International Journal of Medical, Medicine and Health Sciences
ISSN: 2517-9969
Vol:6, No:12, 2012

Quality Evaluation of Compressed MRI Medical Images for Telemedicine Applications

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***Abstract*—**Medical image modalities such as computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US), X-ray are adapted to diagnose disease. These modalities provide flexible means of reviewing anatomical cross-sections and physiological state in different parts of the human body. The raw medical images have a huge file size and need large storage requirements. So it should be such a way to reduce the size of those image files to be valid for telemedicine applications. Thus the image compression is a key factor to reduce the bit rate for transmission or storage while maintaining an acceptable reproduction quality, but it is natural to rise the question of how much an image can be compressed and still preserve sufficient information for a given clinical application. Many techniques for achieving data compression have been introduced. In this study, three different MRI modalities which are Brain, Spine and Knee have been compressed and reconstructed using wavelet transform. Subjective and objective evaluation has been done to investigate the clinical information quality of the compressed images. For the objective evaluation, the results show that the PSNR which indicates the quality of the reconstructed image is ranging from (21.95 dB to 30.80 dB, 27.25 dB to 35.75 dB, and 26.93 dB to 34.93 dB) for Brain, Spine, and Knee respectively. For the subjective evaluation test, the results show that the compression ratio of 40:1 was acceptable for brain image, whereas for spine and knee images 50:1 was acceptable.

***Keywords*—**Medical Image, Magnetic Resonance Imaging, Image Compression, Discrete Wavelet Transform, Telemedicine.

I. Introduction

TELEMEDICINE is defined as the delivery of health care and sharing of medical knowledge over a distance using telecommunication systems. [1]. In most of telemedicine applications medical images are transmitted in real time from one location to another, where the physician can diagnose and advise the treatment strategies.[2].

The raw images have a large file size and require a significant bandwidth and long time for transmission. So it should be such a way to reduce the size of those image files to be valid for telemedicine applications. This way can be represented in image data compression. In this case two techniques of image compression can be used: *Lossy* and *Lossless* [3]. Lossy compression schemes are not acceptable to be used for both clinical and legal reasons. However Lossless compression algorithms such as JPEG2000 and wavelet-based compression can produce images statistically identical diagnostic results compared with the original images without any loss [4, 5], therefore lossless image compression is important and more suitable for medical image because any information loss or error caused by the image compression process could affect the clinical diagnostic process [6]. The aim of this paper is to evaluate and investigate the effect of compression ratio on the quality of a set of magnetic resonance medical images compressed at different compression ratios using wavelet transform technique. Both objective and subjective measures are calculated to carry out the evaluation process.).

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II. Materials and Methods

In this study, three different MRI images have been used and tested. A set of wavelets filters form different families were used to choose the best, then the db1 wavelet is adopted for the compression process of test images.

The process of the evaluation of the compressed test images is carried out using objective and subjective measures. These measures are explained as follows:

A. Objective Measures

The most common used objective measures are 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). Therefore, for any *N x M* image size, the above measures can be calculated using the following relations [7].

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

$$RMSE = \sqrt{MSE} \quad (2)$$

$$MAE = \max\left|f(i,j) - f^{*}(i,j)\right| \quad (3)$$

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

$$PSNR = 20\log\left(\frac{2^{B}-1}{MSE}\right)\text{dB} \quad (5)$$

$$PSNR = 10\log\left(\frac{(255)^{2}}{MSE}\right)\text{dB} \quad (6)$$

where $f(i,j)$ the original image data and $f^{*}(i,j)$ is the compressed image data.

In this study, a MATLAB program is designed using the wavelet and image processing toolbox of MATLAB version 7 [8]. This program has been used to calculate the above statistical objective measures.

B. Subjective Measures

Another common way to measure the quality of the compressed images is called subjective evaluation which is carried out by a group of evaluators. The method which is used in this stage can be represented by Mean Opinion Score (MOS) [9, 10, and 11] which is indicated in Table I. This method has two kinds of scores: absolute and relative scores. The evaluators who are involved in the evaluation process focus on the difference between the quality of compressed image compared with the original image

TABLE I
MEAN OPINION SCORE (MOS) METHOD USED FOR SUBJECTIVE EVALUATION

MOS	Description	Comments
5	Excellent (Imperceptible Distortion)	Valid for Diagnosis Purposes
4	Good (Perceptible Distortion but not Annoying)	Valid for Diagnosis Purposes
3	Fair (Slightly Annoying but acceptable)	Valid for Diagnosis Purposes
2	Bad (Annoying)	Not Valid for Diagnosis Purposes
1	Very Bad (Very Annoying)	Not Valid for Diagnosis Purposes

III. RESULTS DISCUSSION

In this study, the simulation work has been tested on a sample of three MRI images which are Brain, Spine and Knee. The results obtained by both objective and subjective measures are shown in Figs. 1-5. Tables II, III, and IV summarize the statistical objective results for these images. Table V represents the average score of 20 evaluators involved in this study to evaluate the compressed images subjectively. A score of 5 means there is no distortion (Excellent), a score of 4 represents a little distortion which can be ignored (Good), a score of 3 shows that the image is slightly distorted but it can be accepted (Fair), score 2 shows that there is a lot of distortion, which cannot be accepted for clinical applications (Bad), and final score of 1 shows too much distortion, therefore cannot be tolerated (Very Bad). These results have been illustrated in Fig. 5 which shows the average score of the three test images. A comparison between the original and reconstructed images which are compressed at different compression ratios is illustrated in Figs. 1, 2 and 3. Fig. 4 illustrates the PSNR values versus compression ratio for the three test images.

