Medical Image Compression: A Review

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Abstract

Within recent years the use of medical images for diagnosis purposes has become necessity. The limitation in transmission and storage space also growing size of medical images has necessitated the need for efficient method, then image Compression is required as an efficient way to reduces irrelevant and redundancy of the image data in order to be able to store or transmits data. It also reduces the time required for images to be sent over the internet or downloaded from web pages. Medical Image Compression plays a vital role in the field of Telemedicine. Image compression will allow Picture Archiving and Communication Systems (PACS) to reduce the file sizes on their storage requirements while maintaining relevant diagnostic information. Diagnosis is effective only when compression techniques preserve the relevant and important image information needed. In this paper, a review has been based on different image compression methods are presented.

Keywords: Discrete Transform, Wavelet Transform, EZW, EBCOT, SPHIT, Fractal Coding, Contour let Transform

1- Introduction

Medical image processing produce digital form of human body image. The storage and transmission of such data require large capacity and bandwidth, which can be very expensive. Due to the rapid increase in the medical imaging produced by hospital and medical center, which are used for different purpose such as surgical and diagnosis plans medical images must be compressed before transmission and storage. Compression of medical image plays a very significant role in the field of medical image processing. Image compression reduces irrelevant and redundancy of the image data in order to be able to store and transmission data in an efficient form. Image compression can be divided into lossy and lossless [1]. In lossy compression scheme, there is loss of information and a higher compression rate is possible by allowing small difference between original and reconstructed images. Such as standard compression JPEG, JPEG2000 [2]. But lossless is scheme that allows the original image to be perfectly reconstructed from the compressed image, without loss of any information and compression rate achieved is low [3].

Especially in medical image analysis, diagnosis is effective only when the compression technique preserves all off the relevant and important information needed so different compression scheme based lossy and lossless method required.

The compression scheme provides very high compression rate with considerable loss of quality. In medicine, it is necessary to have high image quality in region of interest (ROI), in diagnostically important region [4].

A review on compression technique using different transform and their effectiveness like Discrete Cosine transform (DCT), Discrete Wavelet transform (DWT), Fractal coding and Contourlet transform (CT) are presented in next section.Such transform based image compression algorithms are very popular in medical community. After the introduction of DWT, many compression algorithms were proposed to code wavelet coefficient. Among these algorithms, Embedded Zero trees Wavelet (EZW), Set Partitioning in Hierarchical Trees (SPIHT), Embedded Block Coding with Optimized Truncation (EBCOT) are the most popular procedures. We discussed about such algorithm in this literature.

Basic Model of Compression System

Most of the compression systems are based on reducing the redundant information present in the signal whether it is 1D signal or 2D signal like image. Sometime redundancy reduction process is performed over the transformed signal rather than the original signal itself. The redundancy depends on the entropy of the signal. Figure. 1 shows the basic model of the compression system based on redundancy in data [5].Non significant information is removed from the data by below process.

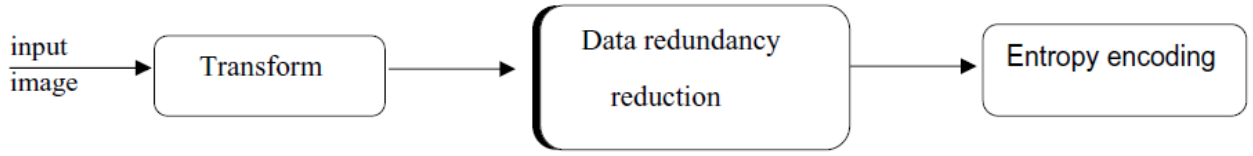

Fig.1. basic model of compression system

2- Discrete Cosine Transform (DCT)

Among the emerging standard compression JPEG[6] is employ a basic technique known as the DCT [7]. The two dimensional DCT of N×N blocks are computed in generally, N is typically 8. After divided up input image into 8×8 pixel blocks, the DCT formula is applied to each row and column of the block. Figure.2 show this process after breaking the image into blocks of pixel and looking at the harmonics in each block. DCT formula is given by (1). The result of this analysis a matrix of coefficient. A quantizer of the DCT coefficient according to the quantization matrix. After quantization, we can code these coefficients using entropy coding very efficiently[8]. The main problem of this compression method is blocking artifact [6].

