COMPRESSION OF HYPERSPECTRAL IMAGES USING WATERSHED METHOD AND WAVELET TRANSFORM

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ABSTRACT: *One of the first processes that is proposed about hyperspectral data due to the increased number of imaging bands and the possibility of increasing the radiometric accuracy, is their compression. In this paper, a method is provided for compressing the hyperspectral images. In the proposed compression method, at first compress the image using the wavelet transform method that is a spectral compression method, then the segmentation is performed on the image using watershed method, so that the image is divided into areas with pixels of similar properties. Considering the high volume of data, the hyperspectral image can be sent rather than the segmented hyperspectral image along with the estimated parameters such as mean, variance, seed pixel and texture block of any area that are obtained from the extraction of spectral feature of wavelet transform and in the receiver side, the image can be reconstructed using the transmitted information. This method, considering that it performs the compression using the image segmentation, identifies the small areas which could be removed in the other compression methods, and maintains them during the compression. This method has been implemented on AVIRIS image and created a high compression ratio and also maintained the information about classification.*

Keywords: Hyperspectral Images, Watershed, Segmentation, Compression.

1. INTRODUCTION

Using the hyperspectral sensors the possibility of imaging from the surface of the Earth at hundreds of spectral bands has been created and the spatial accuracy in this type of imaging has been increased. With the increased number of bands, some problems emerge in terms of the bands number, storage volume and the image processing. In order to fix the problem, the image must be compressed. Compression methods can be divided into two categories: lossless compression and lossy compression methods. In the lossless compression method, the compression is done without losing any data, which has many limitations and moreover it hasn't a high compression ratio. But, the lossy compression methods have a higher compression ratio. There are several suggested methods for compressing the hyperspectral images that are generalized from two-dimensional compression algorithms. A series of compression methods is designed according to the uncorrelation of the spectrums based on JPEG2000 [1]. Discrete wavelet transform and tucker decomposition were applied in [2], while a pairwise orthogonal spectral transform was develop in [3]. In the proposed segmentation method a combination of Wavelet and Watershed segmentation methods has been used for the compression. In the second section of this article the proposed compression method is presented. The wavelet method and watershed segmentation is explained in the third and fourth section. The algorithm of image reconstruction is discussed in the fifth section.

2. PROPOSED METHOD OF COMPRESSION

With the emergence of hyperspectral sensors and increased radiometric accuracy, the volume of images has increased a lot and as a result they faced many problems in processing, storage and sending the pictures. For this purpose, before any processing at first the image is compressed. In the proposed compression method, at first using the wavelet method the image's spectral data is compressed, then using the method of watershed the images are divided into homogeneous area, then the mean, variance, seed pixel and the texture block of each area of each image created by Wavelet method are extracted, and rather than

sending a hyperspectral image, the segmented image along with parameters including the mean, variance, seed pixel and the texture block are sent, and on the receiver side the image is reconstructed using the transmitted information, and instead of sending the whole image the extracted features of the image is sent.

3. WAVELET

Wavelets are functions that breakups the data into separate frequency components and study each component with resolution accuracy proportional to their scale. Unlike Fourier transform which acts based on sine and cosine components, wavelets have irregular and asymmetrical behavior. Wavelets' transform breaks the signals into the shifted and scale-changed signals of a main and base wave.

Wavelet transform like any other transforms has a basic transform based on which transfers the time series into a new domain. The basis of wavelet transform consists from two functions named wavelet function and scale function. These two functions are shown by the symbols $\psi(t), \varphi(t)$.

$$\int_{-\infty}^{+\infty} \psi(t)dt = 0 \quad ; \qquad \int_{-\infty\infty}^{+\infty} |\psi(t)|^2 dt = 1 \quad (1)$$

$$\int_{-\infty}^{+\infty} \varphi(t)dt \neq 0 \quad ; \qquad \int_{-\infty\infty}^{+\infty} |\varphi(t)|^2 dt = 1 \quad (2)$$

For the wavelet transform, each of the two wavelet and scale functions in the range $(+\infty, -\infty)$ move on the main signal and are multiplied by the main function on each movement. Then, their product on this range is integrated. By doing so, two sets of coefficients are obtained. One set is related to low signal frequencies and the other is related to high frequencies.

Wavelet and scale functions due to their features, extract the high frequency components and low frequency components, respectively. Using the high-pass and low-pass filters, each data is divided into two equal parts A_1 and D_1. The category of approximate values A_1 and the category of coefficients details D_1 are at a same level. Then, low-pass and high-pass filters are again applied on the category of coefficients A_1 until the two categories of coefficients details D_2 and approximate coefficients A_2 are produced again. Thus, the two-level wavelet transform creates three categories of coefficients(A_2, D_2, D_1) [4].

4. WATERSHED SEGMENTATION

Using segmenting the image can be divided into its constituent parts, so that the same pixels are placed in an area. Watershed conversion is one of the powerful morphology tools that using identifying continuous borders between areas the images segmentation be done. This conversion operates based on the gray scale of pixels and using the gradient of the image is applicable. In the gray scale of morphology, f(x,y) is a function of the gray level of image and B(s,t) is structural element. Expansion is represented by d(x,y) and erosion is represented by e(x,y) [5].

$$d(x,y) = (f \oplus b)(x,y) = \arg\_max_{(s,t)\in B} \{\acute{D}(f(x+s, y+t), B)\} \quad (3)$$

So that

$$c_B = \frac{1}{M}\sum_s \sum_t f(s,t) \quad (4)$$

$$\acute{D}(f(x,y),B) = dist(f(x,y), c_B) \quad (5)$$

$$e(x,y) = (f \ominus b)(x,y) = \arg\_min_{(s,t)\in B} \{\acute{D}(f(x-s, y-t), B)\} \quad (6)$$

According to this definition, the gradient is defined as follows:

$$G(f(x,y)) = d(x,y) - e(x,y) = (f \oplus B)(x,y) - (f \ominus \mathrm{B})(\mathrm{x,y}) \quad (7)$$

The difference between expansion and erosion specifies the edges [6].

