# Improved ROI Algorithm for Compressing Medical Images

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Abstract: The digital medical images have become an essential part of the electronic patient record. These images may be used for screening, diagnosis, treatment and educational purposes. These images have to be stored, archived, retrieved, and transmitted. Compression techniques are extremely useful when considering large quantities of these images. In this paper, four compression techniques are applied on three medical image modalities. The compression techniques are either lossless or lossy techniques. The applied lossless techniques are Huffman and Arithmetic. The applied lossy techniques are Discrete Cosine Transform (DCT) and Wavelet. The modalities are Ultrasound (US), Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). The observed parameters are both the compression ratio (CR) and total compression time (TCT) (compression time + decompression time). The target is to maximize the CR while preserving images' information using the best compression technique. The maximum accepted CR for each image is chosen by three experts. The last enhancement is done by isolating the region of interest (ROI) in the image then applying the compression procedure. Applying the ROI technique on the studied cases by the experts gave promising results.

## 1 INTRODUCTION

Over the past 30 years, information technology (IT) has facilitated the development of digital medical imaging. This development has mainly concerned US, CT, MRI, angiography, nuclear medicine, mammography, and computed radiology. All these modalities are producing ever-increasing quantities of images. The challenge is the reduction of the images' sizes stored in the medical servers with the decrease of their transmission time without affecting the information in the images. The risk of losing a piece of diagnostic information does not sit well with medical ethics. The evolution of digital imaging, retrieval systems and Picture Archiving and Communication Systems (PACS), alongside compression systems, has resulted in changing attitudes, and compression is now accepted by medical experts.

The digital medical images have specific features. Some of these features are: uniform background, relatively large homogenous regions, and higher resolution than general images. The whole compression process can be described as a method divided into compression and decompression processes. At the compression process, the input file is represented in a more compact format where the number of bits of the compressed file is fewer than the number of bits of the original file. At decompression process, the original file is reconstructed from the compressed file either totally-as in lossless techniques; or approximately-as in lossy techniques (Acharya and Tsai, 2005).

### 1.1 Compression Ratio

CR is the ratio of the reduction in number of bits representing the digital image after compression to the number of bits representing the original digital image. CR is the most significant metric of performance measure of a data compression algorithm. However, the lossless techniques yield modest CRs, while the lossy techniques yield higher CRs. Eq. (1) shows equation used to produce CR (Nait-Ali and Cavaro-Menard, 2008).

$$CR = \frac{a-b}{a} \times 100. \qquad (1)$$

Where CR is the calculated compression ratio, ***a*** is


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the original image size and ***b*** is the compressed image size.

Recent works have studied the use of JPEG 2000 (Joint Photographic Experts Group) compression standard on a variety of medical images. The Discrete Wavelet Transform is the basis of the JPEG2000 image compression standard (Kesavamurthy et al., 2009). Table 1 shows the range of acceptable CRs defined after analyzing the accuracy of the diagnosis based on medical experts (Nait-Ali and Cavaro-Menard, 2008).

Table 1: Applying JPEG 2000 standard on medical images.

| Image Type | Acceptable compression ratio |
|---|---|
| Digital chest radiograph | 20:1 (so that lesions can still be detected) |
| Mammography | 20:1 (detecting lesions) |
| Lung CT image | 10:1 (so that the volume of nodules can still be measured) |
| Ultrasound | 12:1 |
| Coronary angiogram | 30:1 (after optimizing JPEG 2000 options) |

## 1.2 Total Compression Time

TCT is the time delay required for compressing and decompressing the image. TCT is one of the parameters that measure the performance of the compression algorithms. Compression algorithm may be effective at the CR but it needs to be effective at compression time also. The complex compression algorithm requires relatively long time leading to serious problems in interactive applications. The compression algorithm designer may be advised to decrease the complexity of the algorithm so as to decrease the TCT (Acharya and Tsai, 2005).

# 2 MATERIALS AND METHODS

The flow chart shown in figure 1 illustrates the compression process as a whole. The compression process starts with importing the selected image to the program. The imported image is compressed. The compressed file is saved and this is the end of the compression phase. The decompression phase starts by the inverse of the compression technique to give the reconstructed image. Finally, the reconstructed image is saved.

