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HYPERSPECTRAL IMAGE COMPRESSION USING 3D SPIHT, SPECK AND BEZW ALGORITHMS

D. Muthukumar
Assistant Professor in Software Systems, Kamaraj College of Engineering and Technology, Virudhunagar, Tamilnadu

Abstract:

The hyperspectral imaging using in remote sensing. Hyperspectral images include together spectral and spatial redundancies whose exploitation is crucial for compression. In hyperspectral image compression, wavelets have shown a fine adaptability to a wide range of data. Most popular image coding algorithms challenge to transform the image data so that the transformed coefficients are largely uncorrelated. A number of wavelet-based compression methods have been successfully used for hyper spectral image data. In many applications, karhunen–loève transform (KLT) is the well-liked approach to decorrelate spectral redundancies. In this paper, an analysis of efficient compression techniques is done, with more emphasis on 3D set partitioning embedded block (SPECK), binary embedded zero tree wavelet (BEZW), and 3D set partitioning in hierarchical trees (SPIHT). In relationship with the techniques discussed, the BEZW technique has better performance, lower computational cost, high effectiveness and simplified coding algorithm.

Key Words: SPECK, BEZW, SPIHT, Transform Coding, Hyper Spectral & Wavelet Transform.

1. Introduction:

Compression of hyperspectral images has recently become a well-liked research area. Hyper spectral imagery or spectral imagery involves observing the same scene at different wavelengths. Naturally, each image pixel is represented by hundreds of values, corresponding to different wavelengths. These values match up to a sampling of the continuous spectrum emitted by the pixel. This sampling of the spectrum at very high resolution allows pixel identification (materials, minerals, gases etc.). The accessibility of the spectral information for each pixel leads to new applications in all fields that use remote sensing data (environment, military or agriculture), and can facilitate to get better the understanding of the solar system. Hyper spectral data are in a way like to video data, where wavelength corresponds to time, but their statistical properties are dissimilar: There is no motion between hyper spectral planes but changes in color. Preferably compression should be lossless to make sure preservation of the scientific value of data. Still, lossless compression techniques give compression ratios of about two or three, a limitation which is forced in the hyper spectral data due to the noise inherently present in high-resolution sensors that produce such data [2].

Lossless compression becomes an increasingly acceptable choice during the sensor selection, in which the most error between the original and decoded image is bounded to a user defined value. The Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) was innovated by the NASA Laboratory and provides spectral images with 224 adjacent bands covering the spectral ranges from 400 to 2500 nm. The exclusive high spectral resolution has been used in a broad range of scientific research such as agricultural monitoring, terrain classification and military surveillance. The hyperspectral image yields files of several gigabytes of data, which are recoded and stored onboard. Therefore, compression of the hyper spectral image is needed to facilitate storage and transmission [1]. A lot of work has been completed in the field of lossless compression of hyperspectral data, where prediction- based [3] and wavelet based techniques have been typically in work. Lossy compression has also been considered wherein the 3D transform coding move toward has largely been prevalent [4]. A transform such as the wavelet or KLT can be working in the spectral dimension, followed by spatial decorrelation. For example, the apply of the multicomponent transformation feature of JPEG 2000 part 2 has been very popular [5], [6], as well as approaches based on set partitioning. Still, while these approaches realize good performance, particularly at low bit-rates, their computational complexity is too high for onboard compression.

A variety of transform based compression techniques, which compare signal samples from the spatial/spectral domain into another space to produce helpful statistical properties. A few examples are KLT, Discrete Cosine transforms (DCT), and Discrete Fourier transforms (DFT) and Discrete Wavelet Transform (DWT). Penna *et al*. [5] compressed hyperspectral images with JPEG 2000 and investigated the performance in different transform techniques with DCT, WT, KLT and a variety of combinations. In this paper, we learn few compression techniques for lossless compression of hyperspectral images. First, we study the Said and Pearlman projected an improved version recognized as Set Partitioning in Hierarchical Trees (SPIHT) [9], [10]. SPIHT is one of the most capable wavelet-based compression algorithms and has become the benchmark for the current coders. Another wavelet-based compression, Set partitioning embedded block coding (SPECK) was introduced later to provide a less complex alternative for an embedded coder. A SPECK coder has a comparable performance to SPIHT but is faster. The partitioning rule in SPECK is block partitioning [11]. Hyper spectral images need a 3D coder that will exploit the inter-band correlation between each frame; hence, some of the popular existing 2D wavelet coders have been extended to 3D to suit these 3D image sources. Thus, Three Dimensional SPIHT and Three Dimensional SPECK came into the picture. Three Dimensional SPECK is considered to be faster and less complex. Another one of technique BEZW, which uses an asymmetric dual-tree BEZW algorithm based on KLT and DWT. Discrete wavelet transform has been generally used in image compression because of its excellent de-correlation ability. Wavelet based compression achieves rate scalability, high compression and progressive transmission [7]. These outstanding properties have been possible since the introduction of Shapiro's embedded zero tree wavelet (EZW) coder [8]. The EZW coder is based on important tree quantization that exploits the similarities between the sub band of the wavelet transform domain and the energy distribution of images through the sub band.

The Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) was developed by the NASA Jet Propulsion Laboratory in 1987 and provides spectral images with 224 adjacent bands. In our study, we used the standard AVIRIS images-Lunar Lake, Cuprite, Jasper and Low altitude to analyze various methods. The image size used was 225×225×224.

2. Various Hyberspectral Image Compression Methods:

2.1 Asymmetric Tree 3D SPIHT Compression:

The SPIHT algorithm was described by Said and Pearlman in [9]. The algorithm [1] maintains three lists of coefficients: List of Insignificant Pixels (LIP), List of Significant Pixels (LSP), and the List of Insignificant Sets (LIS). In this technique, every output is binary and the coefficient is more dependent on the data. The three-dimensional Set Partitioning in Hierarchical Trees (3D SPIHT) based on zero trees coding for hyper spectral image compression. The statistics of hyper spectral images are not symmetric along 3 different directions namely spatial-slice, spatial- horizontal and spectral-spatial directions. In the paper [18], the authors applied an asymmetric tree 3D SPIHT algorithm for hyper spectral image and the basic structure of coding system is exposed in Figure 1.

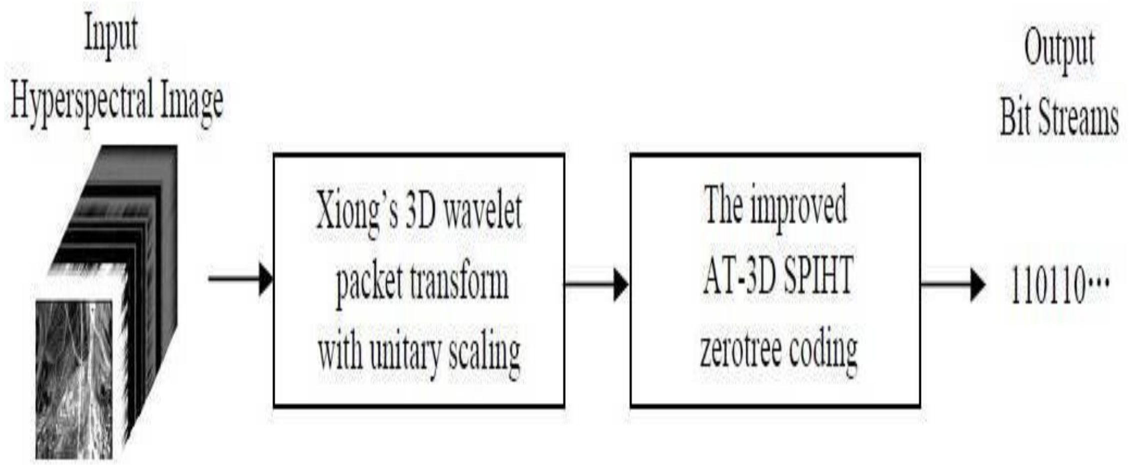

Figure 1: AT-3D SPIHT Coding System

The AT 3D SPIHT algorithm for hyper spectral image is proposed in [18]. In this algorithm, the authors constructed a more effective asymmetric 3D zero tree structure which has longer zero tree wavelet. Xiong's 3D integer wavelet packet transform (WPT) structure [19] is capable of efficiently utilizing the statistical properties to decorrelate and gaining excellent lossless coding performance for hyperspectral image. A hierarchical pyramidal structure was generated by Xiong's 3D integer WPT with Fig.3's. The improved AT-3D SPIHT the authors used the embedded zero tree partitioned bitplane coding technique to progressively encode the wavelet coefficients of each subband from the root coefficients to their descendants, until the significant coefficients are located and coded.

