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A review on region of interest-based hybrid medical image compression algorithms

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ABSTRACT

Digital medical images have become a vital resource that supports decision-making and treatment procedures in healthcare facilities. The medical image consumes large sizes of memory, and the size keeps on growth due to the trend of medical image technology. The technology of telemedicine encourages the medical practitioner to share the medical image to support knowledge sharing to diagnose and analyse the image. The healthcare system needs to ensure distributes the medical image accurately with zero loss of information, fast and secure. Image compression is beneficial in ensuring that achieve the goal of sharing this data. The region of interest-based hybrid medical compression algorithm plays the parts to reduce the image size and shorten the time of medical image compression process. Various studies have enhanced by combining numerous techniques to get an ideal result. This paper reviews the previous works conducted on a region of interest-based hybrid medical image compression algorithms.

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1. INTRODUCTION

The medical images contain a large amount of information that is necessary for correct diagnosis by doctors and medical professionals. The medical image plays essential roles to assist the medical practitioner in easing their work. It is also the most crucial asset of the healthcare system, which is used commonly by medical practitioners to detect, diagnose, treat, and study various types of diseases in electronic form. It is also the best practices for monitoring the person's health condition, which remains used widely nowadays.

Generally, everyone knows that the medical image consumes enormous proportions of memory. There are various type of modalities such as X-Ray, magnetic resonance imaging (MRI), single-photon emission computed tomography (SPECT), computed tomography (CT), positron emission tomography (PET) and ultrasound imaging. Each modality which consumes very large of memory size and requires a massive volume of memory storage space. The administrator of the hospital information system must ensure the availability of memory space is adequate to meet the needs of the system flow. This storage occupies more area for storing images a long time as there is a need to keep the record of numerous patients [1, 2].

Medical practitioners also need to share data, especially medical images, to share opinions, idea, and knowledge to diagnose and analyse the disease. They need to transfer the medical image files over the network, which requires very high bandwidth. The distribution of the medical image needs to deliver accurately, precisely, and safely [3]. Hence, the medical image must be compressed and sent securely through the network in the system.

Thus, compression has attained much attention in medical images. The main purpose is to reduce the volume of transmitted data in order to preserve bandwidth and without significant effect on the quality of the data by removing any redundant information [4]. Medical image compression is utilised in applications to promote faster transmission speed and reliable data and reduce storage costs and increase transmission speed [5]. Compression of medical images is essential since the efficient storage and transmission of data via high bandwidth digital communication networks is crucial. Image compression will enable picture archiving and communication system (PACS) in Hospital Information System to reduce file size while retaining relevant diagnostic information in their storage requirements. Here the compression requirement is realised [6].

In order to decrease the volume of medical images, the region of interest-based (ROI-based) compression algorithm approach was introduced. The practicality of ROI is significant in medicinal applications where certain parts of the picture are of higher symbolic significance than others [7]. This technique can increase the amount of the storage space by segmented the image into ROI and non-ROI area. This technique permits each segment compressed the image using the appropriate technique to further their potential benefit for optimal results [8]. This paper aims to review recent research on the hybrid of the region of interest-based compression medical image algorithm to achieve high compression ratios whereas maintaining image quality.

This paper organised in the following way: The first section of this paper will briefly introduce the whole idea of the article. An overview of the medical image compression method presented in section 2. Section 3 will consider the sources and practices of the related study on ROI-based hybrid medical image compression techniques. The discussion on summarising findings from previous studies will be present in section 4. Finally, section 5 gives the final remarks of the paper.

2. MEDICAL IMAGE COMPRESSION

Medical images contain a great deal of information that is necessary for diagnosis by doctors and medical professionals. It is a process of reducing image data irrelevance and redundancy so that data can practically be stored or transmitted. It minimises the size of a representation document in bytes without degrading the image's nature. Image compression includes a forward process referred to as encoding and a reverse process referred to as decoding. The compression proses start once the encoder received the image as the input. The encoder transformed the input image into a series of binary data called a bit-stream. The decoder then receives and decodes the encoded bit-stream to form the decoded image, also known as the resulting image. Figure 1 shows the basic flow of image compression [9].

