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Efficient Low Bit Rate Lossy and Lossless Mix Coding of Three-Dimensional Images Using ROI with Size Reduction -A Novel Compound Approach Overview

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Abstract:- In this paper ,we present an overview of the implementation of navel compound algorithm for efficient low bit rate lossy and ROI lossless Mix Coding of massive three dimensional images. Moreover the compound algorithm can be used for multitasking Remote Sensing field operations and efficient 3-D image transmission applications such as overall image viewing at low bit rate lossy coding , nearly lossless ROI coding of most desired target area as well as efficient low memory storage or transmission/network transfer of such 3-D images with volume reduction technique.

In the navel compound algorithm, a modification to the conventional 3D-SPIHT algorithm is implemented with 3-D IWT, lossless ROI Coding and observer pre decide image size reduction using Volumetric Interpolation. Comparison to conventional 3-D SPIHT with DWT, the compound algorithm results interpret high PSNR at low bit rate coding and efficient and better perceptive effects in the ROI coded images.

Key-words:- Compound algorithm, Remote sensing (3-D)images, Volumetric interpolation,3-D IWT, lossy and lossless mix coding, modified 3-D SPIHT, (intelligent) network transfer, low bit rate coding ,ROI coding.

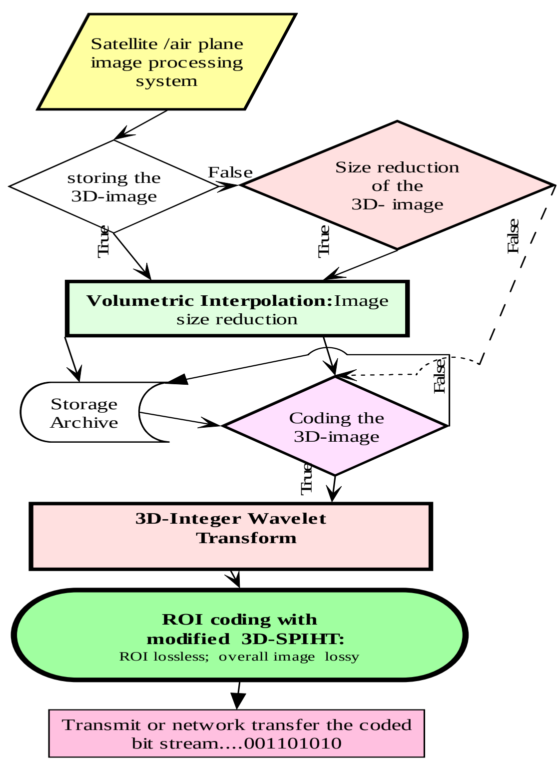
1 Introduction

Three dimensional (3-D) images obtain from airborne Remote Sensors at Satellite/airplane image processing systems are extensively used in the fields such as Defense; target detection,Geo science; mineral explorations, Meteorology, Surveying etc. Such images need nearly lossless reconstruction in efficient manner. Efficiency for such images basically mean;

1.Initially the end user (for example defense expert) would be able to select the Region Of Interest (ROI) or the best positioning of the target image with low bit rate coding, thus be able to reconstruct most significant ROI in nearly lossless manner in less time.

2.Whatever the size of 3-D image, it must be able to reversibly decompose or compress at the earth image processing stations and should be able to transfer over a network within minimum period of time. 3.Such 3-D images with large volumes and quantity should be able to store in local storage archive in highly compressed form using minimal hardware requirements.

Fig.1 Block diagram of the compound algorithm.→



In this paper, we give an overview for a novel compound algorithm to achieve all the above themes in a common platform.

In the image compression research literature it is difficult to find this type of compound algorithmic approach which use **volumetric interpolation,3-D Integer Wavelet Transform(IWT) and modified 3-D SPIHT with lossless ROI coding** to achieve all the above three necessities in one solution.

