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Assessment of pan-sharpening methods applied to image fusion of remotely sensed multi-band data

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ABSTRACT

Image fusion is a useful tool for integrating a high resolution panchromatic image (PI) with a low resolution multispectral image (MIs) to produce a high resolution multispectral image for better understanding of the observed earth surface. Various methods proposed for pan-sharpening satellite images are examined from the viewpoint of accuracies with which the color information and spatial context of the original image are reproduced in the fused product image. In this study, methods such as Gram-Schmidt (GS), Ehler, modified intensity-hue-saturation (M-IHS), high pass filter (HPF), and wavelet-principal component analysis (W-PCA) are compared. The quality assessment of the products using these different methods is implemented by means of noise-based metrics. In order to test the robustness of the image quality, Poisson noise, motion blur, or Gaussian blur is intentionally added to the fused image, and the signal-to-noise and related statistical parameters are evaluated and compared among the fusion methods. And to achieve the assessed accurate classification process, we proposed a support vector machine (SVM) based on radial basis function kernel. By testing five methods with WorldView2 data, it is found that the Ehler method shows a better result for spatial details and color reproduction than GS, M-IHS, HPF and W-PCA. For QuickBird data, it is found that all fusion methods reproduce both color and spatial information close to the original image. Concerning the robustness against the noise, the Ehler method shows a good performance, whereas the W-PCA approach occasionally leads to similar or slightly better results. Comparing the performance of various fusion methods, it is shown that the Ehler method yields the best accuracy, followed by the W-PCA. The producer's and user's accuracies of the Ehler method are 89.94% and 90.34%, respectively, followed by 88.14% and 88.26% of the W-PCA method.

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1. Introduction

The recent increase in earth observing satellites has led to the availability of high resolution images of various types from Remote Sensing (RS). A variety of airborne as well as space-borne sensors have produced various data sets of different spatial, spectral and temporal resolutions. Most of these sensors have multispectral images (MIs) and panchromatic images (PIs). Multi-sensor data fusion has become a discipline to which more and more optimum solutions are needed for a number of application cases (Andrea and Filippo, 2007). The technique has become a very important issue for various RS problems such as land classification, change detection, object identification, image segmentation, map updating, hazard monitoring, and visualization purposes. Image fusion is the process of combining images from different sources to increase quality of the fused image as compared to the original image (Wald et al., 1997; Pohl and Van Genderen, 1998). The technique of image fusion is employed to enhance the resolution of MIs in terms of the spatial information included in the PI. Nowadays, image fusion is also known as pan-sharpening, resolution merge, image integration, or multi-sensor data fusion (Vijayaraj et al., 2006; Kumar et al., 2009). The fusion of RS images can integrate the spectral information of a single sensor (Wang et al., 2005) or the information from different sensors (Andrea and Filippo, 2007; Moser and Serpico, 2009; Bovolo et al., 2010). When applied to MIs, pan-sharpening is implemented on a pixel-by-pixel basis, changing a set of low (coarse) spatial resolution MIs into a high (fine) spatial resolution color image by fusing a co-registered fine spatial resolution black/white (Pan) image of the same area. The PI is usually obtained from the same platform and taken at the same time or within a very short time lag with respect to the acquisition of MIs.

In the fusion methods, so far many researchers have addressed the problem of multiresolution image fusion for RS applications, proposing different pan-sharpening methods (Pohl and Van

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Genderen, 1998). Over the years, various image fusion processes have been developed for improving spatial and spectral resolutions of RS data sets based on intensity-hue-saturation (IHS) (Choi, 2006; Karathanassi et al., 2007), color normalized (CN) Brovey (Du et al., 2007; Bovolo et al., 2010), and principal component analysis (PCA) (Shah et al., 2008). Other methods such as Gram-Schmidt (GS) (Kumar et al., 2009), CN-spectral (Vrabel et al., 2002), and Ehler (Ehler et al., 2010), high pass fusion (HPF) (Wald et al., 1997) rely on the intensity modulation. In addition, several researchers have proposed the use of wavelet transform (Shi et al., 2005; Acerbi et al., 2006) or discrete wavelet transform (Li et al., 2005) to extract geometric edge information from PI images.

Concerning various methods developed for fusing satellite images, it is desirable to give a general assessment of the quality of the fused images from the viewpoint of practical use. Thus, the main purpose of this study is to evaluate different fusion methods, while preserving the spectral information provided in the MIs and examine the classification accuracy for different fusion methods. Also, we apply noise-insensitivity approaches for standardizing and automating the evaluation process, based on different assessment methods described by several authors (Gonzalez et al., 2004; Shi et al., 2005; Acerbi et al., 2006; Petrovic, 2007; Nencini et al., 2007; Karathanassi et al., 2007; Liu et al., 2008; Li et al., 2010; Ehler et al., 2010).

