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MULTISOURCE DATA FUSION FOR THE ENHANCEMENT OF URBAN FEATURES

D.Amarsaikhan[1], M.Ganzorig[1], T-H.Moon[2], H.H.Blotevogel[3] , B.Nergui[1] and R.Gantuya[1]

[1]Institute of Informatics and RS, Mongolian Academy of Sciences
av.Enkhtaivan-54B, Ulaanbaatar-51, Mongolia
Tel: 976-11-453660, Fax: 976-11-458090
E-mail: amar64@arvis.ac.mn

[2]Urban Engineering Major, Construction Division,
Gyeongsang National University, 900 Gazwa Jinju City,
Gyeongnam, Korea
E-mail: thmoon@gnu.ac.kr

[3]Dortmund University of Technology, Faculty of Spatial Planning
Institute of Spatial Planning
August-Schmidt-Str. 10, D-44221 Dortmund
Tel: 49-231-755-2376, Fax: 49-231-7554788
E-mail: hans.blotevogel@tu-dortmund.de

ABSTRACT: The aim of this study is to explore the performances of different data fusion techniques for the enhancement of urban features and evaluate the features obtained by the fusion techniques in terms of separation of urban land cover classes. For the fusion, different ordinary and advanced methods are used and the results are compared. Of these methods, the best result is obtained by the use of the wavelet-based fusion. Overall, the research indicates that multisource information can significantly improve the interpretation and analysis of the land surface features.

KEY WORDS: Data fusion, Multisource images, Urban features, Enhancement

1. INTRODUCTION

Over the years, the image data fusion has become a very valuable approach for the integration of multisource satellite data sets. It has been found that the images acquired at different ranges of electro-magnetic spectrum provide unique information when they are integrated. Now image fusion based on the integration of optical and microwave data sets, is being efficiently used for the interpretation, enhancement and analysis of different land surface features. It is evident that a combined use of the optical and SAR images will have a number of advantages because a specific feature which is not seen on the passive sensor image might be seen on the microwave image and vice versa because of the complementary information provided by the two sources (Amarsaikhan *et al.* 2004, Amarsaikhan *et al.* 2007).

Many authors have proposed and applied different techniques to combine optical and SAR images in order to enhance various features and they all judged that the results from the fused images were better than the results obtained from the individual images (Wang *et al.* 1995, Pohl and Van Genderen 1998, Ricchetti 2001, Nathaniel and Haack 2002, Amarsaikhan and Douglas 2004, Westra *et al.* 2005, Ehlers *et al.* 2008, Saadi and Watanabe 2009). Although, there are many methods of image fusion, the techniques most encountered in the literature are the intensity-hue-saturation (IHS) transform, the Brovey transform, the principal components analysis (PCA) method, the Gram-Schmidt method, the local mean matching method, the local mean and variance matching method, the least square fusion method, the wavelet-based fusion method, the multiplicative and the Ehlers Fusion (Karathanassi *et al.* 2007, Ehlers *et al.* 2008).

The aim of this study is to evaluate and compare different ordinary (multiplicative method, Brovey transform and Gram-Schmidt fusion) and advanced (principal component analysis (PCA), wavelet-based fusion and Elhers fusion) data fusion techniques for the enhancement of spectral variations of different urban land cover features. As a test site, Ulaanbaatar, the capital city of Mongolia has been selected. As data sources, ASTER bands 1,2 and 3 of 2008 as well as polarimetric ALOS PALSAR data of 2006 have been used. The actual analysis was carried out using PC-based ERDAS Imagine 9.1 and ENVI 4.3.

2. TEST SITE AND DATA SOURCES

As a test site, Ulaanbaatar, the capital city of Mongolia has been selected. Ulaanbaatar is situated in the central part of Mongolia, on the Tuul River, at an average height of 1350m above sea level and currently has about 1 million inhabitants. The study area chosen for the present study covers mainly the central and western parts and is characterized by such classes as built-up area, ger (Mongolian national dwelling) area, green area, soil and water. Figure 1 shows ASTER image of the test site, and some examples of its land cover.

