCA and Brovey transform methods compared with wavelet method to achieve the best spectral and spatial quality (Zhou *et al.*, 1998), IHS and wavelet combination of pan-sharpening method used on IKONOS and Quickbird images to decrease the colour distortions (Zhang and

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Hong, 2005). A multi resolution decomposition method based on "a tróus" algorithm was used to improve the image classification (Teggi *et al.*, 2003).

Research on image pan-sharpening in improving the accuracy of image classification has been reported by several authors (Munechika *et al.*, 1993; Printz *et al.*, 1997; Shaban and Dikshit 2002; Colditz *et al.*, 2006; Renza *et al.*, 2009). Renza *et al.* (2009) studied the influence of image pan-sharpening on spectral classification algorithms and their accuracy. The best results in Renza's research were achieved by Dual Tree Complex Wavelet Transform (DT-CWT) on SPOT images. On the other hand, Gangkofner *et al.* (2008) studied an upgraded methodology for high-pass adding-based image pan-sharpening and provided a comparison of results with wavelet-based image pan-sharpening results using spectral and spatial metrics.

Many studies in the field of image pan-sharpening of remotely sensed data aim towards deriving new algorithms for visual enhancement; however, there is little research on the influence of image pan-sharpening on other applications (Colditz *et al.*, 2006). Colditz *et al.* (2006) analyzed influence of image pan-sharpening on spectral classification algorithms and their accuracy using Brovey transformation, hue-saturation-value (HSV), principal component analysis (PCA), multi resolution image fusion technique (MMT), adaptive image fusion (AIF) and wavelet transformation methods. It was found that the adaptive image pan-sharpening approach on a Landsat 7 ETM+ image shows best results with low noise content. It resulted in a major improvement when compared with the reference, especially along object edges. Acceptable results were achieved by wavelet, multisensor multiresolution image pan-sharpening, and principal component analysis. Brovey and hue-saturation value image pan-sharpening performed poorly and cannot be recommended for classification of fused imagery. Pixel-based and object-based classification techniques are employed to classify the pan-sharpening result of MODIS and Radarsat for obtaining crop land use classes (Hong *et al.*, 2007). The classification results demonstrate that pixel-based classification techniques fail to classify the crop types due to radar noise in the fused images, whereas object-based classification yields promising classification results.

The pan-sharpening images in geometric information extraction such as satellite photogrammetry have been used abundantly in feature extraction. However, the evaluation of the pan-sharpening technique in a non-spectral application has seldom been studied and was performed in specific application. Therefore, in our research many types of pan-sharpening techniques were compared from the view of spectral property and feature extraction such as interest point extraction, edge extraction. It is feasible to develop hybrid process design combining results of spatial and spectral pan-sharpened images.

2. Pan-sharpening

In this study, 11 pan-sharpening methods were examined. The pan-sharpening used commercial software. First, pan-sharpening modules from ERDAS software such as the Multiplicative, Modified IHS, PC (Principal Component), Brovey Transform, HPF (High-Pass Filtering), Wavelet-PC, Wavelet-IHS, Wavelet-Single, and Ehlers pan-sharpening algorithms were applied. Also we used Highview software of the GEOSAGE company and the Pansharp (Zhang, 2004) module of the Geomatica company.

IHS method separates the Intensity, Hue and Saturation components of a RGB image. Three bands of an MS image are converted from RGB color to

IHS color. Spatial frequency related I component is replacing the high resolution image and back transformation IHS to RGB is required (Pohl and Van Genderen, 1998).

PCA converts a multivariate data set of inter-correlated variables into new uncorrelated linear combinations of the original values (Pohl and Van Genderen, 1998; Teggi *et al.*, 2003). The difference between IHS and PCA is that while IHS is used for 3 bands, PCA method can be used for more than three bands.

DWT(Discrete Wavelet Transform) concept based transformation of high resolution image using wavelet to four portions that three of them have high frequency and the one has low frequency. Multispectral image is resampled to a size that low frequency portion of the high-resolution image has. Low frequency of high resolution images is replaced by resampled multispectral images. An inverse wavelet transformation is done for the three newly replaced images. These three images combined to one fused image. The fused image keeps in the high spatial resolution with the spectral information of the original multi-spectral image (Shi *et al.*, 2005).