According to volume, demand and the application of the 3-D-image, the relevant path and the related set of algorithms can be chosen as given in the Fig.1 block diagram, shown in page one(1).

Further more, we propose this *compound algorithm* to be adopted in a remote sensing *information gathering intelligent network* deal with the protection of our word from extra terrestrial colliding objects or such network deal with inter world defense activities. In such responsible applications, *information gathering intelligent network* equipped with our *compound (coding) algorithm* used by defense expert observers, will play a crucial role. Initially, the experts can specify the urgency and desired ROI of the 3-D image. Then, the intelligent network will decide the coding path and give priority commands either to immediately reconstruct a clear view of the ROI at the observation station or to efficiently store the 3-D image to be processed later.

This paper is divided in to six (6) sections:1.Gives the introduction.2.Deals with the volumetric image interpolation. Reversible 3-D Integer Wavelet Transform (IWT) explained in 3. 4.Gives overview of the implementation of ROI coding with modified 3-D SPIHT.The experimental and results detailed in 5. Section 6 is for conclusions.

2 Volumetric Image Interpolation

When coding larger size 3-D images, this process is used to resize the image before ROI decomposition;

As shown in Fig.2.We use the finite B-spline kernel equation (1)[1,2]. $e(s)$ is the computed B-spline coefficient for processing image I(z).

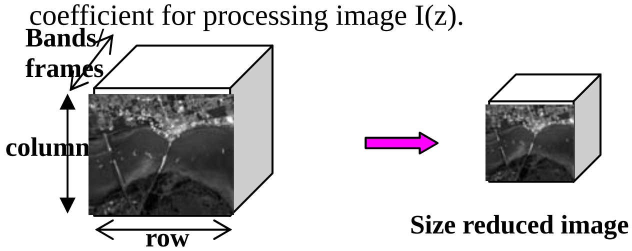


Fig.2 Size reduction before coding

$$I(z) = \sum_{s} e(s)\alpha^{s}(z-s) \quad \text{.......................(1)}$$

$\alpha^{s}(z)$ is box function with *(s+1)* fold convolution and denotes the B-spline of degree *s*. B-spline coefficient $e(s)$ is calculated using casual and anti casual filters [1,2].For the three dimensional box function $e(s) \neq I(z)$. For degree of 3, $\alpha^{s}(z)$ is called cubic spline kernel, it can be easily implemented for better quality large 3-D images.

$$\begin{aligned} \alpha^{3}(z) &= 2/3 - |z|^{2} + |z|^{3}/2 && 0 \le |z| \le 1 \\ &= (2-|z|)^{3}/6 && 1 \le |z| \le 2 \\ &= 0 && \text{otherwise} \quad \text{.... ....(2)} \end{aligned}$$

The interpolation is performed along row, column and band/frame directions separately using 3-one dimensional interpolations. The interpolated value is calculated using four adjacent B-spline coefficients using the equation (3);

$$f = e_{0}\alpha^{s}(1+d) + e_{1}\alpha^{3}(d) + e_{2}\alpha^{3}(1-d) + e_{3}\alpha^{3}(2-d) \text{.....(3)}$$

3 Reversible 3-D Integer Wavelet Transform

The use of Reversible IWT for the 3-D image compression has two sound advantages over Discreet Wavelet Transform(DWT) [2].Firstly, with the use of Lifting Scheme(LS) by W.Sweldens, reversible IWT is less complex and can be used to reconstruct almost lossless images. This circumstance is ideal for our works. Secondly, the use of integers for coefficients in IWT, reduce memory demand of the compression algorithm, instead the use of DWT with decimal numbers.The decomposition procedure of the lifting scheme consists of three common steps as illustrated in Fig.3.

