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Analysis of medical image using wavelet transform

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Abstract
Image compression is a very important aspect of image storage and transmission, Image compression plays a crucial role in medical imaging, allowing efficient manipulation, storage, and transmission. In this work an approach to improve the performance of medical image compression is proposed. A novel near-lossless compression scheme is proposed here and yields significantly better compression rates. In this proposed method, base points, direction images and D-value images are obtained from RGB color space image by transformation. Base points, direction images are encoded by binary coding, distributed arithmetic coding. Wavelet coefficients of D-value images are encoded by adaptive Huffman coding. Here, medical image coding with color space transformation and wavelet transform coding are combined, a high compression and good image quality are achieved by applying the algorithm like adaptive Huffman coding and distributed arithmetic coding.

Keywords: Medical Image, Wavelet transform, Huffman coding, distributed arithmetic coding

Introduction

Image compression is a very important aspect of image storage and transmission. For example, image compression has been and continues to be crucial to the growth of multimedia computing. In addition, it is the natural technology for handling the increased spatial resolutions of today's imaging sensors and evolving broadcast television standards. Furthermore, image compression plays a crucial role in medical imaging, allowing efficient manipulation, storage, and transmission.

This paper will propose an approach to improve the performance of medical image compression while satisfying both the medical team who need to use it, and the legal team who need to defend the hospital against any malpractice resulting from misdiagnosis owing to faulty compression of medical images. The improved compression performance will be accomplished by making use of clinically relevant regions as defined by physicians. Images taken of patients will be aligned to presorted image models stored in an atlas. The atlas will contain models of typical classes of images. If we are trying to compress a chest X-ray image, then it will be matched with a presorted chest X-ray model that is stored in the atlas. If we are trying to compress an X-ray of the right hand, then it will be matched with a presorted right hand X-ray model that is stored in the atlas. Once an image is aligned to its corresponding model in the atlas, the two can then be aligned and the clinically relevant regions defined on this atlas image will be used to define the relevant region on the newly scanned patient image. There are varied approaches for performing the alignment such as maximization of mutual information and deformable contour modeling.

Lossless compression will be applied in the clinically relevant area and lossy compression will be applied in the other areas. One of the reasons to use lossless compression in the relevant areas is not because radiologists think it is fine based on ROC curves. From our interviews, most doctors would prefer using lossy compression with the quality level on high. This would yield an image that is much smaller than it is lossless-compressed counterpart and the image will be ‘visually lossless’. However, the lossy compressed image, when decompressed, is not identical to the original (i.e., there was loss) and the lawyers have a problem here. So this makes the problem not just what is perceptibly ‘good enough’ (i.e., what is ‘visually acceptable’), but rather, what is ‘clinically relevant.

In the last few years, there has been a considerable increase in the volume of medical images and video generated in hospitals. As images are of huge data set and encoding it for a lower bit rate results in loss of data, which intern results in very low image quality under retrievation. Coming to the transmission over a noisy channel this problem becomes more effective due to narrow bandwidth effect. Various algorithms were proposed for encoding and compressing the image data before transmission. These algorithms show high-end results under high bandwidth systems but show poor result under low data rate systems.

The problem of transmission of images over a low bit rate bandwidth can be overcome if the image data bits are such encoded and compressed that the data bit rate is made compatible to the provided low bit rate. In a typical hospital, vast numbers of medical data are generated every year. The medical multimedia information is different from other multimedia data because of its particular properties. There are legal and strict regulations applied to medical multimedia information, since the health of a patient depends on the correctness and accuracy of this information. Moreover, the integrity, confidentiality and security of medical data is crucial to protect it from accidental or malicious alteration during interchange and storage. Another critical property is that the information related to a patient must be available in a short period of time, whenever or wherever it is required, and especially so in the case of emergencies.

The traditional medical image compression techniques (e.g. JPEG, JPEG2K) suffers from low compression rates, low PSNRs, poor reconstructed image quality as well as high MSEs and PRDs (percentage rate distortion).

