Objective and Subjective Evaluation of Compressed Computed Tomography (CT) Images

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Citation

A Saffor, A bin Ramli, K Ng, D Dowsett. *Objective and Subjective Evaluation of Compressed Computed Tomography (CT) Images*. The Internet Journal of Radiology. 2001 Volume 2 Number 2.

Abstract

Background: Techniques commonly employed for image data compression result in some degradation of the reconstructed images. Evaluation of the quality of medical image compression remains an important issue. In our study, we evaluated the diagnostic quality of the compressed Computed Tomography (CT) images using both objective and subjective tests.

Methods: Three different CT images namely brain, chest, and abdomen were compressed and reconstructed by using Wavelet Compression Engine software (standard edition 2.5) for different compression ratios. Both objective and subjective methods were evaluated for 9 reconstructed images. Thirteen observers from Department of Radiology at the University of Malaya Medical Center (UMMC) carried out the subjective test.

Results: The Peak-Signal-to-Noise-Ratio (PSNR), which represents the quality of reconstructed images obtained, was between 57 to 36 dB and 52 to 34 dB for chest and abdomen images respectively, whereas for brain it was 57 to 40 dB. All these images were compressed until 30:1 compression ratio.

Conclusion: By using subjective test, compression ratio of 30:1 is acceptable for diagnosis chest and abdomen images, and 20:1 for brain images.

INTRODUCTION

Evaluation of the quality of medical image compression remains an important issue, by both objective and subjective means. Image quality has two implications: fidelity and intelligibility. The former describes how the reconstructed image differs from the original one, with mean-square-error (MSE) as a typical example, and the latter shows the ability through which the image can offer information to people, with classification-accuracy. Both are fundamental in measuring image quality. It must be pointed out that fidelity is not always objective and intelligibility is not always subjective. Whether an objective measure on image quality is efficient or not depends strongly on its accordance with subjective measure [1]. Most methods for compressing data have been evaluated on the basis of minimizing an objective distortion measure such as MSE at a given level of data compression [4,7]. However, a lower MSE does not always mean better quality in the compressed image because MSE is not necessarily a subjective measure of the quality.

Physiological, anatomical, and psychophysical aspects have been used to study visual perception [2,6]. It has been shown that the human visual perception system is sensitive to changes in luminance rather than the absolute luminance values themselves, and that perception is most sensitive to mid-frequencies and less sensitive to high frequencies in the image [2]. In this paper, we attempt to evaluate both objective and subjective methods for an acceptable degree of the reconstructed CT images for different compression levels.

MATERIALS AND METHODS

Methods for image quality evaluation can be classified as objective and subjective measures. By objective measures some statistical indices are calculated to indicate the reconstructed image quality and by subjective measure viewers read images directly to determine their quality.

OBJECTIVE MEASURE

A widely used measure of reconstructed image for an N x M size image is the mean square error (MSE) as given by [5].

Figure 1

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

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

Figure 2

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

Another quantitative measure is the peak signal-to-noise ratio (PSNR), based on the root mean square error of the reconstructed image. The formula for PSNR is given by

Values for these quantities were obtained using LuraWave Smart Compression software (version 1.7.1) [3]

SUBJECTIVE MEASURE

Subjective evaluation by viewers is still a method commonly used in measuring image quality. The subjective test emphatically examines fidelity and at the same time considers image intelligibility. When taking subjective test, viewer's focus on the difference between reconstructed image and the original image, they notice such details where information loss cannot be accepted. The representative subjective method is Mean Opinion Score (MOS) [1]. It has two kinds of scors: one is absolute and another is relative. Two examples are shown below in Table 1. In our experiment, we use absolute score in order to seek the consistency between subjective and objective measures. Each viewer compares the reconstructed image with the original one to decide which level it belongs to and gives the score.

RESULTS AND DISCUSSION

Three typical CT images namely brain, chest and abdomen as shown in (figure 1) were processed by Wavelet Compression Engine (standard edition 2.5) [8]. Nine reconstructed images were obtained for different compression ratio. Some test results, gained by both objective and subjective measures mentioned above, are shown in Figure 1-4. Table 2 summarizes the result for MSE and PSNR for these images. Figure 2 illustrates the PSNR values against compression ratio. For the subjective result, Table 3 represents the average score of 13 observers, from the University of Malaysia Medical Center (UMMC). A score of 5 is no distortion (Excellent), score of 4 represents a little distortion, which can be ignored (Good), score of 3 shows distortion which can be seen evidently but can be accepted (Fair), score of 2 shows a lot of distortion, which can't be accepted (Bad) and finally score of 1 shows too much distortion, therefore cannot be tolerated (Very Bad). These results are illustrated in (figure 3). The comparison between the original image and reconstructed images for brain, chest and abdomen are illustrated in Figure 4.

