Objective Evaluation on Medical Image Compression Using Wavelet Transform

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Abstract: The use of computers for handling image data in the healthcare is growing. However, the amount of data produced by modern image generating techniques is vast. This data might be a problem from a storage point of view or when the data is sent over a network. This paper using wavelet transform technique for medical images compression. MATLAB program, are designed to evaluate medical images storage and transmission time problem at Sebha Medical Center Libya. In this paper, three different Computed Tomography images which are abdomen, brain and chest have been selected and compressed using wavelet transform. Objective evaluation has been performed to measure the quality of the compressed images. For this evaluation, the results show that the Peak Signal to Noise Ratio (PSNR) which indicates the quality of the compressed image is ranging from (25.89db to 34.35db for abdomen images, 23.26db to 33.3db for brain images and 25.5db to 36.11db for chest images. These values shows that the compression ratio is nearly to 30:1 is acceptable.

Introduction

The need for high-performance image compression is becoming greater and greater as digital imagery finds its way into many areas of everyday life, including multimedia technology, digital photography, Internet viewing, image archiving, and medical imaging. The overall goal of compression is to represent an image with the smallest possible number of bits, or to achieve the best possible fidelity for an available communication or storage bit rate capacity [1]. Technically, all image data compression schemes can be broadly categorized into two types. One is reversible compression, also referred to as "lossless". A reversible scheme achieves only modest compression ratios, but allows exact recovery of the original image from the compressed version. The second type is irreversible scheme, or a "lossy" scheme, which does not allow exact recovery after compression, but can achieve much higher compression ratios [2, 3].

The Discrete Wavelet Transform (DWT), based on time-scale representation, provides efficient multi-resolution sub-band decomposition of signals. It has become a powerful tool for signal processing and finds numerous applications in various fields such as audio compression, pattern recognition, texture discrimination,
computer graphics etc. Specifically the 2-D DWT and its counterpart 2- D Inverse DWT (IDWT) play a significant role in many image/video coding applications.[3]

In medical image compression applications, diagnosis is effective only when compression techniques preserve all the relevant and important image information needed. This is the case with lossless compression techniques. Lossy compression techniques, on the other hand, are more efficient in terms of storage and transmission needs but there is no warranty that they can preserve the characteristics needed in medical image processing and diagnosis. [4]. Wavelet transform image compression involves the use of a new field of applied mathematics often called wavelet theory. Wavelet compression is a subset of a larger class of techniques generally referred to as "transform-based compression". The first step in a transform-based technique typically involves a lossless mathematical transform to provide a sparse representation of an input image. The transformed data are then quantized to achieve the desired level of compression [7, 8, 9]. The quantized Transform domain values can never be restored to their original accuracy, but such quantization is necessary in order to achieve higher compression ratios. The last step in transform-based compression is often referred to as "entropy coding" and involves the application of standard lossless compression techniques that may include run length encoding (RLE) [1], Huffman coding [1], or arithmetic encoding].

Theory of wavelet

Wavelet analysis is a new method, though its mathematical underpinnings date back to the work of Joseph Fourier in the nineteenth century. Mathematical transforms translate the information of signals into different representations [9]. For example, the Fourier transform converts a signal between the time and frequency domains. Wavelet analysis can be used to divide the information of an image into approximation and detail sub-signals. The approximation sub-signal shows the general trend of pixel values, and three detail sub-signals show the vertical, horizontal and diagonal details or changes in the image. If these details are very small then they can be set to zero without significantly changing the image. The greater the number of zeros the greater the compression that can be achieved [9].

Image Quality Measurement Techniques

A top quality image is very necessary in the final diagnosis and medical decisions making. Diagnostic information includes anatomical features and pathological variability relevant to the diagnosis, the ability of the imaging system to record these features, and the ability of the medical expert to extract and use them in diagnostically [2]. Objective method is used to evaluate the image quality. Objective evaluation method in lossless compression, exacting numeric representation of the original image, therefore the reconstructed image is said not to have any distortion. On the other hand in lossy compression the reconstructed image is not as the same as the original and there will be a difference between the original image and the reconstructed image. This difference is called distortion. To evaluate the effectiveness of the compression scheme, it is important to estimate the distortion generated during compression [6,7]. The distortion measures the closeness of the original to the compressed images and can be evaluated using the Peak Signal to Noise Ratio **(**PSNR). The calculation of PSNR involves the estimation of two measures of distortion; namely the Mean Square Error (MSE) squared and the Maximum Absolute Error (MAE) [2,3]. The maximum absolute error (MAE) is calculated as:

$$MAE = Max\left| f(i,j) - f^{'}(i,j) \right| \text{ …….. } (1)$$

Where $f(i,j)$ is the original image data and $f^{'}(i,j)$ is the compressed image value.

