Study and survey on Different Techniques of Hyper spectral Image Compression

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Abstract: *A Hyperspectral image is a sequence of image generated by collecting contiguously spaced spectral bands of data. It produces a huge amount of three-dimensional digital data that can be used to recognize objects and to classify materials on the surface of the earth. Hyperspectral image compression had received considerable interest in recent years due to enormous data volumes. In this paper, the author perspective is to perform a comparative study on different compression algorithms for hyperspectral imagery. Remote sensing images are recorded in various wavelength and spectrum, thus, transmitting them to ground with efficient compression algorithm is perplexing.*

Key Words: *Hyperspectral Images, Compression, Wavelet Transform, PCA, Tucker Decomposition.*

1. INTRODUCTION:

The “hyper” in hyperspectral means “over” as in “too many” and refers to the large number of measured wavelength bands. Hyperspectral images are spectrally over determined, which means that they provide ample spectral information to identify and distinguish spectrally unique materials. Hyperspectral imagery provides the potential for more accurate and detailed information extraction than possible with any other type of remotely sensed data [1].

Hyperspectral image uses hundreds of spectral bands for acquisition of data like 224 for AVIRIS images. It consists of series of images matched to hundreds of continuous spectral bands. This huge amount of data slows down the data transmission and computer processing speeds. Hyperspectral imaging is a powerful technique used for extracting accurate and detailed information of the surface and atmospheric contents, monitoring agriculture and forest status, military surveillance and environmental studies such as geology and pollution monitoring.

Hyperspectral sensors have both spatial and spectral resolution. The economics of transmission and storage of large volume of hyperspectral data collected by such sensors means that image compression must be a challenge. Several factors make the constraints particularly stringent and the challenge exciting. First is the size of the data: as a third dimension is added, the amount of data increases dramatically making the compression necessary at different steps of the processing chain [2]. Also different properties are required at different stages of the processing chain with variable tradeoff. Second, the differences in spatial and spectral relation between values make the more traditional 3D compression algorithms obsolete. And finally, the high expectations from the scientists using hyperspectral data require the assurance that the compression will not degrade the data quality. All these aspects are investigated in the present chapter and the different possible tradeoffs are explored. In conclusion, we see that a number of challenges remain, of which the most important is to find an easier way to qualify the different algorithm proposals.

Compression of an image is necessary as it claims the following advantages: It provides a believable cost savings involved with sending less data over the switched telephone network where the cost of the call is really usually based upon its duration. It not only reduces storage requirements but also overall execution time [3].It reduces the probability of transmission errors since fewer bits are transferred. It provides a level of security against unlawful monitoring.

Image compression is categorized into: Lossless and lossy compressions. In lossless no information is discarded, compression results from a more efficient storage of information. However, compression ratios which can be achieved with lossless techniques are limited. Wavelet Transform can notably reduce the dimensionality of hyperspectral data, while preserving high and low frequency spectral information at different decomposition scales, resulting in effective performance. In lossy, information is discarded, leading to much higher compression ratio. Despite the loss of quality in the reconstructed image, these kinds of techniques have become more popular. These methods generally have parameters that can be adjusted to move along the rate-distortion curve, reducing the bitrate increasing the distortion and vice-versa. Some compression ratios are insufficient to meet the constraint for onboard system; however, they are highly relevant for achieving the data and distortion to the end-user. A majority of compression algorithms in remote sensing are related to hyperspectral images. The Section 2 briefly reviews the literature survey of the compression methods.

2. RELATED WORKS:

Tang Xiaoli, William A. Pearlman and James Modesino, in 2003 [4] developed an embedded, block based 3D- Set Partitioned Embedded block (SPECK) image coder. This is a modified form of SPECK. Two versions of the algorithm for lossless and lossy hyper spectral image compression are implemented. Lossless algorithm is based on integer wavelet filter and lossy algorithm is based on floating point filter. The results obtained using this coder are better than three dimensional compression techniques like 3D- SPIHT, JPEG 2000- multi component.

Ramakrishna B, Antonio Plaza, Du et al., in 2006[5] proposed a hyper spectral image compression method based on the spatial and spectral correlations. This method retains all the critical spectral information while the images are compressed spatially. Two PCA based spectral/spatial compression techniques for hyper spectral images, using Inverse PCA/spatial compression and PCA/ spatial compression are reported. This method uses the concept of Virtual Dimensionality (VD) to determine the number of principal components for information preservation. The results indicate that PCA based spectral/spatial compression can be competitive as the 3D compression techniques for hyper spectral images.

