MEDICAL IMAGE COMPRESSION USING HYBRID CODER WITH FUZZY EDGE DETECTION

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Abstract
Medical imaging techniques produce prohibitive amounts of digitized clinical data. Compression of medical images is a must due to large memory space required for transmission and storage. This paper presents an effective algorithm to compress and to reconstruct medical images. The proposed algorithm first extracts edge information of medical images by using fuzzy edge detector. The images are decomposed using Cohen-Daubechies-Feauveau (CDF) wavelet. The hybrid technique utilizes the efficient wavelet based compression algorithms such as JPEG2000 and Set Partitioning In Hierarchical Trees (SPIHT). The wavelet coefficients in the approximation sub band are encoded using tier 1 part of JPEG2000. The wavelet coefficients in the detailed sub bands are encoded using SPIHT. Consistent quality images are produced by this method at a lower bit rate compared to other standard compression algorithms. Two main approaches to assess image quality are objective testing and subjective testing. The image quality is evaluated by objective quality measures. Objective measures correlate well with the perceived image quality for the proposed compression algorithm.

Keywords:
Image Compression, Medical imaging, Joint Photographic Experts Group (JPEG), JPEG2000, Set Partitioning in Hierarchical Trees (SPIHT), Discrete Wavelet Transform (DWT), Cohen-Daubechies-Feauveau biorthogonal wavelet (CDF), Edge Detector

1. INTRODUCTION

The two major types of compression are lossless and lossy. Lossless compression involves with compressing data which, when decompressed, will be an exact replica of the original data without any loss. Typical compression ratios for lossless techniques are around 2:1 to 4:1. Lossy techniques do not allow for exact recovery of the original image once it has been compressed. But these techniques allow for compression ratios that can exceed 100:1.

The compression of medical images has a great demand due to the use of different imaging modalities. Any compression algorithm will try to find and reduce the most redundant and repetitive information. The image for compression can be a single image or sequence of images. 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.

JPEG and Wavelet compression methods are most popular methods preferred by the medical community. The well-known JPEG compression standard is described in [1]. In this lossy method, the image is divided into sub images. Discrete Cosine Transform (DCT) is performed on the sub-images, and the resulting coefficients are quantized and coded. Image compression schemes such as vector quantization described by [2] and JPEG belong to block-based coding schemes and hence edge information cannot be fully preserved.

Wavelet compression has been developed by many authors [3, 4]. Fast reconstruction of an individual slice in a 3D wavelet domain is presented in [5]. A 2D wavelet transform scheme of adaptive lifting in image coding is described in [6]. The lack of blocking effect is the major advantage of wavelets over JPEG. Algorithms based on wavelets have been shown to work well in image compression. Separating the smooth variations and details of the image can be done by decomposition of the image using a Discrete Wavelet Transform (DWT). For image compression applications a non-expansive DWT be employed which makes image border extension critical. The goal of the extension technique is no distortion should be introduced by the extension technique and subband decomposition process should be non-expansive. The symmetric extension satisfies the goal. The symmetric extension details were being perfected for bi orthogonal wavelets due to the use of symmetric filters. CDF 9/7 bi orthogonal wavelet is preferred for lossy compression as it performs better compared to other wavelets for the compression of images [7]. For lossy compression CDF bi orthogonal wavelet is used in JPEG2000 standard for its best performance at low bit rate. The hybrid compression algorithm presented utilizes CDF bi orthogonal wavelet to provide high compression ratio and also good resolution.

2. BACKGROUND

In [8] a network algorithm to compress and to reconstruct DICOM images is presented. DICOM differs from other data formats in that it groups information together into a data set. A DICOM data object consists of a number of attributes, containing such items as name, ID, etc, and also one special attribute containing the image pixel data. The previewer gives a list of files from a selected directory. Header and image data of the selected file are displayed immediately. DICOM provides extremely rich support for storing image data and all related parameters, which no other image format can provide. DICOM supports compression methods internally to compress pixel buffers in the "Pixel Data" attribute without sacrificing any other attribute data. Current DICOM standard is based on JPEG image compression.

In Fractal Image compression technique [9, 10] possible self similarity within the image is identified and used to reduce the amount of data required to reproduce the image. But fractal methods have been time consuming as it involves pixel-to-pixel comparison between the image blocks [11, 12]. To solve this problem, a fast hybrid image coder [13] is introduced that combines the speed of the wavelet transform to the image quality of the fractal compression.

