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K-means with Empirical Mode Decomposition for Classification of Remote Sensing Image

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Abstract: Noise reduction is a prerequisite step prior to many information extraction attempts from remote sensed images. The noises are introduced into the images during acquisition or transmission process, affecting the classification results of the remote sensing image. In this paper, we propose to combine the K-means method with Bi-dimensional Empirical Mode Decomposition for classification of remote sensing image in order to reduce the effect of noise. We call this method as K-Means with Bi-dimensional Empirical Mode decomposition (KBEMD). We use an adaptive local weighted averaging filter in the BEMD method for removing the noise in the remote sensing image and finally K-means algorithm is used for classification of image. Using the KBEMD method on remote sensing image, we can obtain more reasonable results.

Keywords: Remote Sensing; Empirical Mode Decomposition; Image Classification, Image Processing;

I. INTRODUCTION

Remote sensing can be defined as any process whereby information is gathered about an object, area or phenomenon without making physical contact with the object [1]. The remote sensing technology (aerial sensor technology) is used to classify objects on the Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals. New opportunities to use remote sensing data have arisen, with the increase of spatial and spectral resolution of recently launched satellites. Remote sensing image classification is a key technology in remote sensing applications [2]. Rapid and high accuracy remote sensing image classification algorithm is the precondition of kinds of practical applications. In remote sensing, sensors are available that can generate multispectral data, involving five to more than hundred bands. In these images, a trade-off exists between spatial and spectral resolution and signal-to-noise ratio, which makes noise handling important. This results in conventional classification method such as K-means losing their advantages in classifying high resolution remote sensing images.

In this paper we propose to combine K-means classification method with bi-dimensional Empirical Mode Decomposition (BEMD) for classification of remote sensing image. The Empirical Mode Decomposition (EMD) method was first proposed by Huang [3] and then Lin et al. [4] proposed an iterative filtering as an alternative algorithm for EMD. Usually, EMD is used to analyze the intrinsic components of a signal. These components are called intrinsic mode functions (IMF). Most noisy IMFs are considered as noise in the signal. If we remove noisy IMFs from the raw data, the trend component can be obtained. Then we can use the trend as the de-noised data to perform classification analysis. In this paper we de-noise the remote sensing image using BEMD and finally classify the image with K-means algorithm.

The paper is organized as follows: Section II presents Bi-dimensional Empirical Mode Decomposition and iterative filtering using BEMD, Section III presents, K-Means Algorithm, Section IV presents Experimental results, and finally Section V reports conclusion.

II. BI-DIMENSIONAL EMPIRICAL MODE DECOMPOSITION

The EMD proposed by Dr. Norden Huang [3], was a technique for analyzing nonlinear and non-stationary signals. It serves as an alternative to methods such as wavelet analysis and short-time Fourier transform. It decomposes any complicated signal into a finite and often small number of Bi-dimensional Intrinsic Mode Functions (IMF). The IMF is symmetric with respect to local zero mean and satisfies the following two conditions.

a. The number of extrema and the number of zero crossings must either be equal or differ by one.
b. At any point, the mean value of the envelope defined by local maxima and local minima is zero, indicating the function is locally symmetric.

The decomposition method in EMD is called Shifting Process. The shifting process of the two- dimensional signal such as image can be adapted from the one-dimensional signal as follows.

a. Let $I_{original}$ is defined as an image to be decomposed. Let j=1 (index number of IMF), I= $I_{original}$ (the residue).
b. Identify the local maxima and local minima points in I.
c. By using interpolation, create the upper envelope E_{up} of local maxima and the lower envelope E_{lw} of local minima.
d. Compute the mean of the upper envelope and lower envelope.
$E_{mean}= [E_{up} + E_{lw}]/2$

e. I_{imf} = I- E_{mean}.
f. Repeat steps 2-5 until I_{imf} can be considered as an IMF.
g. IMF(j)= I_{imf}, j=j+1, I = I- I_{imf} ,
h. Repeat steps 2-7 until all the standard deviation of two consecutive IMFs is less than a predefined threshold or the number of extrema in I is less than two.