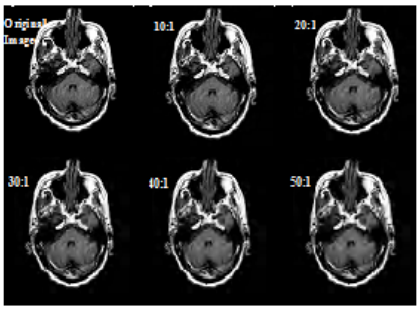

Fig. 1 Comparison between original and compressed MRI Brain images

Fig. 2 Comparison between original and compressed MRI Spine images

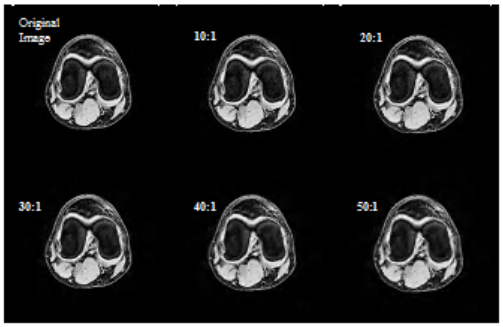

Fig. 3 Comparison between original and compressed MRI Knee images

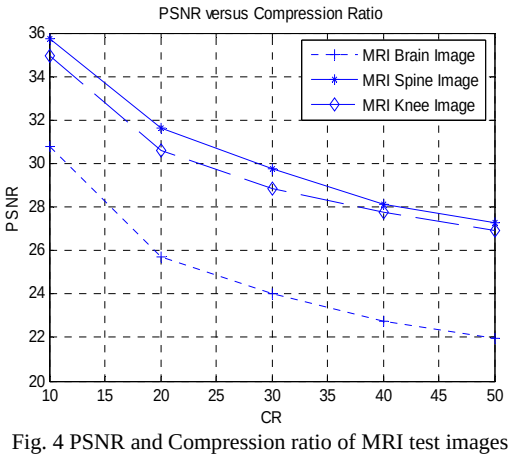

Fig. 4 PSNR and Compression ratio of MRI test images

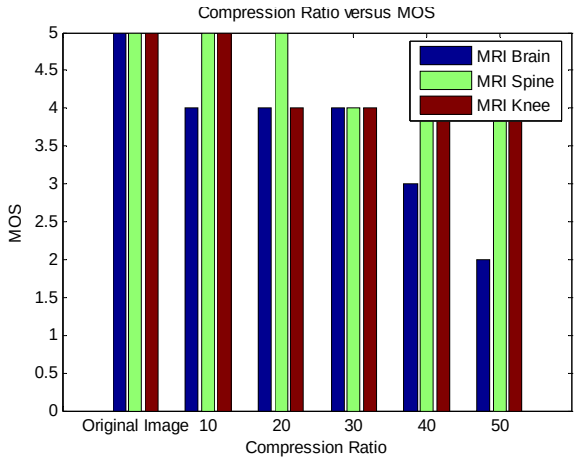

Fig. 5 Subjective score comparison between MRI test images

TABLE II
THE MAE, MSE, RMSE, SNR, AND PSNR RESULTS OF MRI BRAIN IMAGE

CR	Image Size (Byte)	MAE	MSE	RMSE	SNR (dB)	PSNR (dB)
10 :1	19660	4.094	54.233	7.364	21.463	30.788
20 :1	9828	7.067	174.520	13.205	16.391	25.716
30 :1	6552	8.851	259.734	16.116	14.660	23.986
40 :1	4912	10.070	344.410	18.558	13.435	22.760
50 :1	3932	11.277	415.328	20.380	12.622	21.947

TABLE III
THE MAE, MSE, RMSE, SNR, AND PSNR RESULTS OF MRI SPINE IMAGE

CR	Image Size (Byte)	MAE	MSE	RMSE	SNR (dB)	PSNR (dB)
10 :1	38052	2.868	17.250	4.153	28.401	35.753
20 :1	19024	4.545	44.447	6.666	24.290	31.652
30 :1	12684	5.516	68.969	8.305	22.282	29.744
40 :1	9512	6.474	100.823	10.041	20.733	28.095
50 :1	7608	7.199	122.511	11.069	19.887	27.250

TABLE IV
THE MAE, MSE, RMSE, SNR, AND PSNR RESULTS OF MRI KNEE IMAGE

CR	Image Size (Byte)	MAE	MSE	RMSE	SNR (dB)	PSNR (dB)
10 :1	35028	2.420	20.921	4.574	23.093	34.925
20 :1	18372	3.818	56.522	7.518	18.777	30.610
30 :1	12248	4.650	85.362	9.240	16.986	28.818
40 :1	9184	5.290	109.480	10.463	15.906	27.737
50 :1	7348	5.800	131.795	11.480	15.100	26.932

TABLE V
SUBJECTIVE EVALUATION RESULTS FOR BRAIN, SPINE, AND KNEE MRI TEST IMAGES

Compression Ratio	The average score of all readers		
	MRI Brain	MRI Spine	MRI Knee
Original Image	5	5	5
10:1	4	5	5
20:1	4	4	5
30:1	4	4	4
40:1	3	4	4
50:1	2	4	4

IV. CONCLUSION

In this study; three different magnetic resonance medical images which are brain, spine, and knee have been compressed and reconstructed using wavelet transform. The quality of the resulting compressed images is evaluated using the two most commonly used criteria: objective and subjective measures. Under objective criteria some statistical measures are calculated using the equations in section II.A.

Subjectively, a group of 20 evaluators was asked to evaluate and investigate the quality of a set of 6 images from each MRI image (brain, spine, and knee). Each set contains on the original image and the compressed images from 10-50:1 compression ratios. The results show that the compression ratio of 40:1 was acceptable for brain image, whereas for spine and knee images 50:1 was acceptable for clinical applications.

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