The HPF fuses both spectral and spatial information with the band-addition approach. Edge information is extracted from high resolution image and added pixel by pixel basis to the low resolution one. High frequency component of the high resolution image is concerned to spatial information. High pass filter of the high resolution image corresponds to high frequency component. In conclusion, by adding high pass filter to the low resolution band, spatial information content of the high resolution image will be seen in the fused image (Bethune *et al.*, 1998).

The PCI_Pansharp module (Zhang, 2004) was incorporated into Geomatica. The algorithm achieves the maximal spatial detail increase and a minimal color distortion. This image pan-sharpening technology has been licensed the remote sensing software company PCI Geomatics, and the most advanced satellite company DigitalGlobe. It is being used by leading industry, government, academic and military organizations globally across the five continents, including NASA, NOAA, USGS, Google Earth.

Color Normalized (Brovey) sharpening (Vrabel, 1996) uses a mathematical combination of the color image and high resolution data. Each band in the color image is multiplied by a ratio of the high resolution data divided by the sum of the color bands. The function automatically resamples the three color bands to the high-resolution pixel size using one of the techniques you select. The choices are nearest neighbor, bilinear, or cubic convolution.

Multiplicative sharpening uses a simple multiplicative algorithm.

$$(DN_{TM}) \times (DN_{SPOT}) = DN_{new\ TM}$$

The algorithm is derived from the four component technique of Crippen (Crippen, 1989). In this paper, it is argued that of the four possible arithmetic methods to incorporate an intensity image into a chromatic image (addition, subtraction, division, and multiplication), only multiplication is unlikely to distort the color. However, in his study Crippen first removed the intensity component via band ratios, spectral indices, or PC transform. The algorithm shown above operates on the original image.

3. Measuring Pan-sharpening Performance

Shi *et al.*(2005), studied multi-band wavelet based image pan-sharpening and corresponding quality assessment. Mean value used to represent average intensity of an image, standard deviation, information entropy and profile intensity curve are used for assessing details of fused images. Bias and correlation coefficient analyses determined for measuring distortion between the original image and fused image in terms of spectral information. The other best known measurements of fused image quality are the estimation of Universal Image Quality Index (UIQI) (Wang, 2002), and relative dimensionless global error in synthesis (ERGAS-Erreur Relative Globale Adimensionnelle de Synthéese) (Wald, 2002).

In order to evaluate the advanced spectral quality of the fused images, Kompsat Multispectral image is compared with the produced fused images. Bias, Correlation Coefficient (CC), RASE, RMSE, SAM (Spectral Angle Mapper), SID, Qave and Spatial factor were computed and compared. Spatial factor is a spatial quality metric which looks at the correlation coefficients between filtered versions of the panchromatic image and each sharpened band.

Qave and Spatial value used in the accuracy evaluation obtained the best result, when the values were as close as 1. Also, the remaining statistic values obtain the same results near 0.