$$D(u,v)=\sqrt{\frac{2}{N}}\sqrt{\frac{2}{M}}\,C(u)C(v)\sum_{i=1}^{N}\sum_{j=1}^{M}P(x,y)\cos\left[\frac{(2x+1)\prod u}{2N}\right]\cos\left[\frac{(2y+1)\prod v}{2M}\right] \quad (1)$$

$$\text{Where } c(i)=\begin{cases}\frac{1}{\sqrt{2}}, & i=0\\ 1, & i>0\end{cases}$$

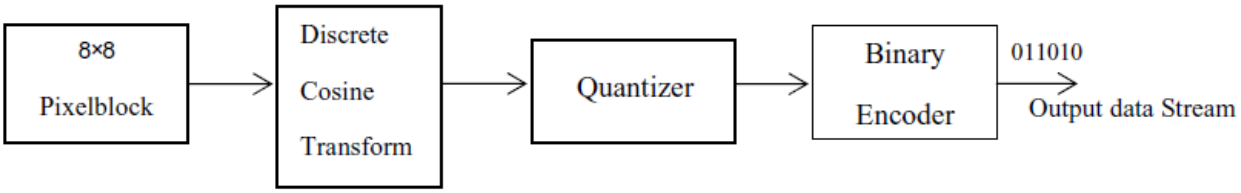

Fig.2. compression using DCT

3- Discrete Wavelet Transform (DWT)

There is a lossy technique based on Wavelet transform for compression images. Two-dimensional Wavelet transform is usually performed by applying filter bank to the image. Filter bank are used to decomposed image. An image can be decomposed along the vertical and horizontal directions and maintains constant the number of pixel required to describe the image [9].N level of decomposition is done. Transform coefficient is resulting by sequence applying low pass and high pass filter. Both horizontally and vertically details are called sub-bands.by applying a one-dimensional transform in each row, produced two sub-band L and H in each row. Then applying a one-dimensional transform in column on these sub-band. Exist four sub-band LL, HH, LH, HL. The LL represents the low pass filtered image, it is a graining version of the original input signal and called approximation image [10]. LH, HL,HH are the high frequency sub-band and containing the images details. Figure.3 show this process.

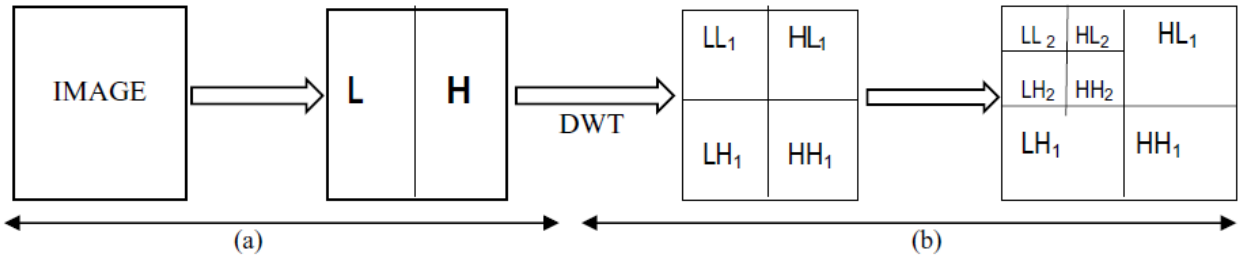

Fig.3. (a)first level decomposition (b)second level decomposition

Quantization is done on the decomposing image where different quantization done on different components thus maximizing the amount of needed details and ignoring irrelevant details. The method used to perform lossy image compression via Wavelet threshold, thus the images are initially transformed by Wavelet transform at one level. Threshold, based on the transform coefficients is defined by (2).

$$Thr = C(r \times n) \quad (2)$$

$$C_{New} = \{Ci \mid \forall i \langle Thr, C(i) = 0\} \quad (3)$$

Where n is the number of detail coefficients, C is the wavelet coefficient vector and r is the remaining rate in percent. Then the renewed wavelet coefficients $C_{New}$is as described in (3) [11]. After the introduction of DWT, other algorithm such as Embedded Zero TreesWavelet (EZW) [12], Set Partitioning in Hierarchical Trees (SPHIT) [13], Embedded Block Coding withOptimized Truncation (EBCOT) [14] introduced to break up the original image into sub-band and encoding. Below we describe briefly each algorithm.

