CLASSIFICATION OF HIGH RESOLUTION OPTICAL AND SAR FUSION IMAGE USING FUZZY KNOWLEDGE AND OBJECT-ORIENTED PARADIGM

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ABSTRACT:

The fusion image of IKONOS optical data and COSMO-SkyMed SAR image is used as the classifier inputs for land cover classification under an object-oriented paradigm. Firstly, Frost filter is selected to reduce speckle noises of SAR image. Three popular methods, including IHS, PCA and wavelet transform, are applied to fuse high resolution optical and SAR images. Comparing with other fusion methods, wavelet transform based fusion scheme is used for classification. Fuzzy knowledge is established based on the spectral, spatial and texture features derived from manual interpretation and expert knowledge. Finally, this proposed approach is compared with other traditional classification methods.

1. INTRODUCTION

Remote sensing data acquisition technology, especially high resolution optical and SAR image, has developed very fast in recent years. Because high resolution imagery can provide extensive information about the earth's surface, it offers the advantages to detect various urban structures especially in complex environment. Comparing with optical image, SAR image can overcome the influence of atrocious weather and have certain penetration capability, so it can continuously observes the earth surface automatically, rapidly and accurately in all-weather and all the time (Hofer, 2009). Nowadays, SAR, especially high resolution SAR imagery is widely used to resources exploration, urban mapping and seismic risk management (Zhao, 1999; Kuntz, 2009; Xu, 2009). But it is difficult to identify and classify land cover types with high accuracy based on the backscatter information of single SAR image, so how to combine or fuse high resolution optical and SAR images becomes a key issue in practice. This paper proposes a general framework to deal with this issue.

When using the traditional pixel-oriented method only based on spectral information of pixel to classify the fusion image of high resolution optical and SAR images, it usually results in not only unsatisfactory accuracy of classification but also spatial data redundant and resource wastes. The object-oriented information extraction approach, however, can solve this problem to a great extent. Object-oriented, or object-based approach, doesn't analyze single pixel, but analyzes pixel sets or polygons derived by image segmentation or ancillary information. So it can take into account relationship between the object and environment sufficiently, and use fuzzy knowledge storeroom, which is established based on the spectral, context and textural and other features by using manual interpretation and expert knowledge, to achieve extraction of remotely sensed image.

This paper presents the approach of classify the high resolution optical and SAR fusion image by using Fuzzy Knowledge and Object-Oriented Paradigm. The remaining part of this paper is organized as follows. Section 2 introduces the high resolution optical and SAR images and related pre-processing operations. Section 3 presents and compares the fusion methods such as IHS, PCA, Wavelet methods, and finds that that the fusion approach using wavelet transform can integrate spatial and texture characteristics of multi-source images more adequately and produce fused image with higher quality and fewer artifacts than other fusion methods. In Section 4, we propose a classification scheme using object-oriented, fuzzy knowledge method and compare with other tradition methods. The results show that the accuracy of object-oriented classifier using fuzzy knowledge is higher than others. Conclusions are drawn in Section 5.

2. IMAGE DATA, STUDY AREA AND IMAGE PRE-PROCESSING

2.1 Image Data and Study Area

The IKONOS satellite was launched September 24th, 1999 to provide global, accurate, high-resolution imagery to individuals, organizations, and governments for mapping, monitoring, and development. The IKONOS satellite simultaneously collects 1-m panchromatic and 4-m multi-spectral images, providing the commercial and scientific community with a dramatic improvement in spatial resolution over previously available satellite imagery (Dial, 2003). COSMO-SkyMed (Constellation of Small Satellites for Mediterranean basin Observation) is a constellation composed by four satellites orbiting in low orbits and deployed by the Italian Space Agency (ASI) (Antonlo, 2009).It has been designed to implement three different operation modes in order to acquire the images at the required

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resolution: Spotlight mode, Stripmap mode and ScanSAR mode (Verdone, 2002).

In this paper, the fusion image of IKONOS at 1m spatial resolution and COSMO-SkyMed image, which is the high resolution of strip-map mode, with 3m spatial resolution and VV polarization mode, are taken as the data source (Fig.1 and Fig.2). The image size is 697*1075.A region of Beijing city is chosen as the case study area.

Figure 1. Original IKONOS image
(R: band 3, G: band 2, B: band 1)

Figure 2. Original COSMO image

2.2 Image Pre-processing

Firstly, we use IKONOS image to rectify COSMO-SkyMed image using 30 ground control points (GCPs) with a root mean square error (RMSE) ranging from 0.2 to 0.5 pixels. The rectified COSMO-SkyMed image was resampled to a 1m pixel size using cubic convolution resampling method. Because the influence of Doppler and Chirp Scaling were removed by image supplier, we selected Frost filter to reduce speckle noises.

3. FUSION OF HIGH RESOLUTION OPTICAL AND SAR IMAGES

Remote sensing image fusion aims at integrating the information conveyed by data acquired with different spatial and spectral resolutions, for purposes of photo analysis, feature extraction, modeling, and classification (Pohl, 1998). The procedures adopted to perform image fusion are IHS, principal components analysis (PCA) and wavelet transform methods.