Approach

There are three stages in the proposed coding, the first stage is color space transformation, and RGB color space image can be transformed into base points, direction images and D-value images. The second state are obtaining primary color component, secondary color components and direction images' wavelet transform, and the third stage are direction's wavelet coefficients, base points and direction images' entropy coding. In this paper, medical image coding with color space transformation and wavelet transform coding are combined; a high compression and good image quality are achieved by applying the algorithm like adaptive Huffman coding and distributed arithmetic coding.

The Flow of Image Compression Coding

What is the so-called image compression coding? Image compression coding is to store the image into bit-stream as compact as possible and to display the decoded image in the monitor as exact as possible. Now consider an encoder and a decoder as shown in Fig. 1. When the encoder receives the original image file, the image file will be converted into a series of binary data, which is called the bit-stream. The decoder then receives the encoded bit-stream and decodes it to form the decoded image. If the total data quantity of the bit-stream is less than the total data quantity of the original image, then this is called image compression. The full compression flow is as shown in Fig 1.

Fig 1: The basic flow of image compression coding

The compression ratio is defined as follows.

$$Cr = \frac{n1}{n2} \quad (1)$$

Where n_1 is the data rate of original image and n_2 is that of the encoded bit stream. In order to evaluate the performance of the image compression coding, it is necessary to define a measurement that can estimate the difference between the original image and the decoded image. Two common used measurements are the Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR), which are defined in (2) and (3), respectively. f(x, y) is the pixel value of the original image, and f'(x,y)is the pixel value of the decoded image. Most image compression systems are designed to minimize the MSE and maximize the PSNR.

$$MSE = \sqrt{\frac{\sum_{x=0}^{W-1}\sum_{y=0}^{H-1}[f(x,y)-f'(x,y)]^2}{WH}} \quad (2)$$

$$PSNR = 20\log_{10}\frac{255}{MSE} \quad (3)$$

The general encoding architecture of image compression system is shown is Fig 2. The fundamental theory and concept of each functional block will be introduced in the following sections.

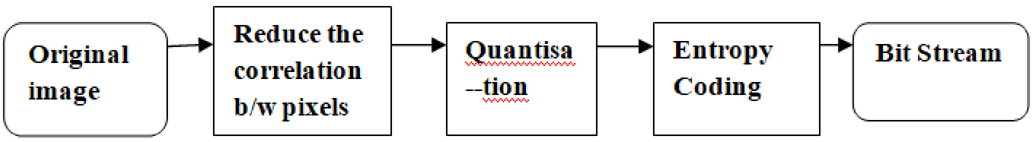

Fig. 2: The general encoding flow of image compression

Reduce the Correlation between Pixels

Why an image can be compressed? The reason is that the correlation between one pixel and its neighbor pixels is very high, or we can say that the values of one pixel and its adjacent pixels are very similar. Once the correlation between the pixels is reduced, we can take advantage of the statistical characteristics and the variable length coding theory to reduce the storage quantity. This is the most important part of the image compression algorithm; there are a lot of relevant processing methods being proposed. The best-known methods are as follows:

Predictive Coding

Predictive Coding such as DPCM (Differential Pulse Code Modulation) is a lossless coding method, which means that the decoded image and the original image have the same value for every corresponding element.

Orthogonal Transform

Karhunen-Loeve Transform (KLT) and Discrete Cosine Transform (DCT) are the two most well-known orthogonal transforms. The DCT-based image compression standard such as JPEG is a lossy coding method that will result in some loss of details and unrecoverable distortion.

Subband Coding

Subband Coding such as Discrete Wavelet Transform (DWT) is also a lossy coding method. The objective of subband coding is to divide the spectrum of one image into the lowpass and the highpass components. JPEG 2000 is a 2-dimension DWT based image compression standard.

Quantization

The objective of quantization is to reduce the precision and to achieve higher compression ratio. For instance, the original image uses 8 bits to store one element for every pixel; if we use less bits such as 6 bits to save the information of the image, then the storage quantity will be reduced, and the image can be compressed. The shortcoming of quantization is that it is a lossy operation, which will result into loss of precision and unrecoverable distortion. The image compression standards such as JPEG and JPEG 2000.