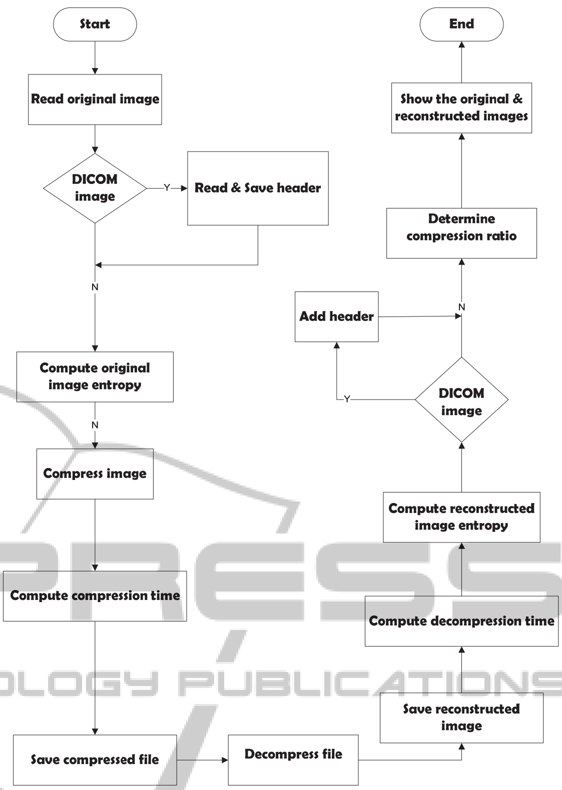


Figure 1: Flow chart of the whole compression process.

Any compression process is preceded by preprocessing steps. These preprocessing steps depend on the different features of the medical modalities. Some of these features that are studied in this paper are listed in table 2.

Table 2: Features of studied medical modalities.

| Modality | DICOM | True color | Bits/Pixel |
|---|---|---|---|
| US | Yes | Yes | 8 |
| MRI | Yes | No | 16 |
| CT | Yes | No | 12 |

If the original image is in the Digital Imaging and Communications in Medicine (DICOM) format, the text will be separated and the image will be dealt with normally, as shown in figure 1. Then, after the compression and decompression phases are completed, the text file is combined again with the reconstructed image to construct the DICOM reconstructed file.

In case of US, the preprocessing step is the separation of the red (R) component, the green (G) component, and the blue (B) component of the true color image. Then, each component is dealt with simultaneously as grayscale image. Each component is compressed then saved then decompressed to form the reconstructed components as shown in figure 2. The post-processing step is the concatenation of the reconstructed components to build up the true color reconstructed image.

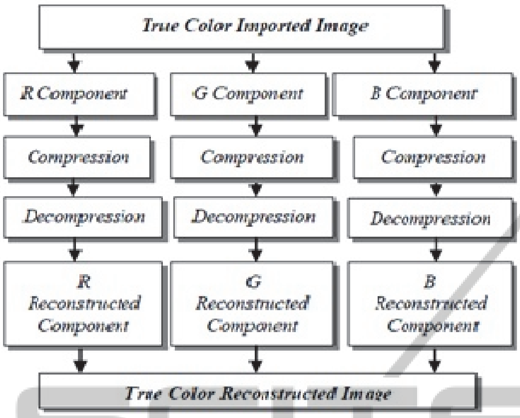


Figure 2: Block diagram for dealing with true color images.

The choice of wavelet family, which is used in wavelet decomposition, is a critical issue that affects image quality. A selected wavelet family must result in perfect reconstruction. To achieve the best CR, the best wavelet family and the best decomposition level must be chosen. The biorthogonal family of wavelets is used for medical modalities compression as shown in table 3 (Tolba, 2002).