3.1 IHS (Intensity-Hue-Saturation) Transform

IHS is one of the most often used methods to merge multi sensor image data. The general IHS procedure uses three bands of a lower spatial resolution dataset and transforms these data to IHS space. A contrast stretch is then applied to the higher spatial resolution image so that the stretched image has approximately the same variance and average as the intensity component image. Then, the stretched, higher resolution image replaces the intensity component before the image is transformed back into the original color space (Chavez, 1991).

3.2 Principal Component Analysis

The principal component analysis (PCA), also recognized as the K-L transform, is a very useful and well-know technique for remote sensing image fusion. However if PCA is applied to SAR data sets with very low correlation coefficient, the detailed surface structures will remarkably loss in the integrated image (Won,1993). In the case of PCA, each pixel in the fused image is the weighted sum of the pixels in the input images, by using as weights the eigenvectors corresponding to the maximum eigenvalue of the covariance matrix. If there is a low correlation between the detailed surface structures in the input images to be fused, the PCA method does not preserve the fine details (similar problems arise also with the IHS method)(Simone, 2002).

3.3 Wavelet Transform

The wavelet transform is a very effective tool for time frequency or phase-space analysis of signals with multiple scales of resolution. Among numerous applications of the wavelet transform, multi-resolution decomposition of an image provides a suitable tool for the SAR image merging study since it can preserve fine details. The wavelet transform fusion method consists of a decomposition of an image into sub-images, which are the approximated component (low-frequency) and three detailed components (high-frequency). The SAR images at different frequencies or polarizations can be fused by computing the wavelet decomposition and linearly combining the wavelet coefficients. In order to acquire the information carried by each detailed component, the salience of each component should be considered (Yue, 2006).

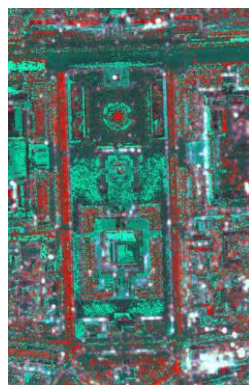### 3.4 Fusion Result Evaluation

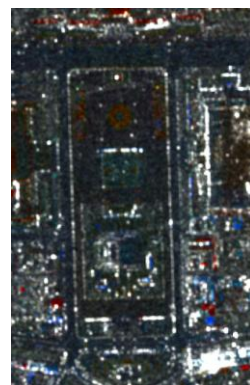
Figure 3. IHS Fusion Result   Figure 4. PCA Fusion Result

Figure 5. Wavelet Transform Fusion Result

3.5 Fusion Results

The fused images of the three approaches are shown in Figure 3-5. In order to evaluate the fusion performance, a quantitative analysis has been carried out on these images. In this paper, entropy, average gradient, distortion index and correlation index are used as the performance evolution measures for fusion effect. Image entropy measures the information contained and average gradient reflects tiny detailed contrast, feature of texture change and definition. Distortion index measures the distortion between the original and fused images, while correlation index indicate the correlation of the original and fused images. Generally speaking, the better fused result has the larger entropy, average gradient, correlation and the smaller distortion.

	Average gradient	Entropy	Distortion Index	Correlation Index
Original	42.2320	8.3958		
IHS	50.9326	7.1256	0.5738	0.0821
PCA	10.8722	3.2252	0.3513	0.0402
Wavelet	44.1735	3.7584	0.1356	0.8297

Table 1. Statistical Performance of Fusion Approaches

The experimental results in Table.1 show that with the lowest average gradient and entropy, the PCA method losses some structure and texture information because of the great difference in gray level and low correlation between the input images. It is also shown in Table.1 that the IHS method has the largest average gradient and entropy. But the definition of fused image is too lower to interpret useful information from it.

Compared with the other two methods, wavelet transform has the highest definition, the largest correlation and the lowest distortion. The average gradient is larger than original image indicating that its fused image has more information and contains more details and texture features. So the wavelet transform is chosen finally.

4. CLASSIFICATION USING FUZZY KNOWLEDGE AND OBJECT-ORIENTED PARADIGM

The first step in this classification method is image segmentation, which creates objects with similar characteristics. This approach is based on image spectral and textual characteristics and some parameters, which influence the shape and size of objects. A scale parameter is used to control the size of the object and a shape criterion is used to decide the object

smoothness and compactness. Here, we segmented the fused image into two different level: one that targeted roads and square (large image-objects), and the other for small features such as house roof (small image-objects). After that, the following were chosen based on small and large object boundaries: (1) large image-objects were created with a scale parameter of 50 and a shape criterion of 0.3, and (2) small image-objects were created with a smaller scale parameter of 20 and a shape criterion of 0.3.

The segmented image was classified using a combination of fuzzy knowledge and nearest neighbour supervised classification. The fuzzy classification method allows the user to convert the range of feature values into fuzzy membership values between 0 and 1, where 1 indicates complete membership in a particular class. To be classed correctly, categories frequently need more than one membership expression, which can be combined using operator such as "and", "or" and "not" (Cleve, 2008).