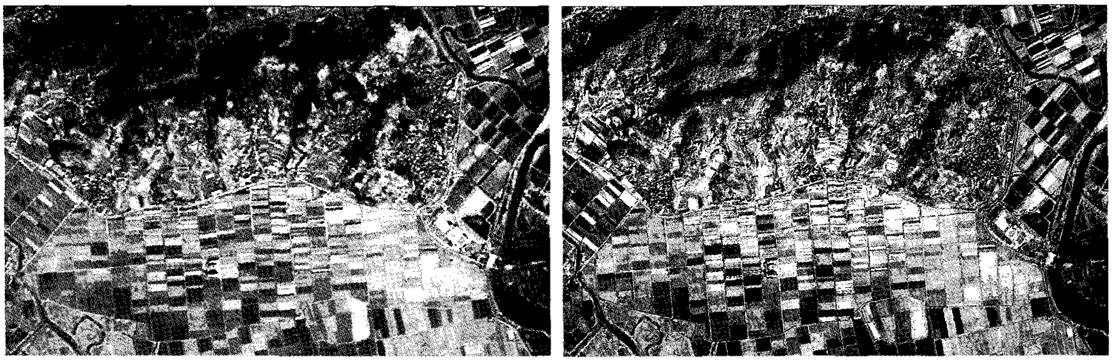
The SIFT method has been widely used to extract tie-points in the image processing field. The SIFT detector acquires the key points using the relative pixel value change patterns in the images and is suitable for finding distinctive regions in an image. It provides a descriptor that is invariant to rotation and scale, and also partially invariant to changes of illumination and 3D camera viewpoint (Lowe, 2004; Mikolajczyk and Schmid, 2005). The region-of-interest SIFT detector that we use was introduced by Lowe(2004). SIFT extracts key points as the maximum response of the difference-of-Gaussian function. Each SIFT feature descriptor is a 128-dimensional vector, which summarizes the gradient magnitude and orientation trend in a region around the key point location. The closest-to-next-closest (CTNC) SIFT ratio is relaxed to identify more key points and obtain more matching points. A CTNC of 0.6 was used in Lowe's implementation. Lowe proved that the CTNC should be sufficiently small such that each matched pair of key points is correct and stable. We used a CTNC of 0.5 in this research.

For Canny algorithm (Canny, 1986), the object finds edges by looking for the local maxima of the gradient of the input image. The calculation derives the gradient using a Gaussian filter. This algorithm is more robust to noise and more likely to detect true weak edges. Canny edge detector is generally used for feature extraction in image preprocessing. The similarities of edges extracted from original image and pan-sharpening images can be compared as another evaluation measure.

4. Experiment

A Kompsat-2 image was used, where four multispectral bands (4m) were fused with the corresponding 1m panchromatic channel (refer to Fig. 1 and Fig. 2). The spatial resolution of the panchromatic and multispectral images are 1m (3200 × 2000 pixels) and 4m (800 × 500 pixels). The study site is approximately 6km2 including the Suncheon Bay Ecological Park. This area includes forests, agriculture, coast and river, as well as the downtown area. The study process can be automatically conducted through Mathworks' Matlab except the image pan-sharpening.

In this paper, we used the objects of the NGII (National Geographic Information Institute) 1:5,000 topographic map as a ground control features and land use reference (Fig. 3). These reference features for georegistration were extracted from road and water layers of the map. Pan-sharpening images were co-registered with the digital map by the Boolean operation algorithm (Han *et al.*, 2007). Visual



(a) False Color (b) Panchromatic

Fig. 1 . Kompsat-2 Images.

