The ISC Int'l Journal of Information Security

August 2019, Volume 11, Number 3 (pp. 29–34)

http://www.isecure-journal.org

Selected Paper at the ICCMIT'19 in Vienna, Austria

Medical Image Compression Based on Region of Interest☆

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ARTICLE INFO.

Keywords:
ROI, Lossless Compression, Medical Images, PSNR.

Abstract

Medical images show a great interest since it is needed in various medical applications. In order to decrease the size of medical images which are needed to be transmitted in a faster way; Region of Interest (ROI) and hybrid lossless compression techniques are applied on medical images to be compressed without losing important data. In this paper, a proposed model will be presented and assessed based on size of the image, the Peak Signal to Noise Ratio (PSNR), and the time that is required to compress and reconstruct the original image. The major objective of the proposed model is to minimize the size of image and the transmission time. Moreover, improving the PSNR is a critical challenge. The results of the proposed model illustrate that applying hybrid lossless techniques on the ROI of medical images reduces size by 39% and gives better results in terms of the compression ratio and PSNR.

1 Introduction

Imaging plays a great part in today's medical systems as MRI scan and X-ray. Medical imaging effectively aids doctors to detect human's diseases. Medical imaging is a very vital issue as its data are very sensitive. It needs huge storage devices. Due to its large capacity and the need for transmission of medical images data, image compression is very important. Such images should be compressed without the loss of any important data. That means, high compression ratio could not be achieved as the reconstructed image has to be identical to the original data.

Image compression is important for many applications that include large data store and transmit [1] for example; multimedia documents, videoconferencing, telemedicine and medical imaging. Medical imaging needs efficient compression techniques to preserve the critical data of patients. Such data should be compressed without losing of important information. Compression methods are categorized into lossy and lossless, depending on the applications [2]. The use of lossless or lossy methods depends on the earnest of data of images. Lossy techniques are widely used in most applications, where losing some information in the decompressed image is not a big issue. On the other side, in lossless compression techniques,

☆ The ICCMIT'19 program committee effort is highly acknowledged for reviewing this paper.

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ISSN: 2008-2045

the main image retrieved from the compressed image without losing information since no noise is added to the image and they provide compression ratios, less than those, provided by lossy compression techniques.

Some applications require efficient compression techniques such as medical imaging; this makes lossless compression techniques the best choice for them. Although, lossless compression techniques save important data of images, they donâĂŹt reduce image size as required. Many techniques are used to achieve lossless compression as Run Length Encoding (RLE). Discrete Wavelet Transform can be used either in lossless or lossy compression models, depending on the quantization step [3]. DWT is one of the most effective compression techniques that is used in many applications [4]. In the DWT, images split into blocks where the transformation is applied on each one. This technique can be considered as a lossy or lossless compression method. The loss of data occurs in the quantization step, not during transformation, where quantization can be uniform or scalar.

Run Length Encoding (RLE) and Zigzag scanning method are straightforward lossless data compression techniques [5]. The RLE counts and stores successive data with the same pixels in a single pixel. This technique minimizes the size of pixels rather than original pixels. Zigzag scanning has been applied before the RLE to convert the matrix into a vector [6]. Splitting images into two parts according to the importance of information is very necessary; such regions are ROI and the non-ROI. The ROI compressed with lossless algorithms, but non-ROI compressed with lossy algorithms. This procedure can obtain more compression ratio than only using lossless algorithms for the whole images. The ROI techniques lead to reduce the image size and maintain the sensitive data simultaneously. Detecting Region of Interest is very important for several cases like medical images of tumours. This can be achieved manually by hand free tools or automatically using Thresholding method. Since the important data can be small, the medical images can be compressed by lossy techniques except the tumour region in the image. This part should be compressed with an efficient lossless technique. This procedure can help in reducing both the image size and the storage space and improving the transmission time.

The paper mainly focuses on applying lossless compression techniques on the ROI of medical images. The main objectives are decreasing the size of compressed images and improving the PSNR. The literature survey is aforesaid in Section 2, The methodology is demonstrated in Section 3. In Section 4, the results of the proposed work are covered then the conclusion is illustrated in section 5.