In the present study, the PI and MIs are taken at the same time with the same sensor. Thus, data fusion can be carried out directly without further registration (Xue, 2005), and the analysis starts from the process of resampling using the nearest neighbor technique (Fig. 1). After the image fusion, the quality of fusion product based on each fusion method is examined by classification accuracy assessment. The noise-insensitivity of the fused image is examined by means of error metrics after adding common type noise of Poisson noise, motion blur, or Gaussian noise (Al-amri et al., 2010). For the classification process, the support vector machines (SVMs) technique is employed (Petropoulos et al., 2010). SVMs have been employed successfully in many fields (Kavzoglu and Colkesen, 2009; Milos et al., 2010), especially in RS studies (Knorn et al., 2009; Otuke and Blaschke, 2010). SVMs are non-parametric classifiers with the additional advantage that they are able to simultaneously minimize the empirical classification error and maximize the class separation using various transformations in hyper planes (Kavzoglu and Colkesen, 2009). This allows the production of better results in comparison with other parametric or non-parametric methods (Van der Linden et al., 2007).

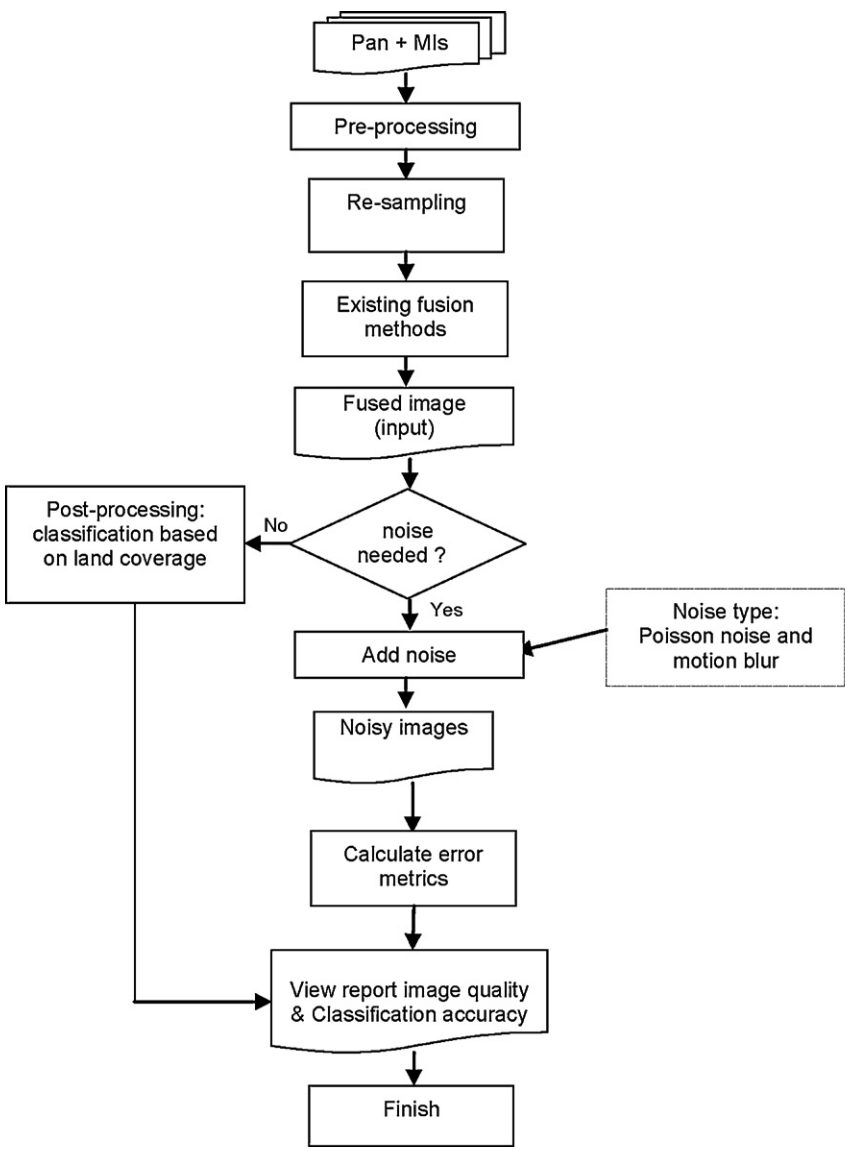

Fig. 1. Flowchart of image fusion and noise-insensitivity test.

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