Table 3: Selected parameters for wavelet coding of medical modalities.

| Parameter | Value or Type |
|---|---|
| Wavelet Family | Biorthogonal 3.9 |
| Decomposition Level | Four |
| Retained Energy (Entropy-Like Criterion) | 99.96% |

# 3 RESULTS

This section of the paper is concerned with the comparative study results of the medical images. A sample of ten images is tested for each modality and average results for each technique are compared to show the best technique. Secondly, five images from each medical dataset are studied. These sample datasets are subjected to three experts. Then, the experts assign the maximum CR that could be reached without affecting the diagnosis process. Then, ROI approach shows it's improvement on CR of the expert studied cases.

## 3.1 Comparative Study Results

At this section of the study, the mean of the ten medical tested images is calculated for CR (%) and TCT (Sec.) at each technique. Figures 3, 5, and 7 show that DCT technique has the highest CR. Also, DCT technique has the shortest TCT as shown in figures 4, 6, and 8.

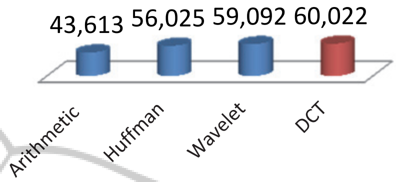


Figure 3: A comparison of CR results among the four compression techniques for US images.

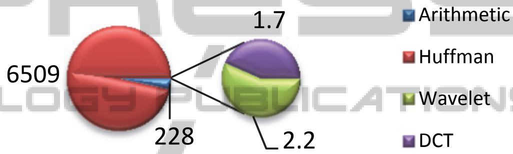


Figure 4: A comparison of TCT for each compression technique related to each other for US images.

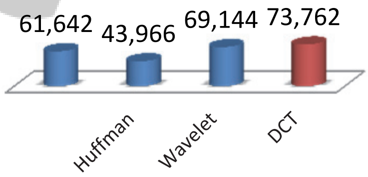


Figure 5: A comparison of CR results among the four compression techniques for CT images.

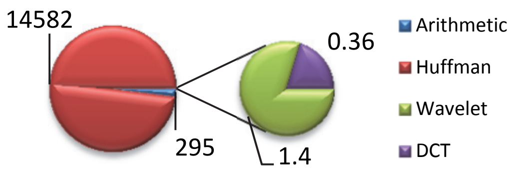


Figure 6: A comparison of TCT for each compression technique related to each other for CT images.

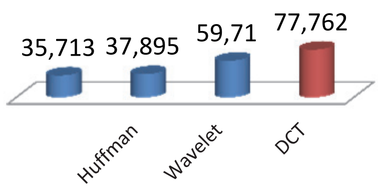


Figure 7: A comparison of CR results among the four compression techniques for MRI images.

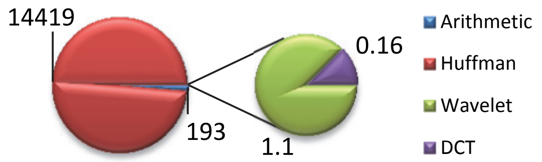


Figure 8: A comparison of TCT for each compression technique related to each other for MRI images.

## 3.2 Experts Studied Cases Results

This section of the paper is concerned with the results of medical studied cases. These medical cases are five of each studied modality. The technique applied on the studied cases is DCT which is the best technique throughout the four compared techniques as shown in the previous section.

The compressed images with different CRs are reviewed by three expert physicians independently. Then, experts specify the accepted compressed images and the rejected compressed images. Figures 9, 10, and 11 show the CR results that are selected by the experts.

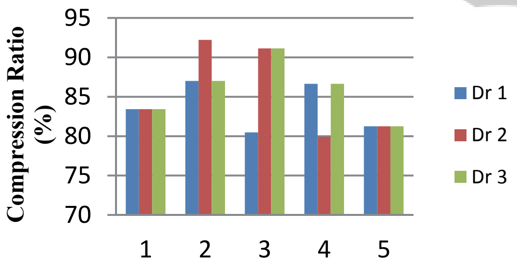


Figure 9: US studied cases results.

## 3.3 ROI Studied Cases Results

The first step in automatic segmentation of the clinical portion of the medical image (eliminating the non-essential background) is converting it from a grayscale image to a binary image by selecting an intensity threshold as shown in figure 12. The second step is discarding the regions other than the ROI by selecting a size threshold as shown in figure 13. The intensity level and the size level used for thresholding depend on the medical modality and are selected manually according to the physician preference.