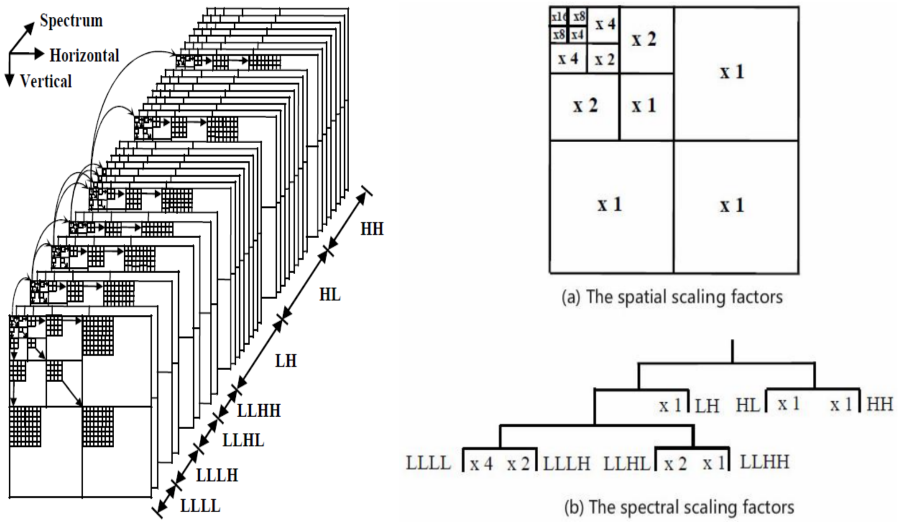

Figure 2: Xiong's 3D integer WPT structure of four spatial levels and four spectral levels.

2.2 Three Dimesnional SPECK Compression:

The three dimensional Set Partitioning Embedded block (3D SPECK) algorithm is explained in [7] is employed for lossless compression of hyperspectral image. A three dimensional discrete wavelet transform (3D DWT) can fully utilize the inter band correlation in a volumetric block. Three Dimensional SPECK maintains a block splitting algorithm to sort the significant pixels. Therefore, if a code block contains significant coefficients it splits into less significant sub-blocks. Furthermore, a hyperspectral images have energy concentration in a high frequency band, Three Dimensional SPECK is estimated to work well among these images.

3D SPECK maintains two linked lists, List of Insignificant Sets (LIS) and List of Significant Pixels (LSP). The process consists of following steps- Initialization, Sorting Pass, Refinement Pass and Quantization step. In the sorting pass, a block splitting method is adopted after a significant test. The future coder in [7] follows the basic sorting algorithm as in Three Dimensional SPECK. Inter-band dependence can be exploited automatically. To map the 3D coefficients to a 1D array, the mapping is based on a recursive *Z* curve or Morton ordering as described in [16] because this performs well at preserving the locality. The Hyperspectral images which were valued with the proposed algorithm were obtained from the AVIRIS sensors [17].

2.3 Dual Tree BEZW Compression:

This technique uses asymmetric dual-tree BEZW algorithm for compression of hyperspectral images. The algorithm has been projected in [2] and adopts KLT and DWT to achieve 3-D integer reversible hybrid transform and decorrelate spectral and spatial data. The 3-D BEZW algorithm compresses hyperspectral images by implementing progressive bitplane coding.

The KLT is a data-dependent and linear orthogonal transform whose matrix consists of the eigenvectors derivative from the covariance matrix of the data. The integer KLT is the integer approximation of KLT, which enables lossless hyperspectral image compression [12]. The authors in [2] utilized the quasi-complete pivoting suggested by Galli and Salzo [13] in the process of matrix factorization.

Later than the two integer transforms, the signs and magnitudes of coefficients are encoded separately, as shown in Fig. 1. The authors [14] showed that when performing lossless compression, arithmetic coding results in better performance for the coding of the sign bits. The future algorithm,the magnitudes of coefficients are encoded through the proposed BEZW algorithm based on the two tree structures.

The algorithm belongs to progressive bitplane coding that encodes all currently significant bits at the same bitplane together and continues encoding others for the next significant bitplane until reaching the least significant bitplane [15].