Entropy Coding

The main objective of entropy coding is to achieve less average length of the image. Entropy coding assigns codewords to the corresponding symbols according to the probability of the symbols. In general, the entropy encoders are used to compress the data by replacing symbols represented by equal-length codes with the codewords whose length is inverse proportional to corresponding probability.

2. Literature survey

K. Grochenig and W.R. Madych on their paper proposed the notion of multiresolution analysis and formulated a very interesting relation between the theory of compactly supported wavelet basis and the theory of similar tiling for construction [1]. Adrian Munteanu, Jan Cornelis, Geert Van Der Auwera, & Paul Cristea introduced a new wavelet based embedded compression technique that efficiently exploits the intraband dependencies and make use of the quad-tree approach to encode he significance maps [2]. Tim Flaherty, Yang Wang in their paper generated the result of Grochenig and W.R. Madych where they showed that a Haar- type wavelet basis of L2 (Rn) can be constructed from the characteristic function XΩ of a compact set Ω, if and only if Ω is an integral affine tile of Lebresgne measure[1] one to the multi-wavelet settings [3]. Edmud Y. Lam & Joseph W. Goodman offered a comprehensive mathematical analysis of the DCT coefficient distribution of natural images to show that by using a doubly stochastic model, the Laplacian distribution of the coefficients can be determined [4]. Albert Cohen & Basarab Matei introduced new multiscale representations for images which incorporates the L^2 error approach method in which the BW method gave the best results while the EA method provides the best results in case of visuality [5]. Sonja Grgic, Mislav Grgic and Zovko- Cihlar presented comparative study of different wavelet-based image compression system by examining wavelets on the basis of different wavelet functions, filter orders, no. of decompositions, compression ratio and image contents for implementation in a still image compression system [6]. Pitor Porwik, Agnieszka Lisowska presented graphic dependencies between the parts of Haar and wavelet spectra and also compared the wavelets in the 2-D space. The work show the graphical way of presentation of decomposition levels for both the Haar matrix based methods & wavelets [7]. R. Sudhakar, Ms R Karthiga, S. Jayaraman, proposed that the latest techniques such as EBCOT, ASWDR perform better than its predecessors such as EZW, WDR. They also produced some of the lowest errors per compression rate & highest perceptual quality by using wavelet coding techniques such as EZW, SPIHT, SPECK, WDR algorithm and ASWDR algorithm [8]. Kamrul Hasan Talukder & Koichi Harada applied DWT to estimate the detail matrices from the information matrix to synthesize the reconstructed image using the estimated detail matrices and information matrix provided by the wavelet transform [9]. P. Raviraj & M.Y. Sanavullah developed computationally efficient & effective algorithm using Haar wavelet transform for compression of lossy images to minimize the computational requirements by applying various thresholding techniques to improve the quality of the reconstructed image [10].

Table 1

S. No.	Authors	Approaches	Merits	Demerits
1	Kanisetty Venkata Swathi et al.	Daubechies wavelet transform	It is able to manage different images resolution	It consider only wavelet coefficient value
2	J. Srikanth et al.	Wavelet Transform	It reduces the storage cost	Not able to maintain edge information efficiently
3	Ch.Bhanusree et al.	Second Generation Wavelet Transform	It is multi scale dimensionality	It has poor directionality
4	Kanaka Raju Penmetsa et al.	DT-CWT method	Image visual eminence is better	Has limited directionality
5	Patil Gaurav Jaywantrao et al.	Dual Tree complex Wavelet Transform (DT-CWT)	It is more flexible and better image visibility and reduces the time variant	It introduce artifacts like aliasing
6	Pavithra C et al.	wavelet transform using gradient and smoothness criterion	It is able to retain the edge information also minimize the noise	It is domain-independent
7	Hasan Demirel et al.	Complex Wavelet Transform (CWT)	magnitude or phase, shift invariant and free from aliasing	Most expensive and computational intensive
8	Singh R.et al	weighted fusion scheme using Daubechies complex wavelet transform (DCxWT)	It is better to retain the edge the information than the DT-CWT	Not able to achieve the expected performance
9	Bull D.R. et al.	3-D separable wavelet transform	It is able to enhance the quality of 3-D image	Poor selectivity for diagonally
10	Ai Deng et al.	discrete wavelet transform (DWT)	It effectively reduce the noise from image	It is a shift- invariant in nature

The above table1 mentions some of the various comparisons of WLT.

