ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Hyperspectral Image Enhancement Using Evolutionary Algorithm

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Manuscript Info

Manuscript History:

Received: 14 December 2015
Final Accepted: 26 January 2016
Published Online: February 2016

Key words:
Image Enhancement, Empirical Mode Decomposition, Genetic Algorithms, Remote Sensing

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Abstract

Hyper spectral remote sensors collect image data for a large number of narrow, adjacent spectral bands. Every pixel in hyperspectral image involves a continuous spectrum that is used to classify the objects with great detail and precision. This paper presents hyperspectral image enhancement mechanism using an evolutionary algorithm. 2-D Empirical mode decomposition method is used to divide the hyperspectral image belonging to a specific band into finite number of components called intrinsic mode functions. The last component is called a residue. Each intrinsic mode function is multiplied by a specific weight and summation of these weighted intrinsic mode functions gives the enhanced image. The weight related to each intrinsic mode function is automatically determined using genetic algorithm. The information entropy is used as objective function in the genetic algorithm. This image enhancement increases the classification accuracy of hyperspectral images with an unsupervised classification algorithm.

Introduction:-

The process of acquiring information about an object on the earth using satellites without making any physical contact is called remote sensing [1]. The classification of objects on the earth by using electromagnetic radiations reflected or emitted by the surface is the main goal of remote sensing technology. New opportunities to use remote sensing data have arisen, with the increase of spatial and spectral resolution of recently launched satellites. Image classification is a key step in remote sensing applications [2]. In remote sensing, sensors are available that can generate hyperspectral data, involving many narrow bands in which each pixel has a continuous reflectance spectrum. Unsupervised image classification is an important research topic in hyperspectral imaging, with the aim to develop efficient algorithms that provide high classification accuracy.

This paper presents hyperspectral image enhancement mechanism using genetic algorithm, as the hyperspectral images suffer from poor contrast due to disturbance of transmission medium in the atmosphere or degradation of sensors etc leading to affect the accuracy of classifications algorithms. Image enhancement is achieved by using two dimensional empirical mode decomposition (EMD) that is applied to a hyperspectral image in a specific band. The EMD decomposes the image into finite non-destructive elements called intrinsic mode functions (IMFs). Each IMF_i is multiplied by a specific weight w_i, and the summation of these IMFs gives the enhanced image. In this paper, the weights are optimized by genetic algorithm (GA) that belongs to the class of evolutionary computation. The information entropy is used as an objective function in GA.

Weizi Liu. et.al, [3] proposed histogram equalization approach for remote sensing image enhancement. First linear transformation function is used to stretch the image to cover larger grey levels and then contrast limited adaptive histogram equalization is applied for further enhancement. This method holds some drawbacks such as lack of discrimination that give rise to increase noise. Liang Xie, et.al [4] presented a remote sensing image enhancement using wavelet and histogram specification. The method decomposes the image into low and high frequency components using wavelets. For low frequency components histogram specification based on Gaussian PDF is used for enhancement and for high frequency components butter-worth low pass filter is used for enhancement of image.

This paper is structured as follows: section 2 presents empirical mode decomposition, section 3 presents genetic algorithm, section 4 presents image enhancement using GA, section 5 presents FCM algorithm for image classification, section 5 shows experimental results and section 6 report conclusions.

Empirical Mode Decomposition:-

Empirical mode decomposition [5] is a signal processing method that nondestructively fragments any non-linear and non-stationary signal into oscillatory functions by means of a mechanism called shifting process. These oscillatory functions are called Intrinsic Mode Functions (IMF), and each IMF satisfies two properties, (a) the number of zero crossings and extrema points should be equal or differ by one. (b) Symmetric envelopes (zero mean) interpret by local maxima and minima. The signal after decomposition using EMD is non-destructive means that the original signal can be obtained by adding the IMFs and residue. The first IMF is a high frequency component and the subsequent IMFs contain from next high frequency to the low frequency components. The shifting process [6] [10] used to obtain IMFs on a 2-D signal (image) is summarized as follows:

a) Let I(x,y) be a Remote Sensing Image used for EMD decomposition. Find all local maxima and local minima points in I(x,y).
b) Upper envelope Up(x,y) is created by interpolating the maxima points and lower envelope Lw(x,y) is created by interpolating minima points. This interpolation is carried out using cubic spline interpolation method.
c) Compute the mean of lower and upper envelopes denoted by Mean(x,y).

$$Mean(x,y) = \frac{(Up(x,y) + Lw(x,y))}{2} \tag{1}$$

d) This mean signal is subtracted from the input signal.

$$Sub(x,y) = I(x,y) - Mean(x,y) \tag{2}$$

e) If Sub(x,y) satisfies the IMF properties, then an IMF is obtained .

$$IMF_i(x,y) = Sub(x,y) \tag{3}$$

f) Subtract the extracted IMF from the input signal. Now the value of I(x,y) is

$$I(x,y) = I(x,y) - IMF_i(x,y) \tag{4}$$

Repeat the above steps (b) to (f) for the generation of next IMFs.

g) This process is repeated until I(x,y) does not have maxima or minima points to create envelopes.

