COMPRESSION EFFECTS OF JPEG AND JPEG2000 ON TEMPORAL-BONE IMAGES

Li Qi[1] & W. Robert J. Funnell[1, 2]
[1] Department of BioMedical Engineering
[2] Department of Otolaryngology
McGill University
Montréal, QC, Canada H3A 2B4

ABSTRACT

The efficient compression of medical images is important for improved storage and network utilization. The Joint Photographic Experts Group (JPEG) baseline compression algorithm has been widely used in medical image compression. In contrast, JPEG2000 is a relative new compression standard. The purpose of this study is to provide a quantitative comparison of JPEG and JPEG2000 compression effects on temporal-bone images. Three types of images are investigated – x-ray microCT, orthogonal-plane fluorescence images (OPFI) and histology images. The image quality with different compressed ratios is evaluated by Peak Signal-to-Noise Ratio (PSNR). The study shows that for our grey-scale images, JPEG2000 compression is superior to JPEG for lossy compression with both high compression ratio (1:64) and low compression ratios (1:4 and 1:8). In the middle range of compression ratios (1:16 – 1:32), JPEG and JPEG2000 have the same effects. For our colour histology images, JPEG2000 is superior to the JPEG at all tested compression ratios.

KEYWORDS

Image compression; JPEG; JPEG2000; Temporal-bone images; PSNR

1. INTRODUCTION

Digital storage and transmission of medical images involve large amounts of data. Therefore, efficient image compression is crucial to reduce the sizes of image data sets, thereby increasing the speed of data transmission and decreasing data storage requirements.

Several lossless and lossy image-compression techniques (Wallace et al., 1991; Wu and Memon, 1997; Bilgin et al., 1998) have been proposed. Lossless compression methods (BMP, TIFF, etc.) enable reversible reduction of image data without alteration, but the degree of compression is limited. Alternatively, lossy compression methods, such as JPEG and JPEG2000, reduce data size more than lossless compression but irreversibly change the original data. Lossy image compression takes into account limitations of the human visual system and throws away some information which people would not easily see.

JPEG has been widely used in medical image compression since the 1990's. JPEG2000 is a new wavelet-based image-compression method. Both JPEG and JPEG2000 have been selected for inclusion in the DICOM standard for medical image transfer. Chai and Bouzerdoum (2001) compared a human-face image using JPEG2000 and JPEG. They found that the JPEG2000 encoder outperforms JPEG from 0.25 to 2.5 bits-per-pixel (bpp). Similar conclusions were reported by Wanigasekara et al. (2002) and by Sung (2002). Although wavelet-based JPEG2000 compression is commonly thought to be superior to JPEG compression, some studies have not fully support this conclusion. Fidler et al. (2002) compared the JPEG and JPEG2000 compression effects in digital subtraction radiography (DSR). They found that the new JPEG2000 compression seemed to yield no improvement over the standard JPEG in the field of DSR. They found that at 1:7 compression ratio JPEG yielded higher PSNR values than JPEG2000; at 1:16 the PSNR's were equal; only at 1:22 and 1:31 did JPEG2000 yield higher PSNR. Grgic et. al. (2001) tested 4 types of grey-scale images with different spatial and frequency characteristics. They concluded that JPEG offers better compression performance than JPEG2000 in the middle and high bit rates (above 1 bpp). At low bit rates (below 0.25 bpp) the JPEG image distortion becomes unacceptable compared with JPEG2000, which provides significantly lower distortion. Tobin (2002) indicated that the level of compression that preserves clinically acceptable image quality may depend on the modality, the anatomy and the pathology.

The aim of this study is to evaluate the compression effects of JPEG and JPEG2000 on temporal-bone images. Three image modalities are investigated: x-ray microCT, orthogonal-plane fluorescence images (OPFI; Voie et al., 1993), and physical serial histological sections. The image quality for different compression ratios is evaluated by the Peak Signal-to-Noise Ratio (PSNR).

2. MATERIALS AND METHODS

2.1 Image Data

The morphology of the temporal-bone is complicated. The smallest bones in the human body are located in the temporal-bone cavity. The entire region is around 8 cm^3, where soft tissue (tympanic membrane, ligaments and tendons), bones (ossicles), and air-filled cavities can be found. In this study, 3 types of temporal-bone images are investigated, as shown in Table 1. A description of temporal-bone imaging modalities can be found elsewhere (Decraemer et al., 2003).

All of the original sets of images are uncompressed. Ten images are used for each set. Each grey-scale image (x-ray microCT and OPFI) were compressed at 5 different levels: 1:4 (2 bpp); 1:8 (1 bpp); 1:16 (0.5 bpp); 1:32 (0.25 bpp); and 1:64 (0.125 bpp). For the histology images, 6 different levels were used: 1:8 (3 bpp); 1:16 (1.5 bpp); 1:32 (0.75 bpp); 1:64 (0.375 bpp); 1:128 (0.1875 bpp); and 1:256 (0.09375 bpp). Altogether, 320 images were investigated.