2 Literature Review

Yee et al. proposed Better Portable Graphic (BPG) compression method for medical images, where both lossless and lossy BPG compression methods were applied on the ROI and non-ROI areas. The final results showed that BPG-based compression method exceeds the compression limit of other methods by at least 10-25% [1].

Kazeminia et al. proposed ROI extraction techniques, based on histogram for x-ray of bones images that are compressed by lossless techniques. The authors employed the RLE lossless compression technique to increase both spatial and statistical redundancies in images. They also compared the final results with other compression techniques [7].

Reddy et al. compared two cases of applying different lossless techniques on the ROI that is detected manually by hand free tool. The results show that the Daubechies Wavelet Transform (DbWT) gives better results, compared with the Haar Wavelet Transform (HWT) for the ROI. Also, the Embedded Zero-tree Wavelet (EZW) technique was applied on non-ROI, as a lossy compression algorithm [8]. M and Sarvagya presented a new scheme of ROI, based on medical image compression. They reported that the PSNR and time response are very important to measure the performance of compression techniques [9]. B. Mohamed and H. Afify proposed algorithm using Haar wavelet-based compression method that was applied on an enhanced images. Better results in terms of CR and PSNR are obtained comparing with other compression techniques applied on the same images [10]. The proposed algorithm save time and achieved higher PSNR with large image size than the related works.

3 Methodology

Some applications require efficient compression techniques such as medical imaging; this makes lossless compression techniques the best choice for them. Although, lossless compression techniques save important data of images, they donâĂŹt reduce image size as required. The region of interest of medical images can be compressed only to reduce image size ignoring noise and background. The target of the proposed algorithm is applying hybrid lossless compression techniques on the separated ROI, where the non-ROI is completely ignored. This in turn improves the PSNR and reduces the image size and the time, consumed by compression and decompression methods. The MSE and compression ratio have been calculated to compare the results of the hybrid lossless technique with or without separating the ROI.

The proposed algorithm, automatically, detects the ROI of medical images, based on thresholding method;

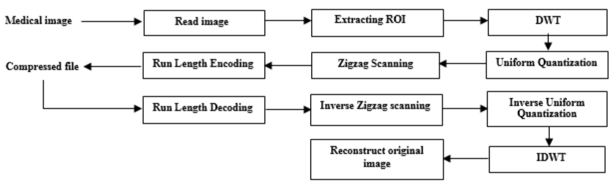

Figure 1. Block diagram for the proposed algorithm

Thresholding method is used to distinguish the pixels of ROI (Data) from those of non-ROI (Background).

Figure 1 clarified the lossless compression method. The medical image is read then the ROI is segmented, and the background is removed, based on a certain threshold that is empirically estimated. After that the lossless compression starts by applying the DWT on the extracted ROI. As mentioned before, lossless compression method, using DWT, depends on the quantization step. In the proposed compression technique, uniform quantization is used, and the quantization value is adapted such that no losing of data during compression. After the DWT step, the zigzag scanning is applied to convert the quantized coefficients into a vector, then the RLE is carried out. All the mentioned processes are then inverted to restore the original region of ROI where the background is set to be black.

4 Experimental Results

In this section, the experimental results of the proposed image compression method are presented. To assess the system, the âĂIJMini MammographicâĂİ dataset was used as the input medical images [11]. The number of images in the âĂIJMammographicâĂİ dataset is 322. The original size of images is 1024 x 1024 pixels. Each two successive films represent the left and right mammograms of a single patient.

In the proposed algorithm, the original dataset is first converted to bmp format to display the medical images. In addition, applying the proposed technique on the original size of images, the image size has been minimized to 512*512 pixels to reduce the execution time and to show how far minimization affects the compression results. The proposed algorithm was implemented in the 64-bi tMATLAB 2015 using image processing toolbox. The computer processor was Intel(R) Core (TM) i5 M450 @ 2.4GHz and the internal memory was (RAM) 4.00 GB. The proposed compression algorithm has been applied on the database images under the following conditions:

- Two different sizes (512*512 and 1024*1024) are used as mentioned before.
- The model has been applied only on the ROI after extracting it and on the whole image without extracting the ROI.