This paper proposes an approach to improve the performance of medical image compression. The key reasons for the proposed wavelet based hybrid algorithm are extensive research has shown that the images obtained with wavelet-based methods yield very good visual quality and many researchers believe that encoders that use wavelets are superior to those that use DCT and fractals. SPIHT employs more sophisticated coding by exploiting the hierarchical structure of the wavelet transformed images by using tree based organization of the coefficients to increase its efficiency. JPEG2000 exploits strong dependencies between wavelet coefficients inside each subband. So the proposed hybrid algorithm combines the wavelet based compression methods JPEG2000 and SPIHT. The standardized image compression scheme known as JPEG2000 uses discrete wavelet transform as the underlying transform algorithm [14]. Said and A. Pearlman developed a SPIHT coding algorithm [15], a refined version of embedded zero tree wavelet coder (EZW) [16].

State-of-the-art coding schemes, JPEG2000 and SPIHT, both use wavelet transform prior to coding and produce embedded bit streams that provide the features of resolution and distortion scalability. So image can be reproduced in different resolutions and qualities, i.e. to preview an image, a lower quality would be extracted first and to see the best quality additional information would be downloaded from image file. SPIHT and JPEG2000 are adapted for hybrid technique due to their superior rate–distortion performance and low computational complexity. Thus, we can reconstruct the source image at low spatial resolution and low quality from part of the embedded bit stream. By progressively decoding more bits, higher spatial resolution and better quality image will be obtained. JPEG2000 exploits intra-band dependency and adopts EBCOT algorithm for coding bit planes of wavelet coefficients. SPIHT exploits inter-scale dependencies between wavelet coefficients based on set partitioning sorting and spatial orientation tree.

Visual evaluation of reconstructed image quality is a highly subjective process. To improve the perceptual quality of the image, DCT based image compression is combined with enhancement algorithm in [17] and the edge information is preserved using edge detector in [18]. The fuzzy edge detector detects edges even in low contrast regions [19, 20].

The rest of the paper is organized as follows. Section 2 presents materials and methods. Experimental results are presented in Section 3. Finally conclusions are given in Section.4.

3. MATERIALS AND METHODS

This paper presents a new technique that combines the wavelet based compression standards JPEG2000 and SPIHT to compress medical images with edge detection. Fig.1 presents the complete block diagram of the proposed coder, which is a hybrid version of tier 1 part of JPEG2000 and SPIHT coders. In the proposed hybrid method of medical image compression, Fuzzy edge detector is used to preserve edge information. The hybrid algorithm is combined with edge detection to extract the boundary where gray level is changed sharply, as the edge of the image is unclear after the transform. The medical images are decomposed into four groups of components, namely low-frequency components (approximation subband) and high frequency components (detailed subbands) using wavelet filter. The wavelet coefficients in the approximation sub band are encoded using tier-1 part of JPEG2000. The wavelet coefficients in the detailed sub bands are encoded using SPIHT.

The edge information is preserved by fuzzy edge detector. The Mamdani fuzzy inference method is chosen. The fuzzy sets obtained by inference rule were joined through add function. There is a fuzzy set for each output variable that needs defuzzification. The membership function of the output separates the edges of the image.

JPEG2000 and SPIHT perform equally well. Both the techniques use wavelet transform prior to coding and produce embedded bit streams that provide the features of resolution. JPEG2000 takes advantage of intra scale dependencies i.e. strong dependencies in the form of spatial clusters exist between wavelet coefficients inside each subband. SPIHT exploits inter-scale dependencies between wavelet coefficients, i.e. the magnitude of wavelet coefficients strongly correlated across scales. This self-similarity across scales is utilized to achieve high compression ratios. The image can be reconstructed at low spatial resolution and low quality from part of embedded bit stream. Then by progressively decoding more bits, higher spatial resolution and better quality image will be obtained.
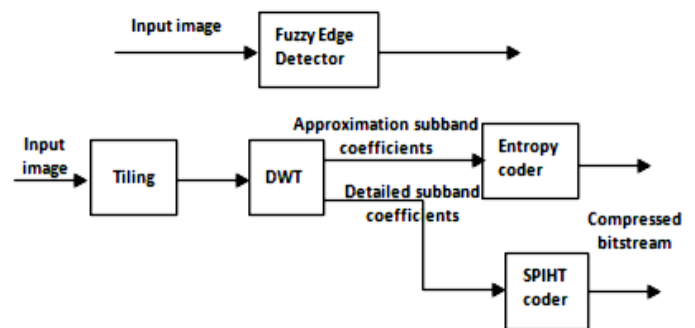

Fig.1. Block diagram of the proposed method

The wavelet coefficients in the approximation sub bands encoded using JPEG2000 utilizes the scalar quantization operation which maps a given value to a quantizer index, which is then encoded one bit at a time, (ii) starting from the most significant bit and proceeding to the least significant bit. Each bit plane is further broken down into blocks. The blocks are coded independently using three coding passes: (i) Significance propagation pass, (ii) Refinement pass and (iii) Clean-up pass. The coefficients that are predicted to be significant are encoded prior to other significance and refinement bits. For this reason, Significance Pass is executed before other passes. For each insignificant coefficient, the significance of its neighbors is tested. Then insignificant coefficients with significant neighbors are encoded before magnitude refinement pass. Refinement pass is followed by cleanup pass which processes remaining (insignificant) bits and sign information for those coefficients that has not been processed during previous two passes. The coding progresses from the most significant bit-plane to the least significant bit-plane. The binary value of a sample in a block of a bit plane of a sub band is coded with arithmetic coder.