Properties \ Modalities	x-ray microCT	Orthogonal-plane fluorescence	Histology
Dimension (pixels)	*1024*1024*	*616*405*	*1799*1581*
Pixel depth (bits)	*8*	*8*	*24*
Size (KB)	*1024*	*245*	*8338*

Table 1: Three sets of images used in this study

2.2 Compression Algorithms

2.2.1 JPEG

JPEG can compress both grey-scale and colour images. It supports only lossy compression. The original image is divided into 8×8 blocks and each block is transformed with a discrete cosine transform (DCT) into frequency map. The transformed blocks are then quantized using a scalar quantizer, which is the critical information-losing step. Details can be found elsewhere (www.jpeg.org/jpeg.htm). In this study, Corel PHOTO-PAINT® 11 is used for the JPEG compression.

2.2.2 JPEG2000

JPEG2000 is a new image-compression standard, based on the discrete wavelet transform. In contrast to JPEG, JPEG2000 supports both lossy and lossless compression. In this paper, however, we only study the lossy compression effects of JPEG2000. The basic idea of JPEG2000 is to transform the original image into the wavelet frequency domain and take advantage of the different spatial resolutions to compress the image. One of JPEG2000's advantages is that blocking artifact is avoided, because wavelets have variable length and the input pixels do not need to be grouped into 8×8 blocks. The detailed JPEG2000 algorithm can be found on the JPEG website (www.jpeg.org/jpeg2000). In this study, JasPer v1.700 (Adams and Kossentini, 2000) is used for JPEG2000 and PSNR calculations.

2.3 Image Quality Evaluation

The most widely applied evaluation criterion for image quality is Peak Signal-to-Noise Ratio (PSNR), which represents the relation between the maximal pixel value within the original image and the noise that is caused by the compression. For an 8-bit grey-scale image, the PSNR (dB) is computed as

$$PSNR_{Grayscale} = 10 \bullet \log\left(\frac{Peak^2}{\frac{1}{n \bullet m}\sum_{i=0}^{n-1}\sum_{j=0}^{m-1}(f_{ij} - F_{ij})^2}\right)$$

[Equation 1]

where:

f_{ij} is the pixel value within the source image

F_{ij} is the pixel value within the compressed image

n is the number of columns

m is the number of rows

Peak is the maximum pixel value

For colour images, the reconstruction of all three colour spaces (R, G, and B) must be considered in the PSNR calculation. The colour-image PSNR equation is computed as

$$PSNR_{Color} = 10 \bullet \log\left(\frac{Peak^2}{\frac{1}{3}\sum_{k=1}^{3}\frac{1}{n \bullet m}\sum_{i=0}^{n-1}\sum_{j=0}^{m-1}(f_{ij}^k - F_{ij}^k)^2}\right)$$

[Equation 2]

where:

f_{ij}^k is the value of channel *k* of a pixel within the source image

F_{ij}^k is the value of channel *k* of a pixel within the compressed image

K=1, 2 and 3 for red, green and blue, respectively

3. RESULTS

Figures 1-6 are plots of PSNR versus compression ratios. Figure 1 is for x-ray microCT; figure 2 is for OPFI; figures 3 to 5 are for the three histology colour channels (R, G, B); and figure 6 is the overall PSNR for the histology images. PSNR's are averaged over the 10 images within each set, and standard errors are calculated and displayed as error bars.

The grey-scale images (x-ray microCT and OPFI) show similar trends. At the lowest compression ratio (1:4), JPEG2000 has higher PSNR values than JPEG.

For intermediate compression rates from 1:16 to 1:32, JPEG and JPEG2000 have almost equal PSNR values; the PSNR difference is less than 1dB, which means that the differences between two images cannot be detected by the human visual system. For the compression ratios from 1:4 to 1:32, the PSNR values for JPEG vary by less than 2 dB, which indicates that the image quality is almost constant in that compression range. At the highest compression ratio (1:64), the PSNR values for JPEG2000 are higher than those for JPEG.

For the colour histology images the JPEG2000 PSNR values show significant differences from those for the grey-scale images. In the JPEG2000 images, PSNR values of the R, G, and B channels are all higher than for JPEG for all compression ratios, which means that the overall PSNR is superior to the JPEG at every tested compression ratio. As shown in figure 6, the PSNR values for JPEG2000 are quite sensitive to the compression ratio (1:8 to 1:256). Unlike the case for the grey-scale images, the JPEG2000 PSNR has an almost constant gradient of about -4.5 dB/oct at all tested compression ratios, while the PSNR values of the JPEG images stay almost constant (less than 2 dB change from 1:8 to 1:128 compression ratios). It indicates that the quality of the JPEG images remains almost the same. From compression ratio 1:128 to 1:256, the JPEG PSNR values significantly decrease (more than 3 dB).