3-1 Embedded Zero trees Wavelet (EZW)

EZW is one of the first techniques which gave image compression a new direction which was superior to JPEG standard.To apply EZW on an image first step is applying DWT on image, there is two passes, dominant pass and subordinate pass named, Dominant pass start with finding a threshold and modifying the image pixel values depending on threshold. Now the image is scanned in a special order as shown in Figure.4. Second step is finding a threshold and qualify the image pixel value, the insignificant coefficient of the last sub-bands, which do not accept descendants and are not themselves descendants of a zerotree. The significance symbols of the image coefficient are then placed in the dominant list. The amplitude of the significant coefficients is placed in the subordinate list. Their values in the transformed image are set to zero in order not to undergo the next step. Also, when image is scanned and assigned with cods POS, NEG, IZ and ZTR [15] for positive, negative, isolated zero and zero tree respectively. The pixel which are coded as POS,NEG sent to subordinate and element which coded with POS and NEG are replaced with zero because we want to achieve less compression and refine value. Repeating this process by making the threshold half of the previous and then finally to the above coefficient, entropy coding applied such as Huffman coding, Arithmetic coding and etc.[16]. Using the coded string the image can be decoded in the same manner of encoding. One of the advantage of EZW is that we can stop decoding at any point of time to view the decoded image.

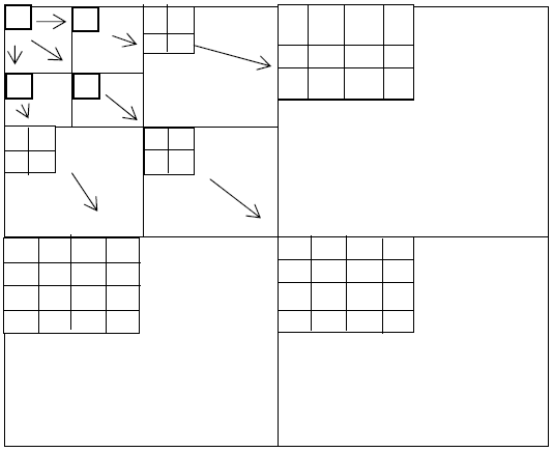

Fig.4. Zero Tree scanning order

3-2 Set Partitioning in Hierarchical Trees (SPIHT)

SPIHT algorithm is an improved version of EZW algorithm. It is based on embedded Zero Tree Wavelet (EZW) coding method. SPIHT was further improvement in this direction and is considered as a basis for compression. To improve coding efficiency, which has the effect of reducing the

flexibility of the bit stream, SPIHT uses the correlation between sub-band[17].

After the Wavelet transform is applied to an image the main algorithm works by partitioning the Wavelet decomposed image into significant and insignificant partitions. The coefficient of the distribution is changed into a tree wavelet domain coefficient are divided into many family blocks.

A family is composed of one coefficient of the HL_3, HH_3,LH_3 sub-band, (a pixel), for coefficient four block of HL_2, HH_2,LH_2sub-bands coefficient in the LL_3 sub-band are stored separately. There are two passes in this algorithm, the sorting pass and refinement pass. The list of significant pixel (LIP) if an entry is found to be significant, output a bit "1" for positive or "0" for negative. Now the significant entry is moved to the list of significant (LSP).

During the sorting pass the pixels in the LIP – which were insignificant in the previous pass- are tasted, and those that became significant are moved to the LSP. If an entry in LIP is insignificant a bit "0" is output. Each entry in LIP, it will decide that it is significant and give the output decision result. If the decision result is significant then moved into the LSP and the coordinate present with their sign. If the rest coordinates are going to be significant then this process is stopped. The sets are sequential evaluated following the list of insignificant pixels(LIS) order, and when a set is found significant it is removed from the list. The new sets with more than one element are added back to LIS, while the one element sets are added to the end of LIP or LSP, they being significant. Briefly in this method, more zero trees are efficiently found and represented by separating the tree root from the tree, so making compression more efficient through Wavelet transform. That Wavelet coefficient value in high frequency region are generally small, so it will appear "0" situation in quantify. Finally, this method combined with Huffman encode for further compression, as shown in Figure.5 [18].

3-3 Embedded Block Coding with ptimized Truncation (EBCOT)

EBCOT introduced at latest idea in this field and is the basis of JPEG2000, JPEG is the international standard for image compression. Entropy coder is the most important in JPEG2000. The EBCOT algorithm uses a wavelet transform to generated sub-bands. After applying DWT coefficient are quantization.