A widely used measure reconstructed image for an N×M size image is the (MSE) as given by [2,3]:

$$MSE = \frac{1}{N.M}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left[\left| f(i,j) - f^{*}(i,j)\right|^{2}\right] \text{ ….. } (2)$$

Where $f(i,j)$ is the original image data and $f^{*}(i,j)$ is the compressed image value. The formula for PSNR is given by:

$$PSNR = 10\log\left(\frac{(255)^{2}}{MSE}\right) \text{ ……… } (3)$$

METHODOLOGY

Data Collection and Applied Algorithm

Medical images used in this study are Computed Tomography images (CT), where it was collected from the Department of Medical Imaging in Sebha Medical Center in the city of Sebha Libya. This Department include two systems for CT scan, the first are Hitachi CT system, and the second is more modern on which is Philips CT system.. From the Philips CT system three types of images were selected (Brain, Abdomen and Chest images) from every case 10 images were selected. All of these images have the same dimensions equal (580×578). Figure 1. Shows types of these images.

Results processed using MATLAB program. This program returns compression ratio and quality of image measurement when given the following inputs: 1. CT Medical images. 2. Level of decomposition. 3. Wavelet Filters. 4. Thresholding value. Medical images used are divided into three groups, each group consisting of 10 images, where the first group contains images of the abdomen, while the second group included brain images, and the third group contains images of the chest. For levels of decomposition, it was a choice of three levels, namely: Level 1, Level 2, and Level 3 The wavelet filters are: Haar Filter, db3 Filter, db6 Filter, and db9 Filter. Algorithm , which was designed in this study contains several successive steps that illustrated in Figure (2).[5]

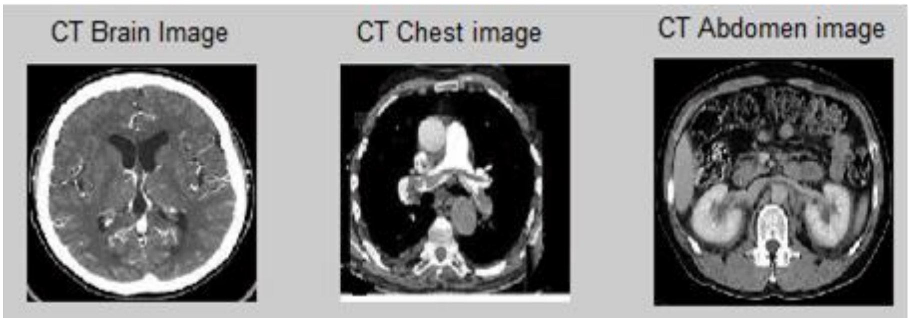

Figure 1. shows CT Brain Chest and Abdomen images

B. The Methodology Structure

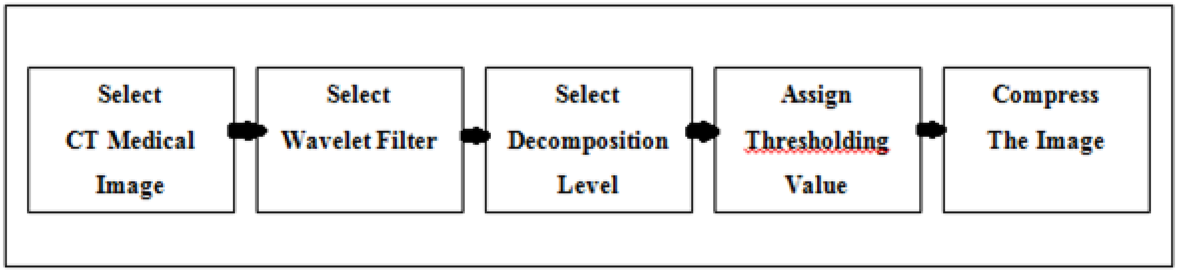

Figure (2): Steps of MATLAB Program

After selecting all the inputs shown in Figure (2), The MATLAB program calculates the compression ratio of the resulting image to the original image. The program also calculates the image quality resulting from the compression process, which represent with Peak Signal to Noise Ratio (PSNR), through the use of equations (1), (2), and (3). The general shape of the MATLAB program can be represented as shown in Figure (3).