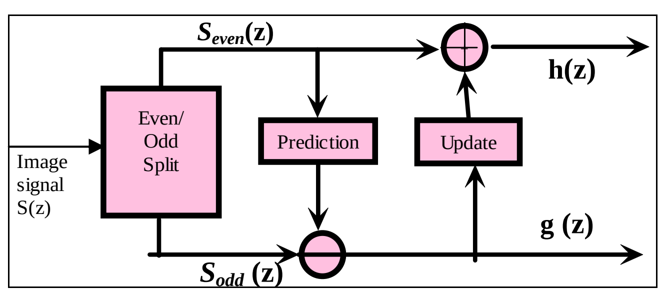


Fig.3 The decomposition procedure of the lifting scheme.

Firstly, the input image signal split in to two signals corresponding to even and odd indexed samples. Secondly, followed by *lifting step*, one signal is convolved with a lifting filter and added to the other one. The role of two signals is then reversed and further lifting steps can be applied.

In general , the lifting steps using low-pass signal are called *prediction steps* (P) and steps using high pass signals are called *update steps.*

In the 3-D-IWT; separable wavelet decomposition is performed using the same wavelet filters used in 1-D case. This is done by first performing 2-D dyadic wavelet decomposition on each band/frame of the 3-D image and then performing the decomposition of wavelet packets along the wavelength axis.[3]

Also the lifting based memory constrained 1-D temporal transform scheme is employed in this work as it is impractical to buffer large number of bands/frames present in such 3-D image using the conventional temporal wavelet transform.

In the lifting steps for every filter bank decomposition, assuming the use of less memory consume short filter ; the Daubechies 9/7 biorthogonal filter,its dual polyphase matrix ;*p*(z) has the form;

$$p(z)=\begin{bmatrix}1 & \alpha(1+z^{-1})\\ 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0\\ \beta(1+z) & 1\end{bmatrix}\begin{bmatrix}1 & \gamma(1+z^{-1})\\ 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0\\ \delta(1+z) & 1\end{bmatrix}\begin{bmatrix}\varsigma & 0\\ 0 & 1/\delta\end{bmatrix} \quad \ldots\ldots(6)$$

; $\alpha=-1.5861, \beta=-0.05298, \gamma=0.8829, \delta=0.4435, \varsigma=1.1496$ are the lifting factors[3].

The co-relation among neighboring image bands /frames in the 3-D image were efficiently found using the same 2-D transform to each image band/frame and then performing the third dimensional wavelet packet transformation[3].

4 ROI Coding With Modified 3-D-SPIHT

The promising advantage of SPIHT algorithm for our work is that it employs the Successive Approximation Quantization(SAQ) which improves the image quality as more bits are added. We can obtain the desired ROI of 3-D image with better quality after initially observing the whole 3-D image details in glance with low bit rate.

Recalling from the ideas of [4] for SPIHT, the following notation of set of descendent labels is introduced to handle the accumulation of wavelet coefficients from the various sections within the spatial orientation tree structure; equation(7).

$$\Gamma(s)=\bigcup_{k\in O(s)}\{c(s)\cup\Gamma(s)\} \quad \ldots\ldots\ldots\ldots(7)$$

In (7), $O(s)$ represents the children or offspring (descendant) nodes spreading from parent node,as shown in Fig. 4[4].

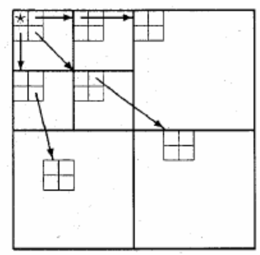


Fig. 4, Parent –Offspring relationship in spatial orientation structure of SPHIT.

