

Compression and Classification of Hyperspectral Images using an Algorithm based on DWT and NTD

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Abstract

Hyperspectral images (HSIs) has become very popular area of research. This paper deals with the compression and classification of Hyperspectral images using Discrete Wavelet Technique in conjunction with Non negative Tucker Decomposition. This algorithm exploits both the spectral and the spatial information of the images. The core idea behind the proposed technique is to apply TD on the DWT coefficients of spectral bands of HSIs. The results obtained by using the proposed method gives a satisfactory performance in terms of PSNR. Classification accuracy of Hyperspectral images is also calculated using the proposed method. It is shown that the classification of Hyperspectral image is affected from the compression of these images.

Keywords: Hyperspectral Images, Image Compression, Discrete Wavelet Transform, Non negative Tucker Decomposition, Classification accuracy.

1. Introduction

In the past several decades, hyperspectral images have been used widely in land management, forest monitoring, meteorology and object identification etc., due to the wealth of spectral and spatial information they contained. However, the huge volume of such kind of data has been caused trouble in the transmission and storage. Therefore, the effective compression techniques are required to deal with these problems. There are two types of redundancy in the HSIs i.e. spatial and spectral redundancies. However, the spectral correlation (band redundancy) is generally but not always stronger than spatial correlation. Several compression methods have recently

been proposed which can be classified into two main types as lossless and lossy compression methods. Lossless compression can only provide limited compression ratios, and the maximum achievable order is around three times (3:1). This ratio is not a reasonable value in many practical applications, especially in remote sensing. Traditional compression algorithms for HSIs have only considered the spectral value in a feature space whose dimensions were spectral bands. HSI compression has relied mainly on the use of the Principal Component Analysis (PCA) transform to transform images in the spectral direction. Its main advantage is that it not only allows the most decorrelation possible among spectral bands, but also the best energy compaction, which in turn results in better mineral classification. On the other hand, a main disadvantage of the PCA is that the covariance matrix, which is used to decorrelate among frequency bands, has to be calculated, and therefore is data dependent. The recent JPEG2000 standard has many advantages compared to earlier compression methods such as PCA. The advantages of JPEG2000 include superior low bit rate performance, bit rate scalability and the progressive transmission by quality or resolution. The coder and the decoder for JPEG2000 use a wavelet based compression method which implements the embedded block coding with optimized truncation (EBCOT) scheme. The use of Discrete Wavelet Transform (DWT) to decompose a signal, unlike the old standard JPEG that relied on the discrete cosine transform (DCT) to approximate a signal, has proved to have numerous advantages but at the same time its picture quality was not so impressive. So looking these problems DWT-TD algorithm is proposed. It provides better picture quality in terms of high PSNR than the other compression methods.

The rest of paper is organized as follows. Section II introduces the Hyperspectral images. Then section III briefly reviews the literature survey of the compression methods. The experimental results of the proposed algorithm is provided in section IV. In the last section conclusion is extracted in section V.

2. Hyperspectral Images

HSIs are used in different practical applications such as the detection of the earth's surface, soil type analysis, agriculture and forest monitoring, environmental studies and so on. The "hyper" in the hyperspectral means "over" as in "too many" and refers to the large number of measured wavelength bands. Hence, because of the hyperspectral datasets have very large in size, making acquisition, storage and transmission of these data. For example, the Airborne Visible Infrared Imaging Spectrometer (AVIRIS) sensor acquires lines containing 614 pixels in 224 spectral bands, requiring hundreds of MBytes for storage. With spectral images the memory or the transmission requirements are very high. Observations of Earth in spatial, spectral, temporal and radiometric methods produce data volume which is growing faster than the transmission bandwidth. This means, that for long term storing or transmission, these databases should be compressed. The compression should be such that the spatial and spectral quality of the reconstructed image is high enough for the application. The

spectral correlation is generally stronger than spatial correlation. The average correlation coefficient p between two spectral bands of 3D-data cube can be measured as follows:

