A Comparative Study of Lossless Compression Algorithms for Medical Images

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Abstract: *The medical enterprise depends on a system that makes diagnostic images available for radiological interpretation, that transmits images to physicians throughout the system, and that efficiently stores images pending retrieval for future medical or legal purposes. Computerized medical imaging generates large, data-rich electronic files. To speed up the electronic transfer and to minimize the computer storage space, medical images often undergo compression into smaller digital files. This paper reports a comparative study of lossless compression algorithms namely EBCOT, DPCM and SPIHT for 3-D medical images. Image quality is measured objectively using peak signal-to-noise ratio (PSNR). Many current compression schemes provide a very high compression rate with considerable loss of quality*.

Keywords: Compression, DPCM , EBCOT, Medical Images, SPIHT

I. INTRODUCTION:

Digital image occupies extensive storage capacity and transmission bandwidth in its original state. In this regard compression is needed for images. Image compression is the process of encoding images such that less storage space is required to archive them and less transmission time is required to retrieve them over a system. Compression is possible because most images contain large sections (e.g. backgrounds) that are often smooth, containing nearly identical pixel values that include duplicate information. This is known as 'statistical redundancy'. Image compression technique strives to remove redundant information, and encode remaining data. Hospitals and clinical atmosphere are rapidly moving towards medical image compression. The basic motivation of medical image compression is to represent medical images in a digital form. This thing usually supports image transfer and archiving, and the manipulation of visual diagnostic information in new and more efficient ways. These ways include image enhancement and 3D volume rendering. The compression of medical images has a great demand which can be compressed as a single image or sequence of images.

The medical community has been very reluctant to adopt lossy algorithms in clinical practice [13]. However, the diagnostic data produced by hospitals has geometrically increased and a compression technique is needed that results with greater data reductions and hence transmission speed. In these cases, a lossy compression method that preserves the diagnostic information is needed. Image compression [11, 12] aims at removing or at least reducing the redundancy present in the original image representation. There is usually an amount of correlation among nearby pixels in real world images, which can be taken advantage of to get a more economical representation. usually the Compression Ratio (CR) term is calculate to measure the degree of compression, i.e., the ratio of the total number of bits used for coding the original image to the total number of bits used to code the compressed image. The average number of bits per pixel (bpp) is referred to as the bit rate of the image.

II.COMPRESSION METHODS:

There are two types of image compression. One is lossy another one is lossless. While using lossy compression methods at low bit rates, that introduce

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2.1 LOSSY COMPRESSION SCHEMES:

A lossy compression involves a loss of information compared to the original signal; therefore it is not possible to reconstruct the original signal from one that has been compressed by using a lossy compression algorithm. A lossy compression is acceptable mainly for three reasons. The human visual system is often able to tolerate loss in image quality without compromising the ability to perceive the contents of the scene. It happens very often and should be considered. Definitely, the image which is reconstructed starting from a finite number of samples, can take only discrete values. A lossless compression would never be able to grant the high levels of compression that can be obtained by using a lossy compression and that are necessary for applications in storage or distribution of images.

2.2 LOSS LESS COMPRESSION SCHEMES:

There are plenty of data compression algorithms in lossless data compression. They allow the exact

compression artifacts. It does not suit for medical images. So in a normal way lossless compression is preferred for medical images. Lossy methods are appropriate for natural images.

original data to be reconstructed from the compressed data. A lossless compression does not involve a loss of information.Also it allows a perfect reconstruction of the original signal after the decompression. Image compression is measured by the means of an index called Compression Ratio which is given by the following equation.

$$\text{Compression Ratio} = \frac{N_1 N_2 B}{\| c \|} \qquad \text{---1}$$

N_1 and N_2 represent the number of pixels along the horizontal and vertical dimension of the image, B is the number of bits required to represent each pixel, while ||c|| is the final bit-stream obtained after the compression. Methods for lossless image compressions are:

- Run-length encoding
- DPCM and Predictive Coding
- Entropy encoding
- Adaptive dictionary algorithms such as LZW
- Deflation
- Chain codes

III.3-DIMENSIONAL MEDICAL IMAGE COMPRESSION TECHNIQUES:

To produce three-dimensional CT and MRI images modern techniques have been developed recently. Traditionally CT and MRI scans produced 2D static output on film. Three-dimensional ultrasounds are produced using a somewhat similar technique. Most of the current medical imaging techniques produce three-dimensional data. Some of them are intrinsically volumetric, like Positron Emission Tomography (PET), Computerized Tomography (CT), Magnetic Resonance (MR), three-dimensional ultrasound, while others describe the temporal evolution of a dynamic phenomenon as a sequence of 2D images.

