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A Review Report on ROI Based Encoding An Effective Technique of Compression for Medical Imaging

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Abstract— Medical image compression plays a key role in modern medical imaging, as hospitals move towards filmless imaging and based on completely digital techniques. Even for a single patient, resolution factor and number of images per diagnosis makes the size of the images to be very large in size. So there is an immense need for efficient compression techniques for these medical images. However, this field poses a great challenge of having compression algorithms such that it reduces the loss of fidelity as much as possible without causing diagnostic errors & yet have high compression rates for reduced storage and transmission time. Fortunately, in some areas of medicine, it may be sufficient to maintain high image quality only in the region of interest (ROI), i.e., in diagnostically important regions. e.g. tumor region of the brain MRI. Thus, the regions of interest can be coded with high spatial resolution than the background while transmitting the images. This paper reviews what is ROI coding, its importance, significance over other compression techniques and ROI based system, focusing on Adaptive SPIHT technique.

Index Terms— compression; region of interest; SPIHT

1 Introduction

IT has become a great challenge to store and share image data effectively in modern communicative and network computing era. Every moment people from all over the world are sharing, transmitting and storing millions of images. Although, with advancement in technology, there have been significant development in storage device capacity field, but in that proportion production of digital images is being increased too. The data or image to be transmitted and stored requires unnecessary space; as a result, it is desirable to represent the information with considerably fewer bits, this is nothing but compression. At the same time, the data/image must be able to reconstruct very close to original data. This can be achieved via an effective and efficient compression and decompression algorithm [1].

This paper investigates mainly on the various types of medical image compression techniques based on Region of Interest that exists, and putting it all together for a literature survey. Scope of this study focuses on the different available ROI based techniques with their performance results. Several ROI-based techniques are reported and compared, for example the general scaling, the MAXSHIFT, the EZW-based, ROI-VQ methods, ROI-based and DICOM image compression for telemedicine.

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2 Image Compression And Medical Imaging

2.1 Importance of Compression in Medical Field

Medical diagnostic data produced by hospitals has increased exponentially. Telemedicine has been proved very important in medical diagnosis, and patient care for the treatment of diseases and surgical planning. But due to resolution factor a very large amount of image data is produced in Medical imaging in the form of Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Ultrasound Images, which can be stored in picture archiving and communication system (PACS) or hospital information system. An average 5 GB to 15 GB of data is produced by a hospital having such systems [2]. So it is really difficult for hospitals to manage the storage and process the same. Even in some cases diagnostic and therapeutic strategies require images among several users have to be shared. Image compression is used to avoid this problem. Due to limitations of transmission medium in Information and Communication Technology (ICT), image compression is significant for telemedicine scenario especially for rural area. Moreover compressed image can be accessed and sent over telemedicine network using personal digital

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assistance (PDA) like mobile.

2.2 Concept of Region of Interest

All regions of medical images and certain real time images do not have equal importance. Special consideration is given only to a few item(s) of the image [3]. For instance the section of image that contains the tumor is examined for instead scanning the whole image in medical images such as the brain MRI. Region of interests (ROI) are the regions that are considered to be important in any given image [4]. If loss of quality is affordable, then many compression schemes produce high compression rates for general images. However, medicine cannot afford any deficiency in diagnostically important regions (ROI). Thus it is necessary to have an approach that brings a high compression rate maintaining good quality of the ROI. To this twofold problem, a very suitable solution is the hybrid-coding scheme. Here, the general theme is to preserve quality in diagnostically critical regions, while allowing lossy encoding for the other regions. Another example may be taken of a photographic image, where people often wish to look into the faces of the people. The regions of an image that contain faces can be coded as ROI's by using automated face detection algorithm and eventually stored with more precision than the non-face sub-images.

3 Principle Behind Compression

Image compression is essentially a redundancy reduction technique. It is the process of reducing the amount of data required to represent a given quantity of information. For the transmission of same amount of information, different amount of data might be used. If the same information can be represented using different amounts of data, and, the representations that require more data than actual information, is referred as data redundancy. A common characteristic of most images is that the neighboring pixels are correlated and therefore contain redundant information. The foremost task then is to find less correlated representation of the image.

Two fundamental components of compression are redundancy and irrelevancy reduction [6].