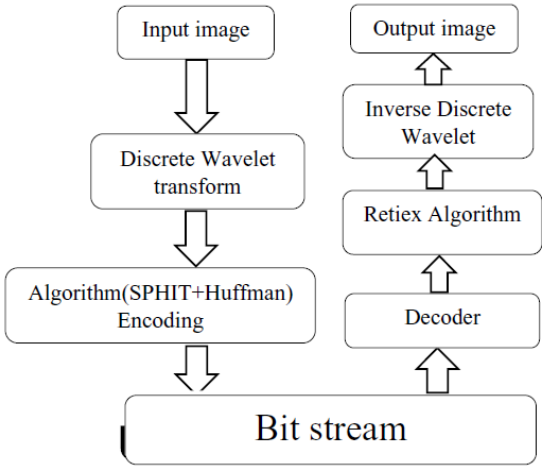

Fig.5. Block diagram

Then each sub-band is divided into block, called code block. Each code block coded independently, it decomposed into bit plan. EBCOT is two tier coders. Tier1 responsible for context based adaptive arithmetic encoding and tier 2 performing optimization and bit stream player formation [19]. EBCOT algorithm divided into 3 stage: bit plan quantization, conditional arithmetic coding of bitplans(tier 1 coding), fractional bit plan coding(tier2).

In bit plan quantization, all code block of a sub-band use the same quantizer, it is encoded one bit at a time, it's starting from the most significant(MSB) and preceding to the least significant bit (LSB). Conditional arithmetic coding of bit plans (tier1 coding), during progressive bit plane coding, substantial redundancy exists between the successive bit plans. The EBCOT algorithm exploited these redundancies in two ways. The first way is to identify whether a coefficient should be coded, and the second way how best the entropy coding can be adopted to the statistics of the neighboring coefficients. Each coefficient in a block assigned a binary state variable called, its significant state that is initialized to zero and then changed to 1 immediately after coding the first nonzero magnitude bit for the sample. Fractional bit plane coding (tier2), the quantized coefficients in a code block are bit plan encode independent of other code blocks in the sub-band. Instead of encoding the entire bit plane in one pass, each bit plane is encoded in three sub-bit.

Plane passes, called fractional bit plane coding. The reason for this is to be able to truncate the bit stream at the end of each pass to create near optimum bit stream finally in the entropy encoding stage, the coefficients in a code block are entropy encoded one bit plane at a time by embedded block coding, as shown in Figure.6 [20].

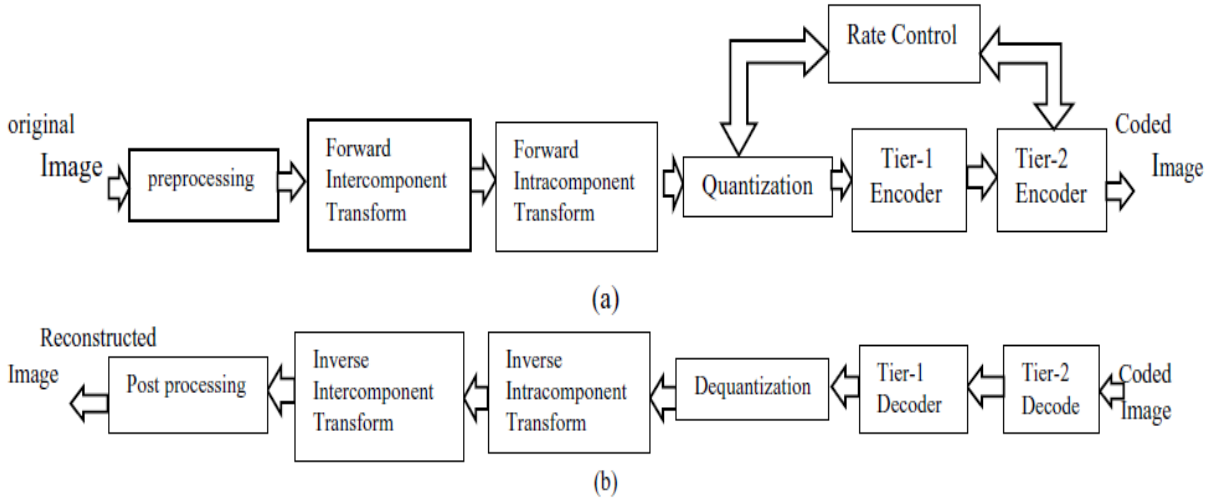

Fig.6. Code structure. The structure of the (a) encoder and (b) decoder.

