Restoration and Merging of Multispectral and Radar Imagery for Land Use Studies

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ABSTRACT

The introduction of remotely sensed multi-spectral and microwave (radar) imagery in the country has opened new avenues for better understanding of land use resources. Numerous studies have been done to combine multi-sensor and multi-resolution imagery in efforts to increase the interpretability and classification accuracy of the resultant image, a process called Data Fusion [4]. The principal objective of this paper is to present initial results of an on-going project involving the restoration and merging of microwave and multispectral imageries. It is the project's goal to combine the advantages that both of these imaging systems offer. In addition, the study presents various methods used and selected to enhance visual interpretation and if possible preserve the spectral content and spatial resolution of the source imageries for subsequent image classification.

For this study, SPOT XS imagery (Figure 1) with Near Infrared or NIR (0.79-0.89 µm), Visible Red (0.61-0.68 µm), and Visible Green (0.50-0.59 µm) are selectively used, combined with the NASA JPL-AIRSAR Polarimetric Synthetic Aperture Radar (POLSAR) imagery.

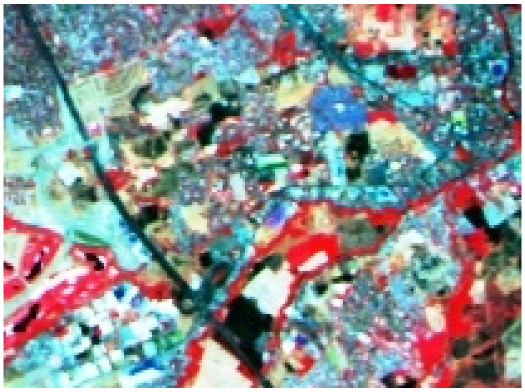

Figure 1. False Color Composite Image using SPOT XS-Multispectral Imagery of Carmona and Biñan, 1997 in RGB=NIR, Visible Red, and Visible Green Display Format. Bright red areas are vegetation, bright blue and green areas are bare and built-up areas, and dark areas are water logged.

The selected radar image has seven distinct channels of various polarizations and wavelengths (C-VV, L-HV, L-VV, L-HH, and P- HH, P-HV, P-VV; h-horizontal and v-vertical). The C-band operates at $\lambda = 5$ cms. the L at $\lambda = 25$ cms. , and the P-band at $\lambda = 63$ cms [6]. Different radar frequencies can also be combined to enhance the various land features in an image (Figure 2). Spatial resolution is about 20 m. per pixel for the multispectral, while the POLSAR is about 10 m.

Figure 2. False color composite image of microwave bands (NASA-JPL AIRSAR-POLSAR, 1996) with Cvv, Lvv, and Pvv mapped to corresponding BGR colors. Green and dark areas are built-up areas, red and brownish yellow areas are agricultural areas, and white areas are open spaces.

The particular area covered is south of Metro Manila, namely the municipalities of Carmona, Cavite and Biñan, Laguna. AIRSAR Imagery was taken on 1996 during the NASA-PACRIM flight, while the SPOT XS Multispectral Imagery was taken in 1997. The area was selected due to its accessibility for field reconnaissance and verification. It was also an ideal site for land cover mapping exercises since the area is subject to a diverse range of land uses. It has good terrain characteristics ranging from flat to hilly and undulating, with differing land covers ranging from urban to agricultural with small patches of forested areas [3].

METHODOLOGY

The typical steps in remote sensing image processing generally entail the following: (1) Preprocessing or radiometric and geometric correction, (2) Enhancement, (3) Interpretation and Analysis, (4) Classification and Error Assessment, and (5) Map Production. This paper will focus on the first three steps, giving further emphasis on methods for combining multispectral and microwave imagery.

Preprocessing

Multispectral image preprocessing generally requires a three-stage correction. These are sensor, radiometric (atmospheric and topographic), and geometric corrections. Sensor calibration was not performed on the image since sensor offset parameters were not available from the image source. However, after performing a preliminary visual inspection, it was felt that these errors (such as striping, and banding, and artifacts) have minimal presence in the image. A sensor correction for the SPOT imaging camera was performed using a restoration convolution filter which improves the sensor pdf response [8]. The matrix coefficients are:

$$\begin{matrix} -0.0562 & 0 & -0.4448 & 0 & -0.0562 \\ 0 & 0 & 0 & 0 & 0 \\ -0.4448 & 0 & 3 & 0 & -0.4448 \\ 0 & 0 & 0 & 0 & 0 \\ -0.0562 & 0 & -0.4448 & 0 & -0.0562 \end{matrix}$$

Radiometric correction for atmospheric effects was also performed by simple (global) estimation of the overall contribution of atmospheric radiance. This derived value (called dark pixel) was then subtracted from the DN values in the image to convert it as close as possible to surface reflectance values. Corrections for topographic effects such as sun azimuth and angle were likewise not necessary since the overpass was taken at a high sun angle (midday) and most of the terrain is flat and level with minimal changes in elevation. See Figure 3 for resulting image.