1. Redundancies reduction aims at removing duplication from the signal source (image/video).
2. Irrelevancy reduction omits parts of the signal that will not be noticed by the signal receiver, namely the Human Visual System.

3.1 Various types of Redundancy

In an image, which consists of a sequence of images, there are three types of redundancies in order to compress file size. Data compression is achieved when one or more of these redundancies are reduced or eliminated.

1. Coding redundancy: which is present when less than optimal (i.e. the smallest length) code words are used i.e. Fewer bits to represent frequently occurring symbols.
2. Interpixel redundancy: When neighboring pixels have almost same value. The term interpixel redundancy encompasses following redundancies-
   a) Spatial Redundancy or correlation between neighboring pixel values.
   b) Spectral or Geometric Redundancy or correlation between different color planes or spectral bands.
   c) Temporal/ Interframe Redundancy or correlation between adjacent frames in a sequence of images (in video applications).
3. Psycho visual redundancy: which is due to data that is ignored by the human visual system (i.e. visually nonessential information). Human visual system cannot simultaneously distinguish all colours.

3.2 Classification of Compression Techniques

In modern days of medical advancement there exist many compression techniques. Compression methods are classified into lossless and lossy methods. In lossless compression schemes, the reconstructed image, after compression, is numerically identical to the original image. However lossless compression can only achieve a modest amount of compression.An image reconstructed following lossy compression contains degradation relative to the original. Often this is because the compression scheme completely discards redundant information. However, lossy schemes are capable of achieving much higher compression [6]. In the medical imaging scenario, the later scheme is not generally used. This is due to possibility of influence diagnosis.

4 Literature Review

To study and analyze more about the ROI based image compression techniques, some literature survey has done and discussed in this section. Recently, utilization of wavelets and techniques like SPIHT and AT-SPIHT for encoding of ROI has received a great deal of attention among the researchers. A brief review of some of the recent research works is presented here.

Nan Zhang [7] have presented an efficient two-description image coding method. With the help of quincunx sub sampling the two side descriptions of an image have been produced. An interpolation process with sample correlation has been used to perform the decoding from any side of the description. A practical MD image encoder could be constructed by rooting the adaptive directional lifting (ADL) transform into the JPEG 2000. They have proved that better coding performance could be achieved by their image MDC scheme by experimental results.

K. Veeraswamy and S. SrinivasKumar [5] have proposed a method to improve the performance of wavelet-based image compression under conditions of entropy. The entire sub-bands of wavelet decomposed image have been quantized, based on the sub-band energy. Quantized and rounded

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coefficients have re-arranged the in the LL sub band, in a predestined manner.), Using a prediction algorithm, they have lowered the entropy i.e. bits/pixel.

Singara Singh et al. [8] have presented a method without altering the syntax of compressed stream of JPEG2000, their method could be employed with ease in image compression. Their method compress the graphics images, after distinguishing the real color images from the graphics images by using a wavelet transform extension under JPEG2000 standard.

E. Logashanmugam and R. Ramachandran [9] have achieved wavelet-based compression of natural image using a visually lossy contrast -based quantization algorithm. They have concentrated on the application of new sub-band coding algorithm of wavelet transform on image compression. By comparing their method with the existing compression technique performance of their method has been proved to be good.

D. Vijendra Babu and N.R. Aflame [10] have utilized Partial EZW Algorithm in the Enhanced Image Compression Method. Concept of their approach was progressive Shapiro's Embedded Zero tree Wavelet (EZW) algorithm. By adding integer wavelet transformation and ROI coding, the Partial EZW has been made better than EZW and SPIHT Algorithm and results have proved this.

Rafeef Abugharbieh [11] presents a novel 3-D scalable compression method for medical images with optimized volume of interest (VOI) coding.

5 Different Scheme For ROI Coding

5.1 JPEG2000 Scaling-Based ROI Coding

In the scaling-based ROI coding [12] adopted in JPEG2000, an entire volumetric image is transformed, and the coefficients associated with the ROI (within and around the ROI) are scaled up by a certain number of bit-shifts. After that, encoding of bit-planes of coefficients is done plane by plane basis. Now the difference between ROI and non ROI image quality is computed and can be further controlled by specifying the scaling value. Although JPEG2000 specifies scaling based ROI coding only for rectangular or elliptic areas of a two-dimensional image, the concept of scaling-based ROI coding can be easily extended to arbitrary -shape ROI coding for volumetric imagery [12]. In this scheme, shape information has to be transmitted to the decoder as shown in fig. unlike the max -shift ROI coding. Therefore, in this case, by discarding all of the background, object can be exactly decoded .But unfortunately, near the object there is some unwanted effect looking at the background. This is because of additional coefficients at an early stage of progressive coding.