As the wavelet coefficients in the detailed sub bands alone are encoded using SPIHT, algorithm consists of two subsets: (i)

List of Significant Pixels (LSP) and (ii) List of Insignificant Sets of Pixels (LIS) [13, 15]. LSP constitutes the coordinates of all coefficients that are significant. LIS contains the roots of insignificant sets of coefficient. During the encoding process these subsets are examined and labeled significant if any of its coefficients has a magnitude larger than a given threshold. The significance map encoding (set partitioning and ordering pass) is followed by a refinement pass, in which the representation of significant coefficients is refined. The threshold is initialized as 2^n where n =$\log_2 c_{max}$, where c_{max} is the coefficient of maximum magnitude. This threshold used to test significance is then successively decreased by a factor of two in each pass of the algorithm. SPIHT algorithm sends the binary representation of the integer value of wavelet coefficients.

The encoded bitstream includes JPEG2000 bitstream, SPIHT bitstream and Fuzzy edge information. The receiver decodes the bit stream.

The hybrid algorithm has been discussed for medical images of sizes 256 pixels by 256 pixels and 512 pixels by 512 pixels. The test results of using hybrid algorithm are compared with JPEG2000+SPIHT, JPEG2000 and SPIHT algorithms. MRI and CT images are used for experiments. The original MRI image and reconstructed images processed by the hybrid algorithm and also for comparison purposes the same image processed using JPEG2000+SPIHT; JPEG2000 and SPIHT techniques are shown in Fig.2 and Fig.3. Fig.4 presents CT image compressed by proposed algorithm, JPEG2000+SPIHT, JPEG2000 and SPIHT.

The distortion represented by mean square error (MSE) between the original image x (i, j) of size M pixels by N pixels and the reconstructed image x_R (i, j) is defined as

$$MSE = \frac{1}{M*N} \sum_i \sum_j (x(i,j) - x_R(i,j))^2 \qquad (1)$$

The Peak Signal to Noise Ratio (PSNR) is defined by

$$PSNR = 10\log_{10} \frac{255^2}{MSE} \qquad (2)$$

4. RESULTS AND DISCUSSION

Various modalities of gray images with size of 256 x 256 pixels and 8 bpp are selected for experiments. Fig.2 and Fig.3 compares the visual quality of MRI images compressed by hybrid algorithm, JPEG2000+SPIHT, JPEG2000 and SPIHT algorithms. Fig.4 compares the reconstructed CT image compressed by hybrid algorithm, JPEG2000+SPIHT, JPEG2000 and SPIHT algorithms.

The evaluated results are presented in Table.1 that compares the PSNR of the MRI image and CT image shown in Fig.2, Fig.3 and Fig.4 respectively. From the Table.1 it is inferred that the bit rate vs. PSNR results for the hybrid algorithm are comparatively better.

The reconstructed images using the hybrid technique at a low bit rate show good quality without distortion. The medical images are tested with various bit rates. The aim is to compare the bit rates and PSNR of the proposed method with JPEG2000+SPIHT, JPEG2000 and SPIHT algorithms. The hybrid algorithm performs well for very low bit rates compared to JPEG2000+SPIHT, JPEG2000 and SPIHT algorithms. Blur is

a perceptual measure of the loss of fine detail and the smearing of edges and it is one of the main artifacts of JPEG2000. As the detailed sub bands are coded with SPIHT better visual quality images are produced. As the edge of the image is unclear after the transform for low bit rates, the hybrid algorithm utilizes edge detection thereby increasing the sharpness of the image.

Fig.2 and Fig.3 shows the MRI image compressed by hybrid algorithm, JPEG2000+SPIHT, JPEG2000 and SPIHT. The proposed method produces better results compared to other techniques. As the bit rate increases the reconstructed images exhibit better subjective quality with a still higher value PSNR.

Fig.4 shows the CT image compressed by hybrid algorithm, JPEG2000+SPIHT, JPEG2000 and SPIHT. For this modality also the proposed algorithm works well producing better subjective quality images with high PSNR. The proposed algorithm produces significant improvements in PSNR with better quality images for a given bit rate.