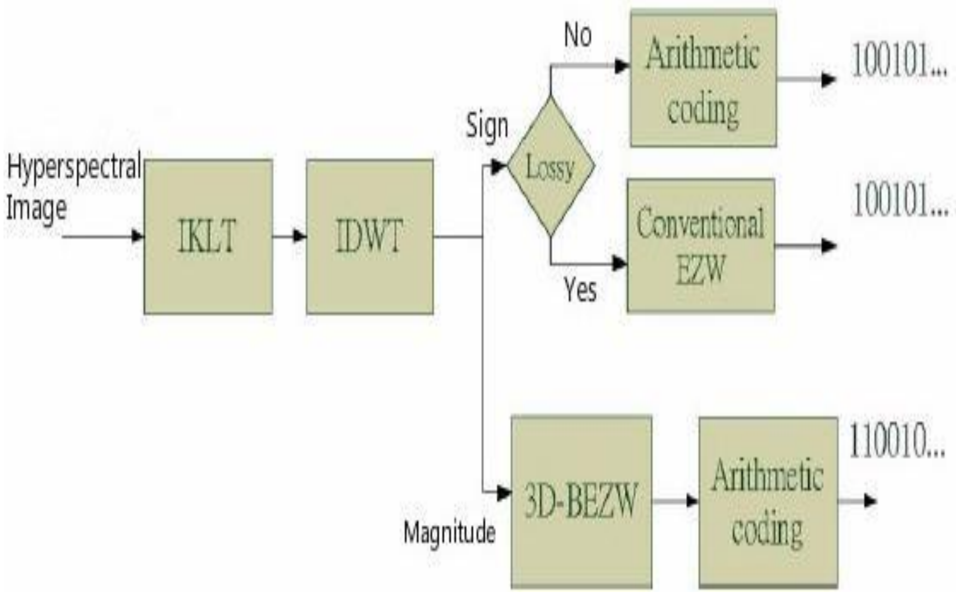

Figure 3: BEZW compression diagram

3. Results and Evaluation:

Based on the Table 1, we can see that for all the AVIRIS images, the BEZW method gives the lowest bpppb value. For Cuprite, Jasper, Lunar Lake and Low Altitude, the values of 3D-SPECK and 3D-SPIHT are nearly equal. The results for JPEG 2000 MC and AT-3D SPIHT vary a little among themselves but are almost the same. The values of all the methods are almost equal, the best result is achieved by BEZW technique. Considering the Jasper image in Table 2, we detect that for every bpppb the SNR of BEZW technique is higher than the other techniques.

Table 1: Lossless Results (in bpppb) for AVIRIS Images

Coding Methods	Cuprite	Jasper	Lunar Lake	Low Altitude
3D-SPIHT	6.80	6.72	6.05	6.61
3D-SPECK	6.73	6.70	5.96	6.38
3D-BEZW	4.76	4.82	4.88	4.90

Table 2: SNR (DB) for Corresponding bpppb for JASPER Image

Coding Methods	BITS PER PIXEL PER BAND (bpppb) for JASPER image						
	0.1	0.5	1.0	1.5	2.0	2.5	3.0
3D-SPIHT	29.07	39.42	45.14	48.91	51.6	53.83	56.03
3D-SPECK	30.11	40.13	45.50	49.25	52.18	54.27	56.39
3D-BEZW	34.15	46.59	49.21	52.60	53.51	56.01	57.97

4. Conclusion:

In this paper, three popular algorithms have been tested for an effective lossless compression of hyper spectral images. The BEZW technique presents desirable results with bpppb as low as 4.76 and SNR as high as 57.97. The computational cost is comparable with the other coding techniques. The 3D SPECK method can reduce memory usage in the coding process and can increase the coding speed efficiently but it has a complex coder. The method discussed was AT 3D-SPIHT which is a very useful technique for hyperspectral image compression. This technique adopts a more efficient 3D zerotree structure but does not provide better results than BEZW algorithm. By comparing SPIHT, SPECK and BEZW techniques, results show that, the dual tree BEZW compression technique is better than the other techniques. This method has a simple coder and the search is based on well-made tree structures. In addition, 3D BEZW compression method combines the merits of Embedded Zerotree Wavelet and set partitioning in hierarchical trees algorithms, and is computationally simpler for lossless compression.

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