The huge amount of data generated every day in the hospital environment yields compression to be unavoidable for efficient storage and transmission purposes. Nowadays, compression methods used in medical applications are most of the time lossless methods in order to preserve the data integrity and to facilitate thus a true diagnosis. In many applications like for example computer aided detection (CAD) it has been shown that a balance between data compression and data fidelity could be achieved. A volumetric medical image is a three-dimensional (3- D) image data set which can be considered as a sequence of two-dimensional (2-D) images (or slices).

A way to perform compression in 3-D image is to apply a compression algorithm to each two dimensional slice independently. Still, the slices are generally highly correlated with one another. Thus, the basic idea of the three-dimensional (3D) medical image compression algorithms is to take advantage of the correlation among the data samples in the three dimensional space to improve compression performances.[8] A three-dimensional (3D) medical data set is a collection of 2D images, henceforth called slices[10].

Several of today's imaging techniques produce three-dimensional (3-D) data sets. Medical imaging techniques, such as computed tomography (CT) and magnetic resonance (MR) generate multiple slices in a single examination, with each slice representing a different cross section of the body part being imaged. [3]

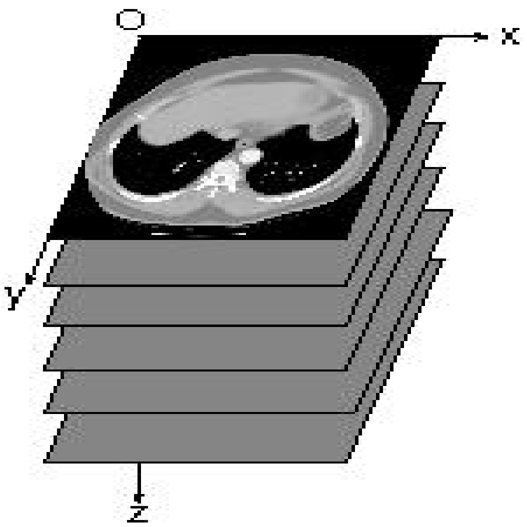

Fig. 1: Stack of 2D Slices in terms of Discrete Volume Dataset for an 3-D medical image

3.1 3-D DIFFERENTIAL PULSE CODE MODULATION (DPCM):

As the well-conducted prediction techniques give good compression rates, DPCM compression depends on the prediction technique. There exists significant correlation between the adjacent slices of volumetric data. So 3-D DPCM can be used to achieve low bit rates [3]. In the context of image sequences, neighboring pixels along the time dimension are also involved. The prediction of a DPCM system involves three types of neighboring pixels: those along the same scan line, those in the same image frame, and those in the different frames, So that the DPCM is called 3-D differential coding. Usually DPCM prediction algorithms calculate the residual data.

3.2 EMBEDDED BLOCK CODING WITH OPTIMIZED TRUNCATION (EBCOT):

EBCOT stands for Embedded Block Coding with Optimal Truncation. Here each and every sub-band is partitioned into tiny blocks (for example 64x64 or 32x32), called code-blocks. Every code-block is codified independently from the other ones thus producing an elementary embedded bit-stream. In order to minimize the distortion the algorithm can find some points of optimal truncation. It uses the wavelet transform to subdivide the energy of the original image into sub-bands. Coefficients are coded after having done an appropriate quantization specified by the standard. Each sub-band is divided into code-blocks before being compressed. As every code- block is codified independently, aimed bit-rate can be achieved by minimizing the distortion. EBCOT algorithm carries out the Rate-Allocation by the means of a particular method called PRCD (Post Compression Rate Distortion). In EBCOT, each sub-band is partitioned into relatively small blocks of samples, which we call code-blocks.