The Hyperspectral images contains high spectral correlation among the bands . A rough classification of the compression methods for the spectral images include the principal component analysis (PCA) for the decorrelation of the spectral data, the wavelet transform for the spatial compression of images, predictive methods applied simultaneously to the spectral and spatial dimensions of the image, and finally the vector quantization of the spectra in the image. Exploiting both of spectral and spatial correlations is the key for the success of a compression algorithm. Standard multispectral image classification techniques were generally developed to classify multispectral images into broad categories. Hyperspectral imagery provides an opportunity for more detailed image analysis. For example, using hyperspectral data, spectrally similar materials can be distinguished, and sub-pixel scale information can be extracted. To fulfill this potential, new image processing techniques have been developed. This papers considered the Hyperspectral cube and moffett field for the experiment. Hyperspectral cubes are generated from airborne sensors like the NASA's Airborne Visible/Infrared Imaging Spectro- meter (AVIRIS) of 224 channel which consist of the extension *png* and the extension of moffet field is *jpg* and then compare the results of all the techniques using different encoding methods. The results shows that the hybrid method DWT-TD using global encoding provides best results in terms of PSNR.



Fig.1: Hyperspectral cube.

3. Proposed Compression Algorithm

Exploiting both of spectral and spatial correlations is the key for the success of a compression algorithm. In this paper, a hybrid scheme based on DWT and TD for compression of HSIs is discussed. The core idea behind this technique is to apply TD on the DWT coefficients of spectral bands of HSIs. Firstly use DWT to effectively separate HSIs into different sub-images and TD to efficiently compact the energy of sub images. Some compression methods currently consider HSIs as 3D data. Those compression methods are called a third order tensor: two spatial dimensions and one spectral dimension. Then try to take into account the spatial and spectral correlation of HSIs simultaneously and not alternatively as is the case for the above techniques. One of the most popular tensor decompositions is the Tucker decomposition (TD), which has been used for the compression of HSIs. TD allows the selection of any values for each dimension of the core tensor. A tensor is a multidimensional array and the tucker decomposition decomposes a tensor into a set of matrices and one small core tensor. More formally, an N-way or Nth-order tensor is an element of the tensor product of N vector spaces, each of which has its own coordinate system.

Table 1: Notations.

Notation	Description
R^n	n-dimensional real vector space
Y	Third order tensor
$Y_{(n)}$	n-mode matricization of tensor Y
$A^{(n)}$	n-mode matrix in tucker model
$\circ$	outer product
X_n	n-mode product of a tensor by matrix

4. Steps used for compression

The tensor $\hat{Y}$ is an estimation of Y and it depends on the values of (J_1, J_2, J_3) which are the dimensions of core tensor G .

$$\begin{aligned}
 Y &= \sum_{j_1=1}^{J_1} \sum_{j_2=1}^{J_2} \sum_{j_3=1}^{J_3} g_{j_1, j_2, j_3} a_{j_1}^{(1)} \circ a_{j_2}^{(2)} \circ a_{j_3}^{(3)} + E \\
 &= G \times_1 A^{(1)} \times_2 A^{(2)} \times_3 A^{(3)} + E \\
 &= \hat{Y} + E
 \end{aligned}$$

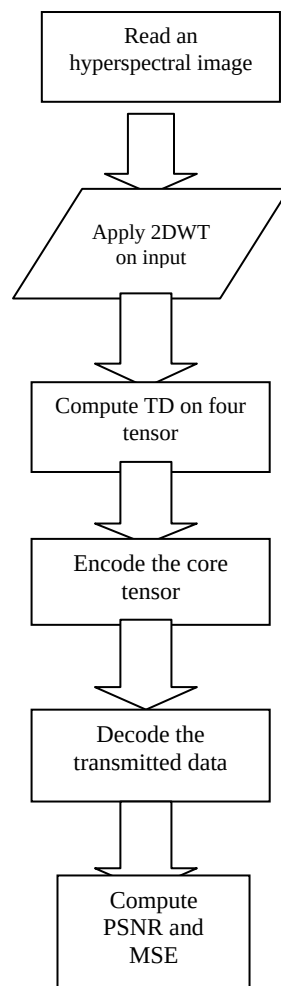


Fig. 3: Flow chart for DWT-TD compression.

