Quantitative Evaluation of the Classification Results Derived from Multisensor Image Fusion Techniques between JERS 1 SAR - Landsat TM Data

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Abstract—Many applications require the classification of land surface into discrete land cover types and the distribution of these communities throughout the landscape being studied. Multisensor image fusion is an effective means of exploiting the complementary nature of different data types. In the image segmentation or classification task, the goal of fusing data from different sources is to reduce the classification error rate obtained by single source classification. A variety of surface characteristics uniquely detected by SAR can lead to an improved capability to map land cover. This paper describes a quantitative evaluation of land cover classification derived from multisensor image fusion between JERS 1 SAR and Landsat TM data. Image smoothing using a small neighborhood are performed prior to the extraction of textural features in order to improve the classification results. The smaller filtering neighborhood removes some of the effects of speckle while preserving the image’s textural information. The best radar data manipulations are fused with Landsat TM through various techniques. Image fusion techniques applied in this study are: wavelet, intensity-hue-saturation (IHS), principal component analysis (PCA), and high pass filtering (HPF). Specifically, the effort of image fusion is conducted at pixel level. Maximum-likelihood classification approaches are conducted in each of resulting images. Classification results derived from multisensor image fusion are very good. The Kappa Coefficient derived from classification using PCA+HPF technique is 0.86 and the Overall Accuracy is significantly high (86.80 percent).

Keywords—land cover, multisensor image fusion, maximum-likelihood classification, Overall Accuracy, Kappa Coefficient.

I. BACKGROUND

Classification of land cover is one of the primary objectives in the analysis of remotely sensed data. Many applications of remote sensing require the classification of the land surface into discrete land cover types, and the distribution of these communities throughout the landscape being studied [5]. The overall objective of image classification procedures is to automatically categorize all pixels in an image into land cover classes or themes [6].

Multisensor image fusion is an effective means of exploiting the complementary nature of different data types. The motivation behind data fusion is to generate an interpretation of the scene that is not available with data from a single sensor, or to reduce the uncertainty associated with the data from individual sensors. For an image segmentation or classification task, the goal of fusing data from different sensors is to reduce the classification error rate obtained by single source classification [14]. A variety of surface characteristics uniquely detected by SAR can lead to an improved capability to map land cover [4]. In [1], the authors obtained the best classification accuracy of 92 percent, by using a combination of the two data types from airborne radar and Landsat TM.

The multispectral TM images traditionally provide good discrimination between different land cover types. The discrimination ability of JERS-1 SAR for land cover classification is lower, partially because the satellite operates on a single frequency, and this frequency is not optimal for all land cover types.

The main objective of speckle filtering is to retrieve the unspeckled scene radar backscatter from the observed images. Speckle carries significant useful information about the SAR system and the illuminated scene. On the other hand, speckle degrades image readability.

It is common to filter radar images in an attempt to reduce the presence of speckle noise, but filtering process may affect the degree of textural information present in the image [10]. Prasad and Gupta [9] found that, when an image is smoothed, a certain degree of textural information is lost. This study also indicates that a loss of information occurred due to the filtering process. The problem then is to filter out the speckle noise while keeping the thematic and textural information intact. Schmoldt and Jarr [10] conducted a similar study where speckle filters were applied prior to the extraction of textural measures. Results indicated that image smoothing using a small neighborhood prior to the extraction of textural features improved classification results. The smaller filtering neighborhood removed some of the effects of speckle, while preserving the images textural information.

Many filtering techniques exist, and we have selected various ones in the spatial domain. Filtering techniques can either assume a speckle model or not [3]. After defining the filtering techniques for classification, we had applied them to real data for a speckle analysis, filtering evaluation, and the assessment of fusion techniques mentioned above. The selected filters use an 5x5 sliding windows to compute the window’s middle pixel intensity.

