FUSION OF SENTINEL-1 DATA AND OPTICAL IMAGES FOR URBAN LAND COVER STUDY AND CLASSIFICATION

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ABSTRACT:

Sentinel-1 satellite (C-band Synthetic Aperture Radar) is lauched by the European Union in August 2014 with the repeat pass is 12 days. As a constellation of two satellites orbiting 180° apart, the mission images the entire Earth every six days. With the spatial resolution of 10m, the image from Sentinel-1 is the good source of data for many purposes . As it is known, optical data contain information on the reflective and emissive characteristics of the Earth's surface features, while SAR data contain information on the surface roughness, texture and dielectric properties of natural and man-made objects. The 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. In the article, the authors present the method of fusion Sentinel-1 image and Landsat 8 image data by principal component analysis are used. The research indicates that multi-source information can significantly improves the interpretation and classification of land cover types such as urban land cover.

1. INTRODUCTION

Remote sensing techniques are used to study the objects on the Earth's surface from a long distance. However, each type of remote sensing data could only study an object or a few characteristics of the objects on the Earth's surface depends on the characteristics of reception of satellite sensors. Optical sensor allows classification land cover based on spectral characteristics of objects in the image. However, optical image depends on weather conditions. So that it is difficult to have a little cloudless satellite image of Vietnam where it is tropical area and humid. Meanwhile, microwave remote sensing is not dependent on weather conditions, day and night. However, if only the data analysis single SAR images are not classified land cover because SAR image reflects surface properties, structure and characteristics polarization of the object .

Scientists around the world have proposed a variety of methods fusion data as optical data and microwave data (SAR). The fusion of optical data and microwave data for various purposes, especially of emphasizing and classification objects in the result image. The research show that fusion SAR images and optical images have a better classification results than individual image classification (D. Amarsaikhan, 2004), (C. Pohl, 1998)...

In the article, the authors present the result of fusion Sentinel-1 image and Landsat 8 image data. Sentinel-1 satellite was launched in 2014 by *European Space Agency* (ESA). Sentinel-1 image is new SAR image data and are provided free of charge, band C and spatial resolution 10 meters. Therefore, the study of using Sentinel-1 data will open up new applications in studies monitoring the Earth in Vietnam.

2. THE METHODOLOGY

2.1 The characteristic of land cover in SAR image and optical images

Microwave remote sensing uses electromagnetic waves with wavelengths between 1cm and 1m. The signal returned to the antenna is known as the backscattered component. There are three main factors that influence the strength of the backscattered received energy:

- Radar system properties, i.e. wavelength, antenna and transmitted power;

- Radar imaging geometry, that is a function of for example, beam-width, incidence angle and range and

- characteristics of interaction of the radar signal with objects, i.e. surface roughness and composition, and terrain topography and orientation.

Surface roughness is the terrain property that most strongly influences the strength of radar returns. A smooth surface reflects the energy away from the antenna without returning a signal, thereby resulting in a black image. With an increase in surface roughness, the amount of energy reflected away is reduced, and there is an increase in the amount of signal returned to the antenna. The greater the amount of energy returned, the brighter the signal is shown on the image (Figure 1).

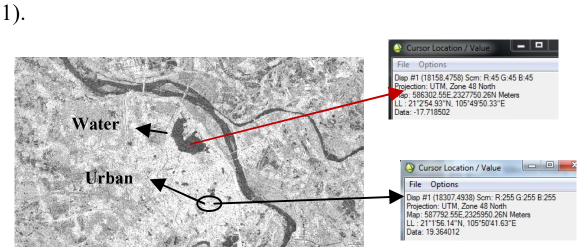


Figure 1. Water and urban in SAR image

Optical remote sensing makes use of visible, near infrared and short-wave infrared sensors to form images of the earth's surface by detecting the solar radiation reflected from targets on the ground. Different materials reflect and absorb differently at different wavelengths. Thus, the targets can be differentiated by their spectral reflectance signatures in the remotely sensed images. Optical remote sensing systems are classified into the following types, depending on the number of spectral bands used in the imaging process (**Figure 2** and **Table 1**).