Figure 2. Decompressed 512X512 image

Figure 3. Decompressed 1024X1024 image

Figure 4. ROI_decompressed 512X512 image

The system performance was evaluated based on the compressed size, compressed time, decompression time, Compression Ratio (CR), MSE, and the PSNR, where the last three terms are calculated as shown in equations (1), (2) and (3) below [12]:

$$CR = \frac{Bits of original image}{Bits of compressed image} \quad (1)$$

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{i=0}^{n-1}[X(i,j) - Y(i,j)]^2 \quad (2)$$

Where X represent the original image, Y represent the output image.

$$PSNR = 10log_{10}(\frac{N^2}{MSE}) \quad (3)$$

N is taken from maximum variation in the input image data type.

Figures 2, 3, 4 and 5 show the descriptive results of a medical image taken as a sample to show the effect of the proposed model under different conditions, where Figure 2 and Figure 3 represent the decompressed images of different sizes 512*512 and 1024*1024. Figure 4 and Figure 5 represent the decompressed images of ROI of different sizes 512*512 and 1024*1024 respectively.

Table 1 and Table 2 lists the results for a number of medical images by applying the proposed compression model where (Comp_S) represent compressed file size and (Time_C &Time_D) stands for time of compression and decompression.

Figure 5. ROI_decompressed 1024X1024 image

Table 1. Quantitative results of several samples at 512*512

	Extracting ROI			Whole Image		
Images	1	2	3	1	2	3
Comp_S	114.8	166	135.4	173.3	235.8	173.1
CR	2.28	1.58	1.94	1.51	1.11	1.56
MSE	0.029	0.043	0.034	0.047	0.06	0.045
PSNR	69.46	67.88	68.83	67.44	66.24	67.65
Time_C	2.77	1.70	1.01	0.621	0.67	0.58
Time_D	2.35	1.45	1.49	2.63	1.43	1.91

Table 2. Quantitative results of several samples at 1024*1024

	Extracting ROI			Whole Image		
Images	1	2	3	1	2	3
Comp_S	455.4	652	530	700	927	680.7
CR	2.30	1.61	1.98	1.50	1.13	1.54
MSE	0.029	0.043	0.03	0.05	0.06	0.05
PSNR	75.52	73.92	74.90	73.38	72.24	73.68
Time_C	4.66	3.18	2.99	2.70	2.59	2.26
Time_D	3.89	2.20	2.32	4.39	2.63	2.29

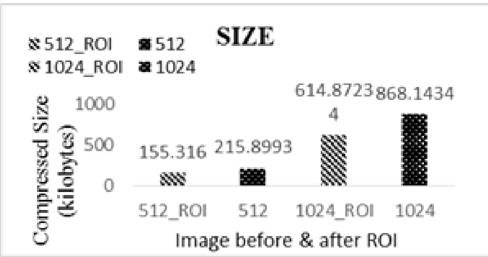

Figure 6. Size Results

Figure 6, 7, 8, 9, 10 and 11 show the average results for sizes of the compressed files, compression ratios (CR), mean square error (MSE), PSNR, compression time and decompression time respectively. The proposed model was applied on all medical images of Mini Mammographic database. The average results show that size of compressed files resulting after applying hybrid compression method on the ROI less than those resulting from compressed the original images. This leads to better PSNR and less MSE in case of the ROI than the whole image for different sizes. Compression and decompression time reduced in case of smaller images.

Table 3 lists the results of the proposed algorithm and those of another alternative lossless compression - based model [10]. They tested their method on the same database but they used a smaller size (256*256).

