Image Compression Using ASWDR and 3D-SPIHT Algorithms for Satellite Data

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ABSTRACT

Compression is the process of representing information in a compact form so as to reduce the bitrate for transmission or storage while maintaining acceptable fidelity or image quality. Algorithms for image compression based on wavelets have been developed. These algorithms have resulted in practical advances such as lossless and lossy compression, accuracy, resolution and others. We concentrate on the following methods of coding of wavelet coefficients, in this paper. ASWDR (Adaptively Scanned Wavelet Difference Reduction) algorithm and 3D-SPIHT (Set Partitioning in Hierarchical Tree) algorithm. These algorithms which achieve some of the lowest errors and highest perceptual quality.

Key words
Remote Sensing Image, Wavelet Decomposition, ASWDR, 3D-SPIHT.

I. INTRODUCTION

Remote sensing in its broadest sense is simply defined as the observation of an object from some distance. Earth observation and weather satellites, medical x-rays for bone fractures are all examples of remote sensing. Remote sensing devices make use of emitted or reflected electromagnetic radiation from the object of interest in a certain frequency domain (infrared, visible light, microwave). Remote sensors are classified as either; active sensors or passive sensors. Active sensors provide their own source of radiation to send out to an object and record the magnitude of radiation returns. Passive sensors record incoming radiation that has been scattered, observed and transmitted from the earth in transmit from its original source, the sun.

In the recent years, operators are getting much more information than ever before due to the development of image sensors. The essential development of sensors has also resulted in the augmentation of the human observer workload. To deal with these situations, there is a strong need of developing an image processing technique which integrates the information from different sensors. It greatly improves the capability of image interpretation and the reliability of image judgement which resulted in enhancing the accuracy of classification and target recognition. A number of techniques and algorithms have been proposed in the last few years for the compression of remote sensing images. The techniques and algorithms to take advantage, in various degrees, of the peculiarities of these images. The improvement of the WDR algorithm of Tian and Wells[1] and [2] referred to as ASWDR. The ASWDR algorithm aims to improve the subjective distortion measures. We shall treat three distortion measures, PSNR, MSE, Correlation which we define in the section on image quality measurements.
The Set Partitioning in Hierarchical Trees (SPIHT) algorithm [3] is one of the best wavelet based coding algorithm for remote sensing images. It is very efficiently exploits the self similarity between different levels in the wavelet pyramid and provides an embedded bit stream which support PSNR, MSE scalability. The excellent performance of SPIHT for remote sensing image makes it an attractive coding strategy. A 3D extension of SPIHT has been proposed by Kim and Pearlman in [4]. They applied 3D wavelet transform and coded the wavelet coefficients by the 3D SPIHT algorithm.

Compression is a commonly used process to reduce the amount of initial data to be stored or transmitted by a channel to a receiver. 3D SPIHT use lists (list of significant and insignificant pixels, list of insignificant sets) which grow very fast compared to list of 2D SPIHT (each pixels has eight children for the 3D version and only four in 2D). 3D SPIHT is necessary to have a wavelet decomposition output corresponding to the input of 3D SPIHT encoder. In this paper we compare the proposed work using ASWDR and 3D SPIHT algorithms.

II. METHODOLOGY

Image Compression is one of the techniques in image processing. There are various types of Algorithms and techniques are used for compressed the images. Some of the Algorithms and techniques are SPECK Algorithm, SPIHT Algorithm, ASWDR Algorithm, LZW Coding, Fractal Coding. Here the proposed work is represented the architecture as shown the fig-1.

![System Architecture](image)

III. THE 3D-SPIHT COMPRESSION

The SPIHT algorithm is a highly refined version of the EZW algorithm. It was introduced by Said and Pearlman. Some of the best results highest PSNR values for given compression ratios for a wide variety of images have been obtained with SPIHT. Consequently, it is probably the most widely used wavelet based algorithm for image compression, providing a basic standard of comparison for all subsequent algorithms. SPIHT stands for Set Partitioning in Hierarchical Trees. The term Hierarchical trees refers to the quadtrees, Set Partitioning refer to the way these quadtrees divide up, partition, the wavelet transform values at a given threshold. The SPIHT algorithm proposed in this paper solves the spatial and temporal scalability through the introduction of multiple resolutions dependent lists and a resolution dependent sorting pass. It keep important feature of the original SPIHT coder such as compression efficiency, full embeddedness, and rate scalability. The full scalability of the algorithm is achieved through the introduction multiple resolution dependent lists of the sorting stage of the algorithm. The idea of bitstream transcoding without decoding to obtain different bitstreams for various spatial and temporal resolutions and bit rates is completely supported by the algorithm.