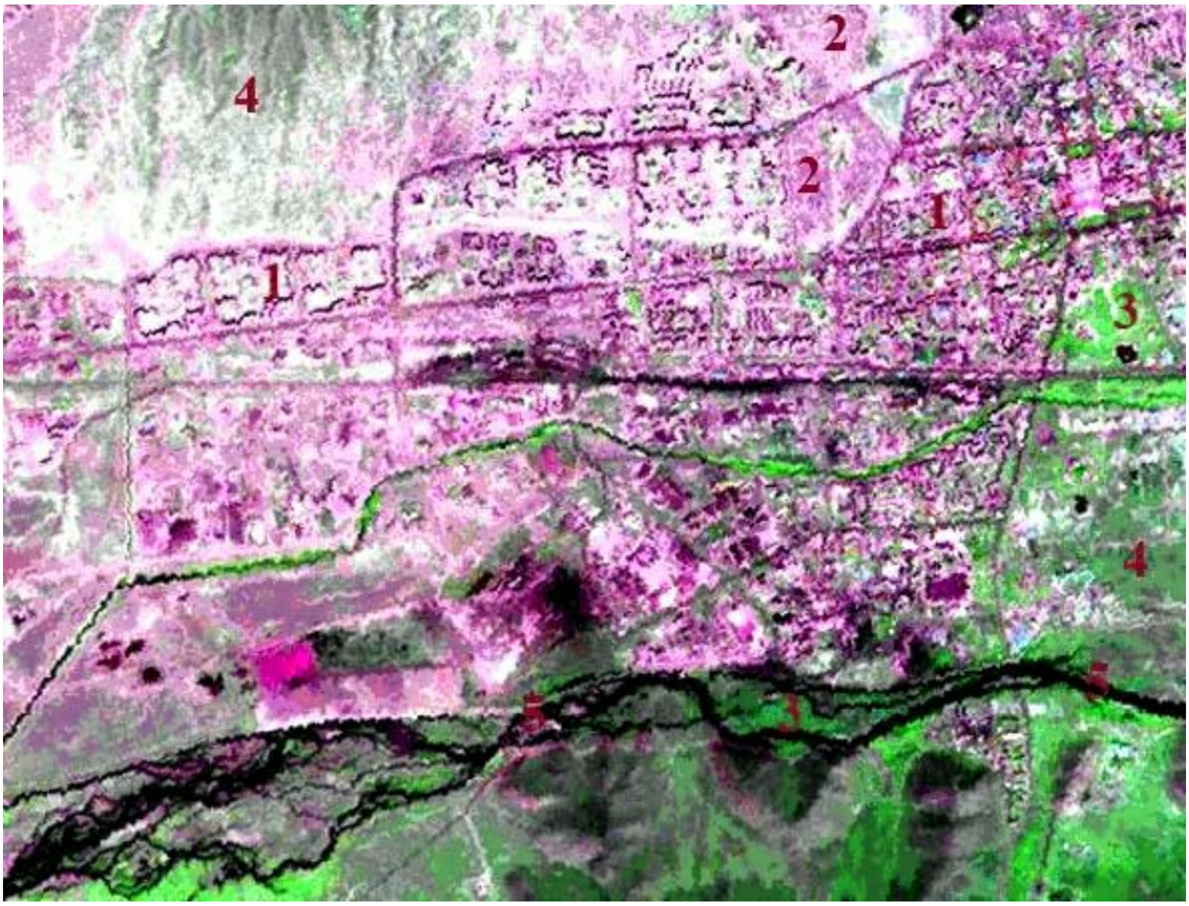

Figure 1. 2008 ASTER image of the selected part of Ulaanbaatar.
1-built-up area; 2-ger area; 3-green area; 4-soil; 5-water.
The size of the displayed area is about 8.01kmx6.08km.

In the present study, for the enhancement of urban features, ASTER data of 23 September 2008 and ALOS PALSAR data of 25 August 2006 have been used. Although ASTER has 14 multispectral bands acquired in visible, near infrared, middle infrared and thermal infrared ranges of electro-magnetic spectrum, in the current study, green (band 1), red (band 2) and near infrared (band 3) bands with a spatial resolution of 15m have been used. ALOS PALSAR is a Japanese Earth observation satellite carrying a cloud-piercing L-band radar which is designed to acquire fully polarimtric images. In the present study, HH, VV and HV polarization images of ALOS PALSAR have been used.