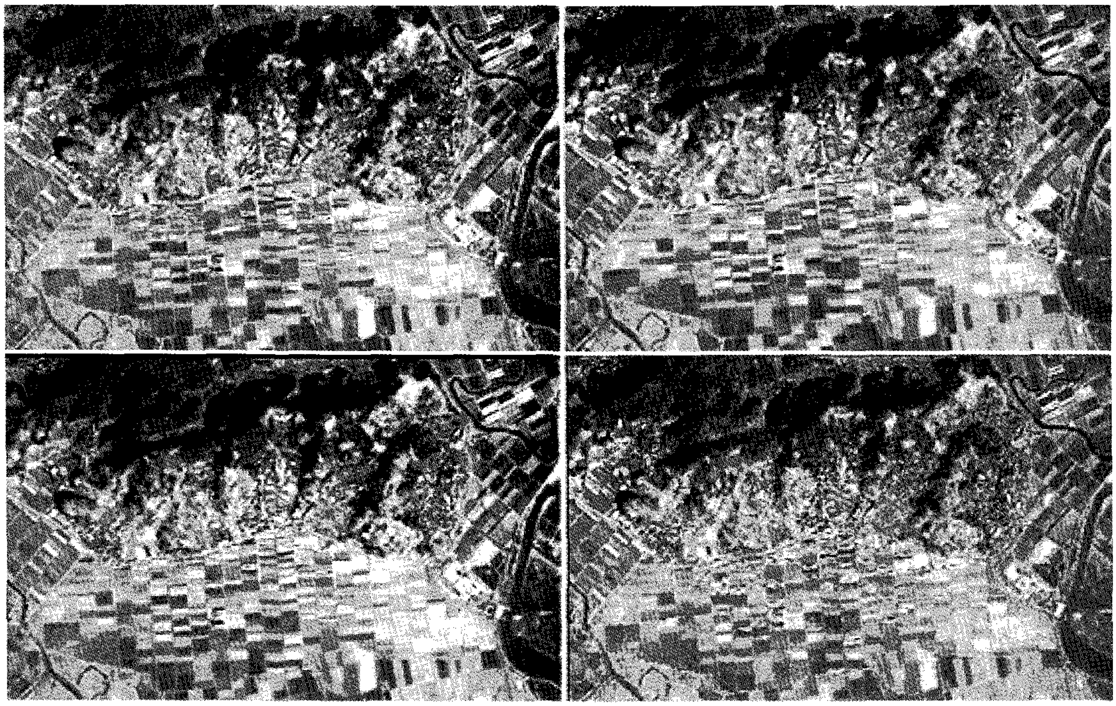


Fig. 2. Result of Pan-sharpening; (upper left) Modified HIS, (upper right) Wavelet Single, (bottom left) GeoSAGE HighView, (bottom right) Geomatica PCI_pansharp.

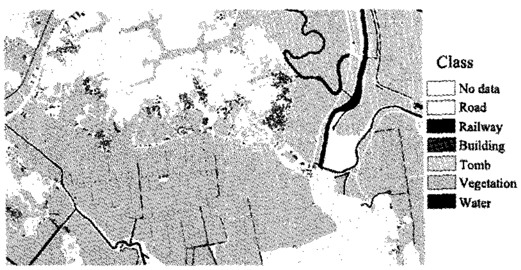


Fig. 3. Reference map of pan-sharpening images

inspection verified good registration with about a two pixel error.

Performing the increased interpretation capabilities, each of the fused images was compared each other (refer to Table 1). In this research, the Highview, HPF, and PCI_pansharp pan-sharpening methods provided the best performance, in which the spatial information of the panchromatic image was

Table 1. Conventional evaluation of pan-sharpening

	Corrcoef	ERGAS	RASE	RMSE	SAM	SID	Qave	Spatial
	0	0	0	0	0	0	1	1
brovey	0.194	120.911	85.563	276.477	0.887	0.030	0.112	0.994
multiplicative	0.261	26.081	24139.853	78002.063	0.888	0.027	0.000	0.975
PCA	0.407	2.152	7.635	24.672	1.462	0.036	0.992	0.823
HPF	0.095	2.063	7.675	24.799	1.269	0.037	0.992	0.935
ehlers_spatial	0.016	1.881	8.956	28.938	2.739	0.006	0.970	0.846
ehlers_spectral	0.004	1.055	3.894	12.582	0.981	0.002	0.996	0.525
modifi_HIS	0.134	1.884	7.544	24.375	1.037	0.007	0.991	0.914
subtractive_merge	0.074	2.122	7.683	24.825	1.260	0.037	0.993	0.970
wavelet_pc	0.007	1.859	6.755	21.826	1.237	0.043	0.993	0.608
highview	0.043	1.820	7.079	22.876	0.689	0.035	0.995	0.922
PCI_pansharp	0.117	2.258	8.206	26.516	1.456	0.039	0.991	0.968