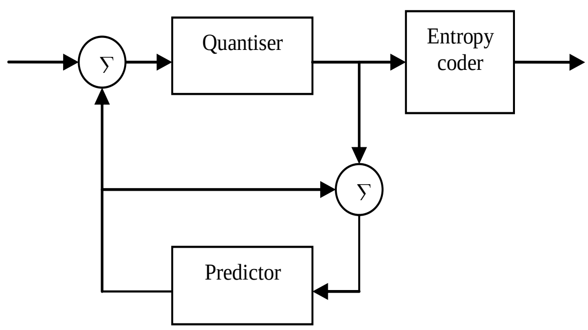

Fig. 2: DPCM coder

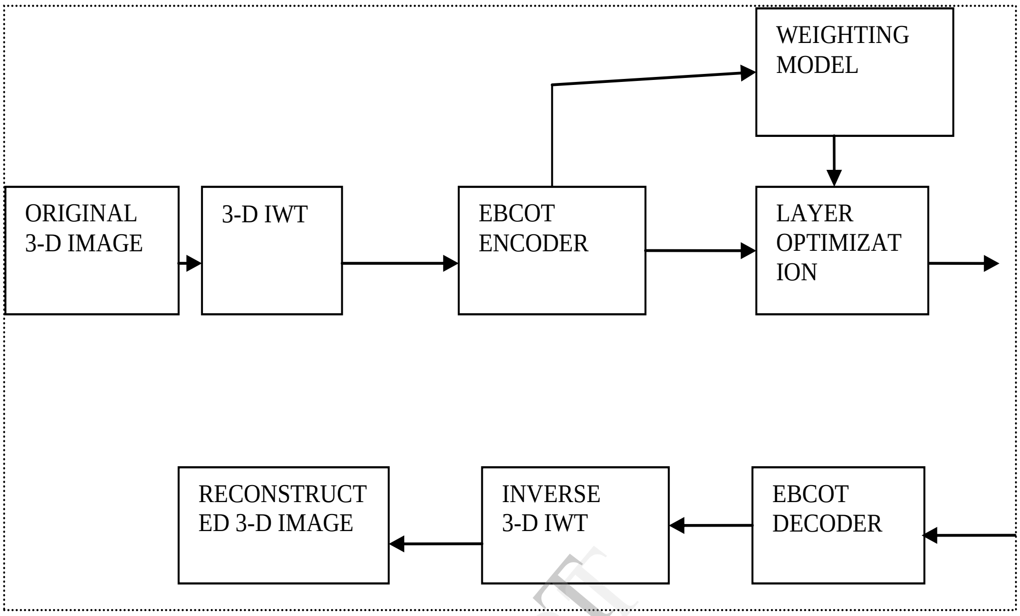

Fig 3: Block diagram of the 3-D scalable lossless compression method.

3.3 3-D SPIHT ALGORITHM (SPATIAL PARTITIONING OF IMAGES IN TO HIERARCHICAL TREE) :

The SPIHT (Spatial Partitioning of images in to Hierarchical trees) algorithm is very efficient in transmission of ordering information, essentially involves a scalar quantization operation. The essence of the set portioning is to first classify the elemental coding units based on their magnitude and then quantize them in a successive refinement frame work. The SPIHT process represents a very effective form of entropy coding. This is shown in two forms of coding. One is binary un coded (extremely simple) and the other is context-based adaptive arithmetic coded (sophisticated). When the difference in compression is small, it is not necessary to use slow methods. One consequence of the compression simplicity is the greater coding/decoding speed. In SPIHT algorithm the time to encode is almost equal to the time to decode.

Table1:Comparison of compression ratio between the methods 3-D DPCM, 3-D EBCOT (VOI), 3-D SPIHT

IMAGE	Method		
	3-D DPCM	3-D EBCOT(VOI)	3-D SPIHT
Image 1	3.68	2.44	1.955
Image 2	4.98	2	1.139
Image 3	3.74	4.34	1.468
Image 4	3.83	3.22	0.934

IV. RESULT AND DISCUSSION:

In this study the Comparison of compression ratio between the methods 3-D DPCM, 3 -D EBCOT (VOI) and 3-D SPIHT has been analyzed by applying on different medical images. The various modalities of medical images like knee MR image, brain MR image and brain CT image have been tested and corresponding graph has been plotted which is shown in Table 1 . Figure 4 a and 4 b shows the original MR image and reconstructed image by applying the SPIHT method. Figure 5 a and 5 b shows the original Input brain MR image and the reconstructed image by applying the SPIHT method. Also Figure 6 a and 6 b shows the original brain CT image and the reconstructed image. From the above analysis we can conclude that original and reconstructed images are almost same and they do not affect the image quality.