The third step is filling the holes in the selected region as shown in figure 14. The fourth step is clearing the borders of the selected region as shown in figure 15. The fifth step is outlining the original image with the selected region as shown in figure 16. This step is performed for verifying that the selected region is the required ROI.

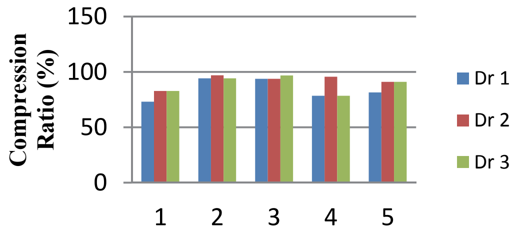


Figure 10: CT studied cases results.

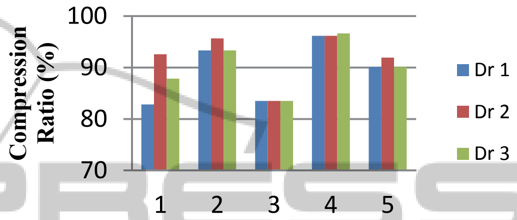


Figure 11: MRI studied cases results.

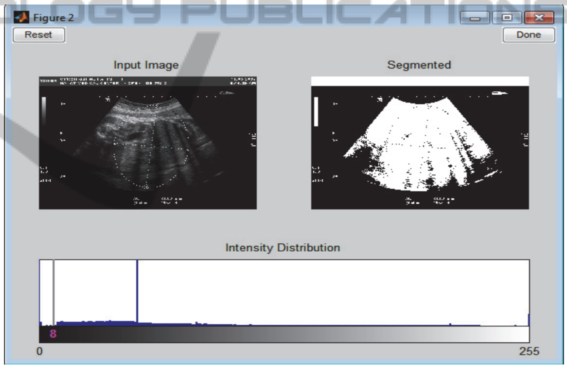


Figure 12: Conversion of grayscale image to binary image based on threshold selection.

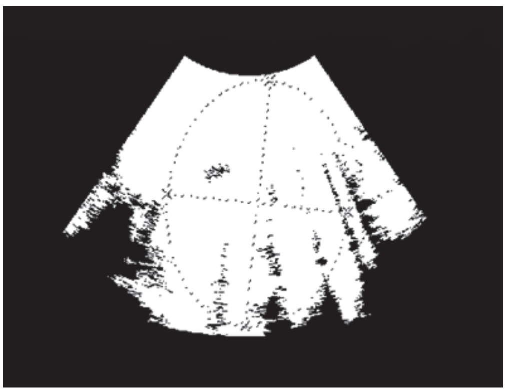

Figure 13: Discarding the regions other than the ROI.

The sixth step is finding the extreme points of the selected region. The extreme points are minimum x-value, minimum y-value, maximum x-value, and maximum y-value of the region of interest. The importance of the extreme points is that they will be the indices of the final ROI image.

Figure 14: ROI without holes.

Figure 15: Clearing the borders of the selected region.

The last step is cropping the ROI in the original image as shown in figure 17. The original image is cropped at the extreme points of the ROI which specify the width and height of the cropped image. Figures 18, 19, 20 show the CR results after applying ROI on the images.

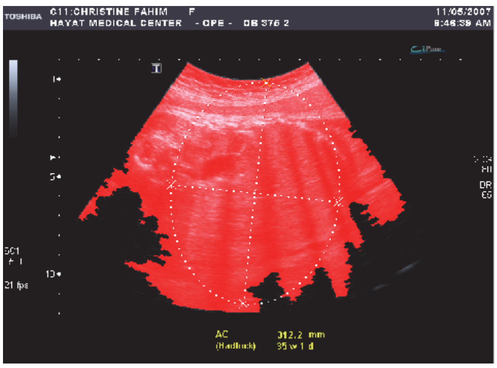

Figure 16: Outlining the original image with the selected region.