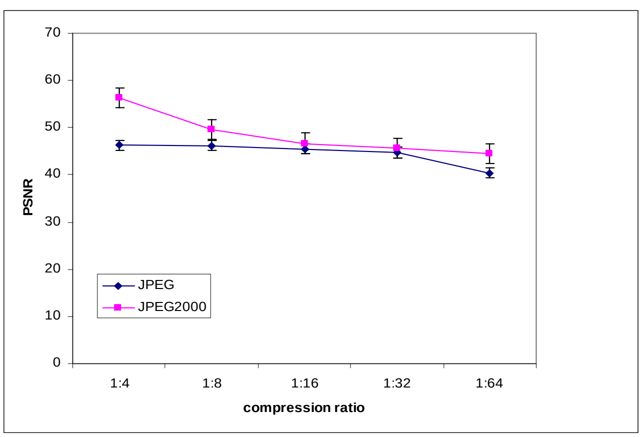

Figure 1: x-ray microCT

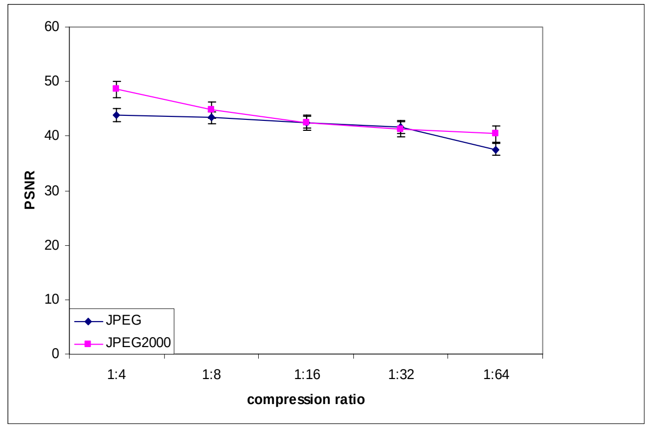

Figure 2: Orthogonal-plane fluorescence images

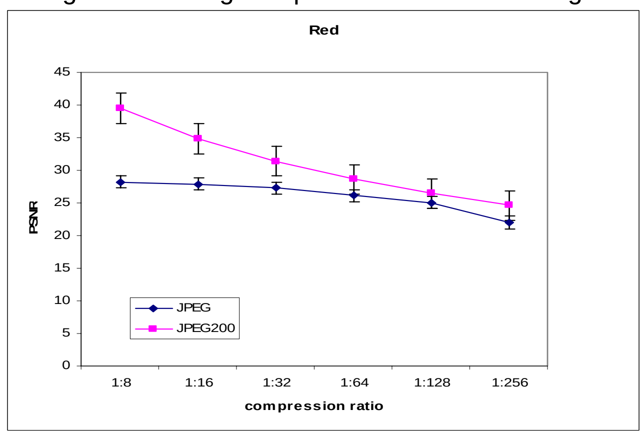

Figure 3: Histology image Red colour

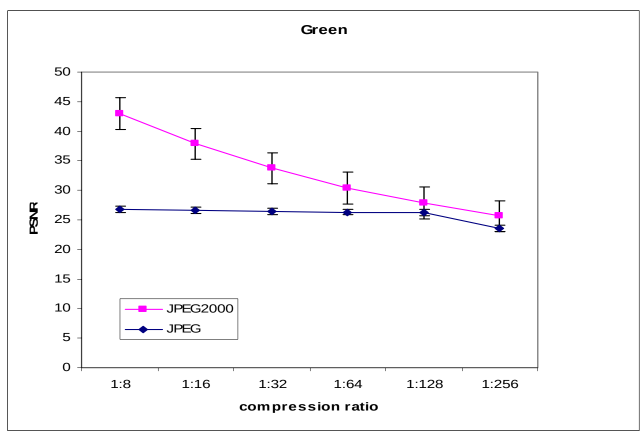

Figure 4: Histology image Green colour

4. CONCLUSIONS

This is the first time that JPEG and JPEG2000 compression effects have been investigated for temporal-bone images. The results show that, although JPEG2000 is a new image standard, it is not superior to JPEG at every compression ratio.

