Quality evaluation in magnetic resonance images compressed with JPEG2000

J. E. Paz y A. Bosch

Universidad Central Marta Abreu, Santa Clara, Villa Clara, Cuba.

RESUMEN / ABSTRACT

Although image compression facilitates storage and transmission due to reduction in allocation space, there is some information loss when compression techniques like JPEG2000 are used. Some significant quantitative measures like the peak signal to noise ratio, the mean square error and the structural similarity index are used to estimate degradation of quality due to compression in a group of magnetic resonance images compressed with JPEG2000. Instead of a single compression rate value, a range between 0.1 and 0.2 of compression factor was estimated where maximum compression with minimum degradation is obtained. The images file sizes decrease in about 90 to 95% while maintaining an acceptable quality for diagnosis.

Key words: image compression, JPEG2000, image quality, quality measures.

Aunque los algoritmos de compresión facilitan la transmisión y el almacenamiento de las imágenes debido a la reducción que logran en el espacio de almacenamiento, existe una determinada cantidad de información que se pierde cuando se utilizan algoritmos con pérdidas como el JPEG 2000. Algunas medidas cuantitativas de calidad tales como la relación señal ruido pico (PSNR), el error cuadrático medio (MSE) y el índice de similitud estructural (SSIM index) son empleados para estimar la degradación en la calidad que sufre un grupo de imágenes de resonancia magnética que han sido comprimidas con JPEG 2000. En lugar de un solo valor de tasa de compresión, se estima un rango de valores entre 0.1 y 0.2 de factor de compresión donde ocurre la máxima compactación con el menor grado de pérdidas. El tamaño de los ficheros que contienen las imágenes decremen entre un 90 a un 95 % manteniendo una calidad aceptable para el diagnóstico.

Palabras clave: compresión, JPEG 2000, calidad de imagen, medidas de calidad.

INTRODUCTION

Magnetic resonance imaging (MRI) is a powerful tool for imaging soft tissue. MRI provides high-resolution images of internal tissue structure through non invasive means and has been extensively used in medical diagnosis and treatment planning.

Although some physicians still have preferences for films or printed images, the most common format for the output of an MRI machine is a digital medical image displayed in an electronic device like an CRT screen. One fundamental difficulty in working with digital medical images, however, is the size of individual files involved. This difficulty increases as the number of necessary images for a single patient also increases. At this point,
compression will be needed to allow long-term and cost-efficient storage, as well as rapid access and transmission of the images over digital communication channels.

Compression-decompression algorithms (codecs) are nowadays broadly used to decrease file size in digital media storage. These algorithms are particularly helpful in medical imaging to reduce the amount of data generated at imaging systems and are classified in two groups: lossless, where the original image information is preserved after reconstruction, and lossy where reconstructed images exhibit degradation in their quality due to information loss.1

Recently, the digital imaging and communications in medicine (DICOM) standard has accepted the new JPEG2000 codec,2 which achieves greater compression ratios than its predecessor the JPEG standard,3 from which it was originated with the development of Wavelet technology.4 Its recent incorporation into the DICOM standard facilitates its use in medical imaging applications, providing lossles and lossy compression.

Figure 1 shows the quality degradation in two different MR images at three different compression rates while figure 2 shows the characteristic behavior of the spatial frequency with compression rate for this two images.

From both figures it is observed that distortion associated with information loss in the images increases as the compression rate decreases, and so, a blurring effect appears better seen along the edges associated with high frequency loss (fine detail structures) in the image.5,6

To find an acceptable value for compression rate in medical images, either using perceptual (qualitative) or mathematical (quantitative) observers, is still a crucial problem to be solved.

Figure 1 shows the quality degradation in two different MR images at three different compression rates while figure 2 shows the characteristic behavior of the spatial frequency with compression rate for this two images.

Several quality metrics have been developed in the last decades in order to predict image quality automatically. The mean square error (MSE) and the peak signal to noise ratio (PSNR) are among the most widely objective image quality/distortion metrics used. Although they are widely criticized as well for not correlating well with perceived quality measurements, they are together with subjective criteria, indispensable metrics in evaluating compression algorithms or real products.7 They are also simple to calculate, have clear physical meanings and are mathematically convenient in the context of optimization.8

These two measures, together with the structural similarity (SSIM) index are used in the present paper in order to calculate the quality loss and so to estimate an acceptable value for the compression rate in a group of MR images compressed with the JPEG2000 standard at different levels.

**Materials and Methods**

**A. Images and Compression Algorithm**

A set of ten different MR monochromatic images obtained from axial and sagittal cuts of the human brain with characteristics shown in table 1 were compressed at different compression rates from 0.6 down to 0.05 times.

The C implementation of JPEG2000 codec known as JasPer was used for this purpose. It belongs to ISO/IEC 15444-1 norm (Part 1: Coding imaging system), it is a part of reference software of the standard and it is of freely access. It uses the compression factor and not the number of bits per pixel to specify rates.
A rate of one corresponds to no compression. The Matlab functions jp2read and jp2write were also used to manipulate the images and were also acquired freely.\(^8\)

This paper deals with three different objective quality metrics for the estimation of an compression level where diagnosis is still not affected by quality degradation due to lossy compression. These metrics are the peak signal to noise ratio (PSNR), the mean square error (MSE) and the structural similarity index (SSIM).

