FUSION OF MODIS AND RADARSAT DATA FOR CROP TYPE CLASSIFICATION — AN INITIAL STUDY

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ABSTRACT:

Agricultural land use mapping and change detection are important for environmental assessment and crop yield estimation. An effective mapping and change detection of crop land use requires large image coverage with sufficient resolutions in spatial, spectral and temporal dimensions. But few earth observation sensors can solely collect image data that meet all these requirements.

The MODIS (Moderate Resolution Imaging Spectroradiometer) satellite images provided by NASA are an optimal data source for collecting high resolution spectral and temporal information of the earth's surface, because of its large coverage (2300 km ground swath), sufficient spectral bands (7 bands between visible and mid infrared at the spatial resolution of 250 to 500 m; and 28 bands between visible and thermal infrared at the spatial resolution of 1000 m), daily revisit rate, and low cost (free of charge). But its spatial resolutions (250 m, 500 m and 1000 m) are too coarse to delineate the crop field boundaries. On the other hand, the Radarsat images provided by the Canadian Space Agency are a good data source for obtaining high resolution spatial information (from 3 m to 100 m depending on the beam mode used) at very frequent repeat rate, because of its all-whether and day-night collection capability, low cost, and large coverage (from 50km×50km to 500km×500km depending on the beam mode). However, Radarsat images, like other radar images, are noisy and have limited spectral information. Even though field boundaries are recognizable in many beam modes, it is not effective to differentiate crop types just using a single radar image.

To find a cost-effective solution for frequent, large coverage crop land use mapping, this paper presents an initial study on combination of low spatial resolution MODIS mulitspectral images and high spatial resolution Radarsat amplitude images for crop classification. The MODIS spectral bands 1 through 7 with a spatial resolution of 250 m and 500 m respectively and the Radarsat standard Mode with a spatial resolution of 12.5 m are used for the combination.

A wavelet and IHS transform integrated technique was developed to effectively fuse (combine) the multispectral information from MODIS and the spatial information from Radarsat, to produce a image which contains spectral (colour) information of crop types and spatial (boundary) information of crop fields. Pixel-based and object-based classification techniques are then employed to classify the MODIS-Radarsat fused images for obtaining crop land use classes. The classification results demonstrate that pixel-based classification techniques fail to classify the crop types due to radar noise in the fused images, while object-based classification yields promising classification results.

1. INTRODUCTION

Remote sensing is commonly used to identify crop type in agriculture applications. This process primarily uses the spectral information and texture of remote sensing data to discriminate among different crop types (Van Niel and McVicar, 2001). Although the remote sensing technique has such a capability to identify the crop type, there still exists a problem in earth observation data: few earth observation sensors can provide data with high resolutions in all the spatial, temporal and spectral dimensions, as required for effective identification of crop type at the national level.

The NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instrument provides a unique opportunity for monitoring agricultural systems (Lobell and Asner, 2004). It can be used in operational mapping of crop type, because it has 7 spectral channels for primary use in land mapping application and also because of its large coverage, high frequency of revisit, small data volume, and low cost compared with higher spatial resolution multispectral satellite data. However, it also has several problems, i.e. mixed pixel problem and number of samples problem, which make it more complicated in crop identification and other types of land cover mapping. The accuracy of a classification process depends mainly on two factors: the sample size and the degree to which the selected sample represents the object of interest (Chang, 2003). If the selected sample is homogeneous, a small sample will suffice; if the selected sample exhibits some heterogeneity, a larger sample is needed to reflect this variability. The problems existing in the MODIS data usually lead to low classification accuracy.

On the other hand, the Radarsat images provided by the Canadian Space Agency are a good data source for obtaining high resolution spatial information (from 3 m to 100 m depending on the beam mode used) at very frequent repeat rate, because of its all-whether and day-night collection capability, low cost, and large coverage (from 50km×50km to 500km×500km depending on the beam mode). However, Radarsat images, like other radar images, are noisy and have limited spectral information. Even though field boundaries are recognizable in many beam modes, it is not effective to differentiate crop types just using a single radar image.

Image fusion is a popular method to integrate different sensors data for obtaining a more suitable image for a variety of applications, such as visual interpretation, image classification, etc. Many research papers have reported problems of existing fusion techniques. The most significant problem is color distortion (Zhang, 2002). This problem could lead to poor accuracy in classifying an image, for example, a particular crop type may have a consistent spectral signature in the original, unfused image. However, due to color distortion in the fusion process, the crop type may have several different spectral signatures in the fused image. This means that if the fused image is classified, the crop type may be incorrectly assigned to two or more classification categories. To reduce the color distortion and improve the fusion quality, a wide variety of strategies has been developed, each specific to a particular fusion technique or image set (Zhang, 2004).