5. ECONSTRUCTION OF THE IMAGE

To obtain the mean and variance in the area, the histogram in the area is drawn and the histogram distribution of each Gaussian area was achieved. Based on the Gaussian distribution the mean and variance of each area of the image obtained by the wavelet method is calculated. With this mean and variance the image can be reconstructed on the receiver side but the resulted image is not a clear and transparent image, so other features such as seed pixel and texture block of each area are also used. The proposed segmentation method is Metropolis method [7]. After the image reconstruction, in order to evaluate the work performance, the image is

classified by the maximum likelihood method, and its accuracy and validity are obtained. Accuracy and validity criteria are achieved in this way:

$p(i)$ = i the number of correctly classified pixels in class

$r(i)$ = i total number of pixels belonging to class

$s(i)$ = i total number pixels with class labeled

Total accuracy = $\frac{\sum_{i=1}^{16} p(i)}{\sum_{i=1}^{16} r(i)} \times 100$

Total validity = $\left(\frac{1}{16}\sum_{i=1}^{16}\frac{p(i)}{s(i)}\right) \times 100$

6. SIMULATION RESULTS

To implement the image segmentation methods an image of an agricultural area was used which was taken by AVIRIS spectrometer.

The image has 220 bands and 145×145 pixels in each band. Its spectral range is 400nm to 2500nm. The segmented image using watershed is shown in figure 1. Wavelet transform is performed in two levels on AVIRIS image. The necessary bites to send are including allocated bites to mean and variance of areas, seed pixels of each area, texture block and segmented image. The first component image of the first compressed image using wavelet transform is shown in figure 2.

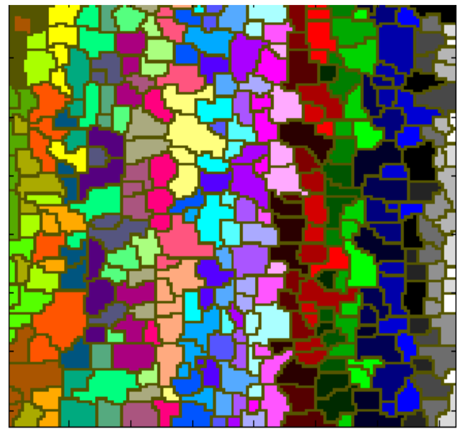

Fig. 1 Segmented image using watershed method.

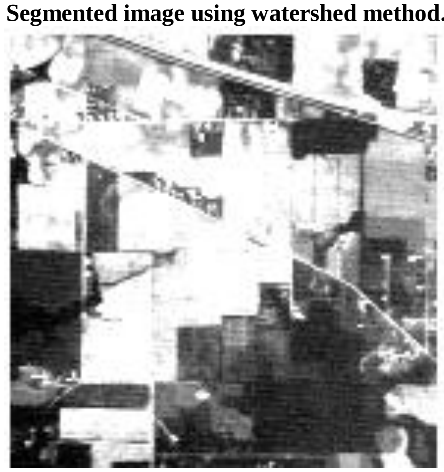

Fig. 2 The first components of compressed image using wavelet transform.

The reconstructed image from sent mean and variance of first component of compressed image using wavelet transform and the final reconstructed image using proposed method are shown in figure3.

(a)

(b)

Fig. 3 a). The reconstructed random image with sent mean and variance of first component of compressed image using wavelet transform method. b).Reconstructed image of figure A using proposed method.

Figure 3.a shows the lack of image clearance due to lack of information in order to reconstruction. Figure 4.b shows clearer and closer image to the original image which is constructed using proposed method.

The compression rate of image using some current methods of compression such as DCT [8], DWT [4], JPEG [9], Neural Network [10] and proposed compression method are shown in table 1.

Table1. Compression rate of compression methods.

Compression methods	Compression rate
DCT	4.38
DWT	4.96
JPEG	6.86
Neural Network	4.43
Proposed method	34.41

According to table 1 the compression rate of proposed method is highest to the current mentioned methods. The classification validity and accuracy of compressed images using wavelet transform and proposed methods are shown in table 2 and 3 in order to maintain the information related to classification.

Table2. Classification validity and accuracy value of compressed image using wavelet transform method.

Total accuracy	77.64
Total validity	77.32

Table3. Classification validity and accuracy value of compressed image using proposed method.

Total accuracy	76.51
Total validity	76.23

There is high probability of error with high value due to high compression rate; however, the comparison results of validity and accuracy in classification of images using these two methods do not show visible and significant differences. This suggests that the necessary information for classification in maintained by spatial and spectral compression.

7. CONCLUSION

Using the Watershed segmentation method, the upper areas have been created. But the high number has caused the heterogeneous areas not to integrating, or avoids the areas' boundaries interference problem. The more the number of the areas, considering that the transmitted information is related to characteristics extracted from each area, the more information is transmitted and the compression ratio is reduced; but compared with the mentioned methods, the proposed method has a higher compression ratio. Due to the small sizes of the areas, however, the partial and small parts of the image have been preserved during the classification. With respect to the amount of the accuracy and validity, it can be concluded that the proposed method was also able to maintain the information required for the classification in addition to the high compression ratio.

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