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IMPROVED QUALITY PRESERVING MEDICAL IMAGE COMPRESSION ALGORITHM

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Abstract:

Compression of digital images becomes essential and is very much desired in medical applications to solve both storage and transmission problems. Efficient compression techniques are required to reduce the size of the image but with no loss of diagnostically relevant information. This paper proposes a medical image compression with edge preservation to improve diagnostic accuracy in medical image compression schemes. Edges in the medical images are vital for accurate detection of boundaries of lesions and tumors, which in turn requires the preservation of edges. So compression method to preserve edges to achieve a decompressed image with a higher content of visual information is presented. Edge detection is a frequently used technique to extract the edge information in image compression system. The compression algorithm is designed to obtain image with optimum compression efficiency and also with high fidelity. The proposed compression algorithm has been applied on Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) imaging modalities.

Keywords: Medical imaging, Compression algorithms, Entropy coder, Edge preservation, Performance measures.

Introduction

Compression of the image is achieved using image compression techniques that remove visual information that is not perceived by the human eye. The issue is not whether to compress medical images using lossless or lossy techniques, but preferably which type of compression can be used without compromising image quality [1]. In teleradiology applications, several research works have been performed to determine the degree of compression that maintains the diagnostic image quality [2].The emphasis in medical applications is to preserve important image features that contribute towards accurate diagnosis. Edge information is an important feature that must be preserved by the medical image compression system. While compressing the image, errors occur usually at edges than inside uniform regions due to loss in high frequency components. Regaining those edges is very important in medical images, as edges in a digital image provide significant information about the objects contained within the image. In images, edges characterize object boundaries and are therefore useful for segmentation, boundary detection, object recognition, image registration, and so on. In medical images, edges indicate the boundary of region of diagnosis, say lesion or tumor and classify the boundaries between various anatomical structures and tissues in the image. As edges contribute towards accurate diagnosis, edge preservation is a vital step in medical image processing to get exact size and location of diagnostically significant regions. Hence, the medical image compression algorithm must be developed such that the edges are preserved. Edge detection methods [3] may be grouped into two categories: gradient and Laplacian. Gradient-based edge detection method, detects the edges by looking for the maximum and minimum in the first derivative of the image. Sobel, Prewitt and Kirsch detectors calculate the first derivative to find the locations of the edges. Though these detectors are simple to implement, they are sensitive to noise. Laplacian-based edge detection method searches for zero crossings in the second derivative of the image to locate edges. The zero-crossing edge detectors use the second derivative along with the Laplacian operator to locate the edges. The high sensitivity of this detector to noise is reduced by smoothing of edges performed by the Laplacian of Gaussian. But these detectors fail to find the orientation of edges. The Canny detector, which is an optimal edge detector is widely used in many applications [4], [5]. The medical image compression algorithm proposed by [6] uses Canny edge detector to detect edges which involves high computational complexity. Even though Gaussian detectors perform better than classical edge detectors, more complex computations are involved and their performance decreases in case of noisy images. Nowadays, polynomial fitting concepts are used to represent the image more efficiently. In this plane fitting method, the image is divided into non-overlapping NxN blocks. The divided blocks are fitted to a plane f(x,y) = ax+by+c by using the intensity values of the image and each block is represented by three coefficients a, b and c [7], [8]. The parameters a, b and c are called plane parameters, where the parameter c is the mean parameter which has maximum information and the parameters a and b form the plane gradient. The parameters a, b and c are defined [7],[8] as a= Z_{10}, b = Z_{01} and c = Z_{00}

where

$$Z_{ij} = \frac{\sum_{x=1}^{N}\sum_{y=1}^{N} f(x)^{i} f(y)^{j} g(x,y)}{\sum_{x=1}^{N}\sum_{y=1}^{N} f(x)^{2i} f(y)^{2j}} \qquad (1)$$

In Eq. 1, N is the block size, f(x) is given as f(x) = 2x-N-1 and f(y) is given as f(y) = 2y-N-1 and g(x,y) is the original intensity value. This paper is organized as follows. Section 2 presents the proposed method. Section 3 presents experimental results. Section 4 presents conclusions.

Materials and Methods

The medical image compression with thresholding (MICT) compression algorithm [9] is combined with edge detection for preserving the edges. The proposed MICT with edge preservation (MICTE) is presented in this section.

