Malaysian Journal of Computer Science, Vol. 14 No. 1, June 2001, pp. 39-45

A COMPARATIVE STUDY OF IMAGE COMPRESSION BETWEEN JPEG AND WAVELET

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ABSTRACT

Image compression is fundamental to the efficient and cost-effective use of digital medical imaging technology and applications. Wavelet transform techniques currently provide the most promising approach to high-quality image compression, which is essential for teleradiology and Picture Archiving and Communication System (PACS). In this study wavelet compression was applied to compress and decompress a digitized chest x-ray image at various compression ratios. The Wavelet Compression Engine (standard edition 2.5) was used in this study. This was then compared with the formal compression standard "Joint Photographic Expert Group" JPEG, using JPEG Wizard (standard edition 1.3.7). Currently there is no standard set of criteria for the clinical acceptability of compression ratio. Thus, histogram analysis, maximum absolute error (MAE), mean square error (MSE), root mean square error (RMSE), signal to noise ratio (SNR), and peak signal to noise ratio (PSNR) were used as a set of criteria to determine the 'acceptability' of image compression. The wavelet algorithm was found to have generally lower average error matrices and higher peak signal to noise ratios. Wavelet methods have been shown to have no significant differences in diagnostic accuracy for compression ratios of up to 30:1. Visual comparison was also made between the original image and compressed image to ascertain if there is any significant image degradation. Using wavelet algorithm, a very high compression ratio of up to 600:1 was achieved.

Keywords: ***Wavelet, JPEG, Image compression, and Medical image***

1.0 INTRODUCTION

Hospitals and clinical environments are rapidly moving toward digitization, processing, storage, and transmission of medical images. The trend in healthcare information technology is oriented towards multimedia [1]. The basic motivation is to represent medical images in a digital form to support image transfer and archiving, and the manipulation of visual diagnostic information in new and more efficient ways, such as image enhancement and 3D-volume rendering. However, to be comparable with current analog film-based medical images, digitized images must be of high quality and high resolution and, therefore, require a very large storage space.

To represent such large medical images with the smallest possible number of bits, data compression is essential and plays a very important role in minimizing storage requirement and speeding transmission across low bandwidth channels. The primary goal of medical image compression is to achieve the best possible fidelity for the available communication and storage channels [2]. Therefore, the objective of compression is to reduce the data volume and to achieve a low bit rate in the digital representation of radiological images without perceived loss of image quality [3]. For still image compression, ISO (International Standards Organization) and IEC (International Electro-Technical Commission) have established the 'Joint Photographic Experts Group' or JPEG [4] standard. The performance of these coders generally degrades at low bit-rates mainly because of the underlying block-based Discrete Cosine Transform (DCT) scheme [5]. More recently, the wavelet transform provides substantial improvements in image quality at higher compression ratio [6].

The goal of this paper is to investigate the effect of wavelet compression and also to compare with JPEG compression standards by using two software called Wavelet Compression Engine (standard edition 2.5) [7], and JPEG Wizard (standard edition 1.3.7) [8] on digitized chest x-ray image. This investigation is carried out by calculating the compression ratio, root mean square error, signal to noise ratio, the histogram result, and peak signal to noise ratio for both wavelet and JPEG for the same chest x-ray image.

Table 1 shows the qualitative transition from simple text to full-motion video data and the disk space, transmission bandwidth, and transmission time needed to store and transmit such uncompressed data. The example clearly illustrates the need for sufficient storage space, large transmission bandwidth, and long transmission time for image, audio, and video data. At the present state of technology, the only solution is to compress multimedia data before its storage and transmission, and decompress it at the receiver for play back.

