An Image Fusion Method Based on Object-Oriented Image Classification

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***Abstract*—Image fusion at pixel level without precise registration always causes pseudo colors and other problem. Classification-based fusion scheme can effectively eliminate the false color at the edge of objective. However, the traditional per-pixel classification results in the well-known salt and pepper effect. The only way to smooth the image is to use filters, while impacted on the result of fusion. This paper proposes a method consist of a sequential application of segmentation, classification and fusion techniques. First, the image was multi-resolutely segmented into "homogenous" areas, and classified it by using the membership functions classifier and additional empirical rules. Subsequently, according to the restriction of the precise classification result, adjusting the multi-spectral image then achieved the fusion by using HSV color transformation. Finally, after compared the statistical properties of the fusion result by different methods, the proposed method showed satisfied result.**

I. INTRODUCTION

With the appearance of plentiful kinds of remote sensing imagery, fusion of satellite images of different spatial resolutions play an important role. Via image fusion, we can obtain more information than can be derived from single kind of image. Pohl prompted that according to the stage which image fusion is performed, there are pixel, feature and decision level. Image fusion at pixel level always was effected by the accuracy of registration, the number of mixed pixel and other factors. The pixel in high-resolution satellite image is smaller sizes and combined with fewer spectral bands that cause greater spectral variation within a class and a greater degree of shadow. Hence, color break and pseudo colors often occur at the edge of object and shadow which fusing the high-resolution image only at pixel levels.

During the high-resolution image fusion, for eliminating color break and pseudo colors, using its classification image as the prior knowledge and restricting the fusion area can take full advantage of spectral information from multi-spectral bands and texture information come from pan band to realize the image fusion. It's a method of image fusion that performing at pixel level and integrate with feature level fusion. In this way, phenomenon of pseudo colors can be avoided.

In this paper, we propose an image fusion method based on object-oriented classification. Via image segmentation, feature extraction and image fusion based on object-oriented classification, the fusion image can be achieved. In this method, object-oriented classification more appropriate for high-resolution image to get accuracy classification result and overcoming the limit of per-pixel image analyses. Because much information is acquired in the relationship between adjacent pixels, including texture and shape information, which allows for identification of individual objects as oppose to single pixels (Thomas et al., 2003). Such an object-oriented approach allows the user to apply locally different strategies for analysis. Incorporating both spectral information (tone and color) as well as spatial arrangements (size, shape, texture, pattern, association with neighboring objects) comes closer to the way humans interpret high-resolution satellite image. Franklin et al. (2000) found that the incorporation of texture in addition to spectral information increased classification accuracy. All of this can help to eliminate pseudo colors and colors break phenomenon in greater degree.

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II. METHODS

A. Study area and materials

Our research was conducted on a part of NanJing city. The available remotely sensed data is a sub-window of QuickBird image of 21 September 2003. The ENVI 4.0 software was used for image pre-processing such as registration, re-sampling the multi-spectral bands and so on. We selected the nearest neighbor arithmetic to resample the multi-spectral bands for achieve the new multi-spectral image which with same spatial resolution as the pan band. For avoiding the spectral degeneration caused by interpolation and remaining more original multi-spectral information to assure the classification accuracy in the next step.

B. Image classification based object-oriented

We used an object-oriented multi-scale image analysis method embedded in the software eCognition (Definiens, 2003). The first step is a segmentation of the image based on four parameters: weight of participation in the segmentation, scale, color, shape (smoothness and compactness). All those parameters are weighted from 0 to 1.In this research, in view of more texture information come from pan band, we set 1.0 to the weight of participation in the segmentation for pan band and 0.5 for multi-spectral bands. We set 20 for the scale parameters to get level 1 and set 40 to achieve level 2. Scale here is describes the magnitude or the level of aggregation on which a certain phenomenon can be described, and is independent of the image resolution.

After the segmentation, we get image objects, which constituted by homogeneous pixels. Then classification is performed using the objects rather than single pixels. The multi-resolution segmentation approach allows for segmentation at different spatial resolutions simultaneously. The images "know" their neighbors, such as adjacent objects, sub-objects and super-objects, and so on. This allows for extract different classes in the image.

The classification of the image objects can be performed by using nearest neighbor classifiers based on user-selected samples or by using membership functions, based on fuzzy logic theory combined with user-defined rules. A membership function ranges from 0 to 1 for each object's values with regard to the object's assigned class. The fuzzy rule base defines criteria such as "all image objects' NDVI value greater than a certain value is vegetation". Spectral, shape, and statistical characteristics as well as relationships between linked levels of the image objects can be used in the rule based on combine objects into meaningful classes (Benz et al., 2004). Table 1 is the classes and the rules of Feature Extraction from Multi-scale Segmentation Image.