The first few IMFs obtained from BEMD contain the high frequency components which correspond to salient features in original image and the residue represents low frequency component in the image. The original image can be recovered by inverse BEMD as follows:

$$I = RES + \sum_{j} IMF(j) \quad (1)$$

The BEMD process and IMFs of the remote sensing image are shown in figure 1 and figure 2.

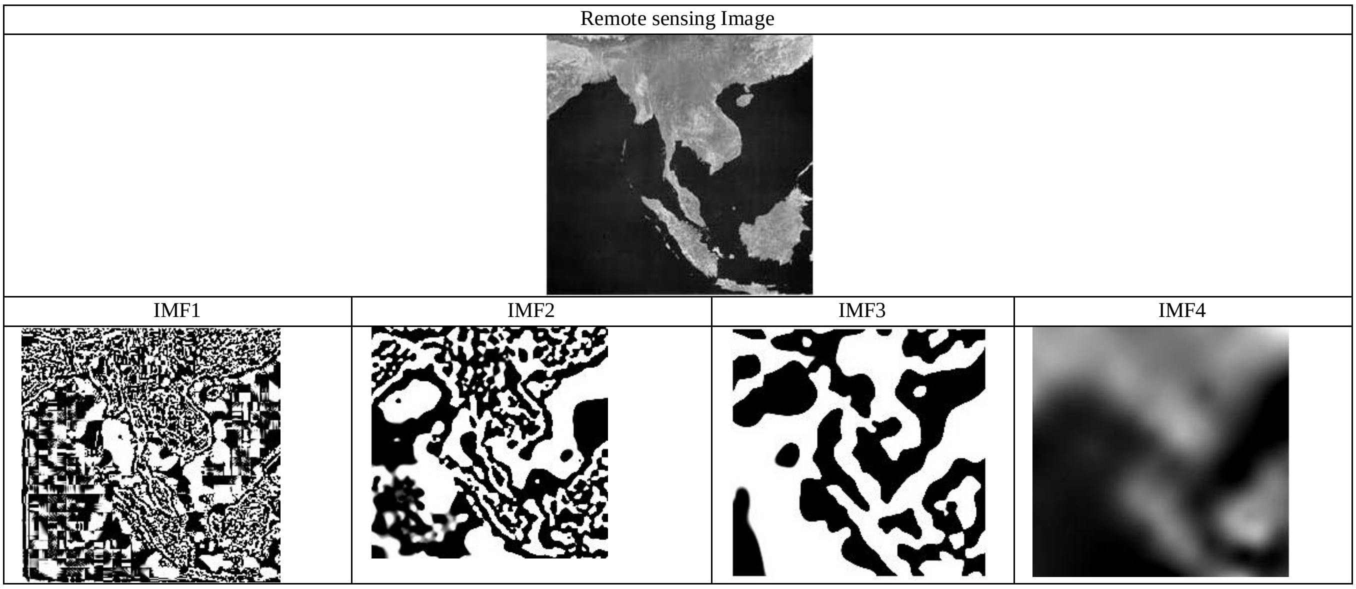


Figure 1: IMF of remote sensing image

Lin et al. [4] proposed iterative filtering as an alternative algorithm for EMD. Instead of using the envelopes generated by spline, in the new algorithm Lin use a "moving average" to replace the mean of the envelope. The essence of the shifting algorithm remains the same. We use a low pass filter to generate a moving average replacing the mean of the envelope. The simplest choice of moving average is an adaptive local weighted average. We use the filter given by $L(x,y)= \sum_{i=-a}^{a} \sum_{j=-b}^{b} w(i,j) I(x+i, y+j)$ where *w(i,j)* is called the mask or filter coefficients at (i,j). We select the mask $w(i,j) = \frac{(a+b)-|(i+j)|+2}{a+b+2}$, i=-a,…..,a and j=-b,…..,b. The shifting process (iterative filtering) of the two- dimensional signal such as image can be adapted from the one-dimensional signal as follows.