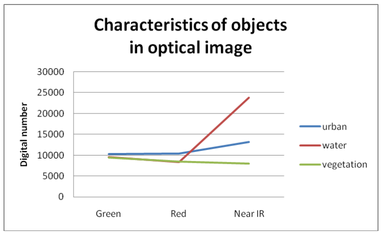


Figure 2. Characteristics of objects in Landsat 8

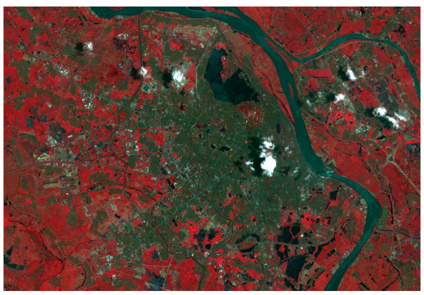


Figure 3. Landcover in Landsat 8 image

Objects	***Characteristics reflection***		
	Optical	**Infrared**	**Radar/band L**
Industrial park	very brightness	dark	very brightness
Built-up	brightness	dark	very brightness
Street	brightness	dark	dark
Urban	light brightness	light brightness	light brightness
Urban with vegetation	dark	brightness	brightness
Forest	dark	brightness	light brightness
Ground in park	dark	brightness	dark

Table 1. Comparison of characteristics reflection of landcover in optical, infrared and radar images (Tung, 2008)

Urban areas are complex and diverse in nature, and many features have similar spectral characteristics. In order to separate urban classes successfully, reliable features derived from different sources as well as an efficient classification technique should be elected.

2.2 Fusion method of SAR and optical images

Data fusion is a process dealing with data and information from multiple sources to achieve refined/improved information for decision marking (Hall 1992). The purpose of fusion optical and radar images is to enhance of various features observed. Multisensor image fusion enhances semantic capabilities of the images and yields information which is otherwise unavailable or hard to obtain from single sensor data. In other while, the classification accuracy of remote sensing images is improved when multiple source image data are introduced to the processing. Images from microwave and optical sensors offer complementary information that helps in discriminating the different classes.

There are some available pixel-based image fusion techniques such as (D. Amarsaikhan 2010):

(1) Principal Component (PC) Analysis (PCA)
(2) Multiplicative approach
(3) Brovey transformation
(4) Wavelet transform

The processing flow chat for image fusion is shown in

Figure 4.

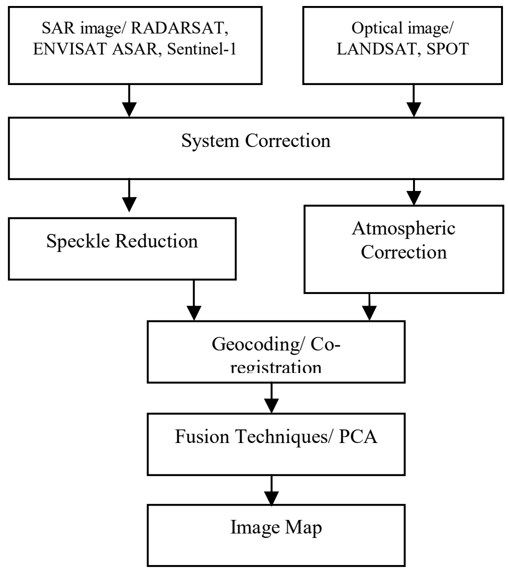


Figure 4: Processing flow chart for image fusion

In the article, the authors experiment the fusion method of SAR and optical image which is principal component analysis (PCA).

The most common understanding of the PCA is that it is a data compression technique used to reduce the dimensionality of the multidimensional data sets. It is also helpful for image encoding, enhancement, change detection and multitemporal dimensionality. 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. PCA translates and rotates the data into a new coordinate system to maximize the variance of the original data. This method calculates the PCs, remaps the high-resolution SAR image into the data range of the first PC (PC-1) and substitutes it for PC-1. Then an inverse PC transformation is carried out from PC-1 back to the original MS data. As this method scales the high-resolution data set to the same data range as PC-1, before the inverse PC calculation is applied, the band histograms of the output file closely resemble those of the input MS image.