In SPIHT algorithm, the List of Insignificant Pixels (LIP) and the List of Insignificant Sets(LIS) are initialized by using the set of wavelet coefficients within the lowest resolution subband, denoted by *H.*

The modified form of 3-D SPHIT algorithm called Asymmetric (Unbalanced)Tree (AT) 3-D SPHIT is employed in our work. It is considered as one of the best compression method for remote sensing 3-D images, among the other 2 are 3-D SPECK and JPEG 2000 with 3-D transform [7]. Also its asymmetric tree allows decoupling of levels of spatial and axial decomposition which is a convenient feature for 3-D-remote sensing image ROI coding

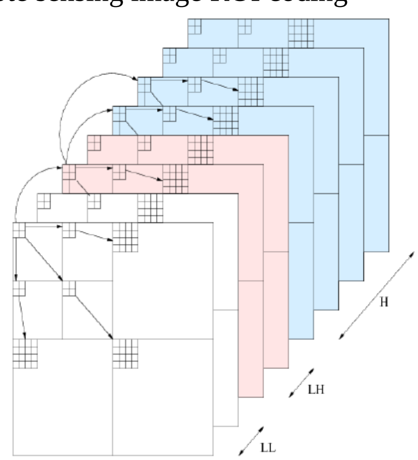


Fig. 5 AT 3-D SPIHT[7].

Similar to two dimensional SPHIT, after the computation of 3-D IWT/DWT coefficients, the Spatial-Wavelength axis(temporal) trees are constructed. These coefficient trees are categorized as follows; 1.All nodes in the tree are inside the wavelet domain ROI and they belongs to ROI.

2. All nodes in the tree are outside ROI and contain no information about ROI.3.Some nodes in the tree are inside the ROI while some are out side ROI.

For the third type, if a coefficient in the tree is outside ROI, all of its descendent (children) coefficients are also outside ROI; then the branch from this coefficient is pruned from the ROI coefficient tree. Also it can have the case called *pseudo-parent*; in which the descendent coefficient is inside ROI and its parent coefficient is outside ROI,then the descendent coefficient is disconnected from its pseudo–parent. Then a searching process within the subband of the coefficient's parent is performed to find a new parent within ROI. If new parent is found, it is called *real-parent*, then the descendent coefficient is connected to its real–parent. Now there are only two kind of coefficients are remaining after the reconnection; one with all coefficients in the tree inside ROI, the other with coefficients outside the ROI. Now, unlike in conventional 3-D SPHIT, the coefficient trees are not balanced.The creation of asymmetric coefficient trees with ROI coding is done by Fig.6 algorithm.

1) For each coefficient (i, j, k) in 3-D subband pyramid do.
  1.1) If (i,j,k) is outside ROI, then
    1.1.1) If all descendants of (i,j,k) are outside ROI, then
      * prune the (i,j,k) branch
  1.2) If (i,j,k) is inside ROI, then
    1.2.1) If parent of (i,j,k) is outside ROI, then
      * disconnect (i,j,k) from its parent and look for real parent within the neighbors of its parent
    1.2.2) If real parent is found ,then
      * connect (i,j,k) to its real parent
    1.2.3) else
      * add (i,j,k) to no parent list

Fig.6 Algorithm

Therefore in AT 3-D SPHIT with ROI coding algorithm, new structure is applied, access to the descendents of a coefficient should be modified along the asymmetric trees. To collect the isolated coefficients without having parents in the lowest resolution subband, the data structure list name List of No Parent (LNP)is used.

ROI are placed in List of Insignificant Pixels(LIP) or List of Insignificant Sets(LIS). The coefficients in LNP are also appended to LIP or LIS.

When this modified SPHIT algorithm is initialized, those coefficients in the lowest subband but outside ROI are skip out.

In order to add lossless ROI coding in the modified 3-D SPIHT, three main points have to be considered. Firstly, the implementation of lossless ROI mask; for this it is necessary to select indispensable wavelet transform coefficients to reconstruct ROI in lossless manner. Secondly, the way to assign greater importance to these selected coefficients. Thirdly, the way to specify the 3-D ROI without adding significant coding overhead.