a. Let $I_{original}$ is defined as an image to be denoised. Let j=1 (index number of IMF), I= $I_{original}$ (the residue).
b. Let L be a low pass filter such that L(I) represents the moving average of I.
c. Now define I_{imf} = I – L(I) .
d. Repeat steps 2-3 until I_{imf} can be considered as an IMF.
e. IMF(j)= I_{imf}, j=j+1, I = I- I_{imf} ,
f. Repeat steps 2-5 until IMF has atmost one local maximum or local minimum.

The original image can be recovered by inverse as follows:

$$I = RES + \sum_{j} IMF(j)$$

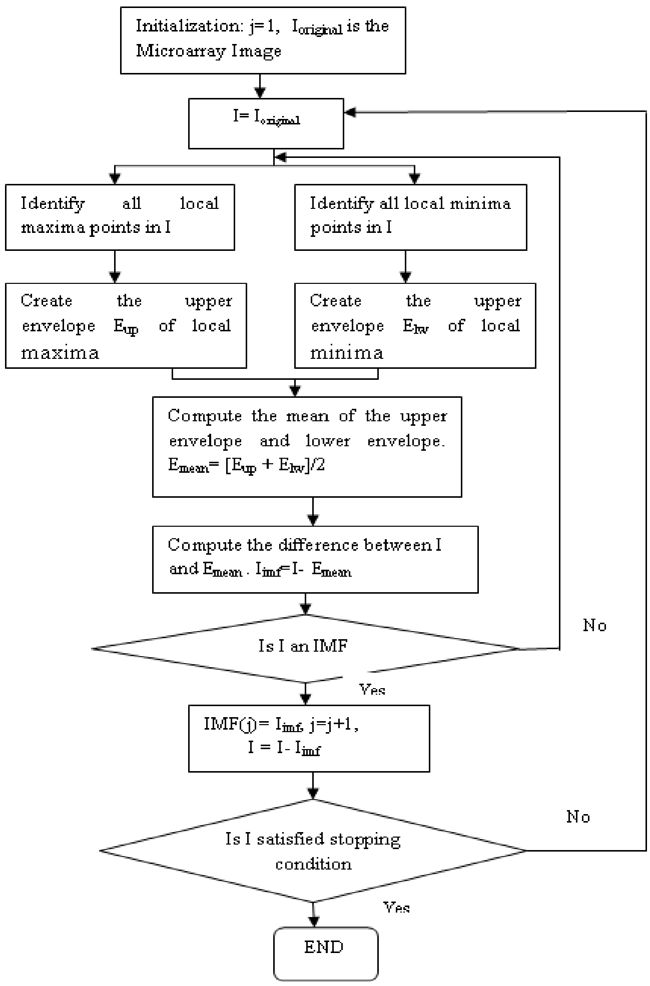


Figure 2: BEMD Process

III. K-MEANS ALGORITHM

K-means is one of the basic clustering method introduced by Hartigan[5]. This method is applied to classify the remote sensing image in recent years. The K-means algorithm for remote sensing image classification is summarized as follows:

Algorithm K-means(x,n,c)

Input:

N: number of pixels to be classify;

x={$x_1, x_2, x_3, \ldots\ldots, x_N$}: pixels of remote sensing image

c={$c_1, c_2, c_3, \ldots., c_j$} clusters respectively.

Output:

cl: clusters of pixels

Begin

Step 1: cluster centroids are initialized.

