EFFICIENT VOLUMETRIC MEDICAL IMAGE COMPRESSION USING WAVELET TRANSFORM WITH SPIHT ALGORITHM

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Abstract:-- This paper focuses on volumetric medical image compression that operates on three-dimensional (3D) reversible wavelet transform methods. We offer an application of the Set Partitioning in Hierarchical Trees (SPIHT) algorithm to volumetric medical images, using a wavelet image transform and a 3D spatial dependence tree. The wavelet image transform consists of techniques to eliminate computation of certain high-pass coefficients as they are represented by small integer values. Because of the numerical distribution of the high pass coefficients and the effect of the quantization step on small valued coefficients, we can eliminate the high pass coefficients to be zeros and incur minimal image quality loss. This will reduce the computation time for compression of an image. The important properties of the wavelet filter include good localization and symmetric properties, which allow for simple edge treatment, high-speed computation and high quality compressed image.

The volumetric medical images are three-dimensional image data sets and can be considered as a sequence of 2D images, or slices. The slices are generally highly correlated with one another, so a transform is used to decorrelate the data and to improve performance of compression efficiency. The most widespread approach for the compression of 3D images combines a three-dimensional decorrelating transform with the extension of a coding algorithm that has proved to be effective on 2D images. The 3D SPIHT coding algorithm developed in this project allows progressive data transmission functionality apart from providing the other advantages such as minimizing computation time and improves the compression ratio and PSNR.

***Index Terms* – 3-D SPIHT, Volumetric data, Wavelet transform, Medical Image compression.**

I. INTRODUCTION

Medical images are widely used in disease diagnosis. The increasing use of three-dimensional imaging modalities like, Computerized Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (US) and Positron Emission Tomography (PET), triggers the need for efficient techniques to transport and store the related volumetric data. These modalities provide flexible means for viewing anatomical cross sections and physiological states and may reduce patient radiation doses. However the medical images have large storage requirement. Due to the limit of network bandwidth and storage capacity, the images must be compressed before being transmitted and stored. Therefore the image compression techniques are needed to reduce space and time for storage and transmission.

In this presentation, the wavelet image transform which consists of techniques to eliminate computation of high pass coefficients of an image has been utilized. The use of this algorithm will minimize the computation needed to compress an image.

In this paper, we report an extension of 2D SPIHT[1] (Set Partitioning in Hierarchical Trees) to 3D that exploits the inter-slice dependence through a 3D wavelet transform and coding along 3D spatial trees. The SPIHT algorithm can be stopped at any compressed file size or let run until nearly better reconstruction is obtained, which is desirable in many applications.

The paper is organized as follows. Wavelet Transform Overview is covered in Section II, we review image compression technique based on wavelet transform for still images. The proposed 3-D wavelet transform coding are presented in Section III. The section IV is devoted to Embedded coding of Wavelet Coefficients, and in particular its application to wavelet coding of volumetric medical data. Experimental results are given in Section V, and conclusions drawn in Section VI.

II.WAVELET TRANSFORM OVERVIEW

The wavelet-based transform uses a 1-D subband decomposition process in which a 1-D set of sample is converted into the low-pass subband (Li) and high-pass subband (Hi). The low-pass subband represents a downsampled low-resolution version of the original image. The high-pass subband represents residual information of the original image. In 2-D subband decomposition, the entire process is carried out by executing a 1-D subband decomposition twice, first in one direction (horizontal), then in the orthogonal (vertical) direction. For example, the low-pass subband (Li) resulting from the horizontal direction is further decomposed in the vertical direction, leading to LLi and LHi subbands. Similarly, the highpass subband (Hi) is further decomposed into HLi and HHi. After one level of transform, the image can be further decomposed by applying the 2-D subband decomposition to the existing LLi subband. This iterative process results in multiple “transform levels”. We refer to the subband LLi as a low-resolution subband and high-pass subbands LHi, HLi, HHi as horizontal, vertical, and diagonal subband respectively since they represent the horizontal, vertical, and diagonal residual information of the original image.