Table. 1: Multimedia data types and uncompressed storage space, transmission bandwidth, and transmission time required [9]

Multimedia Data	Size/Duration	Bits per pixel	Uncompressed Size	Transmission Bandwidth	Transmission Time Using a 28.8k Modem
page of text	11" * 8.5"	Varying resolution	4-8 KB	32-64 Kb/page	1.1 – 2.2 sec
Telephone quality speech	10 sec	8 bps	80KB	64Kb/sec	22.2 sec
Gray scale Image	512*512	8 bps	262 KB	2.1Mb/image	1 min 13 sec
Color Image	512*512	24 bps	786 KB	6.29Mb/image	3 min 39 sec
Medical image	2048*2048	12 bps	5.16MB	41.3 Mb/image	23 min 54 sec
Full-motion Video	640*640, 1 min (30 frames/sec)	24 bps	1.66 GB	221 Mb/sec	5 days 8 hrs

1.1 JPEG: DCT-Based Image Coding Standard

In 1992, the Joint Photographic Experts Group (JPEG) established the first international standard for still image compression where the encoders and decoders are Discrete Cosine Transform (DCT)-based. The JPEG standard specifies three modes namely sequential, progressive, and hierarchical for lossy encoding, and one mode of lossless encoding [4].

The DCT–based encoder worked by segmentating the image into 8*8 blocks. Each block makes its way through each processing step, and yields output in compressed form into the data stream. As image pixels are highly correlated, the DCT achieves data compression by concentrating most of the signal in the lower spatial frequencies. For a typical 8*8 sample block from a typical source image, most of the spatial frequencies have zero or near-zero amplitude and need not be encoded. In principle, the DCT introduces no loss to the source image samples; it transforms them to a domain in which they can be more efficiently encoded.

JPEG Wizard (standard edition 1.3.7) has been used in this study to compare with Wavelet Compression Engine (standard edition 2.5) on digitized chest x-ray image. The JPEG Wizard is an easy-to-use application interface enabling users to manipulate JPEG images in ways never before possible. The JPEG Wizard supports several advanced technology features designed to allow the manipulation of JPEG image data with the least possible degradation.

1.2 Wavelet and Image Compression

Wavelet transform image compression involves the use of a new field of applied mathematics often called 'wavelet theory' or simply "wavelets". 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, in order to achieve the desired level of compression. Transform domain values that are quantized can never be restored to their original accuracy, but such quantization is necessary in order to achieve higher compression ratios.

The greater the reduction in precision or quantization, the greater the compression ratio and the larger the error introduced into the compressed image [10]. 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), Huffman coding, or arithmetic encoding. However, the Wavelet Compression Engine (standard edition 2.5) which we used in this study makes it practical to store a large amount of data. This standard uses a lossy compression method and wavelet image format (WIF) which has the power to reduce an image size from 1 Mbyte to 8KB without losing the image quality. The Compression Engine Pro also allows compression of multiple image files simultaneously, using batch compression. Furthermore, this standard supports many image types. For best results, it is recommended that one begins with images in uncompressed formats such as BMP or TIFF, but even with compressed formats such as JPEG, the resultant WIF discard parts of the image that are unimportant such as color variation that is too small for the eyes to perceive.

2.0 MEASUREMENT OF THE DIFFERENCE BETWEEN THE ORIGINAL AND THE RECONSTRUCTED IMAGE

It is natural to raise the question of how much an image can be compressed and still preserve sufficient information for a given clinical application. This section discusses some parameters used to measure the trade-off between image quality and compression ratio.

Compression ratio is defined as the nominal bit depth of the original image in bits per pixel (bpp) divided by the bpp necessary to store the compressed image. For each compressed and reconstructed image, an error image was calculated. From the error data, maximum absolute error (MAE), mean square error (MSE), root mean square error (RMSE), signal to noise ratio (SNR), and peak signal to noise ratio (PSNR) were calculated.

The maximum absolute error (MAE) is calculated as [11].

$$MAE = \max\left| f(x,y) - f^*(x,y) \right| \qquad 1$$

Where *f (x, y)* is the original image data and *f*(x, y)* is the compressed image value. The formulae for calculated image matrices are:

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

$$RMSE = \sqrt{MSE} \qquad 3$$

Where *M* and *N* are the matrix dimensions in x and y, respectively. In this study, an 8-bit depth digitized chest x-ray image (1-M byte) is used for the analysis.

$$SNR = 10\log\left\{ \frac{\sum_{i=0}^{N-1}\sum_{j=0}^{M-1} f(x,y)^2}{\left[\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left[f(x,y) - f^*(x,y) \right]\right]} \right\} \qquad 4$$

$$PSNR = 20\log\left(\frac{255}{RMSE} \right) \qquad 5$$

3.0 RESULT AND DISCUSSION

By using the formulae in the previous section, the evaluation of the reconstructed image was calculated. Signal-to-noise-ratio (SNR) measures are estimates of the quality of a reconstructed image compared with the original image. SNR measures do not equate with human subjective perception. Typical PSNR values range between 20 dB and 40 dB.

