Performance Evaluation of the JPEG DCT-based Progressive and Hierarchical Codings for Medical Image Communication

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Abstracts

The discrete cosine transform (DCT)-based progressive and hierarchical coding schemes developed by the International *Standardization Organization (ISO) Joint* Photographic Experts Groups (JPEG) are implemented and evaluated for the application of medical image communication. For a series of head sections of magnetic resonance images, a compression ratio of about 10 is obtained by the algorithm without noticeable image degradation.

Introduction

The Joint Photographic Experts Group (JPEG) algorithm is a result of joint efforts by the ISO/IEC JTC1/SC2/WG10 and the CCITT SGVIII to make an international standard for digital compression and coding of continuous-tone still image[1-2]. Through several balloting and revision, four distinct modes of operation, i.e., lossless, sequential DCT-based, progressive DCT-based, and hierarchical are defined. For the sequential DCT-based mode, DCT coefficients of 8x8 sample blocks are typically sent from left to right and from top to bottom, and each received block is reconstructed and displayed in the same order. For the progressive and hierarchical DCT-based modes, however, image is encoded in multiple scans, thus an image of low quality is first reconstructed, and the image quality is progressively improved with more information received from the transmitter. These coding modes appear to be useful when transmission time is long and urgent interpretation is necessary, e.g., medical image communication. Since the DCT-based modes achieve higher compression than the lossless mode, the DCT-based progressive and hierarchical codings are investigated in this paper for medical image communication.

Methods

The four modes of JPEC compression algorithm are implemented by software (C language) in SUN SPARC II station. For the progressive mode, 5 bands of quantized DCT coefficients (frequency components up to 2, 4, 8, 16, and 64) are sent progressively after zigzag scan (spectral selection). For the hierarchical coding, three stages are considered with different resolutions, i.e., 16:1 down-sampled image, 4:1 down-sampled image, 1:1 image. In the hierarchical coding, reconstructed image obtained at the previous stage is used for the estimation of current image and the discrete cosine transform is applied to the difference of the two images. Lossless encoding is employed at the final stage for both methods, thus distortion-free images are obtained at the final stage. For entropy coding, Huffman code optimized for each image is used [3]. Head sections of nuclear magnetic resonance images [4-5] represented by 256 gray levels

are used for the evaluation of the algorithm (16 slices with 256 x 256 matrix size). For quantitative evaluation, compression ratio and the root mean square error are calculated. Reconstructed images are also displayed for subjective evaluation.

Results

Results of the JPEG progressive coding applied to the head sections of MR images are shown in Fig. 1. Five stages of the progressively reconstructed images and original image obtained with the JPEG lossless coding are shown from top left to top right and bottom left to bottom right. Block artifact due to the truncation of high frequency components is observed in the reconstructed images at the initial two stages (frequency components ≤ 4). Reconstructed image with the frequency components up to 16 (compression ratio=10) appears close to the original image. Note that the reconstructed image at the final stage of the DCT-based progressive mode is identical to the image obtained by the sequential mode. Table 1 shows corresponding compression ratio and root mean square error for Fig. 1.

Results of the JPEG hierarchical coding applied to the same image is shown in Fig. 2 and Table 2. As shown in Fig. 2, high compression can be achieved at the cost of resolution (compression ratio of 80 with 16:1 down-sampling). Acceptable image quality is obtained with 4:1 down-sampled image (compression ratio=22). At the final stage, the compressed image with a compression ratio of 6.4 is indistinguishable from the original image.

The compression performance of the JPEG algorithm is slightly different depending on the image complexity (distribution of the spatial frequency components). For example, higher compression is achieved for an image having simpler structure. Figure 3 is results of progressive coding obtained with the same coding parameters as in Fig.1, where higher compression is achieved due to lower image complexity compared with previous image.

Conclusion

The JPEG DCT-based progressive and hierarchical codings provide high compression yet maintaining good image quality for gray scale medical tomographic images. A compression ratio of about 10 is obtained for the test images without noticeable image distortion, and a compression ratio of 20 or even higher compression is also obtained with acceptable image quality. From the evaluation, the JPEG algorithm (progressive and hierarchical codings) appears very promising for medical image archiving and communication.