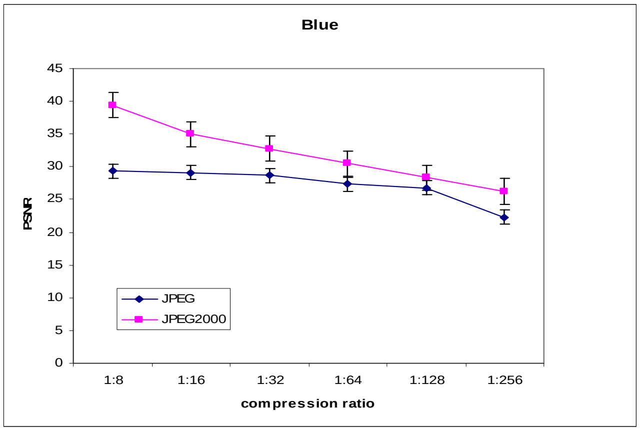

Figure 5: Histology image Blue colour

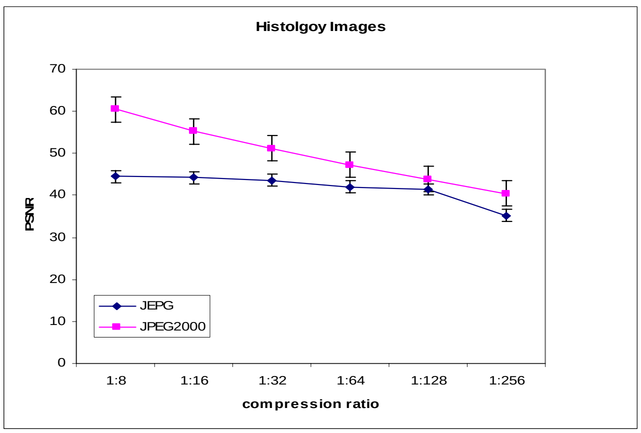

Figure 6: Histology image

The reason that JPEG2000 and JPEG have different compression effects on our grey-scale images than on our colour images is still unclear. One possible reason is that the frequency distributions are different in the two types of images.

In this study an objective evaluation standard, PSNR, is employed. The PSNR values are not, however, directly related to the human visual system's impression of the image quality. In the future, some new methods should be used to compare JPEG and JPEG2000, such as the structural similarity index (SSIM; Wang and Bovik 2004)

5. ACKNOWLEDGEMENTS

This work was supported by the Canadian Institutes of Health Research (CIHR) and by the Natural Sciences & Engineering Research Council (NSERC). The histological sections were kindly provided by C. Northrop (Temporal Bone Foundation, Boston, MA). We are also indebted to A.H. Voie (University of Washington, Seattle, WA) who provided us with orthogonal-plane fluorescence images. JasPer is developed by Dr. Michael D. Adams.

6. REFERENCES

Adams MD and Kossentini F (2000). JasPer: A software-based JPEG2000 codec implementation. Proc. of IEEE International Conference on Image Processing, 53-56.

Bilgin A, Zweig G and Marcellin MW (1998). Efficient lossless coding of medical image volumes using reversible integer wavelet transforms. Proc. 1998 Data Compression Conference, Storer J, Cohn Meds, IEEE Computer Society Press.

Chai D and Bouzerdoum A (2001). JPEG2000 image compression: an overview. Australian and New Zealand Intelligent Information Systems Conference.

Decraemer WF, Dirckx JJJ and Funnell WRJ (2003). Three-dimensional modelling of the middle-ear ossicular chain using a commercial high-resolution x-ray CT scanner. JARO 4(2), 250-263.

Fidler A, Likar B, Pernusǐ F and Skalericǐ U (2002). Comparative evaluation of JPEG and JPEG2000 compression in quantitative digital subtraction-radiography. Dentomaxillofacial Radiology31, 379-384.

Grgic S, Mrak M and Grgic M (2001). Comparison of JPEG image coders. Proc. of the 3rd International Symposium on Video Processing and Multimedia Communications, VIPromCom.

Sung M (2002). Clinical evaluation of compression ratios using JPEG2000 on computed radiography chest images. Journal of Digital Imaging 15(2), 78-83.

Tobin M (2002). Effects of lossless and lossy image compression and decompression on archival image quality in a bone radiograph and an abdominal CT scan. Physicians and Computers 1, 38-40.

Voie AH, Burns DH and Spelman FA (1993). Orthogonal-plane fluorescence optical sectioning: three-dimensional imaging of biological specimens. J. Microsc. 170(3), 229-236.

Wallace GK (1991). The JPEG still picture compression standard. Communication of the ACM, 34(4), 30-44.

Wang Z and Bovik AC (2002). A universal image quality index. IEEE Signal Proc. Letters 9(3), 81-84.

Wanigasekara NR (2002). Quality evaluation for JPEG2000 based on medical image compression. Proc. of the second Joint EMBS/BMES Conference.

Wu X and Memon N (1997). Context-based adaptive lossless image codec. IEEE Trans. On Communications 45(2), 437-444.