Multi-scale classification was used to classify the segmented image. First, we classified some classes, including road, square on the large image-object scale and greenland, water on the small image-object, by using fuzzy knowledge descriptions, which include texture, brightness and shape index (Table 2). This approach could only be used to classify 80% of the classes because the other features of classes are difficult to be found accurately. Therefore, the remaining parts were classified using nearest neighbor supervised classification with samples for training data.

Segmentation Layer	Ground Object Type	Member Function	Feature Space
Level 1(50)	Road	Length/Width>2 Area>100	Brightness, Shape Index, Length/Width, Area, GLCM Homogeneity
	Square	0.5<Rectangular fit<1	
Level 2(20)	Greenland	0.15<GLCM Homogeneity (all nir) <0.25	
	Water	Brightness< 280	

Table 2. Fuzzy knowledge of Some Classes

(a)OO and Fuzzy Knowledge   (b) SVM
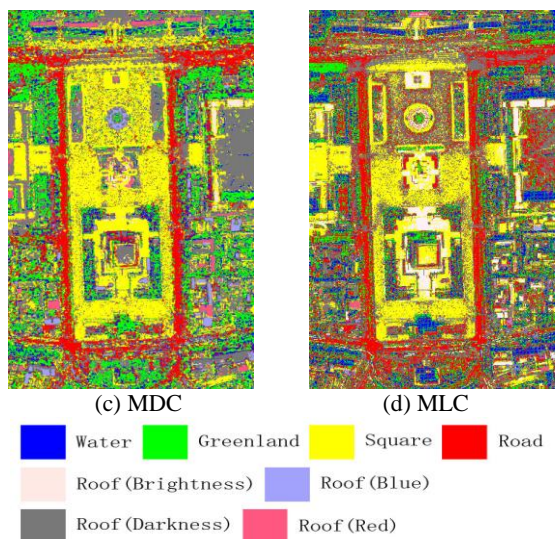
(c) MDC   (d) MLC
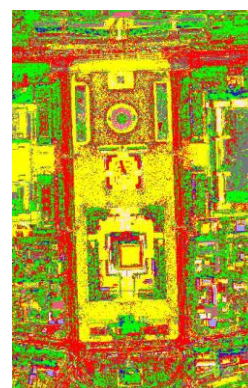
Figure 6. Classification Results

Final results for pixel-based and object-based classification are demonstrated in Figure 6, respectively, and an accuracy comparison among the above methods is found in Table 3. Differences are obvious in these classification results: the object-oriented is a more spatially cohesive map, with none of the spurious pixel effect found with the pixel-based methods. The object-based classification approach yielded a higher accuracy, with an overall accuracy of 84.2468%, a 7.7344% overall accuracy than the best pixel-based approach. This is consistent with other studies that have shown object-based methods outperforming pixel-based method when applied to high resolution images (Zhou, 2009). Our results indicate that an object-based classification approach is a more appropriate mapping technique for high resolution optical and SAR fused image. The water class had the greatest increase from 75.6% using the pixel-based approach to 99.4% with the object-oriented method. The accuracies of road, square and greenland had a great improvement. The above classes were all classified by using fuzzy knowledge, so it indicated that the fuzzy knowledge is helpful for the accuracy improvement. But the other classes such as roof (Brightness, red) are lower than tradition methods.

	OO	SVM	MDC	MLC
Road	100	87.56	81.26	87.22
Square	100	83.54	68.46	95.96
Greenland	72.35	66.67	39.63	52.07
Water	99.4	39.58	75.6	72.62
Roof(Brightness)	73.52	29.44	87.75	8.7
Roof(Blue)	88.6	92.61	54.07	92.51
Roof(Red)	75.49	86.68	53.89	82.68
Roof(Darkness)	57.1	29.59	31.36	81.07
Overall Accuracy	84.247	70.504	62.250	76.516
Kappa Coefficient	0.8156	0.6473	0.5579	0.7249

Table 3. Accuracy Assessment Report For Classification

5. CONCLUSIONS AND PROSPECTS

In order to evaluate the accuracy improvements in the classification of high resolution imagery, the paper proposes a fusion and classification scheme of high resolution optical and SAR images. The fusion results illustrate that the approach using wavelet transform can integrate spatial and texture characteristics of multi-source images more adequately and produce fused image with higher quality and fewer artifacts than other fusion methods. Traditional information extraction method is not suitable for processing high resolution remote sensing image because it only focuses on spectral information and ignores other information in adjacent pixels. The object-oriented information extraction approach can solve this problem. Fuzzy knowledge can play a more important role when high resolution images are partitioned into objects for analysis. The experiments show that the use of fuzzy knowledge markedly improved the classification performance in comparison to traditional classification. This is explained by the fact that the fuzzy knowledge model built in experiments is based on spectral, spatial and texture attributes whose values do not significantly change over time. But the object-oriented method is not suit for all classes' classification. So how to combine the methods or find better approach are the key points in the future work. May be the multi classifier combination can solve the problem.

6. ACKNOWLEDGEMENTS

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