SPIHT coding is applied on each band of the wavelet transform results to achieve compression. In order to take this fact into account, it is preferable to weight each band. As weight we use the energy

\[ E = \sqrt{\sum_{x,y} \frac{I_{\lambda}(x,y)^2}{X,Y}} \],

where \( I_{\lambda} \) is the image band at the \( \lambda \) wavelength, \( X \) and \( Y \) and its dimension,
and x and y are the position of a pixel in the band. Depending on energy band, we allocate proportional number of bits for the output of the SPIHT algorithm. The 3D approach consists in considering the whole remote sensing image as an input for full 3D decomposition. To achieve compression 3D SPIHT [5] is then applied.

The 3D SPIHT algorithm of [6] considers set of coefficients that are related through a parent offspring. In its bitplane coding process, the algorithm deals with the wavelet coefficients as either a root of an insignificant set, an individual insignificant pixel, or a significant pixel. It sorts these coefficients in three ordered lists: the list of insignificant sets (LIS), the list of insignificant pixels (LIP), and the list of significant pixels (LSP). The main concepts of the algorithm is managing these lists in order to efficiently extract insignificant sets in a hierarchical structure and identify significant coefficients which is the core of its high compression performance.

The 3D wavelet decomposition provides a multiresolution structure that consists of different spatio-temporal subbands that can be coded separately by a scalable encoder to provide various spatial and temporal scalabilities. In general by applying $N_s$ levels of 1D temporal decomposition and $N_s$ levels of 2D spatial decomposition, at most $N_s + 1$ levels of spatial resolution and $N_t + 1$ levels of temporal scalability are achievable. The total number of possible spatio-temporal resolution in this case is $\left( N_s + 1 \right) \times \left( N_t + 1 \right)$. To distinguish between different resolutions levels, we denote the lowest spatial resolution levels as level $N_s + 1$ and the lowest temporal resolution levels as $N_t + 1$. Algorithm provides full spatial and temporal scalability would encode the different resolution resolution subbands separately, allowing a transcoder or a decoder to directly access the data needed to reconstruct a desired spatial and temporal resolution.

**IV. ASWDR COMPRESSION**

One of the most recent image compression algorithms is the Adaptively Scanned Wavelet Difference Reduction (ASWDR) algorithm of Walker [7][8]. The adjective adaptively scanned refers to the fact that this algorithm modifies the scanning order used to achieve better performance. Adaptively Scanned Wavelet Difference Reduction (ASWDR) algorithm produces on embedded bit stream with region of interest capability. It is simple generalization of the compression method developed by [1] which they named as Wavelet Difference Reduction (WDR). While the WDR method employs a fixed ordering of the positions of wavelet coefficients, the ASWDR method employs a varying order which aims to adapt itself to specific image features. ASWDR algorithm aims to improve the subjective perceptual qualities of compressed images and improve the results of objective measures. The basic structure of ASWDR is the following.

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Wavelet transform image.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>Initialize scan order and threshold.</td>
</tr>
<tr>
<td>Step 3</td>
<td>Significance Pass, Encode new significant values using difference reduction.</td>
</tr>
<tr>
<td>Step 4</td>
<td>Refinement pass, Generate refinement bits for old significant values.</td>
</tr>
<tr>
<td>Step 5</td>
<td>Update scan order to search through coefficients that are more likely to be significant at half-threshold.</td>
</tr>
<tr>
<td>Step 6</td>
<td>Divide threshold by 2, repeat step 3 and 4.</td>
</tr>
</tbody>
</table>

**V. WAVELET TRANSFORMATION OF IMAGES**

Wavelets are mathematical functions that decompose data into different frequency components, and then study each component with a resolution matched to its scale. Wavelets were developed independently in the field of mathematics, quantum physics, electrical engineering, and seismic geology. Interchanges between these fields during the last ten years have led to many new wavelet applications such as image compression, turbulence, human vision, radar, and earthquake prediction. The wavelet transformation [9] is a mathematical tool for
decomposition. The wavelet transform is identical to a hierarchical sub band filtering system [10], where the sub bands are logarithmically spaced in frequency.

![Wavelet Decomposition](image)

The basic idea of the DWT for a two-dimensional image is described as follows. An image is first decomposed into four parts based on frequency sub bands, by critically sub sampling horizontal and vertical channels using sub band filters and named as Low-Low (LL), Low-High (LH), High-Low (HL), and High-High (HH) sub bands as shown in figure 2.