For Radar imagery, most of the corrections necessary (such as slant to ground, imaging geometry, etc) have already been implemented from the source of the image. The most disturbing aspect present in microwave imagery is speckle. Speckle decreases both visual interpretability and classification accuracy and is dependent on wavelength and spatial resolution [4].

Several popular filters [1] were tested such as the mean, median, and variations of the standard deviation and variance (e.g. Lee, Frost and Sigma). Studies have shown that small median window filter sizes were suitable as they minimize degrading image quality (edge preserving) while at the same time give some improvement in the image signal-to- noise ratio (SNR) [4]. Both 3x3 and 5x5 windows have shown positive results in our initial tests with larger windows providing further smoothing and are therefore undesirable. The mean filter degrades both the spatial and backscatter (radiometric) response. Other popular filters such as the Lee, Frost and Sigma filter were also tried but produced less desirable results and in addition introduced noise 'fringe' effects on edge features. Other more sophisticated adaptive filters were difficult to implement requiring additional programming effort. Perhaps they will be explored at a later time. The application of non-parametric filtering techniques is also being considered, such as the homomorphic (log) with Wiener filtering. These are considered optimal filters for speckle since speckles have a multiplicative effect and are therefore, difficult to separate [9]. Modelling the noise or backscatter response however, is a more daunting task.

Figure 3. False Color Composite Image of pre-processed SPOT Multispectral image. Note improved contrast and sharper edges.

Fourier transformation were also conducted in an attempt to reduce image speckle. However, difficulty was encountered in identifying and specifying the optimum filter shape for each band without introducing distortion.

Finally, geometric correction and map registration was performed first on the radar image, it having a higher spatial resolution. This image provided a better base with which to identify and select ground reference points for subsequent rectification. The next step was to use this geocorrected image as the reference for an image-to-image coregistration of the multispectral image. A nearest neighbor resampling process was selected to preserve the spectral response in both images. Geometric correction for both images has to be done carefully and with sufficient ground control points since mis-registration especially for two separate images that are to be combined will greatly affect classification accuracy. Effects of misregistration usually appear along edges in the classified image.

Enhancement and Data Fusion

The Normalized Difference Vegetation Index (NDVI) is a common but effective method to provide enhancement and discrimination between chlorophyll bearing vegetated areas, bare soil or open areas, and water logged areas. However, ratio methods tend to alter the spectral response of the images and therefore affect classification accuracy [4][8].

After studying the initial statistics of the multispectral image, it was decided that visual interpretation and the final classification stage can benefit from a Principal Components Transformation (PCT). More than 80 percent of the total image variance (i.e., of the three bands) can be found in the first two PCs. Therefore the third PC image was discarded. This process not only reduces the data dimensionality (i.e. the number of bands/channels) which speeds up the data processing, but also reduces undesirable topographic and albedo effects found in the third PC image which can affect classification accuracy. In addition, the PCA being a linear (rotational) transformation does not alter the spectral response of an image.

Data fusion generally entails the combination of multi-sensor, multi-spatial, and multi-band imagery resulting in an enhanced composite image which is suitable for visual interpretation purposes. In addition, preserving as much as possible the spectral response of the original images ensures reliable results from the classification process [4].

There are several popular methods currently being used in data fusion. Most of them involve the manipulation of color space [4]. Three of those were selected namely: the PCA-HIS-RGB, RGB-HIS-RGB, and the Brovey Transform. The PCA–HIS-RGB method maps the PC transformed images (PC1, PC2, PC3) of the SPOT multispectral image to the Hue, Saturation, Intensity color space. However, the Intensity channel was replaced with selected radar channels instead of the usual PC3 (Figure 4a) and retransformed back into RGB color space. Better discrimination especially for between waterlogged areas, bare soil and agricultural areas can be seen in this image. The RGB-HIS-RGB is similar but uses the original channels (green, red, and near infrared) of the multispectral image. The Intensity channel is also replaced with a selected radar band. The result is then re-transformed back to RGB color space (Figure 4b). Good discrimination between land features can also be seen using this method. There is also better enhancement of linear features and edges that were present from the radar image.

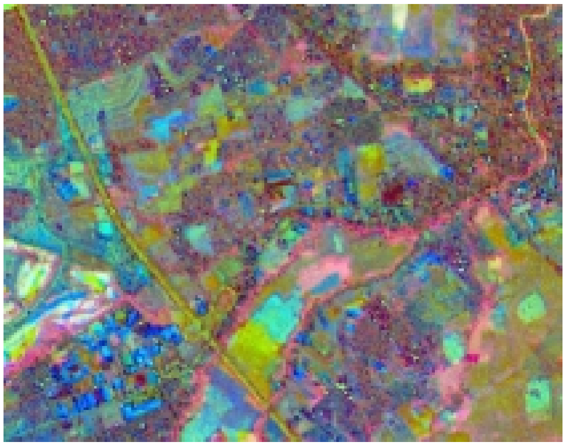

Figure 4a. Principal Component Image of preprocessed SPOT XS. Variance among different landcover types are heightened.