3. Implementation

The block diagram of existing system is as shown below fig 3.

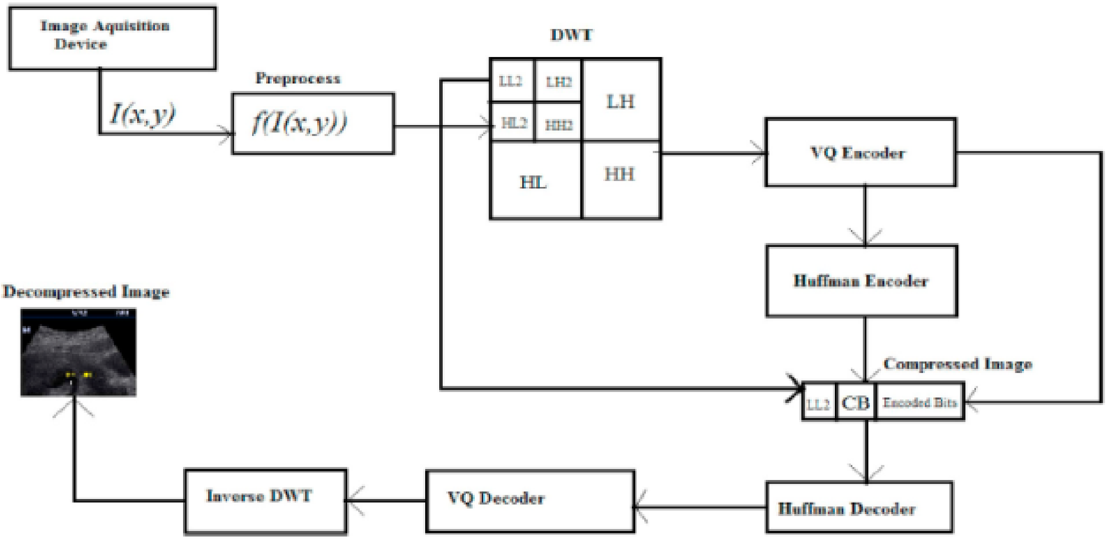

Fig 3: Existing System block diagram

In this technique, images are filtered at the preprocessing stage to remove speckle and salt and pepper noises in ultrasound imaging, since such images are inevitably affected. If the image is not ultrasound it has a negligible effect, but edge preservation is achieved in all situations since it is a crucial step in all medical image diagnosis. The images are then filtered using DWT. A threshold is applied to the generated coefficients with the effect that coefficients that fall below that threshold are replaced by zeroes. The result is then vectored quantized. Finally, the quantized coefficients are Huffman encoded. Fig 3 summarizes the process. The resulting bits that represent the compressed image are then stored or transmitted

Below fig 4 represents the proposed block diagram for encoder and decoder.