The distortion observed in the reconstructed image due to the lossy compression effect is calculated using the Peak Signal to Noise Ratio (PSNR) as follows:

\[
PSNR(dB) = 10 \log_{10} \left( \frac{MAX_p^2}{MSE} \right)
\]

...(2)

where:

- \(MSE\): Mean square error obtained in equation (1).
- \(MAX_p = (2^B - 1)\) where \(B\) is the bit-depth in the image.\(^5\)

On the other hand, the structural similarity index (SSIM) is a quantitative measure of the difference between two signals. In this particular case it will measure the difference between the original and reconstructed images. It takes into account for the luminance, contrast and structure content in both images.\(^10\)

A simplified form for the structural similarity index obtained according to reference\(^11\) results:

\[
SSIM(x, y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}
\]

...(3)

where:

- \(x\): Original image.
- \(y\): Reconstructed one.
- \(\mu_x\) and \(\mu_y\): Luminance values.
- \(\sigma_x\) and \(\sigma_y\): Contrast estimation values.
- \(C_1\) and \(C_2\): Constants.

Although, in order to obtain an overall quality measure of the entire image, the mean value of the latter parameter is calculated as:

\[
MSSIM(X, Y) = \frac{1}{M} \sum_{j=1}^{M} SSIM(x_j, y_j)
\]

...(4)

where:

- \(X\) and \(Y\): Reference and distorted images respectively.
- \(x_j\) and \(y_j\): Image contents at the \(j\)th-local window.
- \(M\): Number of local windows in the image.

Using later equations, the MSE, PSNR and SSIM values where calculated for the set of images in table 1, compressed with JPEG2000 at different rates ranging from 0.05 to 0.6. An estimation of an acceptable compression rate was also evaluated for using this codec with this type of images.
RESULTS AND DISCUSSION

Figure 3 shows the behavior of file size and MSE versus compression ratio (CR) in the range from 0,6 down to 0,05 of compression factor for example image A in figure 1, while figure 4 shows the behavior of PSNR and SSIM index and vs. CR for the same image in the same range of compression factor.

Figure 5 shows the PSNR values vs. CR for all the images tested. The range 0,1 to 0,2 of compression factor (between dashed lines) was found suitable for compressing this kind of images using this codec.

In this range, the values for PSNR are all above 29 dB, which is acceptable in terms of quality for diagnosis securing that no important data would be lost while achieving great compression ratios and so, a great image file size reduction.

Values of CR above this range are related to better quality images but less compression is attained, while for values of CR lower than 0,1 the PSNR values for all images in the set, begin to fall rapidly related with a quality degradation in the images.

Figure 6 shows the SSIM index vs. CR also for all the images tested. This index takes into account luminance, contrast and structural content when comparing two images. In this particular case it stands for similarity between original and reconstructed images.

As seen in the graph, the values of SSIM go from 0,9 up to 1,0 for the range of CR values proposed as suitable for compression without significant quality lost.

Like the PSNR, this parameter would also fall rapidly for values of CR lower then 0,1 of compression factor, while for values greater than 0,2 of CR, the original and reconstructed images would be more alike i.e. showing less distortion from original.
CONCLUSIONS

The quality degradation in a group of MR images compressed at different rates using the JPEG2000 codec was measured using three different quantitative measures.

From the graphics in the last section, it is observed that compression rate values lower than 0.1 will seriously damage image quality, as the PSNR and the SSIM index falls rapidly as this value decreases. Any compression rate value upon 0.1 can be accepted without important information lost and would be chosen by the specialists according to their practical needs at their site.

This conclusion agree with other authors who determined a similar compression rate using the traditional JPEG standard for on-call electronic transmission of body CT images.

Quality degradation due to compression has a strong dependance with image size. It is most present in small size images as in bigger ones. Image A, with 400X400 pixels size, shows almost no quality degradation at 0.05 of compression factor compared to image B (256X256 pixels size) at same rate where fine detail structures are lost and structure boundaries are no longer clearly defined.

Instead of finding a single compression rate value, an acceptable and reduced set of compression ratios is found to be more appropriate. Between values of 0.1 and 0.2 of compression factor, the most compression was attained with an acceptable level of distortion. For these values, any JPEG2000 DICOM compressed image, will reduce its storage space up to 90 to 95 % while maintaining an acceptable quality for diagnosis.

Obtaining a single clinically acceptable compression rate value, can be very imprecise when only quantitative criteria are used. Although recent efforts have been made to include characteristics of the human visual system in quality measurements, objective metrics such as MSE, PSNR or the SSIM index are still suitable for this purpose.

REFERENCES


AUTHORS

Juan E. Paz Viera
Licenciado en Física. Máster en Ingeniería Biomédica. Actualmente se encuentra trabajando en el Centro de Estudios de Electrónica y Tecnologías de la Información, de la Universidad Central de las Villas. Sus áreas de interés científico son el procesamiento digital de imágenes, la compresión y la transmisión de imágenes, calidad de imagen y procesamiento de señales en general. Es miembro de la sociedad cubana de Física y de la Sociedad Cubana de Bioingeniería.
E-mail: jpaz@uclv.edu.cu

Arley Bosch Quirós
Ingeniero en Telecomunicaciones y Electrónica. Trabaja en el proyecto del Consejo de Estado de la República de Cuba para las nuevas tecnologías en la medicina. Sus intereses de investigación son el procesamiento digital, la transmisión y la calidad de las imágenes médicas.
E-mail: boschq@uclv.edu.cu