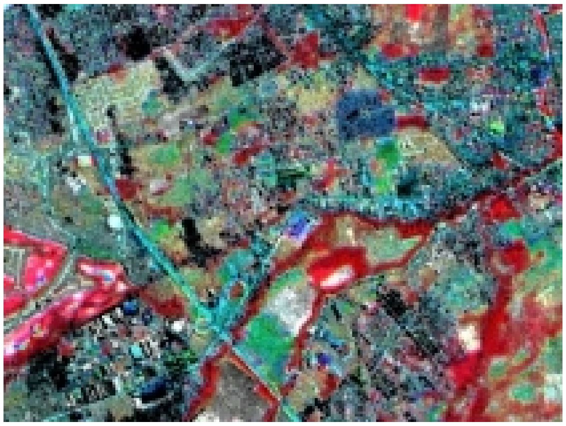

Figure 4b. RGB Combination of SPOT XS and NASA-JPL POLSAR – Cvv of Carmona and Biñan, showing more spectral detail and spatial enhancements. Built-up areas are highlighted in blue and dark areas, while vegetation appear in red and green.

Of the three methods, the Brovey Transform [1], presented the least color enhancement but provided better discrimination of linear and edge features. The SPOT multispectral image was still used as the basis with the selected radar channel being used as the multiplier (Figure 5). The Brovey transform has been used commonly for merging passive multi-sensor (e.g. SPOT XS and SPOT Pan, and LANDSAT TM and SPOT) images. In this case, SPOT XS was used for the spectral/color information. The log-transformed AIRSAR or Radar image was used, on the other hand, for spatial highlights or image sharpness. The dynamic range of values was thus reduced to conform with the SPOT data. For use with the SPOT XS and SAR Imageries, the Brovey formula is redefined as :

RED = B3 / (B1 + B2 + B3) * Radar Band

GREEN = B2 / (B1 + B2 + B3) * Radar Band

BLUE = B1 / (B1 + B2 + B3) * Radar Band

Where B1, B2, and B3 are equivalent to the three Multispectral bands of SPOT. See figure 5.

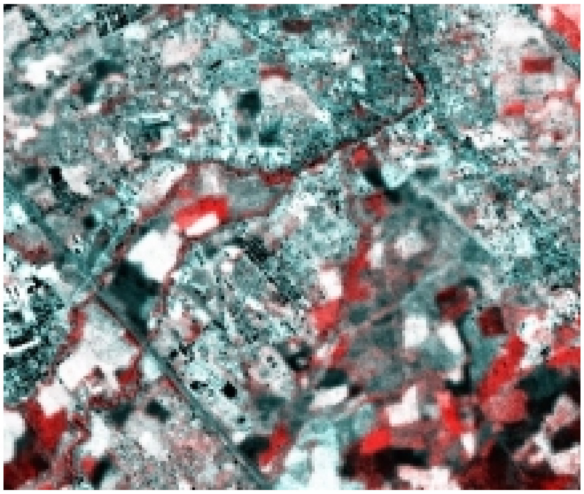

Figure 5. Brovey Transform of SPOT Multispectral Image and NASA/JPL POLSAR-Lhv. More discrimination between man-made structures (blue and dark areas), vegetation (red) and bare soil (white).

RESULTS AND DISCUSSION

Multispectral imagery provide primary information on the spectral characteristics of surface features. Microwave imagery on the other hand, provide additional information in terms of a surface' roughness and dielectric characteristics. In view of this, the proper combination of both types of images can provide better discrimination and enhancement of surface features which can lead to increased classification accuracy [4] .

In addition, the higher spatial resolution that can be derived from the radar image increases visual and contextual discrimination during image interpretation. This aids in the development of better thematic maps that the multispectral image alone cannot provide. It is important however that there must be a proper and careful selection of radar bands to minimize classification errors during data fusion. For instance, the C-band is a good discriminant of vegetation structure vs. soil, while the L-band emphasized vegetation versus built-up areas particularly micro-structures of both surface cover, and between vegetation types such as grasslands vs. tree canopy and crop type (e.g. rice vs. corn). The P-band, on the other hand, was particularly useful in delineating large man-made structures, linear structures (such as roads and waterways), and a more generalized differentiation of built-up versus vegetated areas.

The results of this continuing research may hopefully add to the understanding on how to best use these technologies in a local setting and to rationalize the use of the numerous image processing methods presently available especially for combined multispectral and microwave imageries.

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