Analyses were conducted to determine methods to improve the pixel-based classification accuracy from radar data. These methods include speckle reduction, texture measures, and post-classification smoothing. The best radar manipulation was merged with Landsat TM data through various fusion
techniques.

In standard image classification procedures used to extract information from remotely sensed images, usually ignore spatial information and are based on purely spectral characteristics [4].

The purpose of this study is to examine the classification accuracy derived from multisensor image fusion between JERS-1 SAR and Landsat TM data. Image fusion techniques applied in this study are wavelet, intensity-hue-saturation (IHS), principal component analysis (PCA) and high pass filtering (HPF). The effort of image fusion is conducted at the pixel level. In the pixel-based fusion, the sensor measurements are merged on a pixel-by-pixel basis [8].

II. TEST AREA, IMAGES ACQUISITION AND FUSION TECHNIQUES

The test site chosen for this study is Bandung, which is located in 107° 26'00'' - 107° 34'00'' E and 06° 51'30'' - 06° 58'30'' S, covering an area of about 122 Km². The JERS-1 SAR image employed for this study was acquired on 22 June 1994 and Landsat TM on 4 July 1994.

The wavelet transform applied in this study is a two dimensional Discrete Wavelet Transform (DWT). The original image is reduced in resolution by subsequent low-pas filter and subsampling. The three detail images are a set of independent, spatially oriented frequency channels that detail vertical high frequencies, horizontal high frequencies, and cross-directional high frequencies [7]. The source images are decomposed by DWT to the same resolution. After the wavelet transform the detail coefficients of the more highly resolved band (JERS-1 SAR data) and the approximation coefficients of the multispectral image (Landsat TM data) are used to create the synthetic wavelet image. Finally, the more highly resolved multispectral image is created using the inverse DWT.

IHS concept is based on the representation of low-resolution multispectral images in the IHS system and then substituting the I component with the high spatial resolution image. The Intensity component-the sum of the bands-is replaced with a stretched higher spatial resolution value (JERS-1 SAR data) and performing an inverse IHS transform. An inverse PCA transformation produces a much high resolution multispectral image.

In PCA, the original inter-correlated data are mathematically transformed into new, uncorrelated images called components or axes [2]. PCA is a relevant method for merging remotely sensed imagery because of its ability to reduce the dimensionality of the original data from n to 2 or 3 transformed principal component images, which contains majority of information. PCA in image fusion has two approaches: a) first PC of multi-channel image was replaced by different sensor image; b) all multi-image data channels were used as input to PCA procedure.

The HPF method introduced by [11] extracts edge information of the high resolutions image which is then added to the low resolution channel on a pixel by pixel basis. The high pass filter of the high resolution image corresponds to its high frequency component which is mostly related to the spatial information. Hence, by adding this filter to the low resolution channel some of the high spatial information content of the high resolution image will become apparent in the fused product [12].

III. METHODOLOGY

All sensor-specific corrections and enhancement of image data have to be applied prior to image fusion. Any spatial enhancement performed prior to image fusion will benefit the resulting fused image. The JERS-1 image is first registered to map coordinates and resampled by cubic convolution. The Landsat TM image is then registered by image-to-image procedure directly to their corresponding JERS-1 images and was resampled at the same resolution, also by cubic convolution, in order to avoid the blockiness due to the enlargement process. A minor coregistration error can lead to a slightly mismatched edge (edge-blurring problem).

The input SAR image is preprocessed or smoothed to reduce noise. In addition to the band reflectances, additional features such as, textural features that can help in classification, can also be included. To reduce the effects of speckle on the classification of imagery, filtering techniques for speckle reduction are commonly applied to the input SAR data. While this filters result in improved visual interpretation, statistical variability in measured backscatter caused by speckle still remains at the pixel level. Different moving window sizes were examined and the results were compared each other.