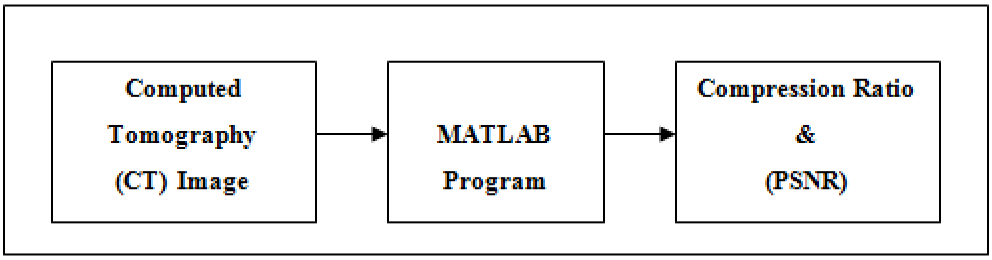

Figure (3): General shape of the MATLAB program

The Flowchart of the program

The flowchart of this program is illustrated in Figure (4), It shows the stages of the program based on the priorities of the program inputs to give the desired results. This program was implemented using Matlab [5].

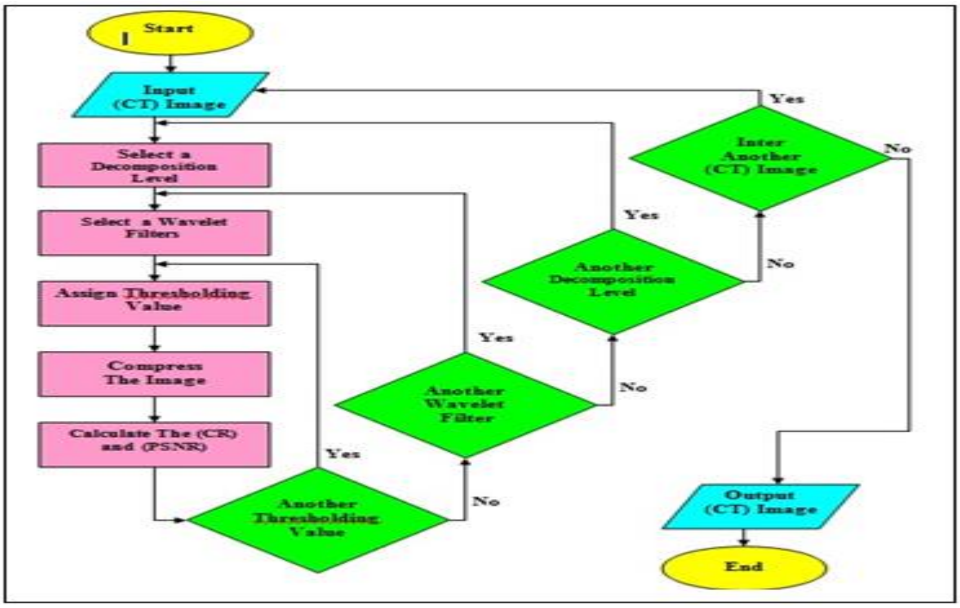

Figure 4 illustrated the flowchart of Matlab program

Results and Discussion

The results of this study and the evaluation of the effectiveness of compression on three different CT medical images (Abdomen, Brain and chest) were evaluated. The two different methods to evaluate image quality, these are objective and subjective methods were discussed. The calculated compression ratio (CR) and (PSNR) for all different CT images have been reported in table 1. Secondly in subjective measure method, CT image used have been viewed by a group of emasculative in CT scan imaging, were involved to see and investigates the compressed images to determine their quality. These results shows that the mean effects of threshold values on CR and PSNR for all CT images have been used, but with varied rates as shown in the Figures (5) and (6).