Table.1. Numerical Results of MRI Image and CT image for the images shown in Fig.2, 3 and 4

Bit Rate	Technique	PSNR (dB)		
		MRI Image 1	MRI Image 2	CT Image
0.15bpp	SPIHT	29.83	28.62	26.54
	JPEG2000	36.88	36.46	26.00
	JPEG2000+SPIHT	37.14	37.01	26.03
	Hybrid Algorithm	39.53	38.40	31.20
0.2bpp	SPIHT	30.75	29.90	27.87
	JPEG2000	37.30	37.43	28.05
	JPEG2000+SPIHT	38.69	37.69	28.00
	Hybrid Algorithm	42.04	41.53	34.09
0.25bpp	SPIHT	33.30	33.42	30.67
	JPEG2000	37.74	36.62	28.68
	JPEG2000+SPIHT	38.18	36.79	28.71
	Hybrid Algorithm	42.70	40.50	32.45

Fig.2. Visual quality of MRI image 1 using different compression algorithms for various bit rates

5. CONCLUSION

This paper has discussed a new hybrid image coder which combines edge detection algorithm with JPEG2000 and SPIHT compression standards. Subjective quality is significantly improved avoiding blurring. In this hybrid method important edge information is extracted first and approximation sub band of wavelet decomposed image is encoded using JPEG2000 and detailed sub band is encoded using SPIHT. The encoded bitstream includes JPEG2000 bitstream, SPIHT bitstream and edge information. The results show that images with a higher content of visual details without observable loss of diagnostic information can be obtained. The PSNR of the proposed algorithm is better compared to JPEG2000+SPIHT, JPEG2000 and SPIHT. The evaluations are carried out among different medical images at various bit rates.
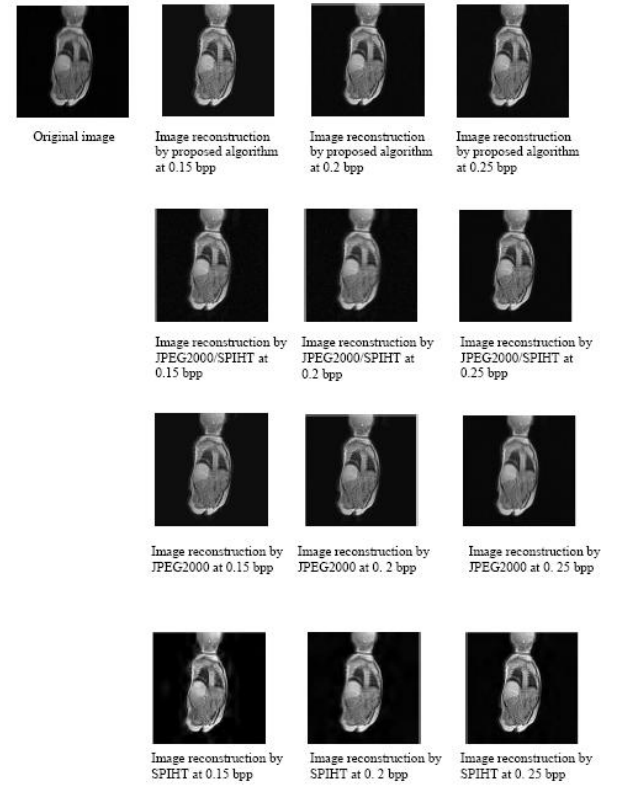

Fig.3. Visual quality of MRI image 2 CT image using different compression algorithms for various bit rates
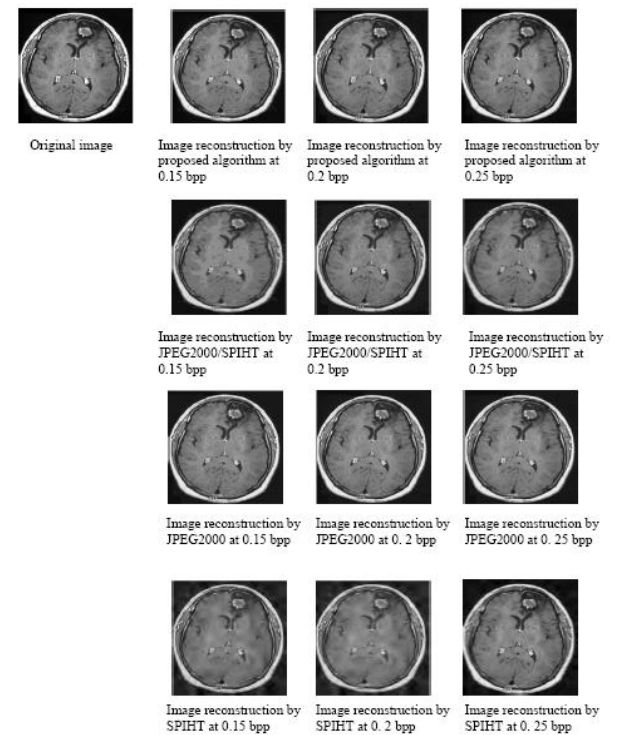

Fig.4. Visual quality of CT image using different compression algorithms for various bit rates

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