5. Experimental Results

The simulation is done on MATLAB with Intel Pentium IV Processor and 4 GB RAM. To measure the perceptual quality of images, the signal-to noise ratio (SNR) can be well used. PSNR will be measure in dB. For HSIs, one measures the bit rate as the number of bits per pixel, which gives the average number of bits to represent a single sample of the hyperspectral data set.

This result is calculated at the bit rate is 0.375 *bpp*. The popular AVIRIS datasets (mofett field) is used in this experiment. First, apply the traditional algorithms to these images. Next, compare the PSNRs achieved by the algorithm using three types of encoding on a set of HSIs. The experimental results of different compression methods is shown in the table II. The performance of given methods is measure in term of their PSNR and time taken for the execution (T_{ex}) by the respective algorithms. As shown above in the table row-wise encoding has the less PSNR as compared with the other

encoding methods. Whereas DWT-TD gives a better performance for the moffett field with 57.7249 dB PSNR by using global encoding and the execution time taken by this method is also less which is about 1.1388 seconds.

Table II: Effect of encoding type on performance of compression techniques.

Encoding type	PSNR	MSE	Execution time
Row-wise	56.6991	0.1391	1.1700
Column-wise	57.1703	0.1248	1.1700
Global encoding	57.7249	0.1098	1.1388

6. Classification accuracy of Moffett field

The image is also classified by using non-linear classification method which can be implemented with the help of MATLAB. At the end, after the classification is performed on the moffett field which has 224 spectral channels, the correct rate and error rate is calculated by using 'rbf - kernel function'. The classification results of the moffett field is shown in fig4.

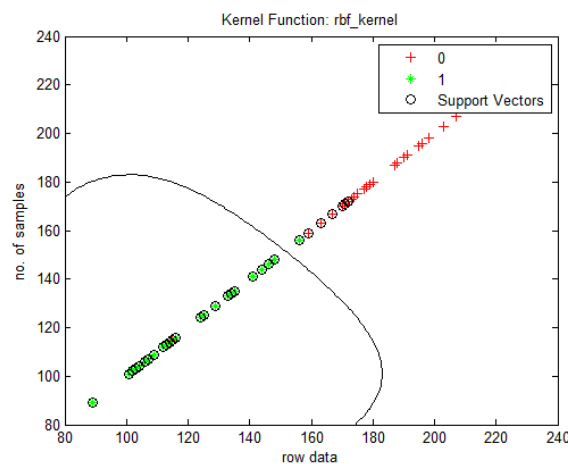


Fig.4: Classification of moffett field

7. Conclusion & Future Scope

In this paper, one technique based on (DWT-TD) using different encoding are studied for the compression of hyperspectral images. The performance of all the mentioned

method is measure on the basis of their PSNR and time taken by the respective methods for execution. The performance of (DWT-TD) using global encoding is more desirable when compared with the other methods as it provides higher PSNR and less MSE for the picture of moffett field. This is carried out by reducing the size of 3D tensors computed from four wavelet sub-images of the spectral bands of HSIs. Hence the proposed technique is best because of following reasons:

- 1) DWT-TD using global encoding achieves higher PSNR, less execution time and high compression ratio for the moffett field.
- 2) Classification of moffett field using the hybrid compression method (DWT-TD) is desirable because it provides a detailed information about the spectral bands of the image.

In future works, main aim is to lower the computational load of the proposed method i.e. to reduce the core tensor computation.

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