The results show that as increase in the value of the thresholds result increase in image compression ratios, while the quality is decreasing. From this results we find the best thresholding value was found to be ranging from (11 to 28, 5 to 21, and 7 to 24) for abdomen, brain, and chest respectively, with level 2 decomposition level and Haar filter. In this work no clear different between looking at the compression ratio and the image quality with different wavelet filters for all images used (Haar, db3, db6, db9). Changing the decomposition level changes the amount of detail in the decomposition. Thus, at higher decomposition levels, higher compression ratio can be gained, while more energy of the signal is vulnerable to loss, and thus a decrease in the level of image quality. The results show that level 2 of decomposition level is suitable to use with abdomen, brain and chest images. From Figure 5, shows more compression ratio gained on Chest image compared with other images. This is because, depending on characteristic on these images

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Table (1) Compression Ratio (CR) and Peak Signal to Noise Ratio (PSNR) for CT test images in level (3) decomposition with Haar filter

Type of image (CT)		Abdomen image		Brain image		Chest image	
	Threshold value	CR	PSNR	CR	PSNR	CR	PSNR
Image number1 for all types used	30	25:1	33.98	15:1	33.10	26:1	35.76
	60	47:1	30.39	28:1	28.69	45:1	31.32
	90	68:1	28.34	40:1	26.41	69:1	28.65
	120	85:1	27.14	51:1	24.94	92:1	27.05
	150	100:1	26.16	64:1	23.73	112:1	25.99
	170	110:1	25.54	70:1	23.23	125:1	25.40
	200	124:1	24.80	79:1	22.50	143:1	24.66
	220	130:1	24.47	84:1	22.12	153:1	24.29
	230	133:1	24.31	86:1	21.95	158:1	24.11
	250	137:1	24.07	91:1	21.62	165:1	23.84

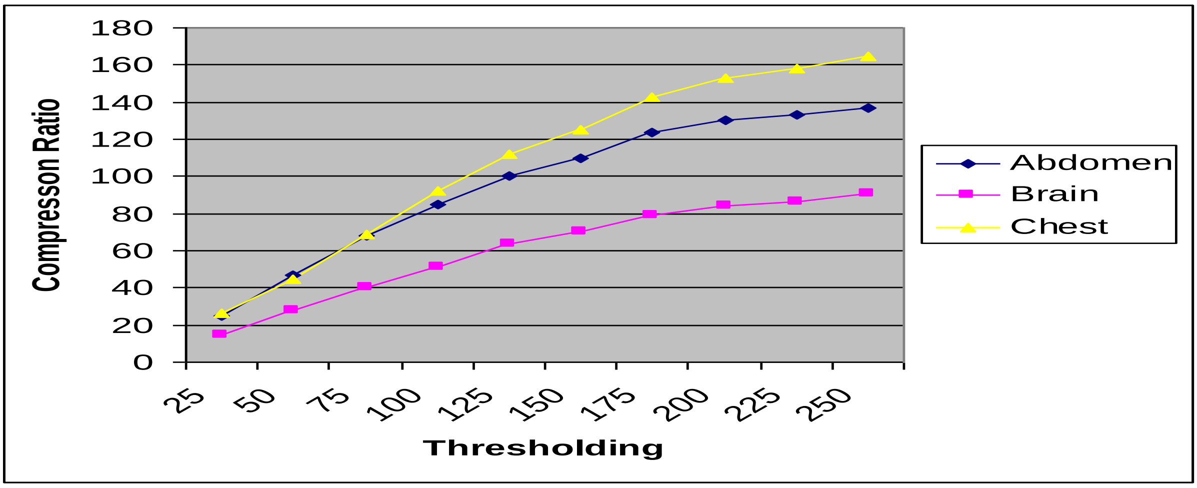

Figure (5): Effect of Changing of the Thresholding on Compression Ratio (CR) for CT test images