References

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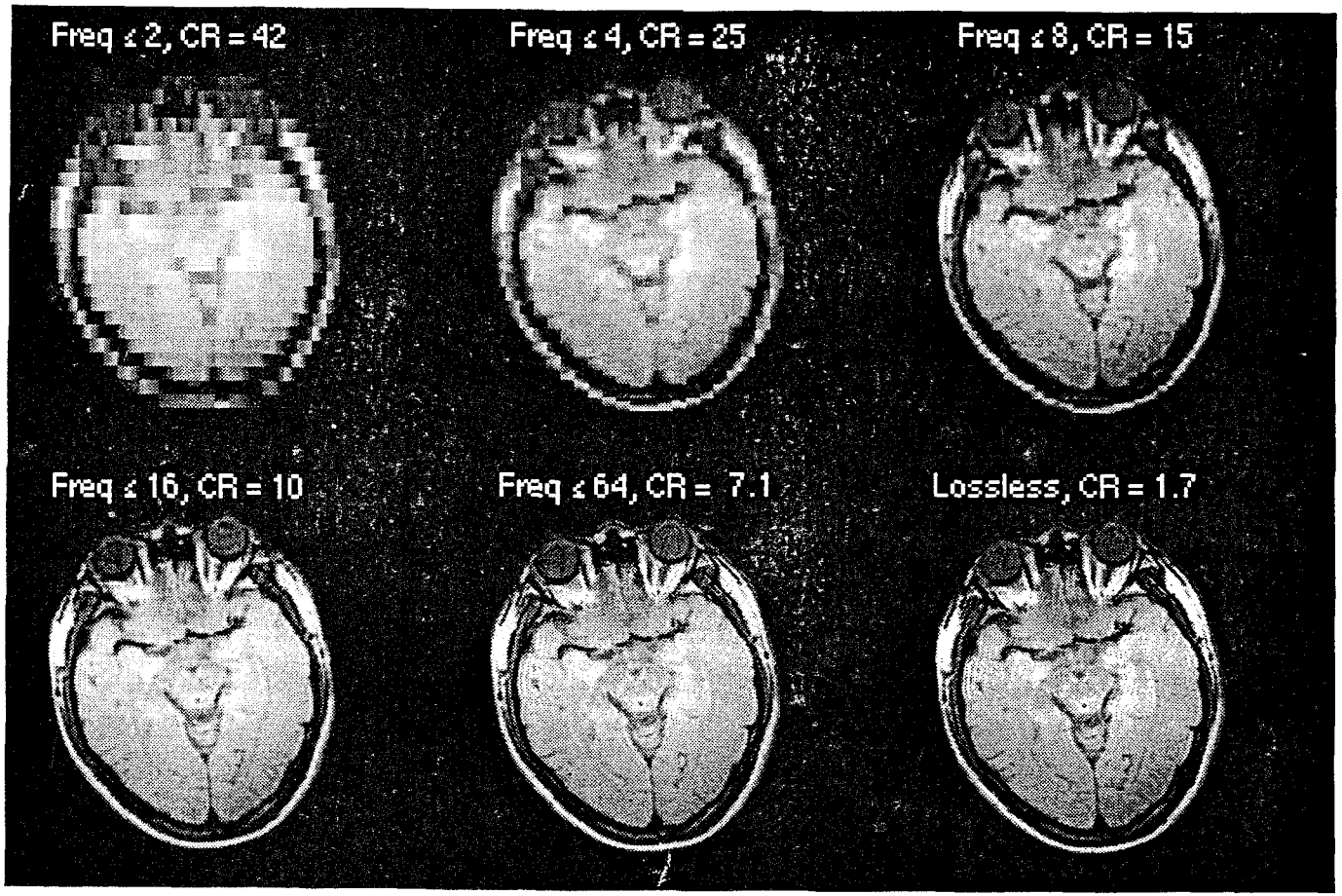

Fig.1 DCT-based progressive coding. Freq denotes frequency components and CR denotes compression ratio.

Fig.2 DCT-based hierarchical coding. CR denotes compression ratio.

Table 1 Performance evaluation of the DCT-based progressive coding for medical image (256 x 256, 8 bit gray scale image).

Stage	Max. Frequency	CR	RMSE
1	2	42	24
2	4	25	20
3	8	15	14
4	16	10	9.4
5	64	7.1	4.0
6	64	1.7	0

Table 2 Performance evaluation of the DCT-based hierarchical coding for medical image (256 x 256, 8 bit gray scale image).