Methodology

The original image is processed using MICT algorithm [9].The original image is decomposed using Daubechies wavelet transform which decomposes the image into four frequency subbands, namely approximation subband LL and detail subbands LH, HL and HH. Optimum number of coefficients is selected by choosing the threshold. The threshold for selection of coefficients is computed based on the information content of the image. The threshold is determined by examining the number of occurrences of each coefficient [9]. For processing the approximation subband LL, the threshold is determined by examining the occurrences of each coefficient in that particular subband. Initially the threshold is the most frequently occurring approximation coefficient, the contribution of which is high in the decomposed image. The approximation subband coefficients are selected by testing their significance by comparing with the determined threshold. Then the approximation subband coefficients that have a magnitude greater than or equal to the threshold are identified as significant coefficients. The same procedure is applied independently to identify the significant coefficients from the detail subbands LH, HL and HH by comparing with the threshold, which is the coefficient with maximum occurrence in each of the detail subbands. LL, LH, HL and HH coefficients greater than or equal to their respective thresholds are significant coefficients. The remaining coefficients of the subbands are retained. With the chosen significant coefficients by the above procedure, the pixel information is reconstructed by performing inverse DWT (IDWT). Then Peak Signal to Noise Ratio (PSNR) is calculated. If PSNR is greater than or equal to 36 dB, then the procedure of selection of coefficients is stopped, as there is no visual degradations in images reconstructed with PSNR greater than 36 dB [10-12]. If the condition is not arrived, the significant coefficients from the remaining coefficients of LL, LH, HL and HH subbands are identified by comparing with their next subsequent threshold. The procedure is repeated until the condition of PSNR $\geq$ 36 dB is satisfied. Then the significant approximation and detail coefficients are arithmetic coded [13]. The edges of the image are detected by polynomial fitting method. The image is divided into into non-overlapping NxN blocks and each block is represented by the coefficients a, b and c. In Ameer's method [8], the parameters a, b and c are used for achieving compression. But in the proposed MICTE method, only the parameters a and b are utilized with the intention of obtaining the edge information. The edges of the original image are preserved using plane gradients a and b. Hence in this proposed MICTE, these plane fitting parameters indicate the presence of horizontal and vertical edges and are used to preserve edges. The coefficients a and b will be having higher values for edges of the image compared to non-edge information. Using this fact, the locations of edges in the original image are identified by finding the locations in a and b where we have higher coefficients. From these locations in the original image edge pixels are extracted and coded. The edge information is utilized as the assisting information because of its significance in preserving good visual quality. The original image is processed using MICT algorithm. In the images reconstructed with MICT, the edges are replaced with the decoded edge information to obtain MICTE image, thereby the edges of the images are well preserved in the final output image.

Algorithm of the Proposed Method

The steps present in the above said proposed MICT algorithm are as follows:

1. Read the input image.
2. Edge extraction

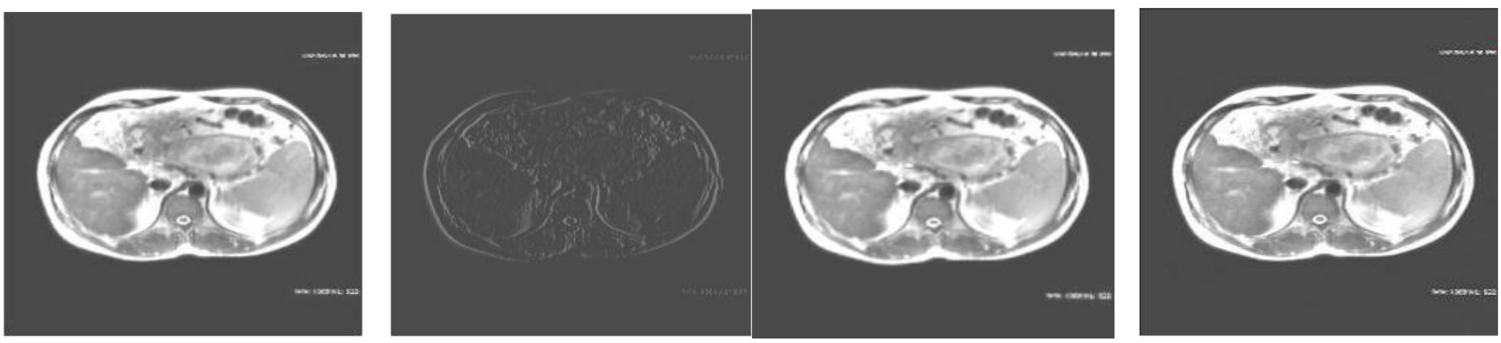
2.1 Determine a and b which are given by $a = Z_{10}$ and $b = Z_{01}$ using Equation 1.

2.2 Extract the original edge pixels using the parameters a and b which indicate the edges.

3. Encode the edge information.
4. Process the image using MICT algorithm.
5. Decode the edge information.
6. Replace the edges of the reconstructed MICT image with decoded edge information to obtain MICTE image.