In this study it was found that for JPEG compression, the PSNR was between 32dB to 54dB, whereas for Wavelet it was between 35dB to 48dB. The actual value of PSNR is not meaningful, but the comparison between the two values of different reconstructed images gives a measure of quality. The difference between the compressed image and the original image was also calculated. Table 2 represents the results for MAE, MSE, SNR, RMSE, and PSNR for chest x-ray image by using JPEG wizard software. These results illustrate that, as compression ratio increases the MSE and RMSE will also increase whereas the PSNR decreases.

Table 2: Analysis using JPEG wizard on the digitized chest x-rays image

Compression Ratio	Image Size (bytes)	MAE	RMSE	MSE	SNR(dB)	PSNR(dB)	Bits per pixel
7.8 :1	400270	0.222	0.4738	0.224	51.75	54.62	8
29 :1	104900	0.806	1.266	1.6	43.22	46.07	8
71 :1	43181	1.247	2.183	4.772	38.48	41.34	8
100 :1	29998	1.45	2.49	6.22	37.53	40.19	8
279 :1	11007	2.96	4.07	16.59	33.0	35.90	8
300 :1	8375	4.60	5.75	33.11	30	32.90	8

These results were also plotted in Fig 1 to show the changes for MAE, MSE and the RMSE as compression ratio changes. The same formulae were used to calculate MAE, MSE, RMSE, SNR, and PSNR by using Wavelet Compression Engine, for the same image. The results are given in Table 3.

These results illustrate that as compression ratio increases the MSE and RMSE will also increase whereas the PSNR will decrease. These results were also plotted in Fig. 2 to show the changes for MAE, MSE and the RMSE as compression ratio changes. Fig. 3 illustrates the comparison between both results (JPEG & Wavelet). From this graph, it can be concluded that wavelet compression is more efficient than JPEG technique and can achieve higher compression ratio.

For visual comparison, Fig. 4 illustrates the difference between JPEG and wavelet images for digitized chest x-ray image for different compression ratio (CR). This comparison illustrates that the wavelet image was much better than JPEG in terms of image quality preservation as compression ratio increases.

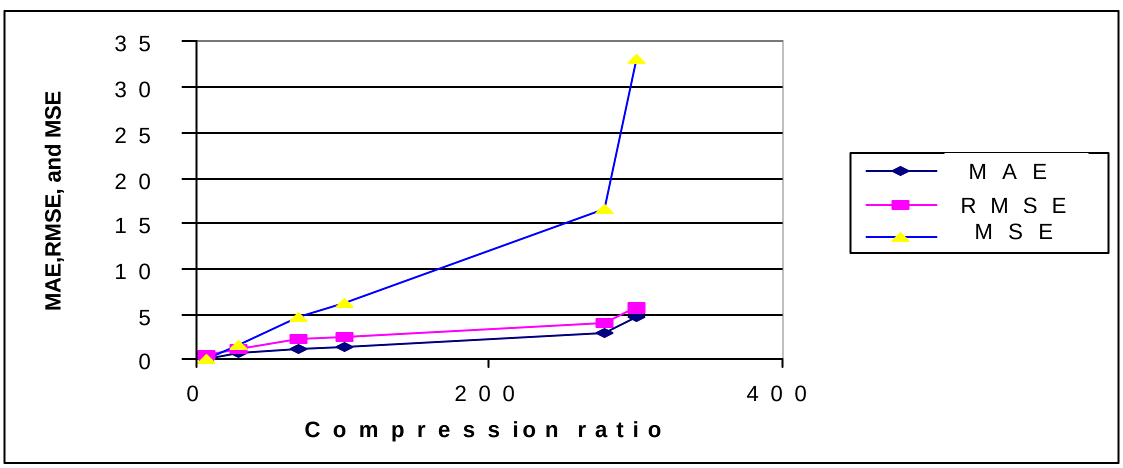


Fig. 1: MAE, RMSE, and MSE values against compression ratio for JPEG Wizard

Table 3: Analysis using wavelet compression Engine V2.5 on the digitized chest x-ray image