Table 2. Extraction result of SIFT matching pairs

	FuseM-OrigM					FuseM-OrigP				
	Band1	Band2	Band3	Band4	SUM	Band1	Band2	Band3	Band4	SUM
OrigP-OrigM	15	46	35	377	473					
brovey	32	184	508	3002	3726	60271	74034	40598	16212	191115
multiplicative	77	403	459	2527	3466	49192	32969	15638	4104	101903
PCA	127	201	436	1034	1798	566	2898	600	4854	8918
HPF	1187	1872	2154	3622	8835	5028	10562	5133	14262	34985
ehlers_spatial	1579	2822	3881	6162	14444	433	681	109	294	1517
ehlers_spectral	1951	3214	4192	5721	15078	4	13	10	237	264
modifi_HIS	26	267	964	2676	3933	19584	30897	16243	17779	84503
subtractive_merge	719	1085	1192	2123	5119	11047	21319	11710	43625	87701
wavelet_pc	1648	2461	2720	4535	11364	6	13	22	239	280
highview	1442	1957	2947	5444	11790	106	74	30	374	584
PCI_pansharp	643	926	1112	1859	4540	3444	10853	7308	34851	56456

relatively well preserved and the spectral distortion of multispectral images was minimized.

To assess the feature extraction technique of the pan-sharpening images, the matching point pairs were extracted using the SIFT descriptor. The experiment that compares the pan-sharpening multispectral image (FuseM) and the original multispectral image (OrigM) for the matching pairs and the experiment that compares FuseM and the original panchromatic image (OrigP) for the matching pairs was performed. The extraction result of the two matching pairs differed (refer to Table 2). In other words, 'FuseM-OrigM' result for spectral quality and 'FuseM-OrigP' result for spatial quality can be used. In 'SUM' fields, HPF pan-sharpening technique shows moderate result in two experiment ranked fifth and sixth respectively.

Image classification, in a broad sense, is defined as the process of extracting differentiated classes or themes (e.g. land use categories, vegetation species) from raw remotely sensed satellite data. Edges extracted from pan-sharpening image and classified image were compared with edges from original images. Image classification was performed with

Table 3. Edge similarities

	*classification similarities	**edge of classified images with morphological operation	edge of images		
	FuseM-OrigM	FuseM-Map2.0	** FuseM-OrigP	FuseM-OrigM (Subsample)	FuseM-OrigM (Upsample)
brovey	0.483	0.387	0.803	0.235	0.148
multiplicative	0.569	0.360	0.639	0.241	0.134
PCA	0.561	0.342	0.610	0.232	0.149
HPF	0.542	0.264	0.703	0.223	0.159
ehlers_spatial	0.721	0.277	0.519	0.215	0.151
ehlers_spectral	0.766	0.115	0.107	0.220	0.098
modifi_HIS	0.549	0.296	0.770	0.229	0.156
subtractive_merge	0.620	0.282	0.785	0.238	0.155
wavelet_pc	0.627	0.285	0.383	0.200	0.172
highview	0.661	0.302	0.584	0.226	0.179
PCI_pansharp	0.569	0.272	0.731	0.239	0.153

* spectral similarities
** spatial similarities

supervised methods, e.g. Bayes classifier. The simple ratios of edge pixels simultaneously extracted from both images were computed. Table 3 shows edge similarities of 11 classified pan-sharpening images. The class similarities on second column of Table 3 represent the similarities of classified items irrespective of true classes. Conclusively, we can see that each pan-sharpening method represents a different effect for feature extraction, unlike spectral evaluation. Moderate results in these cases were achieved by HPF, subtractive_merge and PCI_pansharp.

5. Conclusion and Future work

Pan-sharpening method experiences a trade-off between spectral and spatial quality. Researchers have created variants of conventional methods to improve their spectral and spatial quality. In this study, we found that the HPF pan-sharpening technique distorted the spectrum-information relatively minimally and maintained spatial detail. Nevertheless, each pan-sharpening technique differs in spectral and spatial preservation. HPF pan-sharpening technique may not be appropriate for spectral or spatial applications. Therefore, it is necessary to select and apply the appropriate pan-sharpening technique according to the purpose and application. For example, the importance for a classification task is to preserve the spectral information while other applications depend on a sharp and detailed display of the scene. In practice, a variety of criteria applied to scenes with different characteristics (e.g. urban, agricultural) should be used to compare the pan-sharpening methods.

Hereafter, we are planning to find a spatially effective algorithm with the pan-sharpening of various high-resolution images such as QuickBird or WorldView. Also, the object-oriented classification will be analyzed in the future research because the results produced by the object-oriented classification on the fused image show great promise.

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