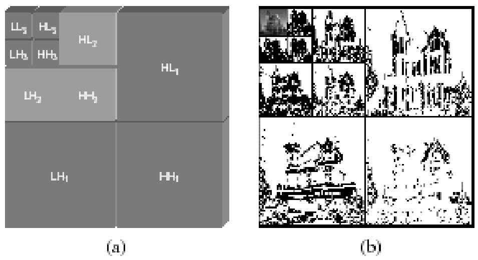


Fig. 1. (a) The process of 2-D wavelet transform applied through three transform levels (b) Demonstration using image *CASTLE[4]*

An example of three-level decomposition into subbands of the image *CASTLE* is illustrated in Fig. 1.

III. THREE-DIMENSIONAL WAVELET TRANSFORM

The 3D wavelet-based transform supports heterogeneous selection of filter types and a different amount of decomposition levels for each spatial directions (x, y or z directions). This allows for adapting the size of the wavelet pyramid in each spatial direction when the spatial resolution is limited. The elimination of high pass components by 3D wavelet transform algorithm reduces the computation time (by reducing the number of arithmetic operations and memory accesses) and communication energy (by reducing the number of transmitted bits). The numerical distribution of the high-pass coefficients for successive levels of decomposition permits elimination of large number of samples from consideration in the image compression process. Fig. 2 illustrates the distribution of high-pass coefficients after applying a 2 level wavelet transform to the 512×512 Lena image sample. We observe that the high-pass coefficients are generally represented by small integer values. For example, 80 % of the high-pass coefficients for level 1 are less than 5.[4] Because of the numerical distribution of the high-pass coefficients and the effect of the quantization step on small valued coefficients, we can estimate the high-pass coefficients to be zeros (and hence avoid computing them) and incur minimal image quality loss.

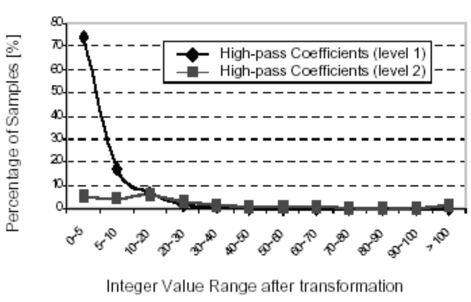


Fig. 2. Numerical distribution of high-pass coefficients after wavelet transform through level 2.

The wavelet filter used for a transform has good localization and symmetric properties, which allow for simple edge treatment, high speed computation and high quality compressed image. This filter consists of binary shifter and integer adder units rather than multiplier/divider units.

The wavelet filters are used in all three dimensions to perform separable wavelet decomposition. The 2-D spatial transform and temporal transform (along image slices) are done separately for each image slices. Experiments show better compression results with separable wavelet decomposition. If the data is of size N1 by N2 by N3, then after applying the 1D analysis filter bank to the first dimension we have two subband data sets, each of size N1/2 by N2 by N3. After applying the 1D analysis filter bank to the second dimension we have four subband data sets, each of size N1/2 by N2/2 by N3. Applying the 1D analysis filter bank to the third dimension gives eight subband data sets, each of size N1/2 by N2/2 by N3/2. This is illustrated in the diagram below.

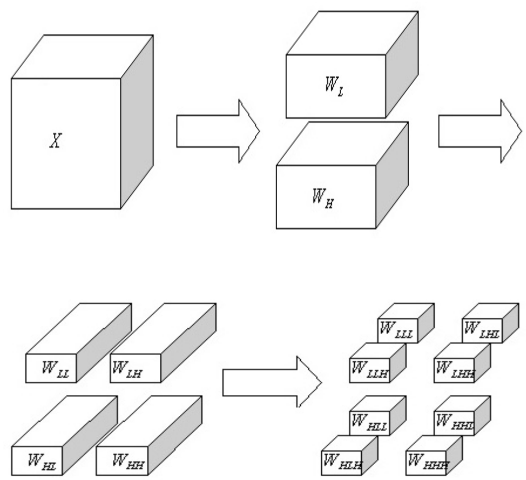


Fig. 4. The 3-D signal is reduced in each dimension.