In 2007, Du.Q and Fowler .J.E [6] proposed a method for hyper spectral image compression using PCA deployed in JPEG 2000 for spectral de-correlation and also compared the performance with JPEG 2000 with DWT. The results prove that the PCA+JPEG 2000 method is well suited for dimensionality reduction and provides better rate distortion performance than DWT +JPEG 2000.

In 2007, Wang.H et al [7] proposed an algorithm for lossless hyper spectral image compression using a context- match method. The spectral correlation between the spectral bands, using context match method is carried out. A context table is built up for fast context search and context match. The advantage of this method is its low complexity and low cost which is suitable for on board applications.

In 2008, Christophe. E et al [8] focused on the optimization of 3D wavelet compression of hyper spectral images using various tree structures applied in the EZW and SPIHT.The results are compared with JPEG 2000. The proposed methods are suitable for on-board processing of hyper spectral images on the space systems.

In 2008, Du. Q and Fowler .J.E [9] discussed several strategies for reducing the computational complexity of PCA transform matrix. The hyper spectral images are sub-sampled spatially before calculating the covariance matrix for eigen decomposition for PCA design. The computation of the covariance matrix is avoided in this technique by directly calculating the eigen vectors by iterative method.

In 2009, Magli. E [10] proposed a theoretical model for lossless compression algorithm that employs a Kalman filter in the prediction stage. More than one previous band is used in the prediction stage for lossless hyper spectral data employing Kalman filter. From the results, it is observed that the performance of this method is better than other prediction and transform based algorithms that employ only the previous band for prediction.

In 2010, Chang C. et al [11] proposed a low-bit rate compression problems arising in hyperspectral data by introducing a new concept of exploitation-based hyperspectral data compression where a performance criterion is actually determined by an exploitation-based application instead of an objective measure such as MSE or SNR. In other words, an effective compression performance should be determined by features of objects of interest in data exploitation rather than the data itself such as data size

In 2012, Karami.A et.al [12], developed an algorithm based on DWT and Tucker Decompositions, exploiting both the spectral and spatial information in the hyper spectral image. The results are compared with 3D- SPECK and PCA+JPEG 2000. The proposed method has higher SNR and better pixel based Support Vector Machine (SVM) classification accuracy.

In 2014, Du.Q et al [13] proposed a method for operational bitrate with the aim of preserving both the majority of information in a dataset as well as its anomalous pixels.

The performance of AR+SubPCA+JPEG2000 compression at the determined operational bitrate was Considered, observing that compression at the operational bitrate may, yield superior classification and unmixing performance than that achieved at higher bitrates. The result shows that AR+SubPCA+JPEG2000 is designed to preserve both the majority of data information as well as the anomalous pixels.

3. ARCHITECTURE FOR HYPER SPECTRAL COMPRESSION

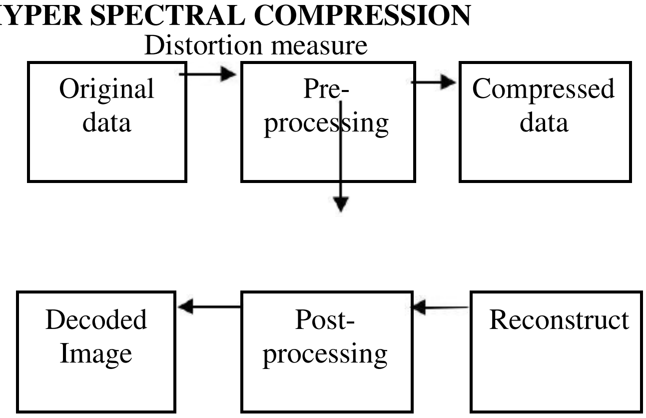

Fig 1: Architecture of hyperspectral compression system.