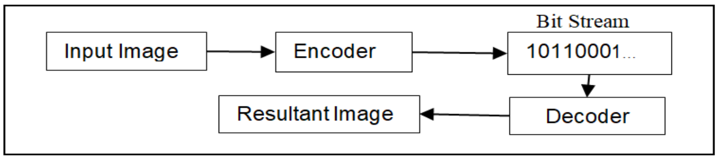

Figure 1. Basic flow of image compression [9]

Generally, there are two categories of image compression, lossy and lossless [10]. In lossless compression, the recovered data identical to the original, whereas the recovered data is a close replica of the original with minimal data loss in the case of lossy compression [11, 12]. The study shows that both compressions had significant advantages and disadvantages in the field of data compression. Thus, the hybrid image compression techniques have been introduced by manipulating the benefits of these two techniques to get the maximum impact [13]. Therefore, the region of interest (ROI) is present to resolve this issue. The medical image is fraction into the small segment, and each segment categorised into ROI or non-ROI segment. Next, the hybrid technique is used to achieve better results by in hybrid the lossy and lossless method of compression to the appropriate on the segment category [9, 14]. The ROI section is compressed by techniques of lossless compression while the non-ROI compresses with lossy compression.

There are three parts of the image in the medical image, which is ROI (region of interest), non-ROI, and background. ROI is the most critical part of the image found in tiny regions of the image. Also included is Non-ROI so that the user can identify the most critical part of the entire image quickly. Another part of the image's content is known as the background and the image's most ignored part. In the medical field, these critical parts had to compress without any loss compared to other parts of the image with high-quality compression [15]. Figure 2 (a) demonstrates an example MRI picture. Figure 2 (b) and Figure 2 (c) show the ROI region and non-ROI region of the sample image, respectively.

(a) (b) (c)

Figure 2. (a) Original MRI scan, (b) ROI part of the image,
(c) Non-ROI part of the image [16]

Many different parameters can be used to describe and compare the performance of a compression technique such as mean square error (MSE), peak signal to noise ratio (PSNR), compression ratio (CR), and time consumption to compress the image [11,17,18]. The compression ratio indicates the efficiency of the compression algorithm. The higher the percentage of compression ratio, the smaller the size of the image is compressed. The following equation can calculate the compression ratio:

$$Compression\ ratio = \frac{Original\ Image\ Size}{Compress\ Image\ Size} \quad (1)$$

Besides, the execution time is also crucial in determining the successfulness of a medical image compression algorithm. The MSE and PSNR is the way to measure the quality of the appropriate image. The MSE defined as the square of the pixel value differences between the two images corresponding pixels. The MSE of N * M size image is given by:

$$MSE = \sum M, N \, [I_1(m,n) - I_2(m,n)]^2 (M * N) \quad (2)$$

I − the input images
M, m − number of rows in the input images
N, n − number of columns in the input images
While the PSNR is the parameter between the compressed image and the original image to calculate the maximum error. To measure the PSNR, MSE is first measured. MSE is the cumulative difference between the original image and the compressed image. A low MSE value improves the quality of the image and eliminates the error. The higher PSNR value implies a higher image quality [9]. The following is used for calculating the value of PSNR:

$$PSNR = 10 \, log_{10} \left(\frac{R^2}{MSE}\right) \quad (3)$$

R is the maximum fluctuation in the input image data type

3. VARIOUS ROI-BASED HYBRID MEDICAL IMAGE COMPRESSION ALGORITHMS

Recently we have identified the technique of compressing the medical image thoroughly. In this segment, we will discuss the analysis of the research associated with the compression of ROI-based hybrid medical image. Hybrid refers to a combination of two or more techniques that combine the excellent properties of each image compression group to increase the image quality [19]. This technique incorporates lossy and lossless compression technique to achieve a compression ratio of high quality while retaining the norm of the reconstructed image.

B. Venkateswara et discovered the combination of both lossless and lossless methods as their compression algorithm. The principal aim of these medical image compression strategies is to store large quantities of medical images [20]. In this research, the MRI medical image is considered. The algorithm begins with the image being segmented to ROI and non-ROI. The MRI images are divided into free-hand tools using MATLAB. The ROI segment is compressed using HAAR wavelet (HWT) and the Daubechies (Db) lossless compression techniques. While the non-ROI segment is compressed using lossy compression technique, in this case, the researcher using embedded zerotree wavelet (EZW) algorithm as the compression algorithm. These studies will be simulated with the Intel Pentium I3 processor and MATLAB software. The output image results are evaluated via MSE and PSNR. The result shows that this technique offered a better result which the best MSE and the PSNR are 0.8546 and 97.6266.