3. EXPERIMENT RESULTS AND DISCUSSION

3.1 Image preparation

3.1.1 Test site

As a test site, Hanoi, the capital of Vietnam has been selected. Hanoi is located in northern region of Vietnam, situated in the Vietnam's Red River delta, nearly 90 km away from the coastal area. Hanoi contains three basic kind of terrain, which are the delta area, the midland area and mountainous zone. In general, the terrain is gradually lower from the north to the south and from the west to the east, with the average height ranging from 5 to 20 meters above the sea level. The hills and mountainous zones are located in the northern and western part of the city. The highest peak is at Ba Vi with 1281 m, located in the western part of the region.

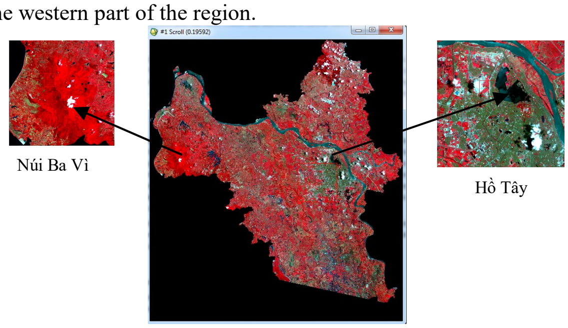


Figure 5. Location of Hanoi capital

3.1.2 Data sources

In this study, for the urban land cover studies, a Landsat 8 OLI image of 30 May 2015 and a Sentinel-1 image of 30 May 2015 have been used.

The Landsat 8 OLI data have eight multispectral bands (B1: Coastal/Aerosol; B2: Blue; B3: Green; B4: Red; B5: NIR; B6: SWIR-1; B7: SWIR-2; B8: Pan). The spatial resolution is 15m for the panchromatic image, while it is 30m for the multispectral bands. In this study, green, red and near infrared bands have been used.

Sentinel-1 is a space mission funded by the European Union and carried out by the ESA within the Copernicus Programme, consisting of a constellation of two satellites. The payload of Sentinel-1 is a Synthetic Aperture Radar in C-band that provides continuous imagery (day, night and all weather). The characteristics of the Sentinel-1 data used in the current study are shown in Table 2.

Sensor	Characteristics of data		
	Data	**Date**	**Level**
Sentinel-1	- IW – Interferometric Wide Swath - Polarization: VV - Spatial resolution: 10m	30/05/2015 Time UTC: 00h:13:12	Level 1 ground range (GRDH).
Landsat 8	- 8 bands - Used Band 3 (Green); Band 4 (Red); Band 5 (Near Infared) - Spatial resolution: 30m	- 30/05/2015 - Time UTC: 11h:02:39	Level 1T Converted to UTM/WGS 84

Table 2. Data sources for experiment

Time data acquisition of optical and SAR images is chosen the same day. So that there is no big difference in objects of land cover in both data.

3.1.3 . Experimental results and analysis

Processing data for fusion Sentinel-1 and the optical image is performed in

Figure 6. In this article, we used PCA method to fusion the Sentinel-1 and MS Landsat 8 image. After that we compare the result classification land cover such as urban, water, forest and vegetation by SAR image, MS Landsat 8 and the fusion image. The threshold method is applied for classification urban in SAR image. For the MS Landsat 8 and fusion image data, the Maximumlikehood method is used.

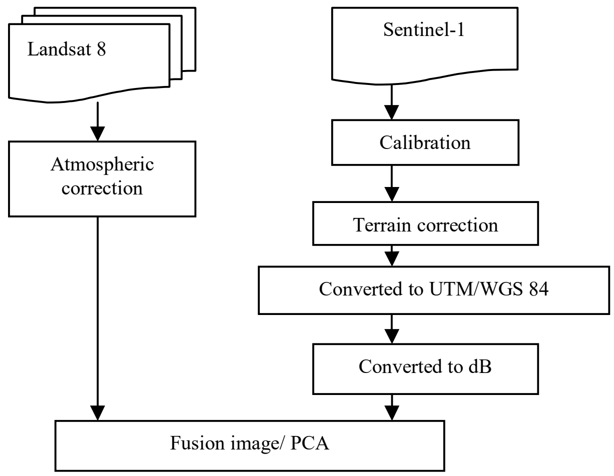
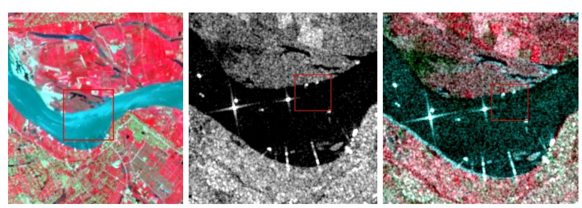