Table 1 – A summary of Literature survey for HSI compression

Sr.No	Reference	Technique applied	Year	Results
1	Tang Xiaoli et al	Embedded block based 3D-SPECK image coder.	2003	The result using this coder is better than Compression algorithm like 3D_SPHIT, JPEG 200.
2	Ramakrishnan B, et al	PCA and Virtual dimensionality(VD)	2006	The result indicates that PCA based spatial/spectral compression can be competitive as it retains all spectral information.
3	Du.Q and Fowler J.E.	PCA + JPEG 2000	2007	This method is well suited for dimensionality Reduction and provides better rate in distortion performance.
4	Wang H. et al	Context based conditional average	2007	The result proposes that this method is advantageous for its low complexity and low cost. It is thus suitable for on board Application.
5	Du Q and Fowler J.E.	Low complexity PCA(Principal Component Analysis)	2008	The propo scheme subsamples the image for calculating covariance for decomposition for PCA design. The covariance matrix is avoided in this technique by directly calculating the Eigen vectors
6	Magli E	Lossless compression using Kalman filer	2009	It is observed that the performance of this method is better than other prediction based algorithms
7	Chang C et al	Low-bit rate compression by exploitation based compression	2010	The result gives an effective compression performance on feature of object of interest in data exploitation rather than Data itself.
8	Karami et al.	DWT and Tucker Decomposition(TD)	2014	The proposed method exploits redundancies between bands and uses spatial correlation of every image band resulting in better compression ratio.
9	Du.Q and Fowler J.E.	PCA + JPEG 2000	2015	The proposed method offered information preservation in data set and anomaly Reduction. The performance of AR+ SubPCA + JPEG2000 achieves higher bitrates.

This architecture consists of following components: Pre-processing, Compression, Post-processing, Decoded image. Post-processing typically involves applying some simple reversible process, that can easily be communicated to decoder .It may include band reordering and normalization, Principal component analysis and pre-clustering.
The compression stage uses one of the compression techniques like transform coding, vector quantization etc. The compression stage may also require the generation of side information that is required at the encoder to reconstruct the data. The compression stage should use a suitable distortion measure to determine the effect of compression algorithm on the application of reconstructed data. The reconstruction and post-processing stage simply reverses the pre-processing and compression step so as the data can be retained in standard form for classification stage. An additional goal of compression algorithm is o be independent of the choice of classification stage.

4. APPLICATION:

Remotely sensed data for the classification and mapping of vegetation provide a detailed accurate product in a time-and cost-effective manner. The availability of satellite and airborne hyperspectral data with its increased spatial and more critically fine spectral resolution offers an enhanced potential for the classification and mapping of land use and vegetation. The need for exploring these spectral properties is particularly important for identification of specific land cover and detection of individual species, agricultural elements and military vehicles [1].

The major applications of hyper spectral imagery are:

a. Target detection
b. Material mapping
c. Material detection
d. Mapping details of surface

e. Flood detection and monitoring

In target detection investigators are generally trying to locate known target materials. This can sometimes involve distinguishing target from very similar background, or locating targets that are similar than the nominal pixel size. Hyperspectral imagery has been used to detect land and soil properties [11].The conditions and parameters is one of the major advantages of hyperspectral remote sensing technologies. Hyperspectral reflectance has been widely used to assess the quality conditions of ecosystems.

Remotely sensed data for the classification and mapping of vegetation provide a detailed accurate product in a time-and cost-effective manner. The availability of satellite and airborne hyperspectral data with its increased spatial and more critically fine spectral resolution offers an enhanced potential for the classification and mapping of land use and vegetation. Due to the large number of wavebands, image processing is able to capitalize on both the biochemical and structural properties of vegetation.

Flood detection and monitoring constrained by the ina-bility to obtain timely information of water conditions from ground measurements and airborne observations at sufficient temporal and spatial resolutions. Satellite remote sensing allows for timely investigation of areas of large regional extent and provides frequent imaging of the region of interest [15]. Moisture classes in flood plain areas in relation to high water changes, the accumulation of sediments and silts for different land-use classes and erosive impacts of floods were investigated.

5. CONCLUSION:

This paper presents survey on hyperspectral image compression techniques. It is worth observing that there are numerous compression algorithms available for compression of hyperspectral images. Which algorithm can be considered as the best one for hyper spectral Imagery? But based on case study, it is observed that some are suitable for better compression. It could be summarized that wavelet transform based provides better compression and PSNR ratio, for lossy compression of hyper spectral remote sense images.

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