C. Peter Devadoss, as well as B. Sankaragomathi, use block Burrow-Wheeler transform-move to front Transform (BWT-MTF) with Huffman encoding and hybrid fractal encoding to efficiently transmit medical images. [21]. This study was conducted using an open-source MedPix database using the ultrasound, MRI, CT scan, and XRay image. This algorithm operates with the lossless compression technique for the ROI section, a combination of BWT-MTF and Huffman encoding. The author uses the lossy hybrid Fractal Encoding for the non-ROI section. The proposed compression scheme will eliminate this obstacle by using region of interest-based compression, resulting in lossless compression of the required area where the most critical details and loss compression are stored in the remaining region. The performance of the compression system assessed with PSNR, CR, savings in space and time consumption. The empirical outcome indicates that the proposed method offers better PSNR outcomes than conventional methods. Most outstanding results obtained with an average value of 36.166 dB.for ultrasound images and magnetic resonance imaging of 34.097 dB. The optimum CR found with a maximum CR of 9.621.

David Yee et al. compress the image using the better portable graphics (BPG) format, which based on high-efficiency video encoding (HEVC). This technique also uses brain scanning images from DICOM format of MRI to combine lossy and lossless compression of medical image [16]. First, the medical image divides into two parts: ROI and non-ROI using the algorithm for flood filling. Then the lossless BPG compression algorithm applied to the ROI areas and the loss BPG applied to regions other than the ROI. Ultimately, the resulting reconstructed images are combined to create a compressed image complete as the evaluation matrix for the algorithm, David Yee et al. applied root mean square error (RMSE). The compression method's performance suggested showing an improvement in the compression rate between 10% and 25% compared to standard image compression techniques used in the medical industry.

P. Eben Sophia and J. Anitha have to propose the compression technique of MRI images with utilised ROI based compression, which increases the compression ratio compared to the block-based method [22]. They are locating ROI with split and merge technique and ROI mask generation. The ROI region is compressed using a combination of lossless compression algorithm; run-length coding, Huffman coding, and arithmetic coding. The non-ROI are using lossy compression, which is Vector Quantization. The effectiveness of this algorithm is measured using CR, PNSR, MSE and time performance. The reconstruct medical image shows good compression ratio of about 4.2 with PNSR 20.76.

Sid Ahmed Elhannachi, Nacra Benamrane, and Taleb-Ahmed Abdelmalik identified an efficient embedded image encoder based on reversible discrete cosine transformation (RDCT) designed for lossless ROI coding at a very high compression ratio [23]. The ROI assortment is made manually by the researcher using the various kind of medical images including MRI, X-rays, CT Scan and ultrasound. Then, the non-ROI region is compressed using the set partitioning in hierarchical tree (SPIHT) technique while a reversible DCT with the lossless embedded method is used to compress the ROI region. Finally, an entropy coding based on adaptive arithmetic coder applied to the final bitstream. This research is evaluate using PNSR and correlation coefficient (CoC) as metrics for the assessment of total quality and bit rate (bit per pixel, bpp) for the evaluation of lossless compression. The compression results show that the performances of the proposed new encoder are much higher than those of different methods of compression of the latest generation of still images.

Manpreet Kaur and Vikas Wasson have introduced ROI-based hybrid medical image compression [24]. The work starts with medical images pre-processing, such as X-Ray and ultrasound, to eliminate the noise of an image. Thus segmentation is applied to divide the image into two uniform parts, namely ROI and non-ROI. Compression finally performed. The author managed to use two compression methods in the research; non-ROI loss fractal compression during context tree weighting lossless for the ROI part. These results compare with the scalable compression techniques used by IWT and RBC using the compression ratio, MSE, and PSNR. For this technique, the average compression ratio is 89.6005.

4. DISCUSSION

Medical image is a crucial asset for the medical practitioner. The transfer of image data to printed or optical media has become insufficient for current needs. Furthermore, the widespread dissemination and accessibility of image data make sense for an efficient medical ecosystem and exchange between health organisations. While archiving and accessing medical image data is a rather tricky technical problem, such as the volume of image, time constraint and privacy regulations to generate public confidence in centralised storage of confidential data, healthcare organisations increasingly depend on their hybrid cloud environments. This has generated continuous requests for secure telemedicine implementations that will provide confidentiality, authenticity, and integrity for the medical data transmitted in the health sector. It is crucial to ensure that all hospital information system transactions and communications are carried out accurately and without loss of data.