The average compression ratio obtained during experimentation for the test images is shown in Table 1. From the above said analysis, results illustrate that we can achieve higher compression ratio in 3-D DPCM comparing the other two methods .The results for all the compression methods are shown in tabular form and graphs have been plotted which gives the precise results of compression methods on the basis of a parameter compression ratio. All the experiments are carried out on a computer with Intel 2.5GHZ and 512M RAM in the Win2000 professional operating system

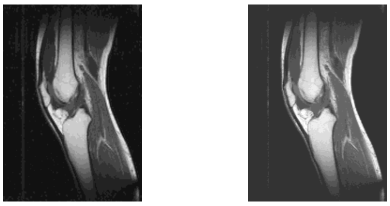

Fig: 4 a) Input Knee MR Image **b) compressed MR Image**

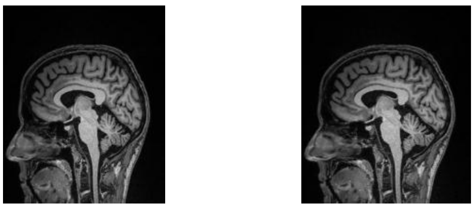

Fig :5 a) Input brain MR Image **b) Compressed MR Image**

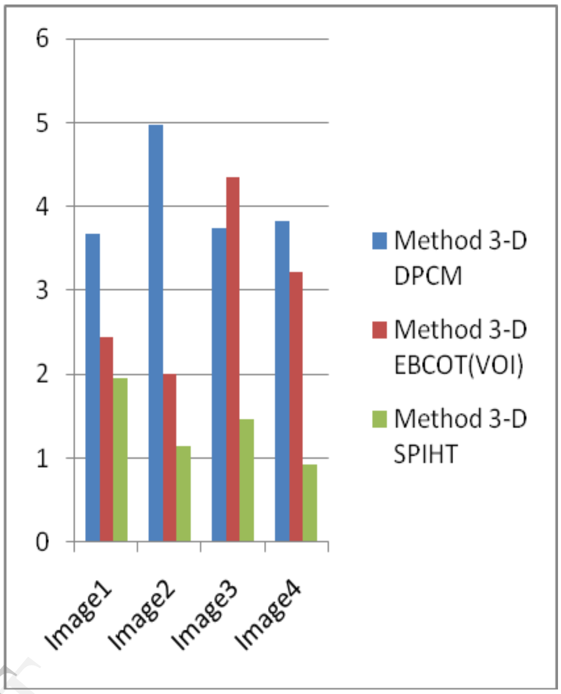

Fig:7 Performance of compression ratio for the three methods 3-D DPCM, 3-D EBCOT (VOI) and 3-D SPIHT

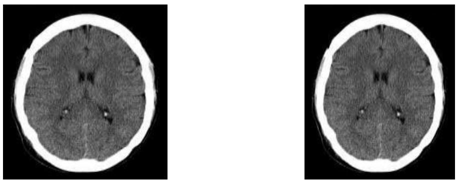

Fig : 6 a) Input brain CT Image **b) compressed CT Image**

V.CONCLUSION:

Various compression algorithms like 3-D DPCM, 3-D EBCOT (VOI) and 3-D SPIHT have been analyzed for different Medical images and comparisons have been done. For this experiment several medical images have been selected from http://www.imaios.com/en. These images include CT-scans MR images of different parts of human body. Results illustrate that we can achieve higher compression ratio in 3-D DPCM by comparing the other methods. There are many possible directions for future investigation. In order to obtain better compression rates, three of the algorithms can be improved, and can be combined with one dimensional interval wavelet algorithm.

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