Results and Discussion

The proposed MICTE method has been applied and discussed for 20 images each in MRI and CT imaging modalities. Fig. 1 and Fig. 2 present the results of MRI images compressed with the MICT [9] and proposed MICTE. The original MRI image, edge information and reconstructed images using MICT and proposed MICTE are shown in Fig. 1 (a) - (d) respectively. Table 1 compares Compression Ratio (CR) and PSNR obtained using MICT and proposed MICTE for MRI images. And CT images. The average CR of 20 images achieved with MICT and MICTE are 5.3 and 5.0, respectively. The average PSNR obtained with MICT and MICTE are 45.12 dB and 45.50 dB respectively. It is observed that due to edge data, there is a slight increase in compressed bitstream of MICTE algorithm or in other words CR is slightly decreased in MICTE in comparison with MICT, but perceptual quality of the images is improved compared to MICT image. This can be clearly seen by comparing the edges of images obtained by MICT and MICTE methods. MICT algorithm has a slightly blurred effect on the alphabets whereas MICTE retains it as in the original image. Other quality measures namely, Image Quality Index (IQI) and Mean Structural Similarity Index Measure (MSSIM) [14], [15] that supports PSNR value are also computed and listed. The higher values of image quality index and MSSIM with MICTE compared to MICT validate the preservation of edge information. The average CR achieved with MICT and MICTE are 4.9 and 4.7, respectively. The average PSNR obtained with MICT and MICTE are 41.27 dB and 41.38 dB, respectively. Table also shows the resulting IQI and MSSIM in case of CT images. The MICTE has an average image quality index of 0.8664 which is higher compared to 0.8609 for MICT. In the same way, the average value of MSSIM for MICTE is 0.9623 and 0.9568 for MICT. It can thus be inferred that in case of CT images, MICTE confirms the preservation of vital edge information. Fig. 2 presents CT images compressed with the proposed MICTE. The original CT image, edge information and reconstructed images using MICT and MICTE are shown in Fig. 2 (a) - (d) respectively. MICTE method uses the edge information extracted from plane parameters to reconstruct the edges with accuracy. Fig. 1 and Fig. 2 illustrates that the MICTE method yields images with clear edges compared to MICT. From the results, it is observed that due to edge preservation, there is a slight increase in compressed image size, thereby deserving penalty in terms of overall achievable CRs compared to MICT. But from the figures, it can be seen that edge preservation improves the visual fidelity of the reconstructed MICTE images over that of MICT images. From the table, it can be inferred that the CR is affected by a small margin only, with increase in PSNR. The image quality index and MSSIM assessments show greater similarity between original and reconstructed images than MICT.



(a) *(b)* *(c)* *(d)*

Fig. 1. (a) Original MRI image (b) Edge information (c) Reconstructed image using MICT (CR=6.2, PSNR=42.14 dB)

(d) Reconstructed image using MICTE (CR=6.0, PSNR=42.90 dB)

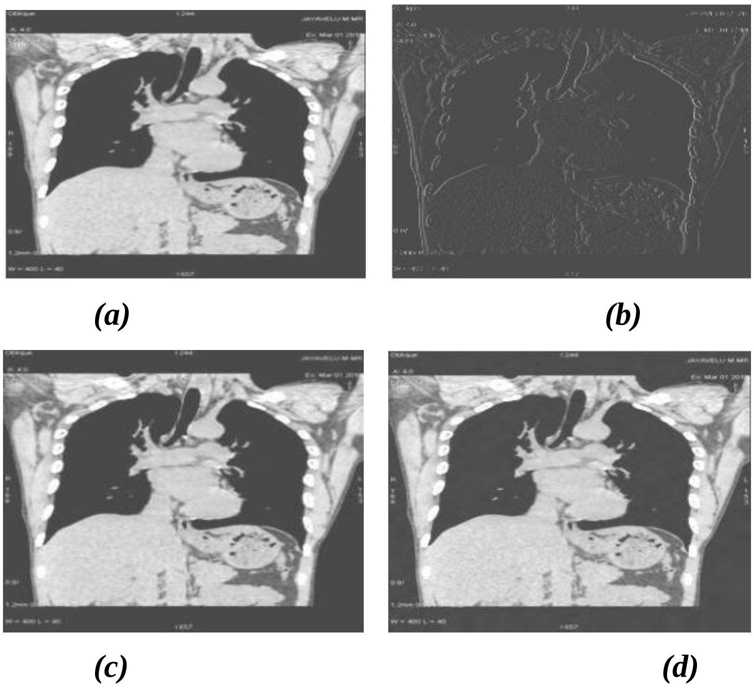


Fig. 2. (a) Original CT image (b) Edge information (c) Reconstructed image using MICT (CR=3.4, PSNR=40.79 dB)

(d) Reconstructed image using MICTE (CR=3.1, PSNR=40.80 dB)

Table 1. Comparison of PSNR, IQI and MSSIM of MICT with MICTE for MRI and CT images./

Images	**CR**	**PSNR**		**IQI**		**MSSIM**	
		MICT	**MICTE**	**MICT**	**MICTE**	**MICT**	**MICTE**
MRI images	5.3	45.12	45.50	0.8232	0.8349	0.9716	0.9758
CT images	4.9	41.27	41.38	0.8609	0.8664	0.9568	0.9623

Conclusion

A medical image compression algorithm with edge preservation is presented. For preserving the vital information of the image, edge detector extracts important edge information. The original image is processed using MICT algorithm. The edge information is merged with the decompressed image to get the resultant image. From the results, it has been recognized that the extended method produces visually better results at the cost of slight increase in the compressed sizes of the images. In the proposed MICTE algorithm, edge preservation improves the fidelity of the reconstructed image compared to MICT algorithm.

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