Figure 6. Fusion Sentinel-1 and optical image

The fused Sentinel-1 and Landsat 8 OLI images is shown as follow:



(a) (b) (c)

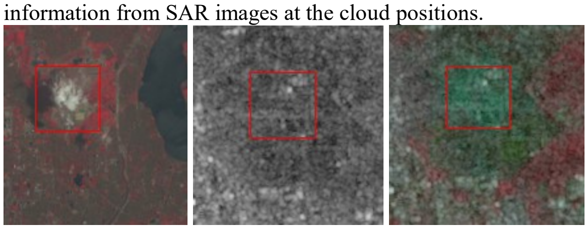
Figure 7. Comparison of the fused Sentinel-1 and optical image

(a) Landsat 8 OLI image – Spatial resolution 30 m; (b) Sentinel-1 image – Spatial resolution 10m; (c) The image obtained by PCA method - Spatial resolution 10m

a. Visual examination

Compared with from Figure 7 urban and built up areas, as well as roads are clearly enhanced and almost perfect preservation of spectral signatures is visible in the fused images. Visual examination suggests that the fused images are higher in spatial resolution than that of the Landsat images, and have better visual effect.

There are some invisible on the optical image which is covered by cloudy. On the other while, SAR images are not affected by the weather. Therefore, the fused image have the information from SAR images at the cloud positions.

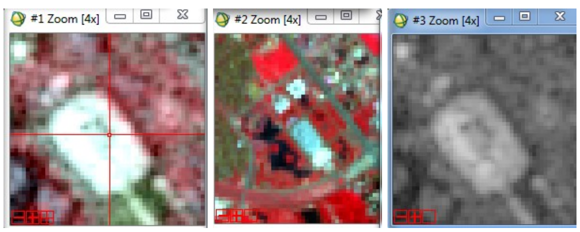


(a) (b) (c)

Figure 8. The cloud position in the fused image

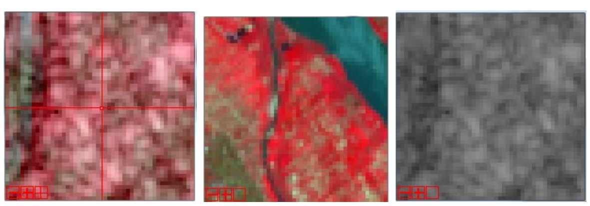
(a) Cloudy in Landsat 8 image; (b) Correspond position in Sentinel-1 image; (c) Correspond position in the fused image

Fused image identified the boundaries of landcover objects such as vegetation, bare soil, water based on the advantages of optical images and SAR images. On SAR images urban and water are featured by difference backscatering but plant objects, vacant land is difficult to distinguish. Therefore landcover objects can be identified based on the difference intensity in the fused image.



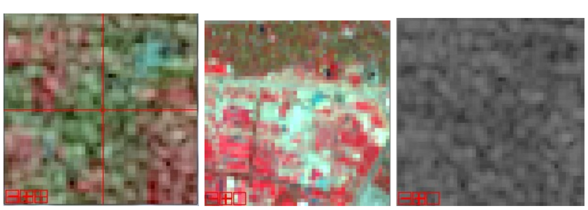
(a) (b) (c)

Figure 9. Urban objects in the fused image



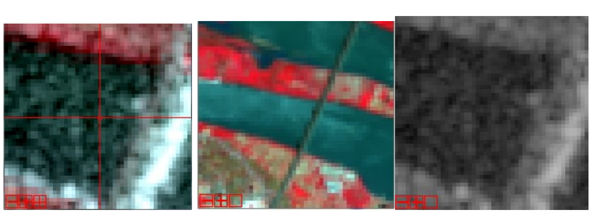
(a) (b) (c)

Figure 10. Vegetation objects in the fused image



(a) (b) (c)

Figure 11. Bare ground objects in the fused image



(a) (b) (c)

Figure 12. Water objects in the fused image

b. Classification landcover in the fused image

The result of landcover classification in Sentinel-1 image, Landsat 8 OLI image and the fused image are shown in Figure 13, Figure 14, Figure 15.