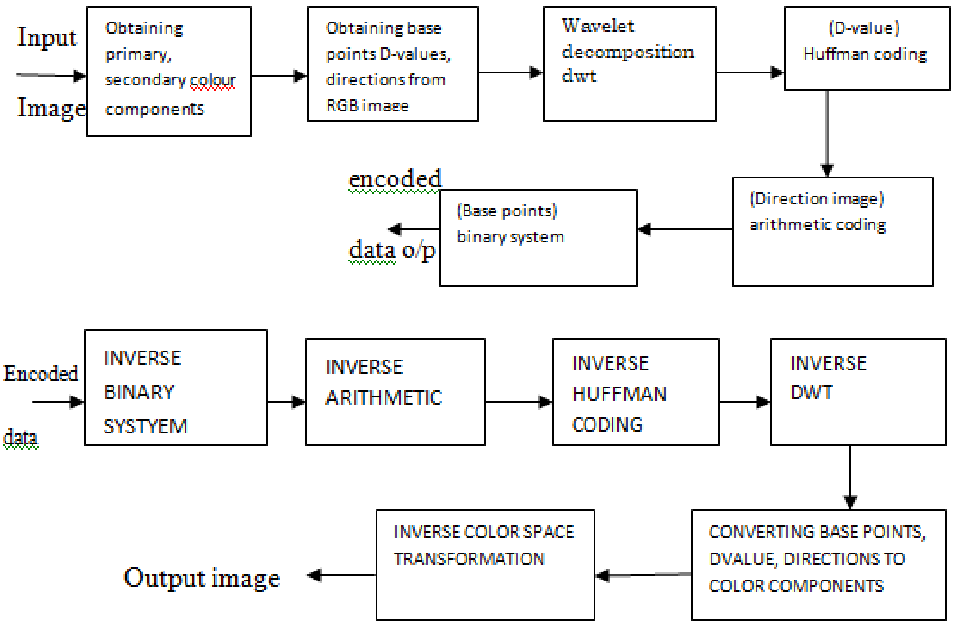

Fig 4: Encoder and Decoder

The Huffman encoding algorithm starts by constructing a list of all the alphabet symbols in descending order of their probabilities. It then constructs, from the bottom up, a binary tree with a symbol at every leaf. This is done in steps, where at each step two symbols with the smallest probabilities are selected, added to the top of the partial tree, deleted from the list, and replaced with an auxiliary symbol representing the two original symbols. When the list is reduced to just one auxiliary symbol (representing the entire alphabet), the tree is complete. The tree is then traversed to determine the codewords of the symbols.

Before starting the compression of a data file, the compressor (encoder) has to determine the codes. It does that based on the probabilities (or frequencies of occurrence) of the symbols. The probabilities or frequencies have to be written, as side information, on the output, so that any Huffman decompressor (decoder) will be able to decompress the data. This is easy, because the frequencies are integers and the probabilities can be written as scaled integers. It normally adds just a few hundred bytes to the output.

It is also possible to write the variable-length codes themselves on the output, but this may be awkward, because the codes have different sizes. It is also possible to write the Huffman tree on the output, but this may require more space than just the frequencies. In any case, the decoder must know what is at the start of the compressed file, read it, and construct the Huffman tree for the alphabet. Only then can it read and decode the rest of its input. The algorithm for decoding is simple. Start at the root and read the first bit off the input (the compressed file). If it is zero, follow the bottom edge of the tree; if it is one, follow the top edge. Read the next bit and move another edge toward the leaves of the tree. When the decoder arrives at a leaf, it finds there the original, uncompressed symbol (normally its ASCII code), and that code is emitted by the decoder. The process starts again at the root with the next bit.

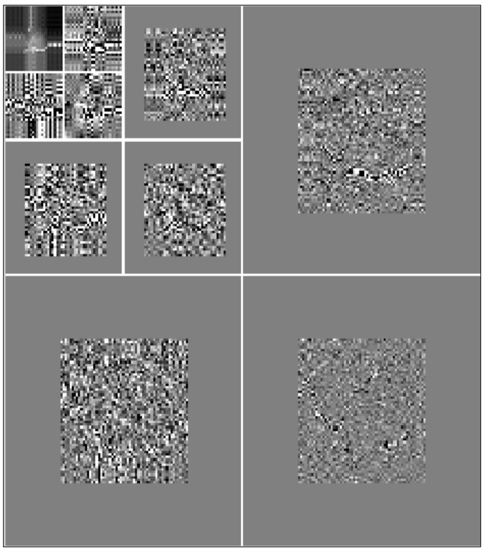

Fig 5: Wavelet Decomposition

The above result shows the wavelet decomposition the original image by scale value 3.