TABLE I. CLASSES AND RULES OF FEATURE EXTRACTION FROM MULTI-SCALE SEGMENTATION IMAGE

Layer	Classes	Super-object	Sub-object		Rules
			Super-class1	*Super-class2*	
Level 2	Water body				$NDWI >$ 0.23
	Vegetation				$NDVI >$ 0.31
	Others				Not water body&not vegetation
Level 1	Water body 1	Water body			Heritage from water body in level 2
	Vegetation 1	Vegetation			Heritage from vegetation in level 2
	Others 1	Others			Heritage from others in level 2
	Shadow		Others 1		165 < brightness < 210
	Not shadow		Others 1		Not shadow
	White roof			Not shadow	Band 1 mean diff. To scene >264
	Blue roof			Not shadow	0.20 < Ratio of band 1< 0.24
	Road 1			Not shadow	length/width>4 & 0.185<Ratio of Band 4<0.22
	Road 2			Not shadow	length/width>4 & 0.22<Ratio of Band 4<0.28
	Bare land			Not shadow	0.24<Ratio of Band 4<0.278

C. *Image fusion based on object-oriented classification*

Generally, fusing the pan and multi-spectral images directly often show color distortion due to pan image contain fewer spectral information and widely exist the phenomenon that different spectrum character for one matter. However, using classification image to constrain the digital number of the panchromatic band, can reduce the phenomenon mention before. After that, fusing with the multi-spectral bands, which adjusted by the pan image and gain the fusion image with less color distortion and more clearly at the edge of ground object.

The main steps of image fusion based on classification are more detailed as follow:

- Let the classification image overlay with the pan image to run mask operation. That is aim to extract all pixels belong to every class.
- Counting the histogram of every class on the pan image, and thought the water shed arithmetic to inverse-operate the digital number (DN) of classes by the histogram. After that, we can attain the spatial position information (Xs,Ys)of every DN in pan image.
- Adjusting the every multi-spectral band by the spatial position information (Xs,Ys) from pan image. That is to say, according to the spatial position of same DN from pan image, to search the same position pixel in multi-spectral band and calculate all the DN and assign a mean value to the pixels with same position (Xs,Ys). Modifying the three multi-spectral bands by this way respectively, and gain new multi-spectral bands.
- After performing the HSV transform to the new multi-spectral image, let V channel histogram match to the pan image. Using the new pan image to replace the V channel, and we get the fusion image though the HSV inverse transform.

III. RESULTS

In the field of remotely sensed image fusion, the evaluation of the achieved results becomes relatively complex because of the different sources of data that are involved. The different aspects of image acquisition of the various sensors have to be considered as well as the approach of the image fusion itself plays a role. Generally, mathematical conditions to judge the quality of merged image in respect to their improvement of spatial resolution while preserving the spectral content of the data.

In this paper, we select visual method and statistic parameters as the assessment criteria. And compare the new method with other approaches: principal component method (PC), wavelet method, and based on pixel classification image fusion method. By visual assessment, we can find that the image merged based on classification show more texture information than other approaches. For we can more clearly to see the texture of the roof and so on from the fusion image. Turn to the spectral information reservation, wavelet method done the best, and the better one is the method of fusion based on classification. As for the objective assessment, from the table Ⅱ, we can see the detail of comparative result.

TABLE II. COMPARISON OF THE OBJECTIVE ASSESSMENT PARAMETER OF THE FUSED IMAGES BY DIFFERENT METHOD

Method \ Parameter	**PC**	**Wavelet**	**Based on pixel classification**	**Based on object-oriented classification**	**Pan image**	**Multi-spectral image**
Mean	60.91	61.76	72.16	86.32	88.15	61.17
Variance	55.66	56.97	40.25	41.12	44.90	56.61
Entropy	5.45	5.08	7.01	7.07	7.01	6.83
Sharpness	11.94	12.54	8.60	9.12	8.73	4.80
Warping degree	39.57	8.00	50.27	46.16		
Correlation coefficient	0.53	0.95	0.49	0.55		

After the analysis, we can find that the image fusion based on classification is the better merge approach than PC and wavelet method. Since the method can adjust the mixed pixel of the multi-spectral image via the classification image, it can enhance the definition of the ground object and reduce the occurrence of pseudo colors. All of those can make the fusion image closer to reality and improve assessment parameters. And from the statistical parameters, we can fine that based on object-oriented classification fusion method is better than the based on single pixel classification mergence approach.

IV. CONCLUSIONS

Owing to the variety aim of image fusion, we can gain different outcome. In this paper, we propose the based on object-oriented classification fusion method is more fit for high-resolution remotely sensed image. During the initial stage—image segmentation, the method take the homogenous pixels of image into account, which can be indirectly in restraint of the fusion and lessening the appearance of pseudo colors as well as more clearly in the edge of object. In the next step, add fuzzy rule and expertise knowledge as well as image semantics to the multi-resolution segmentation image, make the image processing methods similar to human understanding processes. All that can make the classification result more closely to reality and eliminate the influence of the salt and pepper effect caused by traditional per-pixel classification approach.

Shadow is an important part of high-resolution image, and we cannot help thinking about the influence of it. With object-oriented classification approach, we can easier to extract the shadow from high-resolution image. How to treat with it, however, will need to do further discussion and research.

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