VI. EMBEDDED CODING OF WAVELET COEFFICIENTS

The SPIHT algorithm is used for quantization and coding of the wavelet coefficients. SPIHT is a high performance coder with the property of producing embedded bit-streams[2]. The SPIHT consists of two passes, the ordering pass and the refinement pass. In the ordering pass SPIHT attempts to order the coefficients according to their magnitude. In the refinement pass the quantization of coefficients is refined. The ordering and refining is made relative to a threshold. The threshold is appropriately initialized and then continuously made smaller with each round of the algorithm.

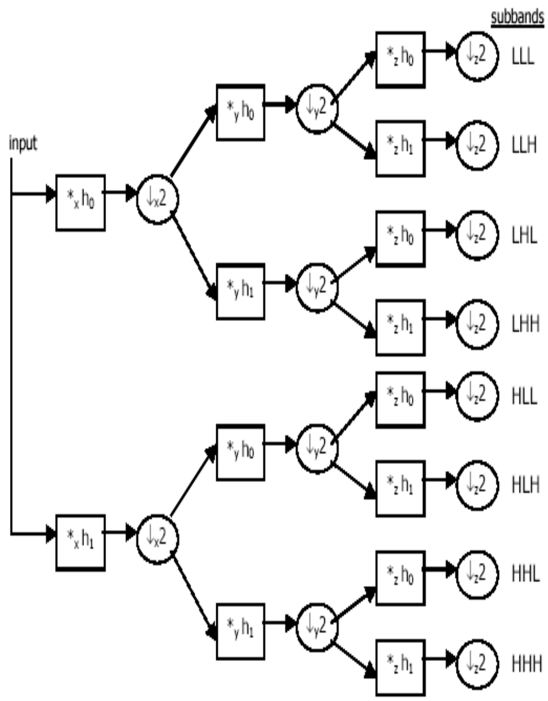
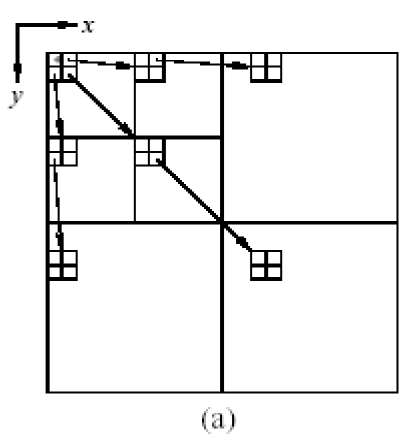


Fig. 5 Block diagram of a single level decomposition for the 3D DWT

The 2-D SPIHT algorithm views wavelet coefficients as a collection of spatial orientation trees, with each tree consisting of coefficients from all subbands that correspond to the same spatial location in an image. It uses multipass "zerotree" coding to transmit the largest wavelet coefficients (in magnitude) first. A set of tree coefficients is significant if the largest coefficient magnitude in the set is greater than or equal to a certain threshold (e.g., a power of two); otherwise, it is insignificant. Similarly, a coefficient is significant if its magnitude is greater than or equal to the threshold, otherwise, it is insignificant. In each pass the significance of a larger set in the tree is tested first: if the set is insignificant, a binary "zerotree" bit is used to set all coefficients in the set to zero; otherwise, the set is partitioned into subsets (or child sets) for further significance tests. After all coefficients are tested in one pass, the threshold is halved before the next pass.



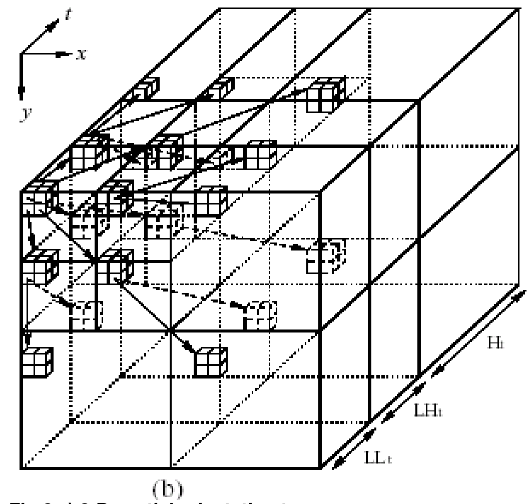


Fig 6 a) 2-D spatial orientation tree
b) 3-D spatio-temporal orientation tree

The main assumption of SPIHT coding is that most images can be modeled as having decaying power spectral density[3]. It means if parent node in the wavelet coefficient tree is insignificant then its descendents are also insignificant. The Zero tree symbol is used very efficiently in this case to signify a spatial subtree of zeros.