4. **Simulation results**

Using matlab the results are obtained as shown below with the algorithms implemented

Sample 1

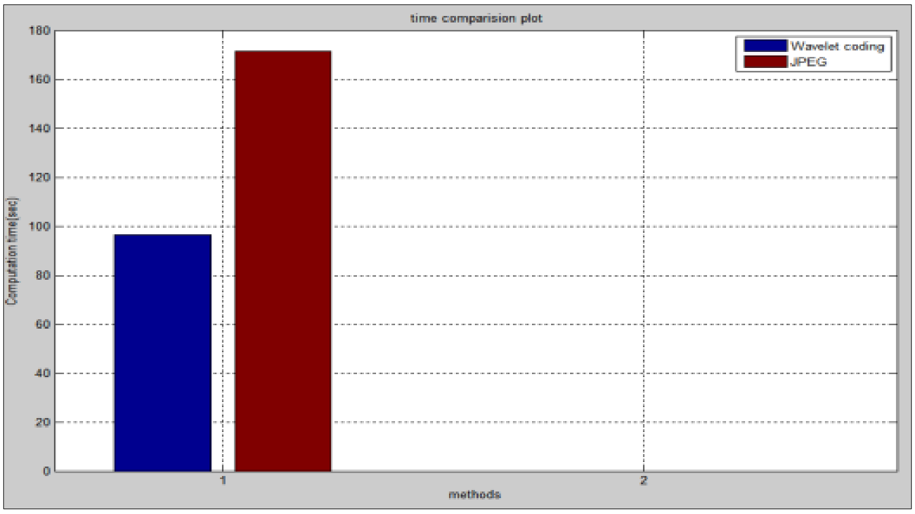

Fig 6: Time comparison plot

The above graph shows the time comparison plot between JPEG and WAVELET

From the above result we observe that the computational time in wavelet is very less than in JPEG.

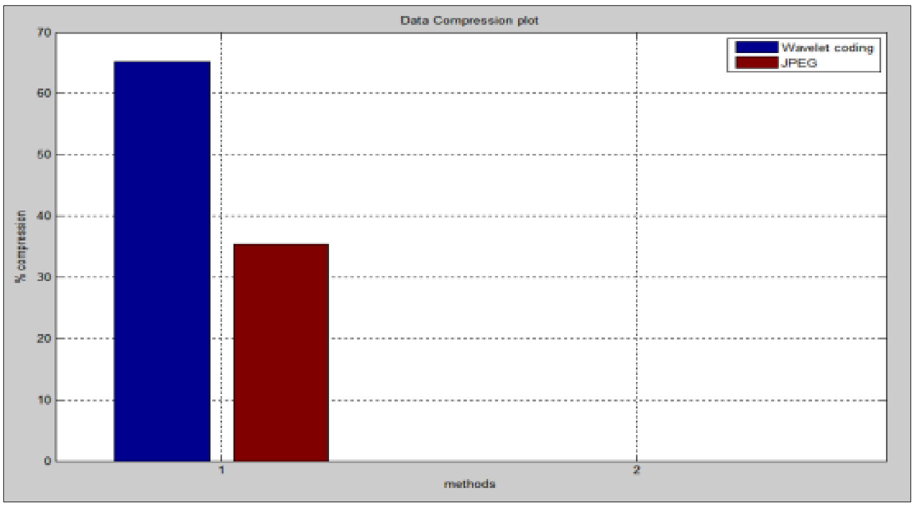

Fig 7: data compression rate plot

The above graph shows the data compression rate plot between JPEG and wavelet

From the above result we observe that the wavelet produces high compression rates compare to JPEG