ROI is first implemented in image domain. Thereafter represent in terms of coefficients of the wavelet decomposition which is encoded and later decoded. ROI coding in the modified 3-D SPHIT employs shape adoptive DWT/IWT for wavelet decomposition of an image containing ROI. The coding algorithm needs to keep track of the location of wavelet coefficients according to the shape of the ROI. The 3-D bitmap mask is maintained at encoder indicating the coefficients that effect on the ROI[5,1] and it undergoes a similar transformation to that of the forward wavelet transform of the image[5].

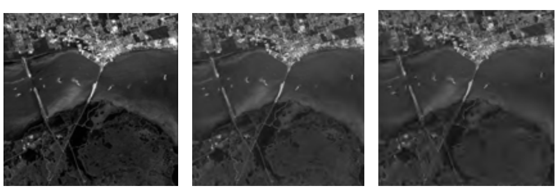
Based on the region of support of the synthesis filters, the coefficients that will be necessary at the decoder for perfect reconstruction of ROI at the current level will be selected after consulting the inverse wavelet transform. Moreover to the spatial X and Y direction expansion of ROI mask in 2D-case, the wavelength axis direction expansion is also performed for the 3-D image.At each bit plane, the algorithm checks for the significant coefficients in all the bit planes and hence only code ROI coefficients above the current threshold. At the decoder end, in order to reconstruct the mask and to carry out ROI scaling, the two important information have to be received- The number of shifts applied to the ROI(the speed of reconstruction) and the description of ROI. Furthermore, for the compound algorithm, size reduction of 3-D image through volumetric interpolation, the third information; enlarging (;the decoded 3-D image need resizing) also has to be sent to decoder. To improve the coding performance of the algorithm concerned, all three information have to be kept compact without adding significant overhead to final encoded bit stream. Regular shape Cubic ROI of the 3-D image was specified and implemented without adding significant overhead to the bit stream.

5 Experiments and Results

Remote Sensing 3-D image(40 spectral bands with each band has 512×512 resolution obtained for defense applications) of a harbor based town area was used to perform the coding experiment. The size reduction path procedures of proposed algorithm were also performed on the image.

For (nearly) lossless 3-D ROI coding , sub region ROI mask of 256×256 spatial resolution and 16 bands/frames were selected.Fig.6(b),(c) convince slightly better performance of compound algorithm.

For this image, each pixel has 16 bit depth,1bpp indicate 1bit per pixel for each band with compression rate of 1/16 bpp. This fact was considered for the overall image PSNR calculations. The PSNR values for Lossy Coding were compared with conventional 3-D SPIHT.The overall image PSNR curves shown in Fig.7 interpret better performance of the proposed algorithm at low bit rates.



(a) (b) (c)

Fig.6 ROI (nearly)lossless coding: 256×256 resolution (a)original,(b)using proposed algorithm, (c)using conventional 3-D SPIHT (b) and (c) reconstructed at 0.02 bpp for 1st frame.

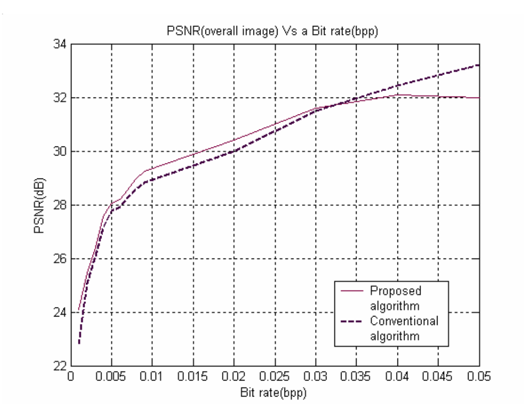


Fig.7 Overall image PSNR curves(lossy coding) for hyperspectral image of harbor based town area.

6 Conclusions

The proposed novel compound algorithm performed with the volume size reduction of massive remote sensing 3-D images, excel almost most of the conditions and necessities for initial overall image viewing under low bit rate coding, efficient ROI coding of 3-D images also the efficient storage of them in a less memory space or the coded image transmission/network transfer requirements suitable for *intelligent network* environment in time saving manner.

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