Compression Ratio	Size of Compressed Image (bytes)	MAE	RMSE	MSE	SNR(dB)	PSNR(dB)	Bit per pixel
7.5 :1	137649	0.680	0.989	0.9795	45.35	48.22	8
20 :1	46858	1.04	1.499	2.247	41.75	44.60	8
70 :1	14651	1.618	2.654	7.04	36.79	39.65	8
100 :1	10207	1.749	2.895	8.38	36.00	38.89	8
278 :1	3687	2.133	3.423	11.71	34.90	37.40	8
300 :1	3418	2.167	3.462	11.985	34.40	37.34	8
364 :1	2808	2.273	3.59	12.9	34.16	37.00	8
600 :1	1519	2.817	4.20	17.66	32.79	35.66	8

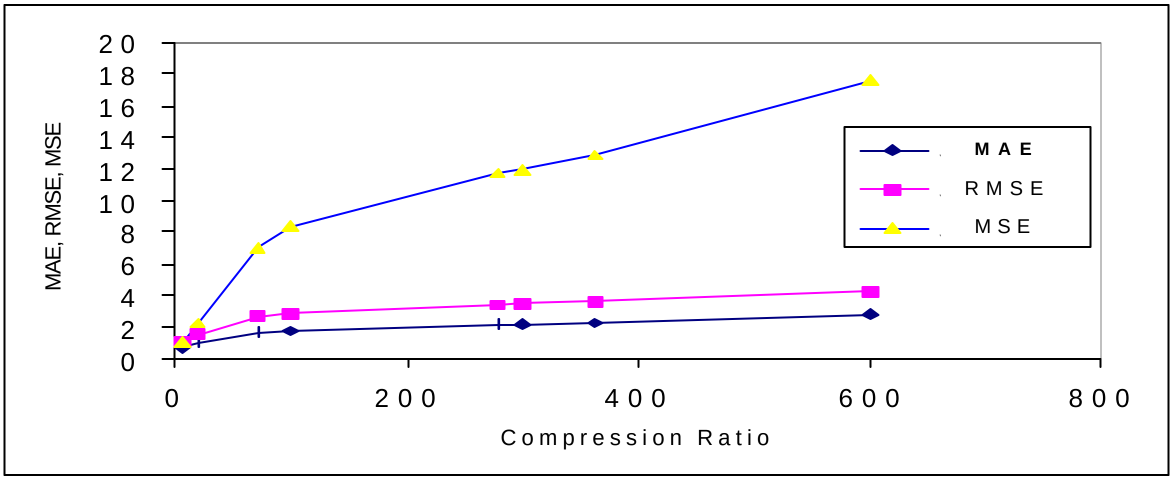


Fig. 2: MAE, RMSE, MSE values against compression ratio for Wavelet Compression Engine (standard edition 2.5)