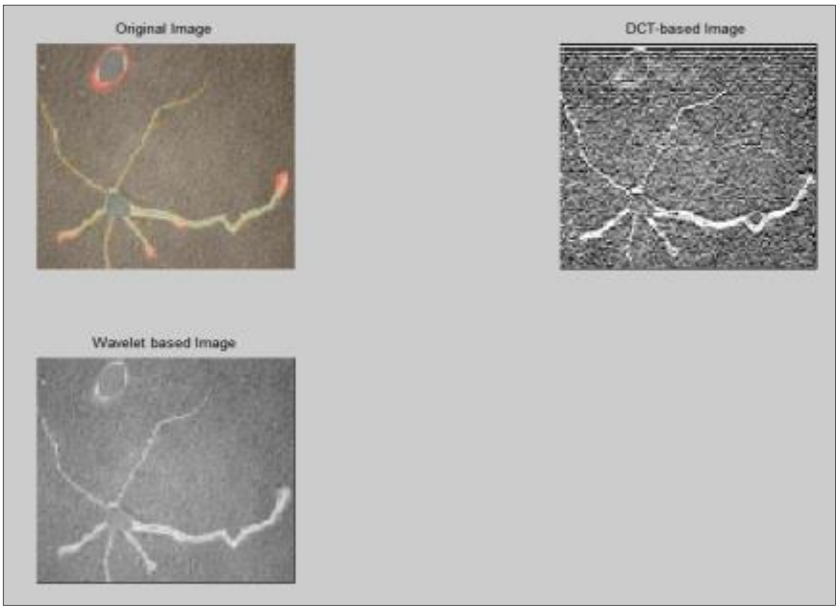

Fig 8: Comparison of DWT and DCT

The above result shows the diagnostic image clarity is more in wavelet based Image compared to DCT-based image.

Sample 2

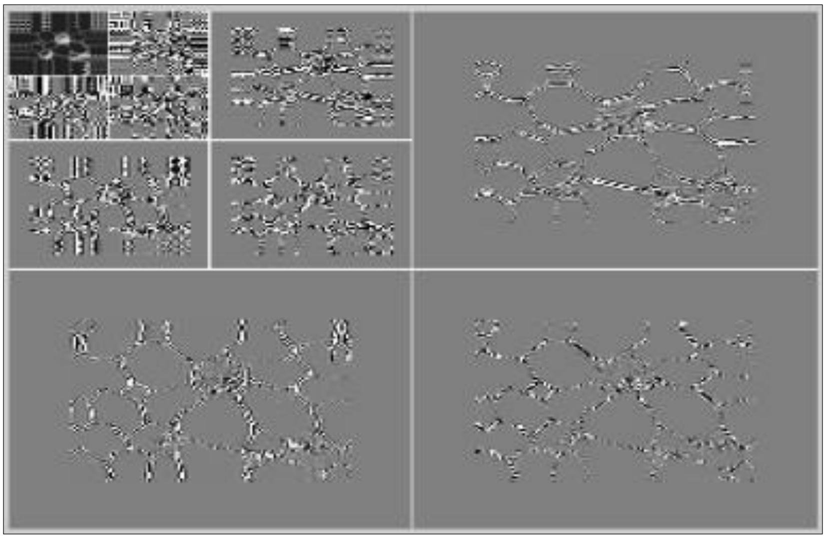

Fig 9: Wavelet Decomposition

The above result shows the wavelet decomposition of the original image by scale value 3.

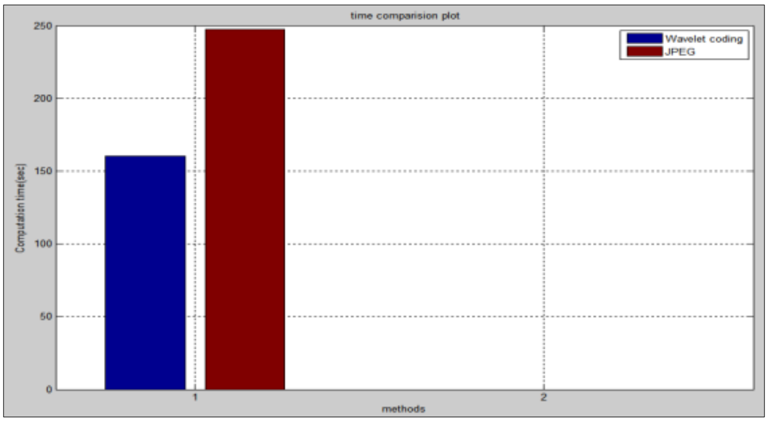

Fig 10: Time comparison plot

The above graph shows the time comparison plot between JPEG and WAVELET

From the above result we observe that the computational time in wavelet is very less than in JPEG.