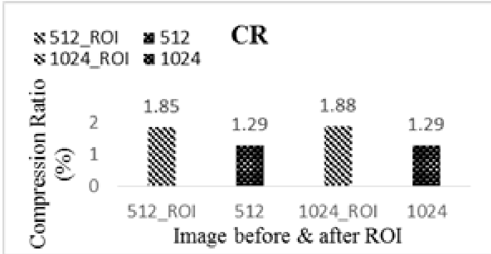

Figure 7. CompressionRatio Results

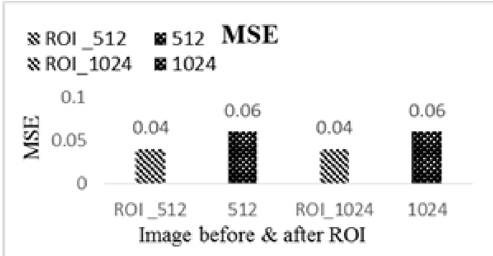

Figure 8. MSE Results

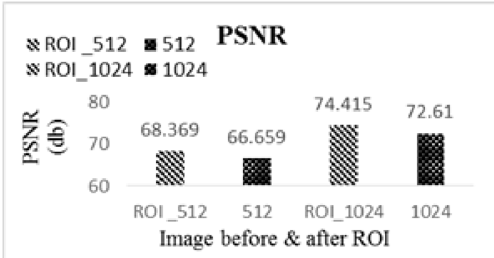

Figure 9. PSNR Results

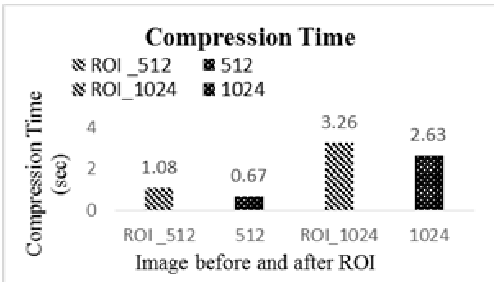

Figure 10. Compression Time Results

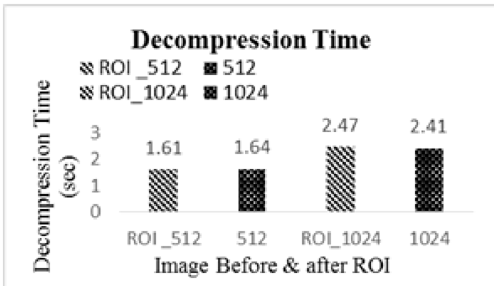

Figure 11. Decompression Time Results

Table 3. Compared average results

	CR	PSNR	Time_C (sec)	Time_D (sec)
Whole Image (512*512)	1.294	66.65	0.67	1.64
ROI Image (512*512)	1.85	68.37	1.077	1.61
Whole Image (1024*1024)	1.290	72.60	2.63	2.41
ROI Image (1024*1024)	1.89	74.42	3.26	2.47
Haar wavelet (Original Image)	12.75	45.8	458.780	516.9388
Haar wavelet (Enhanced Image)	26.25	47.27	312.73	547.4
Quadtree and Huffman (Original Image)	21.39	31.16	413.0816	2100.867
Quadtree and Huffman (Enhanced Image)	9.76	29.6	611.8	5924.8

From Table 2 it can be noticed that the compression and decompression times of the proposed algorithm are much better than those of the other technique. The proposed algorithm also achieved higher PSNR for large image size. Although, the other method achieved better compression ratio but one should take into account that they only applied their algorithm on one small size (256*256), while two different sizes are used in the proposed algorithm (512*512 and 1024*1024). In addition, the size of images, by compressing only the ROI, is reduced by 39% compared to the compressed size of the whole image. Reducing the image size, in turn, reduces the transmission time that is an important parameter in medical applications, such as telemedicine.

5 Conclusion and Future Works

In this paper a hybrid lossless compression model has been proposed. The model has been applied on two cases the whole image and only the ROI in the medical image, discarding the non-ROI. The proposed model was applied on all images in database. The average results show that size of compressed files resulting after applying the compression method on ROI less than those resulting from compressed original images. Compression and decompression time reduced in case of smaller images. Also, the model provided higher PSNR and less MSE when applied on the ROI than the whole image. The CR improved in case of the ROI. The experimental results show that the proposed technique gives better performance in terms PSNR and time if it is compared to related works. Some related works had more compression ratio considering that the images size were 256*256 whereas the proposed model save time and achieved better PSNR with large images.

In the future work, this research could be extended by improving ROI detection by using Fractional Edge Detection that can provide high signal to noise ratio and detect edges more effectively.

Acknowledgment

I would like to thank Dr. Noha Ahmed Younis, lecturer of Electronics Engineering Radiation Department, Atomic Energy Authority. I am deeply grateful for her support, helpful notices and valuable time.

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