The compression of images is a compression method of data, encoding a unique image with fewer bits. The goal of image compression is to reduce the image size from the original image, and the compressed image must be similar to the original image. Here we can develop an idea of the different types of redundancies that need to manage while compressing an image, following different compression techniques and their approach to compressing an image. Each method has the goal of achieving a clear objective. In the success of any medical image compression technique, selecting the type of compression plays an essential role.

In general practice of image diagnostics, lossy compression schemes rarely used in the medical image because of the possible loss of useful clinical information and operations such as improvement can lead to further impairments in lossy compression. Therefore, there is a need for efficient schemes without loss of data for medical imaging. Because of that, most of the previous study research apply lossless compression technique to compress the medical data. It is because the lossless algorithm will compress the image without losing any information. However, lossless compression has limited performance in terms of compression ratio, while the size of the image kept on growth directly proportional to the time and technology development [25].

Handling a vast amount of medical image is very challenging. Hence the studies show that the practical way to get the maximum compression ratio is by segmentized the image into ROI and non-ROI area [26]. It is imperative that the effectiveness of resolution, as well as perceptual quality, be restored while performing compression on the medical images. The specific loss of significant information accompanies compression if the data is massive and channel capacity is highly inadequate for transmission. The optimum implementation time by splitting the image into a smaller size will reduce the power and time required to execute the image in the hospital information system [25]. Many researchers try to generate hybrid compression algorithm by combining various compression techniques to enhance the compression algorithm.

Figure 3 shows the general block diagram of ROI-based hybrid medical image compression. The preprocessing stage of the ROI-based hybrid medical image compression process is the segmentation of the original image. The image is sub-divided into ROI and non-ROI area. Generally, the ROI segment implements the lossless algorithm and non-ROI compressed using the lossy algorithm. The selection of techniques and algorithms for compress image depends on the objective of the research conducted by the appropriate researcher [22]. Then the resulting compression image for both ROI and non-ROI is reconstructed. Finally, the ideal compression image that meets the main objectives of the study being carried out.

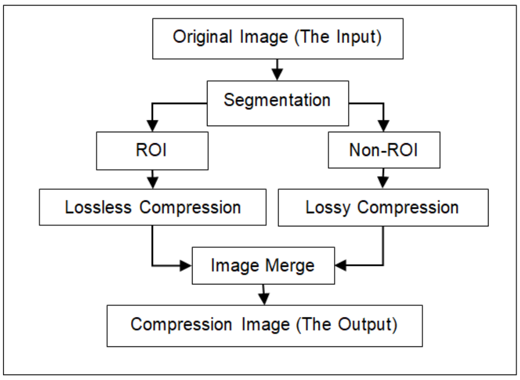

Figure 3. The general block diagram Of ROI-based hybrid medical image compression

Table 1 shows the comparison of the techniques that have been using by the previous studies. There are various segmentation techniques to split the ROI and non-ROI of the medical image.

Such as MATLAB manually freehand tools, morphological segmentation, flood fill algorithm, split and merge, and ROI masks. Most researchers choose to use MATLAB manually freehand tools techniques for segmentation for the medical image because the main objective is to focus on the compression algorithm rather than segmentation techniques. In column 3 and column 4, it shows that all researcher use the lossless compression algorithm to compress the ROI segment, and the non-ROI segment is compressed using the lossy compression algorithm.

There are many forms to evaluate the success of the compression algorithm, such as MSE, PSNR, CR, Bit Rate, and time performance [27]. We found that the selection of the evaluation technique must be in line with the objective of the studies to get the optimum result of the survey is essential [28]. Table 2 shows the evaluation metrics used by the previous studies.

Table 1. Comparison of technique used by previous studies

Ref	Segmentation	ROI (lossless compression)	Non-ROI (lossy compression)
[20]	MATLAB manually freehand tool	HAAR wavelet (HWT) and the Daubechies (Db) lossless compression Techniques	Embedded Zerotree Wavelet
[21]	Morphological segmentation	1. Burrow-Wheeler Transform-Move to front Transform 2. Huffman Coding	Quadratree Decomposition
[16]	Flood Fill Algorithm	Lossless Better Portable Graphics	Lossy Better Portable Graphics
[22]	1. Split and Merge 2. ROI Mask	1. Run Length Coding 2. Huffman Coding 3. Arithmetic Coding	Vector Quantization
[23]	MATLAB manually freehand tool	Reversible Discrete Cosine Transformation	Set Partitioning In Hierarchical Tree
[24]	MATLAB manually freehand tool	Context Tree Weighting	Fractal Lossy Compression