A new image fusion technique is proposed to resolve these problems encountered in classifying MODIS data or using Radarsat data to identify the crop type. The rationale to resolve this problem is that image fusion integrates a high-resolution Radarsat image with a low-resolution MODIS image to produce a high resolution synthetic image, which contains both the high-resolution spatial information of the Radarsat image and the color information of MODIS image. The fused image can spatially separate the mixed pixels in MODIS to a certain degree, resulting in improved the accuracy of classification. The research on image fusion in improving the accuracy of image classification has been reported by at least four authors (Munechika et al., 1993; Printz et al., 1997; Shaban and Dikshit 2002; Colditz et al., 2006).

2. METHODOLOGY

Compared with the traditional fusion methods, such as IHS (intensity, hue, and saturation), PCA (principal component analysis), brovey transform etc., the wavelet transform is an advanced mathematical tool developed in the realm of signal processing. It can decompose a digital image into a set of multi-resolution images accompanied by wavelet coefficients for each resolution level. The wavelet coefficients for each level contain the spatial (detail) differences between two successive resolution levels. Wavelets-based approach is appropriate for performing fusion because (Pajares and de la Cruz, 2004):

(1) It is a multiscale or multiresolution approach, which is well suited to manage the different image resolutions.
(2) The discrete wavelet transform allows the image decomposition in different kinds of coefficients to preserve the image information.
(3) Coefficients from different images can be appropriately combined to obtain new

coefficients, thus the information from the original images can be selected appropriately.
(4) Once the coefficients are merged, the final fused image can be achieved through the inverse discrete wavelet transform, where the information in the merged coefficients can also be preserved.

The major advantage of the wavelet based fusion method lies in the minimal distortion of the spectral characteristics in the fusion result. However, it also has problems. The spectral content of small objects—one or two pixels—is lost with the substitution of the multispectral image approximation into the panchromatic pyramid. Also, because the wavelet based fusion acts as high- and low-pass filters, the final fusion image may suffer from ringing. It may also have problems in distributing pixel intensities in large, featureless areas (Yocky, 1996). However, if wavelet transform and a traditional fusion method, i.e., IHS transform, are integrated, better fusion results may be achieved. Because the substitution in IHS transform is limited to only one component, the integration of wavelet transform with IHS to improve or modify the component and using IHS transform to fuse the image can make the fusion process simpler and faster. This integration can also better preserve color information.

To better utilize the advantages of the IHS and the wavelet fusion techniques for the fusion of SAR and MODIS images, and to overcome the shortcomings of the two techniques, we proposed an IHS and wavelet integrated fusion approach. The concept of this approach uses the IHS transform to integrate the low-resolution multispectral colour information with the high-resolution panchromatic spatial detail information to achieve a smooth integration of colour and spatial features. The wavelet transform is utilized to generate a new SAR image (new intensity) that has a high correlation to the intensity image and contains the spatial detail of the original SAR image.

3. EXPERIMENT RESULTS

MODIS data (Bands 6, 2 and 1; July, 2001) and Radarsat standard mode (June, 2001) have been used in this experiment. Selecting Bands 6, 2 and 1 from MODIS is because those bands are more sensitive to the vegetation. Band 6 has been upgraded to 250 m by using a simulation technique developed at the Canada Center for Remote Sensing. Thus, Band 6, 2 and 1 are all 250 m. The spatial resolution of SAR has been degraded to 25m meter from 12.5 meter in order to reduce the spatial difference between those two sensors.

Figure 1 shows the original SAR data (a), MODIS data (b) and their fusion result (c). From the fusion result, it is easy to find that the fusion result can preserve the color information of the multispectral image while it has the spatial detail from the SAR image.

(a) SAR data

(b) MODIS (band 6, 2,1)

(c) MODIS-SAR fusion result

(d) Classification result(Pixel-based)