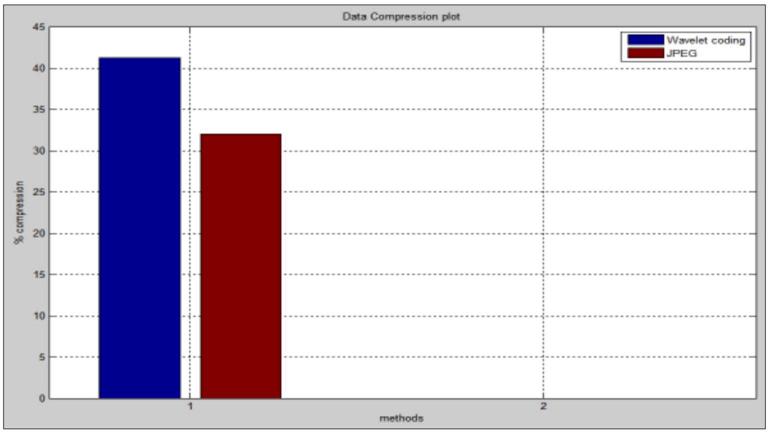

Fig 11: Data compression rate

The above graph shows the data compression rate plot between JPEG and WAVELET

From the above result we observe that the wavelet produces high compression rates compare to JPEG

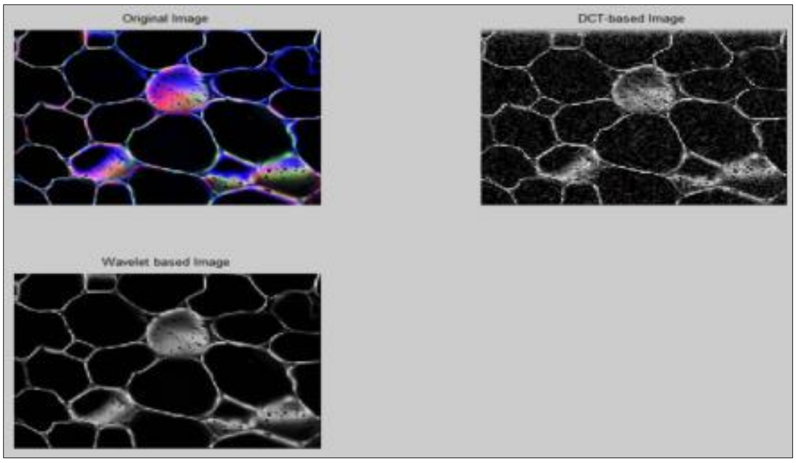

Fig 12: Comparison of DWT and DCT

The above result shows the diagnostic image clarity is more in wavelet based Image compared to DCT-based image.

Table 2: Wavelet based values for proposed system

Sample	PSNR Previous	PSNR proposed	MSE previous	MSE proposed
Sample 1	67.6292	67.6292	46.49	48.35
Sample 2	68.3284	68.3284	49.51	51.86

5. Conclusion

This work implemented an enhanced image coding system for image compression compared to the existing JPEG system. It is observed that Discrete Wavelet Transform is able to achieve its good performance with a relatively simple algorithm. The previous methods used for medical image compression and restoration are not efficient because the compression rate is not better and diagnostic quality of the image using Discrete Cosine Transform is very less. The above problem can be overcome using the Discrete Wavelet Transform. In DWT the better compression rates are achieved and the diagnostic quality of the improved.

From the obtained results it is concluded that discrete wavelet Transform takes comparatively less time than the JPEG coding system. The coding also shows less percentage of error in retrieved image compare to the existing JPEG coding system. It is observed that image coded with Discrete Wavelet Transform shows clearer image than other coding system.

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