4- Fractal Coding

Fractal image compression is a technique for encoding images 21]. Fractal compression is a lossy image compression method to achieve high levels of compression in which an image is compressed by sorting it as a transformation basically as function involved in the process use functional programming technique to model fractal image compression. With fractal compression, encoding is computationally expensive because of the search used to find the self-similarities. This method requires a long encoding time. It is from a large number of domain blocks. That must be examined to match each range block. The fractal image compression at first step is partitioned into domain of size B×B. then domain blocks are created from the original image of size 2B×2B in horizontal and vertical direction. After constructing domain pool related to each range block we must select the best domain block from domain pool and find affine transformation. Selected domain block with minimum distance. Applied affine transformation, very closelyto the main block. It is important to find similar block to represent the input image. So, a sufficient number of candidate blocks for D_i need to be considered. Afterward a fractal image format file is generated for the image. That contain information on the choice of domain region and the image. So, all pixels in a given region are compressed [22].

5- ContourLet Transform

Contour let Transform is also another algorithm to compression medical images. Contour let is a new multi scale, directional transform. It is used to decompose the image into coefficient. It has a fast implementation based on Laplacian Pyramid decomposition followed by directional filter banks applied on each band pass sub-band. In double filter bank, the Laplacian Pyramid (LP) and Directional Filter Bank (DFB). As shown in Figure.7 [23].

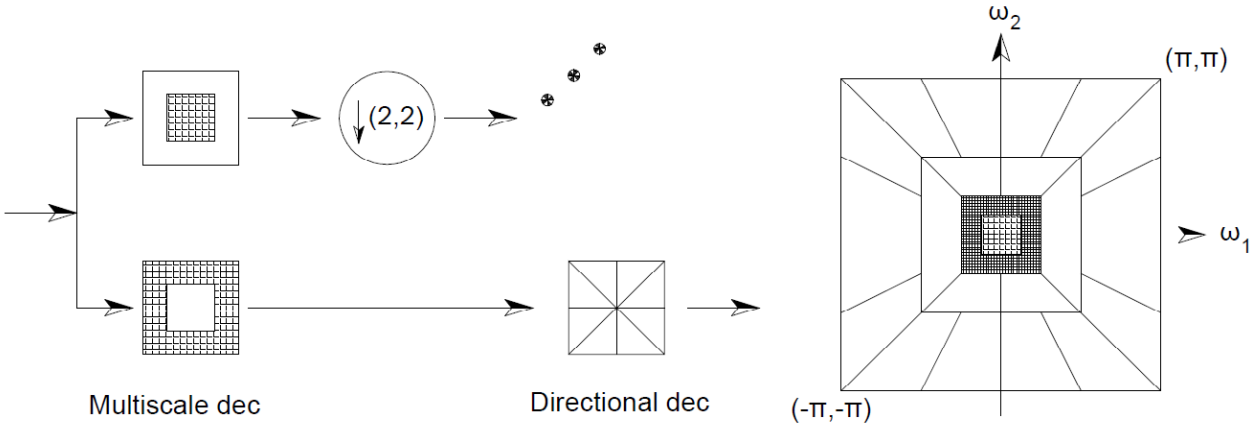

Fig.7. Pyramidal directional filter banks

Using DFB make it possible to capture important details of the image and capture the smooth contours of image and the LP decomposed image into sub-band, it allows sub-bands decomposition to avoid leaking of low frequencies into several directional sub-band, and thus directional information can be captured efficiency. After chosen decomposing threshold is important, applied thresholding process on coefficient then quantized, Huffman coding is applied on quantized coefficient and coded bit-stream is a generated it include coefficient and Contour let filter information [24].

6- Conclusion

In this paper, various compression methods are reviewed. Image data compression in previous two decades achieves substantial progress. We already discussed about compression techniques, they are done using different quantization methods, Entropy coding and mathematical transformation. These techniques propose a unique characteristic which is used to compress medical image,basically data compression most applicable when we need to transmit or store a huge amount of data.The observation from literature survey revealed superior performance of Contour let Transform[25],the main difference between these present methods and contour let is that, these methods do not allow different numbers of direction at each scale. It has excellent properties for image representation, such as multire solution, localization and directionality, which are the key characteristics of human vision system.The research is going on to find a technique will overcome performance and also to enhance of the reconstructed quality of compressed image with high compression rate for medical image.

Acknowledgment

We thank those individuals, institutions who have contributed and motivated us to come up with this literature survey successfully. This study would not be possible if compression researchers did not routinely place their implementation techniques and papers on the Internet for public access.

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