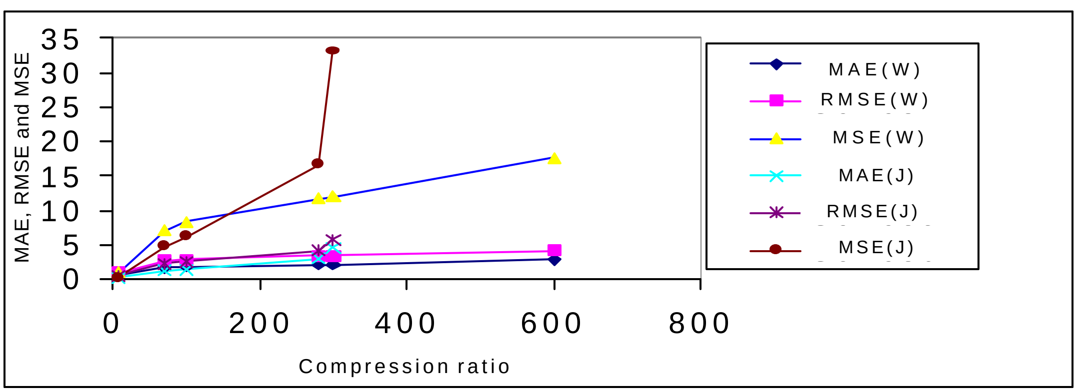
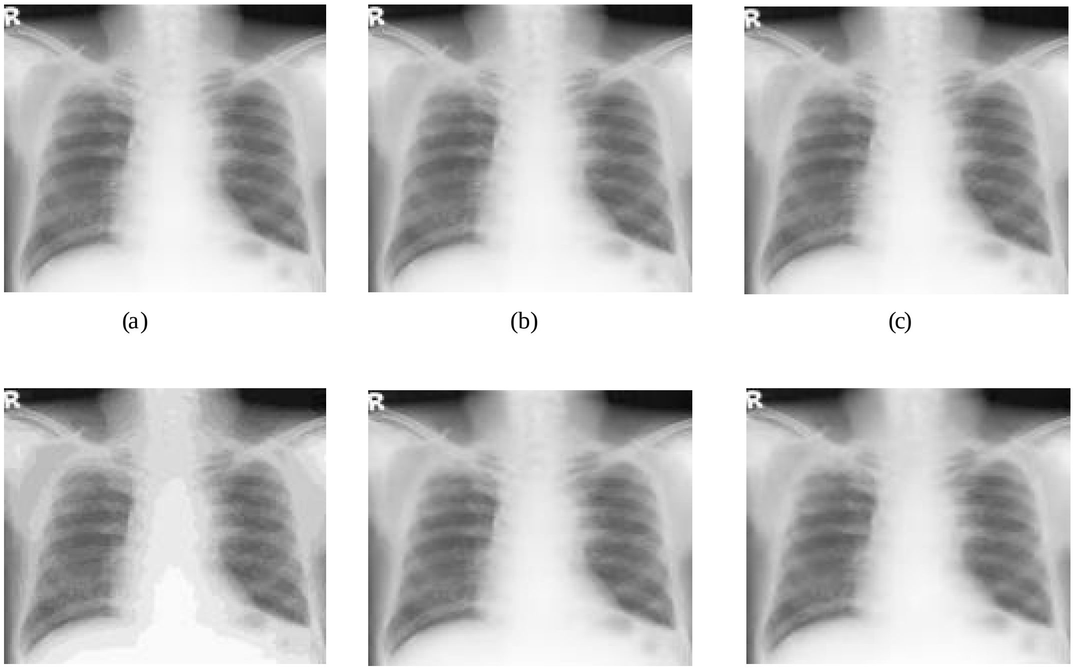


Fig. 3: MAE, RMSE, MSE values against compression ratio for JPEG Wizard (standard edition 1.3.7) and Wavelet Compression Engine (standard edition 2.5)



(a) (b) (c)

(d) (e) (f)

Fig. 4: Visual Comparison between JPEG and wavelet compression for digitized chest x-ray image.
(a) Original image; (b) CR=100:1 JPEG; (c) CR=100:1 wavelet;
(d) CR=300:1 JPEG; (e) CR=300:1 wavelet; (f) CR=600:1 wavelet

4.0 CONCLUSION

JPEG suffers from block-shaped artifacts at higher compression ratio, particularly at ratios over 10:1 for radiological images. The artifacts result from the fundamental of compression algorithm, which is to divide the image into smaller pixel blocks (8*8) that are processed independently. Peak signal to noise ratio (PSNR) is another qualitative measure based on the root-mean-square-error of the reconstructed image. Typical value of PSNR values range between 20 and 40 dB. The actual value is not meaningful, but the comparison between the two values for different reconstructed images gives a measure of image quality. Wavelets are highly efficient for image compression because they organize the image data in a way that closely resembles the human visual system. Wavelet is better than JPEG compression in terms of compression ratio as it can achieve as high as 600:1 by using Wavelet Compression Engine (standard edition 2.5) for digitized chest x- ray image, whereas in JPEG 300:1 is achieved by using JPEG Wizard. Generally, wavelet could achieve 2 or 3 times higher compression efficiency than JPEG for high compression ratios without compromising image quality.

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