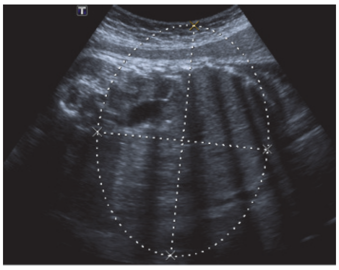

Figure 17: Cropping the ROI in the original image.

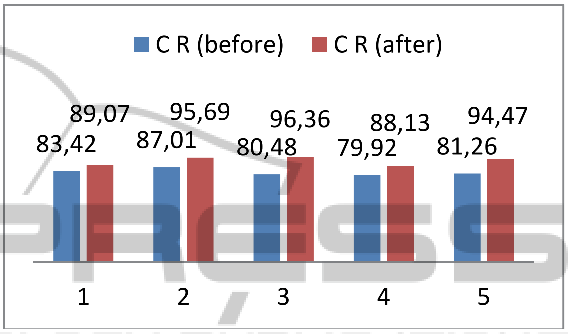


Figure 18: US ROI studied cases results.



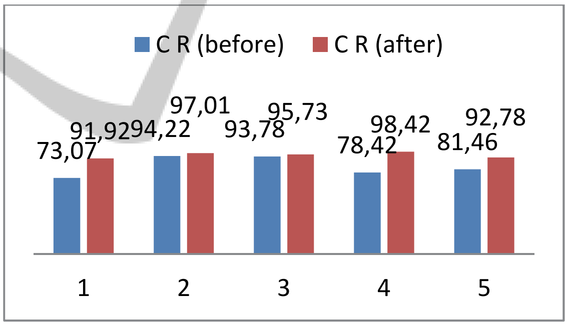


Figure 19: CT ROI studied cases results.

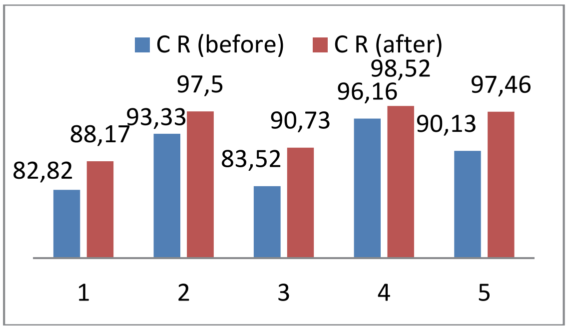


Figure 20: MRI ROI studied cases results.

## 4 CONCLUSIONS

The best compression technique is the one who reaches a high CR without any deterioration in image quality. In the considered comparative study, The DCT technique has proved high efficiency by reaching maximum CR within minimum TCT. The experts studied cases results in average CR for US of 82.4%, for CT of 84.2%, and for MRI of 89.2%. The most valuable point is the isolation of the ROI for the experts studied cases which results in a considerable enhancement of the CR results. The average improvement in CR for US is 10.3%, for CT is 11%, and for MRI is 5.3%.

A comparison between JPEG-LS, JPEG2000, and the applied algorithm is shown in table 4. For CT modality results on JPEG2000, the study was applied on the lung organ. For CT modality results on JPEG-LS and the ROI algorithm, the study was applied on different organs. For MRI modality results on JPEG2000, the study was applied on the brain organ. For MRI modality results on JPEG-LS and the ROI algorithm, the study was applied on different organs.

Table 4: Comparison between the ROI Algorithm and Previous Studies.

| | JPEG-LS | JPEG2000 | ROI |
|---|---|---|---|
| US | **3.4:1** (Clunie, 2000) | **12:1** (Nait-Ali and Cavaro-Menard, 2008) | **13.78:1** |
| CT | **4:1** (Clunie, 2000) | **10:1** (Nait-Ali and Cavaro-Menard, 2008) | **20.71:1** |
| MRI | **3.6:1** (Clunie, 2000) | **20:1** (Terae et al., 2000) | **18.1:1** |

From table 4, the applied algorithm gives promising results for US & CT modalities. JPEG2000 gave the best results for MRI modality.

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