The median filter is considered to be a more appropriate in speckle filtering technique. The Median filter uses the middle value in the range of existing pixel neighbors as the value with which it replaces the pixel of interest in the filtering process. This new value can be directly associated with an original class, because it was present within the original (unfiltered) radar image, and this filtering process will preserve the boundaries of land cover classes in noise-free areas [11].

The pre-processed Landsat TM and JERS-1 data were merged using wavelet, IHS, PCA and the combined PCA and HPF techniques (PCA+HPF). In the first PCA technique, all channels of Landsat TM (Figure 1 (a)) and JERS-1 (Figure 1 (b)) were used as input to PCA. In the PCA+HPF technique the high pass filtered JERS-1 data was inserted into the three channels of the PCA product from Landsat TM image. Figure 1 shows the resulting images using these techniques (in c, d, e and f).

Initial analysis for this study was to conduct digital classification of the selected surface classes applied to various combinations of the fused images. The training fields were organized into categories so as to construct the training set necessary for the supervised classification. Spectral signatures were extracted for the various cover types using supervised training sites. After the signature extraction, a maximum-likelihood decision rule was employed to classify the data. Taking into account that filtered training distributions are very close to being Gaussian, we have used the maximum-likelihood classification with Gaussian assumptions.
both with and without a priori probabilities.

The resulting classified images has been smoothed by a simple algorithm of relaxation: each classified pixel has been replaced by the most common class in a 3x3 window centered on this pixel.

The standard approach for assessing classification accuracy is to select a sample of locations and determining the reference land cover present using field observation and/or fine resolution images [15].

A set of 55 ground truth data points was selected for each class. Half were used for training and half for testing. Training sites were selected by the authors using a combination of field surveys and land cover maps prepared by visual interpretation. The training data were randomly sampled to select independent samples for training and verification. A confusion matrix (contingency table) was produced, and Overall Accuracy (OA) and Kappa Coefficients (K) were generated along with Producer’s Accuracy (PA) and User’s Accuracy (UA). The Kappa Coefficient describes how well the classification performed in comparison to a random correlation, and is independent of imagery, sampling types, and classification schemes. Kappa values can range from 0 (random) to 1 (completely non-random). Table 1 and 2 show the comparison of statistical significance among the output datasets. PA and UA provide information on omission and commission errors.

IV. COMPARISON OF CLASSIFICATION RESULTS

The best results were achieved through the fusion of the best speckle filtered image (5 by 5 Median) with the multispectral TM data using PCA+HPF technique. The Kappa value for this technique is very good (0.86) and the OA is significantly high (86.80 percent). The comparison for those techniques applied can be seen in Table 1. Except for IHS technique, classification results derived from multisensor image fusion are very good. In IHS technique the improved results are only for certain classes i.e., paddy field and urban land cover types (Table 2).

TABLE 1

<table>
<thead>
<tr>
<th>Image Classification</th>
<th>Accuracy (%)</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Image</td>
<td>70.2</td>
<td>0.68</td>
</tr>
<tr>
<td>Wavelet</td>
<td>81.69</td>
<td>0.76</td>
</tr>
<tr>
<td>IHS</td>
<td>54.84</td>
<td>0.51</td>
</tr>
<tr>
<td>PCA</td>
<td>82.69</td>
<td>0.78</td>
</tr>
<tr>
<td>PCA+HPF</td>
<td>86.80</td>
<td>0.86</td>
</tr>
</tbody>
</table>

V. CONCLUSION

The use of the combination of radar and optical data would increase the accuracy of classification, because the data contain different information for target being sensed. It was demonstrated that multisource classification techniques using image fusion between JER-1 SAR and Landsat TM data yielded improved results, except in IHS technique the improved results only for a certain class. The Median filter at 5 by 5 window was determined to be most appropriate for despoccking the input SAR data. The ability to get more accurate land cover classification results from optical-radar fusion images is a significant achievement. Future application of this study will include a comparison of other classifier, such as neural classifier, fuzzy ARTMAP classifier, neuro fuzzy classifier, etc.

REFERENCES