Table 2. Summarised of the evaluation metrics by previous studies

References	Evaluation Metrics					
	CR	MSE	PNSR	Space	Time	CoC
[20]		√	√			
[21]	√		√	√	√	
[16]	√	√	√			
[22]	√	√	√		√	
[23]			√			√
[24]	√	√	√			

The CR is used to evaluate the ratio of compression that the proposed technique. The higher the compression ratio, the more effective the compression algorithm will be in the image. MSE and PSNR are used to evaluate the quality of the image. MSE is referring to the noise in the image, while the PSNR indicates the quality of compression image compared to the original image. The value of MSE and PSNR is inversely proportional. The outstanding compression technique will show low of MSE and high of PSNR. Most researchers prefer to use PSNR as the primary evaluation techniques and support by the compression ratio and MSE [17].

Figure 4 and Figure 5 shows the trend result of the compression image using CR and PSNR for the particular ROI-based hybrid medical image compression by previous studies. The graph shows that the researcher [20, 22, 24] are using both CR and PSNR as the evaluation matrix to measure the algorithm. The best result is by the research [24], which generate the highest CR and PSNR compress image. This research utilised fractal lossy compression for non-ROI and context tree weighting lossless for the ROI segment. The researcher [16] not considered the quality of the output image; therefore, he did not consider the PSNR value. The researcher [21, 23] aim for the quality of the output image. Thus, the compression ratio is not measured by them. Here we can see that the selection of evaluation methods for compression images depending on the objectives and goals of the study.

The researcher realises the compression algorithm by executing and evaluate using MATLAB. MATLAB widely used by the image processing and computer vision community [29]. MATLAB and the Image Processing Toolbox provides functions and interactive tools for improved and analyzing digital images and developing image processing algorithms. The latest version is MATLAB R2019b [30].

Medical science evolution is a gap between medical science and available technologies to support it with a purpose. It is imperative to restore the efficiency of resolution and quality of perception when performing compression in medical images. The massive data with minimal channel capacity for transmission purposes leads to a loss of vital information. Therefore, compression of the medical image performs as an essential research topic about the degree of compression and maintenance of the relevant information [31].

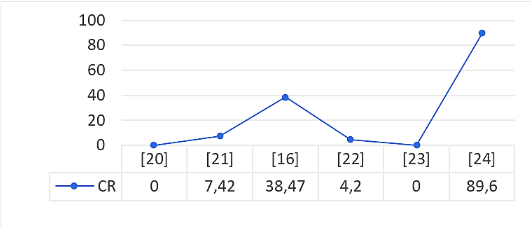

Figure 4. The CR of the compression image trends by the previous studies

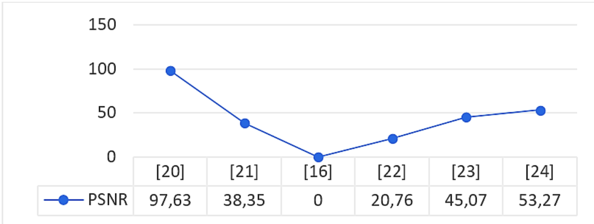

Figure 5. The PSNR of the compression image trends by the previous studies

5. CONCLUSION

The medical image is an essential digital resource in the hospital information system. There are different types of modalities for medical images, such as CT, X-ray, MRI, PET, and SPEC. Generally known that the medical image consumes a high volume of size. The medical practitioner demand to share the image in order to diagnose and analyse the disease with an accurate, secure and fast transition. Therefore, the most challenging issue with sharing medical image is on data storage and network performance. This matter, which motivated the compression of the medical image to ensure accuracy, security and fast medical image sharing.

This paper discusses the review on a region of interest-based hybrid medical image compression algorithms. Compression is useful as a result of it helps to cut back resource consumption such as disk space and also the bandwidth of network transmission. In the region of interest-based hybrid medical image compression algorithms, ROI, and non-ROI each are essential to reconstruct the ideal compression image. This paper summarises the comparison of the algorithm and performance. The reconstruct medical image using this technique helps to reduce the size of the image while not degrading the quality of the medical data.

This review paper offers a transparent idea concerning essential compression algorithm. The choice of the analysis technique is additionally essential to confirm that the algorithm achieves optimum performance. The project objective engages the practical demand of compression of medical image procedures and therefore, the evaluation techniques. For this purpose, we tend to should make sure that the evaluation techniques got to be in line with the target of the studies. We tend to conclude that the three factors that influence the choice of compression algorithm are: image quality, compression ratio, and compression speed.

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