VI. IMAGE QUALITY MEASUREMENTS

A. Mean Square Error (MSE)

The simplest of image quality measurement is Mean Square Error (MSE). The large value of MSE means that image is poor quality [11]. MSE is defined as follow:

\[
MSE = \frac{1}{MN} \sum_{m=1}^{M} \sum_{n=1}^{N} (x(m,n) - \overline{x}(m,n))^2
\]

B. Peak Signal to Noise Ratio (PSNR)

The small value of Peak Signal to Noise Ratio (PSNR) means that image is poor quality. In general, a good reconstructed image is one with low MSE and high PSNR [11]. PSNR is defined as follow:

\[
PSNR = 10 \log_{10} \frac{255^2}{MSE}
\]

C. Correlation

Correlation coefficient quantifies the closeness between two images. The correlation coefficient is computed by using the following equation [12].

\[
Corr\left(\frac{A}{B}\right) = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} (A_{i,j} - \overline{A}) (B_{i,j} - \overline{B})}{\sqrt{\sum_{i=1}^{M} \sum_{j=1}^{N} (A_{i,j} - \overline{A})^2} \sqrt{\sum_{i=1}^{M} \sum_{j=1}^{N} (B_{i,j} - \overline{B})^2}}
\]

A correlation is a number between -1 and +1 that measures the degree of association between two variables (call them X and Y). A positive value for the correlation implies a positive association (large values of X tend to be associated with large values of Y and small values of X tend to be associated with small values of Y). A negative value for the correlation implies a negative or inverse association (large values of X tend to be associated with small values of Y and vice versa).

VII. DATASET DESCRIPTION

Remote sensing image is defined as an image produced by a recording device that is not in physical or intimate contact with the object under study. Remote sensing image is used to obtained information about a target or an area or phenomenon through the analysis of certain information which is obtain by the remote sensing imagery generally require correction of undesirable sensor characteristics and other disturbing effects before performing data analysis. Images obtained by satellite are useful in many environmental applications such as tracking of earth resources, geographical mapping, prediction of agriculture crops, urban growth, weather, flood and fire control etc. When capturing image using sensors, the resulting image may contain Noise from dirtiness on the image data acquisition process. So in this paper, we have analysed a remote sensing image. It is downloaded from Google sites.

VIII. RESULTS

The fig-3 shows the experimental results of the proposed work. The test image is taken as Input image. It has very high frequency components, so the ASWDR and 3D-SPIHT algorithm is used to compress the Image. Both of the Algorithms compress the image. When compared to the ASWDR, 3D-SPIHT produces better compression when compared to ASWDR algorithm which is shown in fig-3. This shows that the 3D-SPIHT Algorithm has shown good efficiency for image compression. The proposed work is done using MATLAB. 2010 version.
Fig 3: Compression of ASWDR and 3D-SPIHT

<table>
<thead>
<tr>
<th>IMAGES</th>
<th>PSNR</th>
<th>MSE</th>
<th>CORRELATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image1</td>
<td>31.5316</td>
<td>45.7007</td>
<td>0.9812</td>
</tr>
<tr>
<td>Image2</td>
<td>31.1684</td>
<td>49.6864</td>
<td>0.9906</td>
</tr>
<tr>
<td>Image3</td>
<td>29.7595</td>
<td>68.7274</td>
<td>0.9700</td>
</tr>
<tr>
<td>Image4</td>
<td>32.0921</td>
<td>40.1675</td>
<td>0.9903</td>
</tr>
<tr>
<td>Image5</td>
<td>30.0326</td>
<td>64.5394</td>
<td>0.9544</td>
</tr>
</tbody>
</table>
Table 1: Results of PSNR, MSE, CORRELATION Value for ASWDR Algorithm

<table>
<thead>
<tr>
<th>IMAGES</th>
<th>PSNR</th>
<th>MSE</th>
<th>CORRELATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image1</td>
<td>34.8830</td>
<td>21.1242</td>
<td>0.9909</td>
</tr>
<tr>
<td>Image2</td>
<td>32.0620</td>
<td>40.4464</td>
<td>0.9963</td>
</tr>
<tr>
<td>Image3</td>
<td>33.5381</td>
<td>28.7919</td>
<td>0.9938</td>
</tr>
<tr>
<td>Image4</td>
<td>33.3305</td>
<td>30.2015</td>
<td>0.9930</td>
</tr>
<tr>
<td>Image5</td>
<td>31.8227</td>
<td>42.7380</td>
<td>0.9949</td>
</tr>
</tbody>
</table>

Table 2: Results of PSNR, MSE, CORRELATION Value for 3D-SPIHT Algorithm

IX. CONCLUSION

In this paper, we compared ASWDR algorithm 3D-SPIHT algorithm for the compression of remote sensing images. The interesting features of the original 3D-SPIHT algorithm such as high compression efficiency, embeddedness and very fine granularity of the bitstream are kept. Our experiment shows as 3D-SPIHT algorithm seems to be preferable for compression than ASWDR algorithm because of its quality of image. Results show that 3D-SPIHT Algorithm maintaining the full embeddedness required by colour image compression and gives better performance in terms of the PSNR and compression ratio than the ASWDR algorithm.

X. REFERENCES