Stage	Sampling	CR	RMSE
1	1/16	80	21
2	1/4	22	13
3	1/1	6.4	4.2
4	1/1	1.7	0

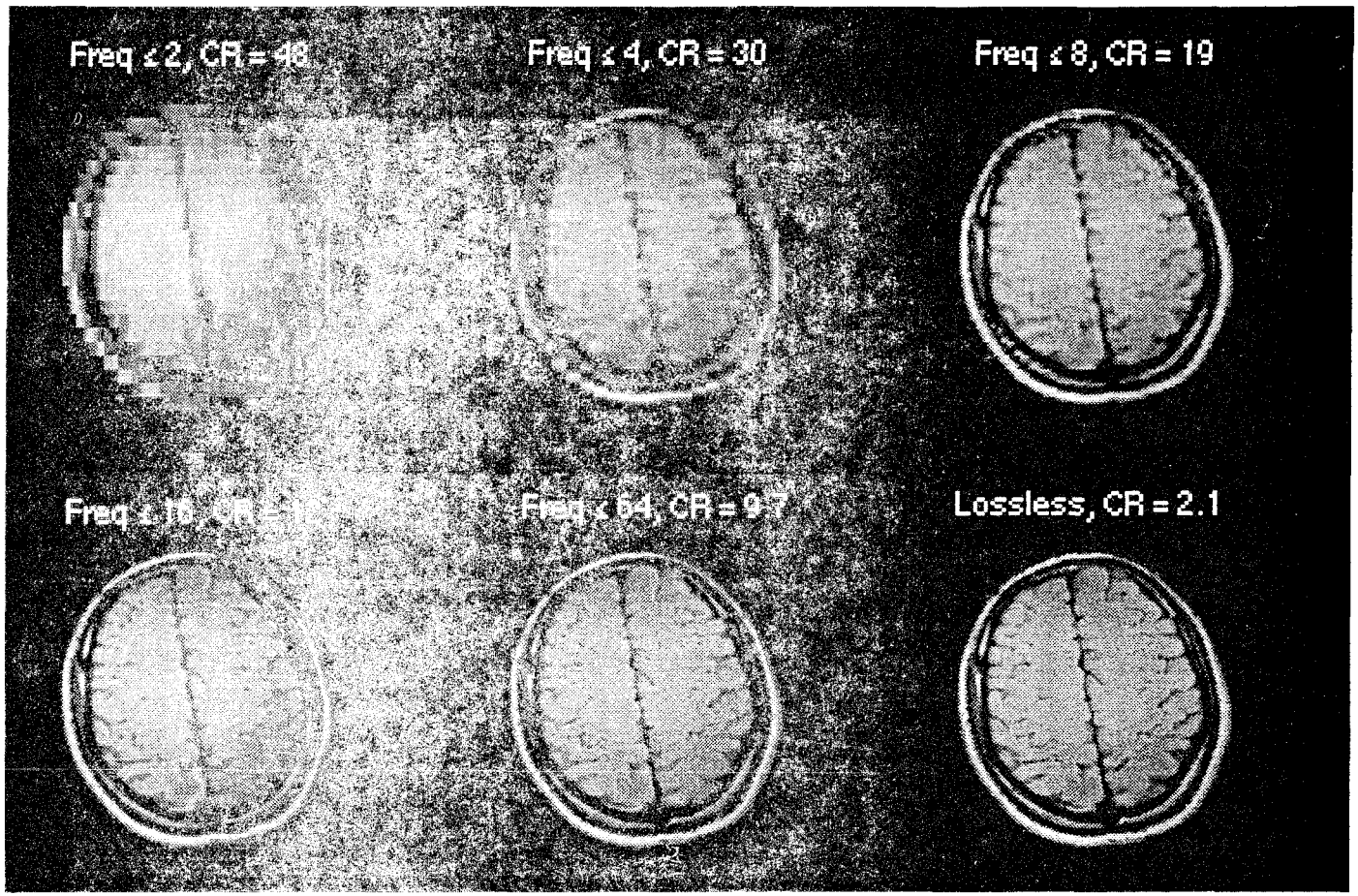

Fig.3 Progressive coding applied to a slice having simpler structure. Note higher compression compared with Fig. 1.