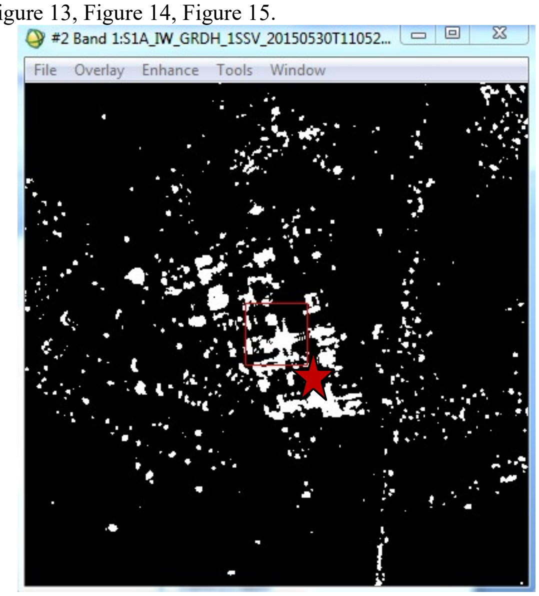


Figure 13. Urban objects in Sentinel-1

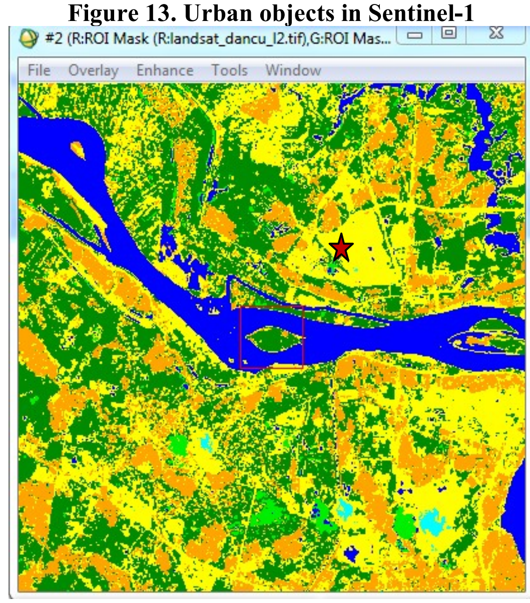


Figure 14. Landcover classification in Landsat 8

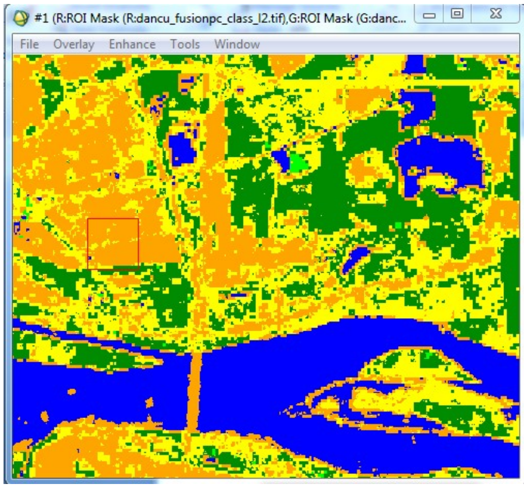


Figure 15. Landcover classification in the fused image

Figure 16. Legend of landcover classification image

Classification method is applied for Sentinel-1 image by thresholding method. And in Landsat 8 OLI image and the fused image the Maximum Likehood method is used. The accuracy classification is determined by the index Kappa. The accuracy landcover classification in Landsat 8 is 97% and in the fused image is 99%. In Figure 13, Figure 15, the location marked in the images is urban. But in Figure 14 this position is not urban, is bare ground.

4. CONCLUSION

The overall idea of the research was to compare the performances of different result landcover classification in SAR image, in optical image and the fused image. The Principal Component Analysis image gave a superior image in terms of the spatial separation among different urban features. To extract the reliable urban land cover information from the selected RS data sets, the supervised classification algorithm that uses to classify. Overall, the study demonstrated that multi-source information can significantly improve the interpretation and classification of land cover types, specially urban objects in the fused image.

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