Original Image can be reconstructed by inverse EMD given by

$$I(x,y) = \sum_{i=1}^{n} IMF_i(x,y) + res(x,y) \tag{5}$$

Genetic Algorithm:-

Genetic Algorithms [7] belong to the class of evolutionary algorithms that are based on principles of natural selection and genetics. It is a search technique used in computing true solutions to optimization problems that is driven by natural evolution process. GA performs parallel search of the solution space rather than point by point search. Genetic Algorithm consists of three operators namely, Selection, Crossover and Mutation.

The Genetic Algorithm mechanism can be abstracted as follows [10].

1) The initial population of solutions is randomly generated across the search space.
2) Using an objective function, the fitness of each individual solution in the population is evaluated.
3) Using this fitness values, the solutions in the population are selected.
4) New population is created from selected solutions using the crossover and mutation operators.
5) The new population is replaced instead of old population.
6) Repeat iteratively from (2) to (5) until a stop criterion is satisfied. Each iteration of this GA process is called generation.

GA is a method of parallel search of the solution space based on two assumptions inspired by evolutionary biology. 1) The measure of problem solving ability by an individual in the population is determined by its fitness value. 2)

New individuals which are obtained by combining different individuals in the population have more problem solving ability.

Image Enhancement Using Genetic Algorithm:-

The proposed method for image enhancement can be summarized as follows.

1) Given Remote sensing image I is divided into IMFs using 2-D empirical mode decomposition method.

$$EMD(I) = [imf_1, imf_2, ..., imf_n] \tag{6}$$

2) The obtained IMFs are used to reconstruct the enhanced image. Each IMF is multiplied with a weight w, and the summation of IMFs with weights gives the enhanced image. The weight for each IMF is obtained using GA.

$$RI = \sum_{i=1}^{n} w_i * imf_i \tag{7}$$

Where w_i denotes the weight corresponding to imf_i, and RI represents the reconstructed image with enhancement.

3) The Genetic Algorithm is applied as follows.

a) First randomly generate the weights of IMFs representing initial population. The length of elements of each chromosome in the population is equal to the number of IMFs generated by EMD and the element value represents the weight of corresponding IMF. The values of weights differ between 0 and 1 and the summation of weights is equal to 1.

b) Using an objective function, the fitness value of each chromosome is evaluated. The information entropy is used as the fitness function in this GA process. The entropy is defined as

H= -sum(p.*log2(p)) (8)

c) The selection of chromosomes is done based on the fitness value using roulette wheel technique.

d) By applying crossover and mutation operators with rate 0.7 and 0.07, a new population is produced from the parents. This new population replaces the old population.

e) Maximum number of iterations is used as stopping criteria.

After the execution stops, the highest fitness value chromosome is selected and the IMF's optimum weights are the values in this chromosome. With this weights and IMFs, the enhanced image is constructed.

Fuzzy C-Means (Unsupervised) Algorithm:-

1. The membership matrix u_{ij} is initialized with value from 0 to 1 and value of m=2. The summation of pixel memberships representing particular cluster should meet the condition given as

$$\sum_{j=1}^{c} u_{ij} = 1 \tag{9}$$

2. Every pixel should contain a membership degree to those represented clusters. So the idea is to calculate the pixel membership quantities that are member to every cluster. The algorithm is an iterative mechanism that optimizes the following function

$$F = \sum_{j=1}^{N} \sum_{i=1}^{c} u_{ij}^{m} \, || x_j - c_i ||^2 \tag{10}$$

3. Evaluate the new membership values and centroids of clusters using the following equation

$$u_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{\|x_j - v_i\|}{\|x_j - v_k\|} \right)^{2/(m-1)}}$$

(11)

$$v_i = \frac{\sum_{j=1}^{N} u_{ij}^{m} x_j}{\sum_{j=1}^{N} u_{ij}^{m}}$$

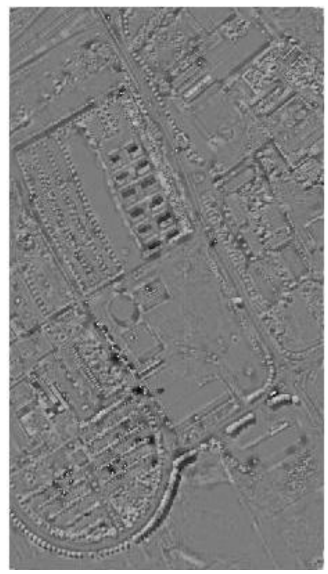
4. Continue 2-3 until minimizing the function F [8].