(e) Classification result (object-oriented)
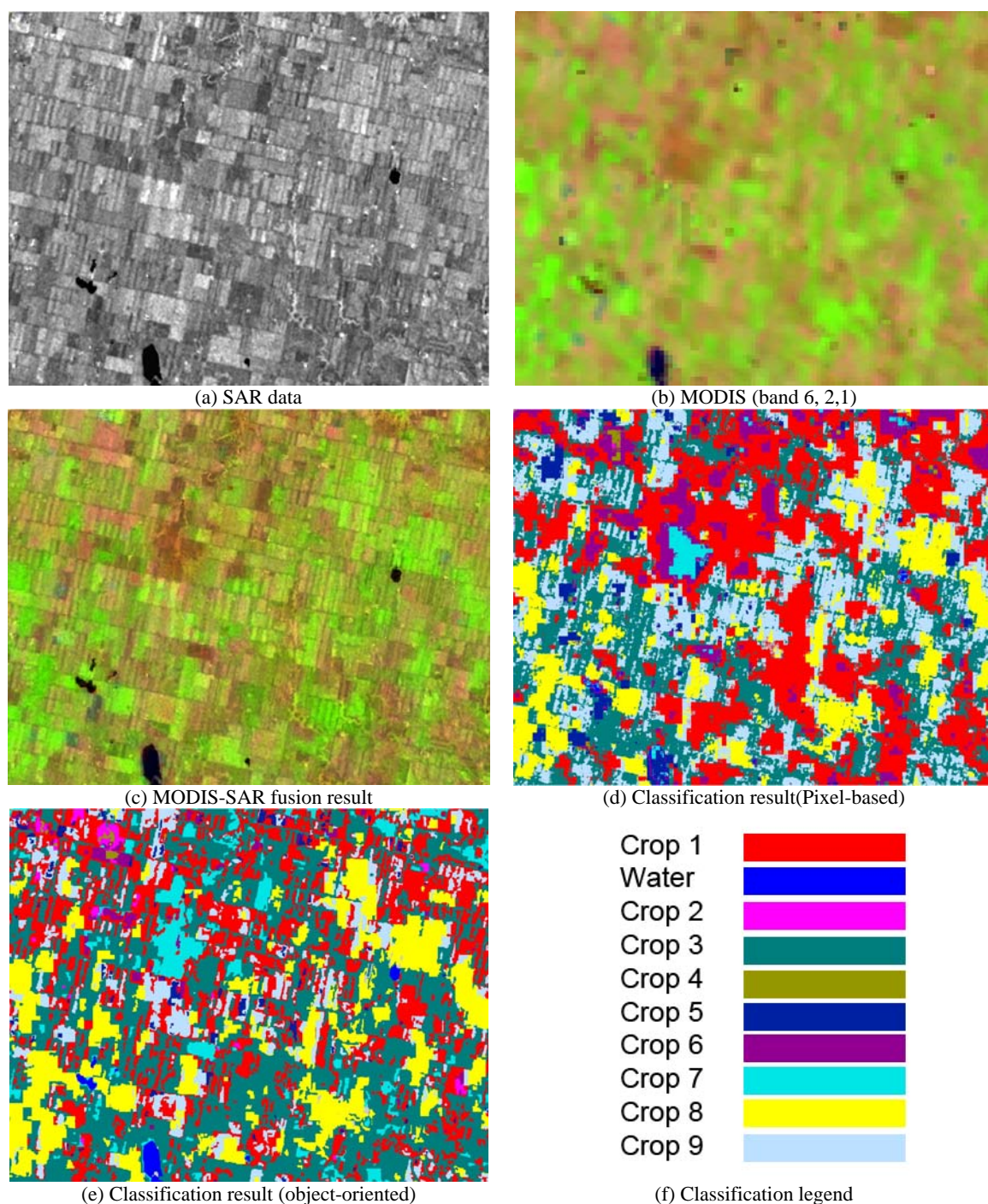
(f) Classification legend

Figure 1. SAR, MODIS, and their fusion result and classification results

Figure 1 (d) shows the classification result of the fused MODIS-SAR image by using maximum likelihood method (pixel-based) in PCI. The result demonstrates that the classification result is mostly based on the color information from multispectral information (the appearance of the classification looks like the classification result of the multispectral result solely). The information from the SAR integrated into the fusion result does not help too much in the pixel based classification. Neural-network based classification module has also been tested; the result is similar to the result produced by maximum likelihood classification method. That means, for the pixel-based

classification method, the classifier, itself, does not contribute too much in the final classification result.

Figure 1 (e) shows the classification result of the MODIS-SAR fused image produced by eCognition (object-oriented based method). The result in Figure 1 (e) is much better than the result in Figure 1 (d), i.e. the object-based classification result can discriminate the crops among different fields, whereas the pixel-based classification cannot. There are two theoretical reasons to support this result: first, the SAR has a lot of structural or geometrical information, which have been integrated into the fusion result. It is easy to see that the fusion result can show the boundary among crop field clearly.

The structural information is very useful for the segmentation in the object-based classification process, thus, the crop fields can be segmented accurately. Second, the object-based classification use the average of the pixel gray value of a segment, the speckle of the gray value at the pixel level will be filtered out in the object-based classification (although the SAR image has been filtered to get rid of the noise before image fusion, there still exists noise more or less in the filtered SAR).

Because the ground truth is not available for the moment, the quantitative analysis will be analyzed in the future research. The classification results have only analyzed by visual analysis method. Although this kind of analysis method is not so objective, it still can demonstrate the limitation of the pixel-based classification method in classifying the fusion result. The results produced by the object-oriented classification on the fused image shows a great promise in identifying the crop types.

4. CONCLUSION

Only one sensor data from MODIS or Radarsat does not work well in identifying the crop types because of the limitation of spatial resolution or spectral information. This study has proposed a new image fusion method to fuse MODIS and Radarsat data for identifying the crop types. The fusion result can preserve the color information from multispectral image very well and it has the spatial detail of SAR. The fusion image can help interpret the crop types more easily compared with the single SAR data or MODIS image.

Pixel-based and object-based classification techniques are employed to classify the fusion result of MODIS and Radarsat for obtaining crop land use classes. The classification results demonstrate that pixel-based classification techniques fail to classify the crop types due to radar noise in the fused images, whereas object-based classification yields promising classification results.

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