Step 2: Compute the closest cluster for each pixel and classify it to that cluster, ie: the objective is to minimize the sum of squares of the distances given by the following:

$$\Delta_{ij} = || x_i - c_j ||. \quad arg\ min \sum_{i=1}^{N} \sum_{j=1}^{C} \Delta_{ij}^{2} \qquad (3)$$

Step 3: Compute new centroids after all the pixels are clustered. The new centroids of a cluster is calculated by the following

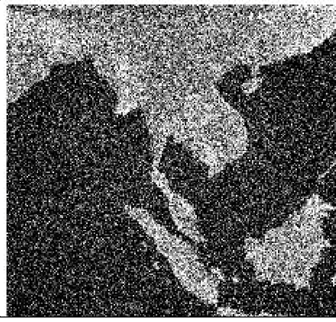
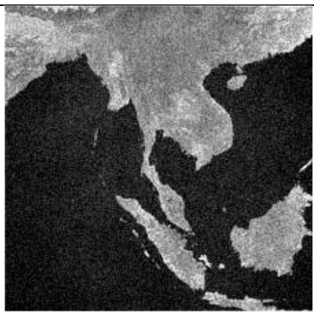
$$c_j = \frac{1}{N\,j} \sum x_i \quad where\ x_i\ belongs\ to\ c_j . \qquad (4)$$

Step 4: Repeat steps 2-3 till the sum of squares given in equation is minimized.

End.

IV. EXPERIMENTAL RESULTS

The proposed KBEMD method of the image processing is performed on a remote sensing image. The sample image is a 198*196 pixel image that consists of a total of 38808 pixels. In-order to check the efficiency of the proposed method, Gaussian noise is added into the remote sensing image. The noisy image is filtered by an iterative filtering algorithm using BEMD. In the 9th IMF, we obtain the smooth image, which we used as a de-noised image for analysis purpose. The K-means algorithm is used for classification of filtered remote sensing image. The experimental results show that noise in the image affects the classification results. After removing noise using the proposed method, the classification of the image is done accurately. The experimental results of the proposed method are shown in figure 3.

Noisy RS Image	IMF1
	
IMF3	IMF5
	
IMF7	IMF9
	
Classification using K-means on IMF9	Classification using K-means on a noisy Image

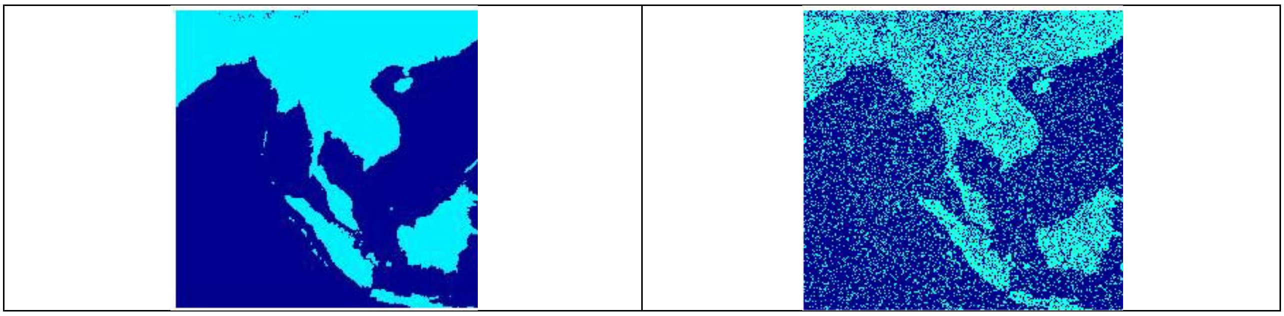


Figure 3: Experimental results on a Remote Sensing image

V. CONCLUSION

In this paper, we proposed to combine K-means with empirical mode decomposition for classification of remote sensing image. The noisy remote sensing image is first filtered by an iterative filtering algorithm using BEMD. Then, the filtered remote sensing image is classified using K-means algorithm. In the future work, the same BEMD concept can also be applied to Fuzzy c-means algorithms for classification of remote sensing image.

VI. REFERENCES

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