3. CO-REGISTRATION OF THE MULTISOURCE IMAGES AND SPECKLE SUPPRESSION OF THE ALOS PALSAR IMAGE

There should be needed a high geometric accuracy and good geometric correlation between the images in order to perform successful data fusion. At the beginning, the ALOS PALSAR image was rectified to the coordinates of the ASTER image using 12 ground control points (GCPs) defined from a topograpic map of the study area. The GCPs have been selected on clearly delineated crossings of roads, streets and city building corners. For the transformation, a second-order transformation and nearest-neighbour resampling approach were applied and the related root mean square error was 1.18 pixel. Then, in order to reduce the speckle of the SAR image a 3x3 gammamap filter has been applied to the ALOS PALSAR image.

4. IMAGE FUSION

The concept of image fusion refers to a process, which integrates different images from different sources to obtain more information from a single and more complete image, considering a minimum loss or distortion of the original data. Generally, image fusion can be performed at pixel, feature and decision levels (Abidi and Gonzalez 1992, Pohl and Van Genderen 1998). In this study, data fusion has been performed at a pixel level and the following rather common and more complex techniques were compared: Each of these techniques is briefly discussed below.

Multiplicative Method: This is the most simple image fusion technique. It takes two digital images, for example, high resolution panchromatic and low resolution multispectral data, and multiplies them pixel by pixel to get a new image (Seetha *et al.* 2007).

Brovey transform: This is a simple numerical method used to merge different digital data sets. The algorithm based on a Brovey transform uses a formula that normalises multispectral bands used for a red, green, blue colour display and multiplies the result by high resolution data to add the intensity or brightness component of the image (Vrabel 1996). For the Brovey transform, the bands of Quickbird data were considered as the multispectral bands, while the HH-polarization of TerraSAR image was considered as the multiplying panchromatic band.

Gram-Schmidt fusion method: Gram-Schmidt process is a procedure which takes a non-orthogonal set of linearly independent functions and constructs an orthogonal basis over an arbitrary interval with respect to an arbitrary weighting function. In other words, this method creates from the correlated components non- or less correlated components by applying orthogonalization process. Generally, orthogonalization is important in diverse applications in mathematics and other applied sciences because it can often simplifiy calculations or computations by making it possible, for instance, to do the calculation in a recursive manner (Karathanassi *et al.* 2008).

PCA: The most common understanding of the PCA is that it is a data compression technique used to reduce the dimensionality of the multidimensional datasets (Richards and Xia, 1999). It is also helpful for image encoding, enhancement, change detection and multitemporal dimensionality (Pohl and Van Genderen 1998). PCA is a statistical technique that transforms a multivariate data set of intercorrelated variables into a set of new uncorrelated linear combinations of the original variables, thus generating a new set of orthogonal axes.

Wavelet-based fusion: The wavelet transform decomposes the signal based on elementary functions, that is the wavelets. By using this, an image is decomposed into a set of multi-resolution images with wavelet coefficients. For each level, the coefficients contain spatial differences between two successive resolution levels. In general, a wavelet-based image fusion can be performed by either replacing some wavelet coefficients of the low-resolution image by the corresponding coefficients of the high-resolution image or by adding high resolution coefficients to the low-resolution data (Pajares and Cruz, 2004). In this study, the first approach which is based on bi-orthogonal transforms has been applied.

Elhers fusion: This is a fusion technique used for the spectral characteristics preservation of multitemporal and multi-sensor data sets. The fusion is based on an IHS transformation combined with filtering in the Fourier domain and the IHS transform is used for optimal colour separation. As the spectral characteristics of the multispectral bands are preserved during the fusion process, there is no dependency on the selection or order of bands for the IHS transform (Ehlers 2004, Ehlers *et al.* 2008).