Figure 3

Table 1: Mean Opinion Score (MOS) method used for subjective evaluation

Absolute score		Relative score	
5	Excellent	5	The best in the group
4	Good	4	Better than the average
3	Fair	3	The average of the group
2	Bad	2	Worse than average
1	Very bad	1	The worst in the group

Figure 4

Table 2: Results of MSE and PSNR for CT-brain, chest and abdomen images by using Wavelet Compression

Compression ratio	CT- brain image		CT- chest image		CT-abdomen image	
	MSE	PSNR (dB)	MSE	PSNR (dB)	MSE	PSNR (dB)
5:1	0.1	57	0.1	57	0.5	52
10:1	0.5	51	1.1	47	4	42
15:1	1.3	47	3.9	42	9	39
20:1	2.6	44	7.8	39	14	37
25:1	4.2	42	12.4	37	20	35
30:1	6.2	40	17.5	36	26	34

Figure 5

Table 3: Results of the average score for all readers for CT brain, chest and abdomen images

	The average score of all readers		
	Score for CT brain image	Score for CT chest image	Score for CT abdomen image
Original image	4	5	5
10	3	4	5
20	3	4	4
30	2	4	3

Figure 6

Figure 1: Images used in this study (a) CT-brain image, (b) CT- chest image, and (c) CT-abdomen image

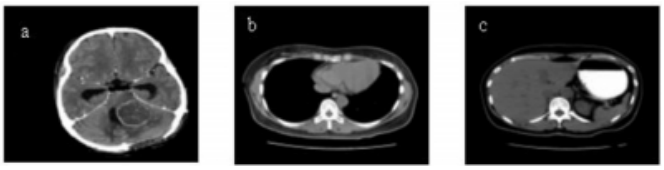


Figure 7

Figure 2: PSNR against Compression ratio for CT brain, chest and abdomen images

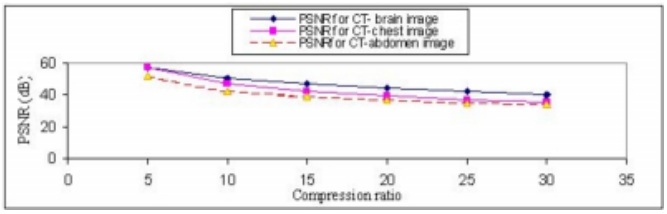


Figure 8

Figure 3: Comparison between CT brain, chest and abdomen images in terms of subjective score

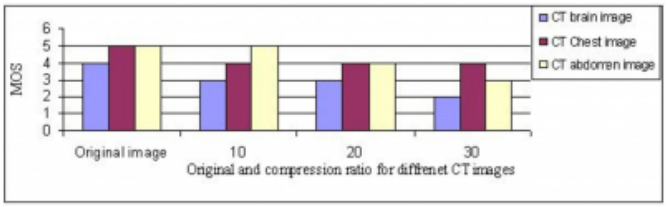
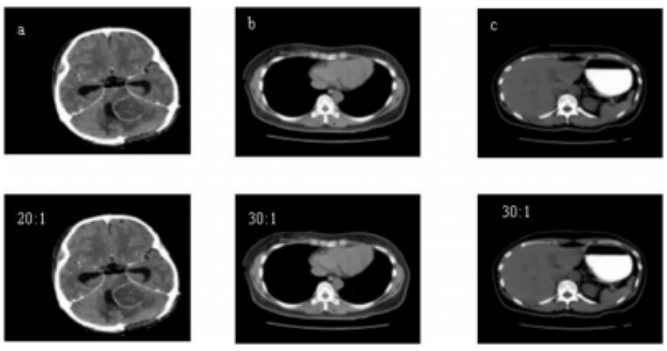


Figure 9

Figure 4: Comparison between original image and compressed CT brain, chest and abdomen image



CONCLUSION

Study on the criteria for image quality evaluation is a meaningful but complicated task. The criteria can be used to evaluate the compression algorithm and to guide the design of algorithm as well. PSNR can reflect the quality of reconstructed images approximately. PSNR must be above certain value if the reconstructed image reaches the level of "good". This result shows that by using objective method, PSNR which represents the quality of reconstructed images was between (57 to 36 dB and 52 to 34 dB) for chest and abdomen images respectively, whereas for brain was between 57 to 40 dB. All these images were compressed and decompressed until 30:1 compression ratio. For subjective test, the results indicated that compression ratio 30:1 was acceptable for chest and abdomen images, whereas for brain image 20:1 was acceptable.

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