When the thresholds are powers of two, SPIHT coding can be thought of as a bit plane coding scheme. It encodes one bit coding in the wavelet domain using three lists. The list of significant pixels (LSP); the list of insignificant pixels (LIP); and the list of insignificant sets(LIS). Besides motion compensation, the 3-D SPIHT algorithm is in principle the same as 2-D SPIHT, except that 3-D wavelet coefficients are treated as a collection of 3-D spatio-temporal orientation trees Fig. 6(b).The parent- children relation-ship to three dimensions as parent =(x,y,z)
Children=[(2x+2y+2z),(2x+1,2y,2z),(2x,2y,2z+1),(2x,2y+1,2z)(2x+1,2y+1,2z),(2x+1,2y2z+1),(2x,2y+1,2z+1),(2x+1,2y+1,2z+1)]

To increase the coding efficiency of 3-D SPIHT, each node in the spatial-temporal orientation tree represents a group of 2 x 2 x 2 wavelet coefficients. Since the amount of information to be coded depends on the number of significant pixels in each node, we use different context models, each with 2^m symbols, where $m \in \{1,2,3,4,5,6,7,8\}$, to code the information in a group of 8 pixels.

By using different contexts for the different number of significant pixels, each context model contains better estimates of the probabilities conditioned on the fact that a certain number of adjacent pixels are significant or insignificant. The implementation of this paper contains the non-expansive symmetric transform and the implementation of the SPIHT algorithm. The entire algorithm was implemented and tested in Matlab 6.5.

V.EXPERIMENTAL RESULTS

The compression performance of the proposed coders was evaluated on a set of volumetric data of MRI (128 x 128 x 8). First the data were compressed with the existing coder and the same data were compressed with proposed new coding algorithm. The result shows that our new coder improves the compression by 28% on average. This results suggest that the three dimensional approach to compress
the volumetric medical images should be used to exploit their inter-slice dependences. The fig7.shows the visual results of the encoding process for the MRI data set. The result also shows that the total computation time required for complete compression on a Pentium IV- 1 GHz PC, takes 30 sec.

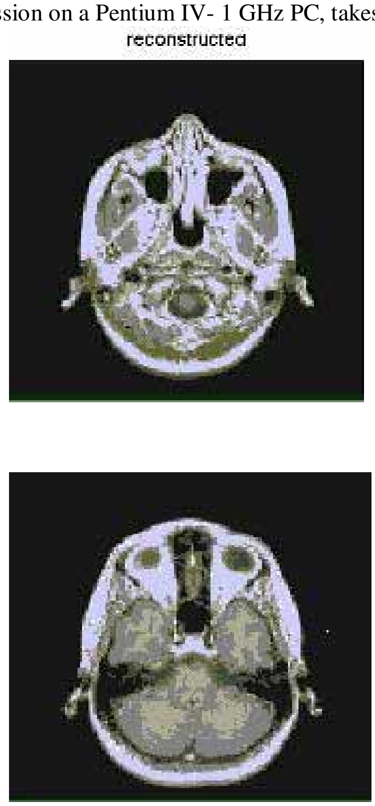


fig. 7. Two decoded slices of MRI 3-D SPIHT for the 8-slice unit, top slice_1 (PSNR = 37.38 dB), bottom slice_6 (PSNR=32.43dB)

VI. CONCLUSION

In this paper, we proposed 3D-SPIHT medical image compression methods for volumetric medical images that operate on 3D reversible wavelet transforms. The wavelet image transform consists of techniques to eliminate computation of certain high-pass coefficients as they are represented by small integer values. The result shows that this algorithm performs quite well for 3D medical images. This algorithm produces up to 30-32% decrease in compressed file sizes compared to 2D image compression algorithms. The computation time required for the compression also reduced to some extent.

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