5. COMPARISON OF THE FUSION METHODS

Initially, the above mentioned fusion methods have been applied to such combinations as ASTER and HH polarization of PALSAR, ASTER and HV polarization of PALSAR, ASTER and VV polarization of PALSAR. Then, in order to obtain good colour images that can illustrate spectral and spatial variations of the classes on the selected optical and SAR images, all the fused images have been visually inspected and compared. In the case of the multiplicative method, the fused image of ASTER and HH polarization of PALSAR demonstrated a better result compared to other combinations, while in the case of Brovey transform the combination of ASTER and VV polarization of PALSAR created a good image. On the image obtained by the multiplicative method, the built-up and ger areas have similar appearances, however, the green area, soil and water classes have total separations. Likewise, on the image obtained by the Brovey transform, the built-up and ger areas have similar appearances, whereas the green area and soil classes have total separations. Moreover, on this image, a part of the water class is mixed with other classes.

Table 1. Principal component coefficients from ASTER and PALSAR images.

	PC1	PC2	PC3	PC4	PC5	PC6
ASTER band1	0.33	0.44	0.42	0.35	0.44	0.39
ASTER band2	0.50	0.37	0.34	-0.34	-0.38	-0.33
ASTER band3	0.02	0.07	0.11	-0.09	-0.32	-0.19
PALSAR HH	-0.77	0.34	0.47	-0.14	0.06	-0.15
PALSAR HV	0.14	-0.07	-0.06	-0.49	0.73	-0.40
PALSAR VV	0.02	-0.01	0.01	0.69	0.08	-0.71
Eigenvalues	8792.9	4687.2	1138.6	916.1	447.3	129.1
Variance (%)	54.6	29.1	7.1	5.7	2.8	0.7

PCA has been applied to the combined image of ASTER and PALSAR. The result of the final PCA is shown in table 1. As can be seen from table 1, HH polarisation of PALSAR has very high negative loading in PC1. In the PC1 and PC2, visible bands of ASTER as well as HH polarisation of PALSAR have moderate to high loadings. This means that PC1 and PC2 contain the characteristics of both optical and SAR images. Although, PC3 contained 7.1% of the overall variance and had moderate to high loadings of ASTER band1 and HH polarisation of PALSAR, visual inspection revealed that it contained less information related to the selected classes. However, visual inspection of PC4 that contained 5.7% of the overall variance, in which VV polarisation of PALSAR has a high loading, revealed that this feature contained very useful information related to the textural difference between the built-up and ger areas. The inspection of the last PCs indicated that they contained noise from the total data set. As can be seen from figure 3c, although the PC image could separate the two urban classes, in some parts of the image, it created a mixed class of green area and soil.

In the case of the Gram-Schmidt fusion, the combined image of ASTER and VV polarization of PALSAR demonstrated a better result compared to other combinations. Although, the image contained some layover effects available on the SAR image, looked very similar to the image obtained by the multiplicative method. In the case of the wavelet-based fusion, the fused image of ASTER and HV polarization of PALSAR ERS-2 SAR demonstrated a better result compared to other combinations, too. Also, this image looked better than any other images obtained by other fusion methods. On this image, all available five classes could be distinguished by their spectral properties. Moreover, it could be seen that some textural information has been added for differentiation between the classes: built-up area and ger area. In the case of the Elhers fusion, the combined image of ASTER and VV polarization of PALSAR demonstrated a better result compared to other combinations. Although, this image had a blurred appearance due to speckle noise, still could very well separate green area, soil and water classes.

6. CONCLUSIONS

The main aim of the research was to compare the performances of different data fusion techniques for the enhancement of different surface features and evaluate the features obtained by the fusion techniques in terms of separation of urban land cover classes. For the data fusion, multiplicative method, Brovey transform, PCA, Gram-Schmidt fusion, wavelet-based fusion and Elhers fusion were used. Although, fusion methods demonstrated different results, detailed analysis of each image revealed that the image obtained by the wavelet-based fusion gave a superior image in terms of the spatial and spectral separations among different urban features. Overall, the research indicated that multisource information can significantly improve the interpretation and analysis of the land surface features.

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