Experimental Results:-

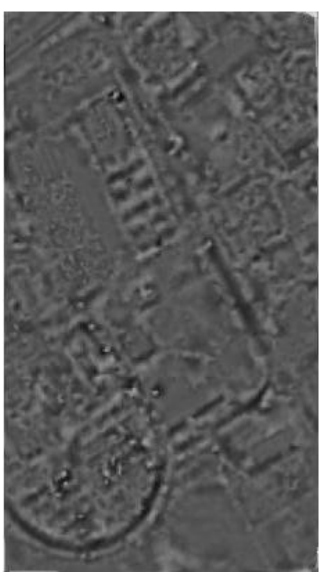
The proposed algorithm is tested on Pavia University hyperspectral image data set. The data set contains 103 spectral bands and image in each band consists of 610*340 pixels. The data set is collected from [9] that consist of nine classes and the geometric resolution is 1.3 meters. The experimental result is conducted on band 100 and is shown in figure 1. The same procedure is executed for all bands in the data set in-order to enhance the image and finally increase the classification accuracy. The accuracy of classification algorithm before and after enhancement is compared with the standard values of each class given in [9] is shown in figure 1.

Pavia University image in band 100

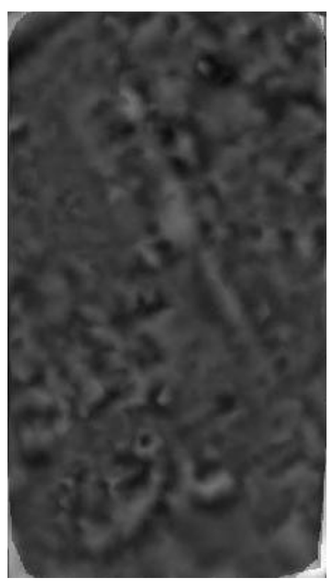
IMF1



IMF2



IMF3



Weights obtained using GA

Weight of IMF1-0.057
Weight of IMF2-0.103
Weight of IMF3-0.840

Classification Accuracy (in percentage)

Before Enhancement: 79
After Enhancement: 91

Enhanced Image
Classified Image
(Using FCM after enhancement)

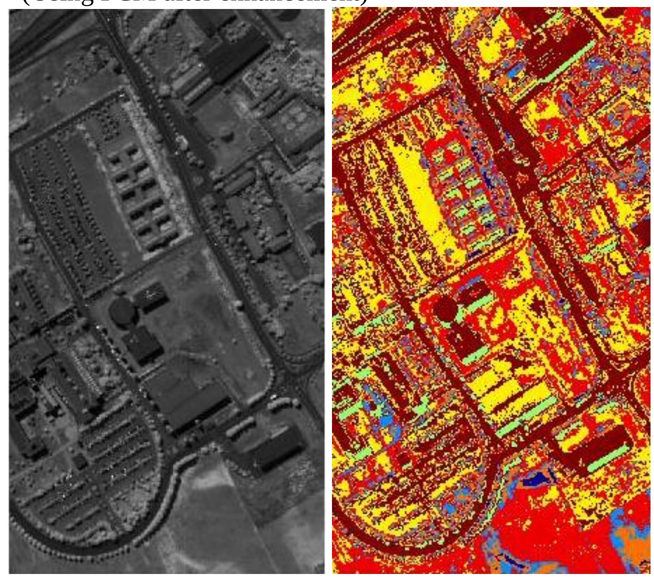


Figure 1: Hyperspectral Image Enhancement

Conclusions:-

In this paper, hyperspectral image enhancement method based on evolutionary algorithm has been proposed. The hyperspectral image data set involves many consecutive narrow bands, resulting in a continuous reflectance spectrum for each pixel. EMD is used for decomposition of an image in a specific band into IMFs. Each IMF is multiplied by a specific weight and the summation of these IMFs produces an enhanced image. The weights are determined by genetic algorithm optimizing the information entropy in the image. The experiment result shows significant enhancement in the image and thus producing more classification accuracy.

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