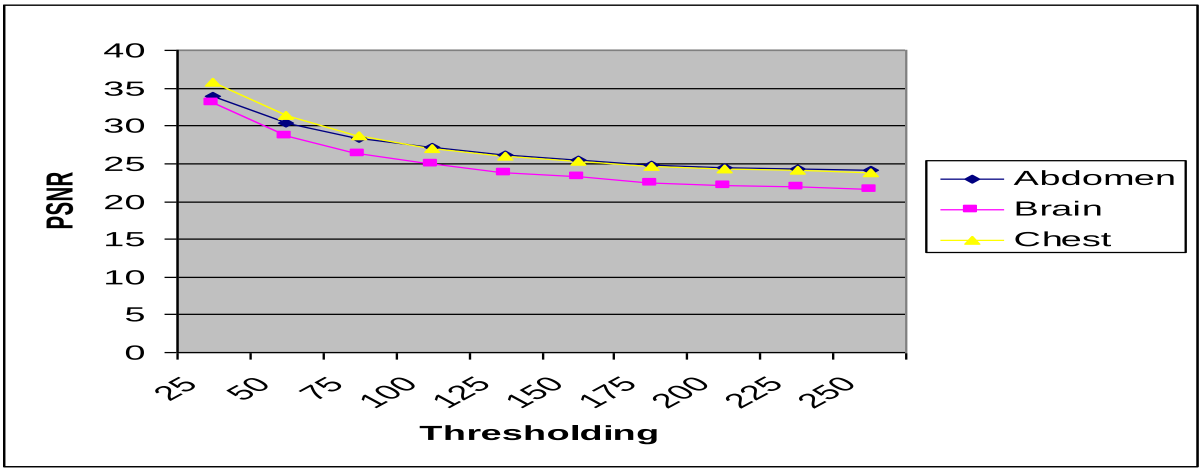

Figure (6): Effect of Changing of the Thresholding on Peak Signal to Noise Ratio (PSNR) for CT test images

Conclusions

Objective evaluation has been done to measure the quality of the compressed images. The calculated compression ratio (CR) and peak signal to noise ratio (PSNR) for all different CT images have been used. Thresholding can modify the coefficients to produce more zeros, and hence the image data can be stored in much less space. Medical image itself has effect on the compression rates and the image quality after the compression process. This is because it is the image's pixel values that determine the size of the coefficients. This difference comes from pixels distribution for every image. The results show that the peak signal to noise ratio (PSNR) which indicates the quality of the compressed image is ranging from (25.89db to 34.35db, 23.26db to 33.3db, and 25.5db to 36.11db) for abdomen, brain, and chest respectively, with level 2 decomposition level and Haar filter. This results show that the compression ratio of 20:1 was good for abdomen and chest images, whereas for brain image 10:1 was good. Compared with reference [9],was conclude that using HAAR Wavelet Transform compression ratio 40:1 was good

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التقييم الرياضي للصور الطبية المضغوطة باستخدام تحويل ويفلت (Wavelet Transformation)

امحمد صفور مصطفى محمد حمدان

الملخص. ان استعمال الحاسبات في معالجة بيانات الصور في المجال الطبي بدأت تزداد. حجم البيانات التي انتجت بواسطة التقنيات الحديثة والمتطورة اصبحت كبيرة. هذه البيانات الضخمة المكونة للصور الطبية خلقت مشكلة في عملية تخزينها او في حالة ارسال هذه البيانات عبر شبكه الاتصال. هذه الورقة تدرس استخدام تقنية تحويل ويفلت (wavelet transform) لضغط الصور الطبية . الصور الطبية التي طبقت عليها الدراسة من مركز سبها الطبي .
برنامج بلغة ال MATLAB صمم لتطبيق تقنية الضغط المقترحة وكذلك تقيم جودة الصور الطبية المضغوطة . في هذه الورقة ثلاث صور مقطعية (CT Scan) وهي (المخ و الصدر و البطن) تم ضغطها باستخدام تقنية ويفلت
(wavelet transform). التقييم الرياضي انجز لحساب وتقدير جودة الصور التي تم ضغطها بالطريقة المقترحة.

النتائج المتحصل عليها اوضحت ان نسبة اعلى اشارة الى نسبة الضوضاء (PSNR) والتي من خلالها تعكس جودة الصورة المضغوطة تتراوح ما بين (25.89 الى 34.35) dB في حالة صورة البطن بينما في صورة المخ فكانت (23.26 الى 33.30) dB(, اما في حالة صورة الصدر فكانت النتائج (25.5 الى 36.11)dB . هذه القيم اوضحت ان جودة الصورة جيدة وان نسبة الضغط 30:1 مقبولة في المجال الطبي وهى غير مؤثرة في عملية التشخيص.

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