5.2 JPEG2000 MAX-SHIFT ROI Coding

In this method, the transmitting shape information is not transmitted to decoder as shown in fig.; in fact scaling value is computed in such a way that arbitrarily shaped ROIs are generated. It means that the decoder does not have to perform ROI mask generation. Fig.1, shows flowchart to perform Maxshift ROI coding.

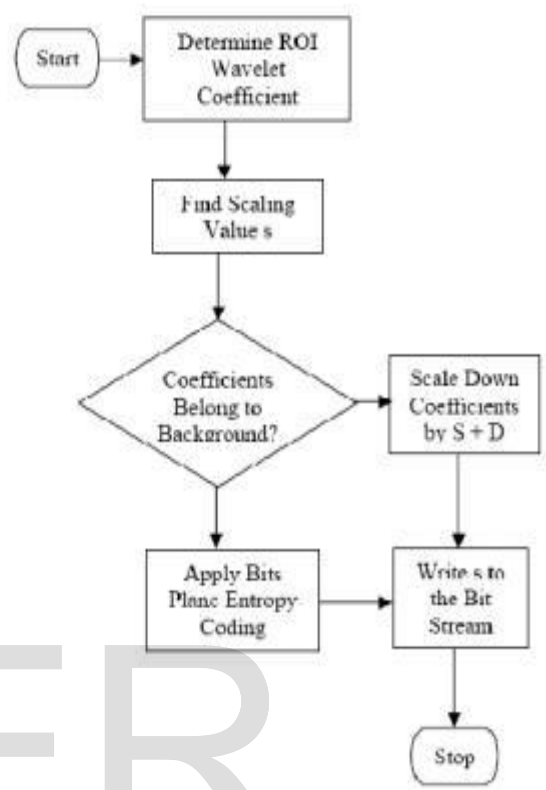

Fig. 1. Flowchart for Maxshift ROI coding

5.3 Adaptive SPIHT: A Hybrid Approach

The Adaptive SPIHT compression scheme provides selective compression on medical images by compressing the ROI using JPEG2000 and the rest of the image by standard SPIHT, making it energy efficient. SPIHT displays exceptional characteristics over several properties all at once including [15]:

1. Good image quality with a high PSNR (Peak Signal to Noise Ratio)
2. Fast coding and decoding
3. A fully progressive bit-stream
4. Can be used for lossless compression
5. May be combined with error protection
6. Ability to code for exact bit rate or PSNR

Adaptive SPIHT involves following two phases:

1. Separation of ROI from image

Fig.2. shows a CT or MRI image contains mainly three parts, ROI (the diagnostically important part), Non-ROI image part, and the background (part other than image contents) [2].

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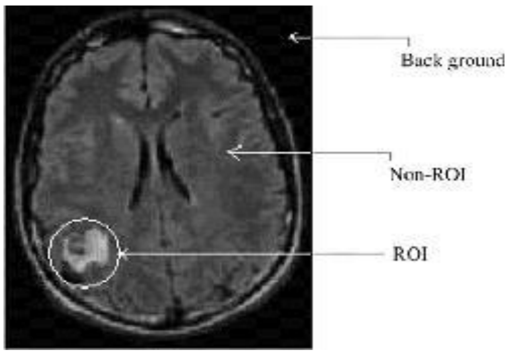

Fig. 2. Different parts of the medical image.

Now the ROI is selected by expert radiologists as per requirement. Next step is to generate ROI- mask in such a way that the foreground is totally included and the pixel values in the background are made zero. This mask will depend upon selected region. The background regions though they appear to be black in colour, they do not have zero grey level values [2].

The background can be made zero using

if $\quad simg[i, j] \leq z$, then

$$simg[i, j] = 0 \qquad (1)$$

Where, z is the threshold value of background and simg is the sample image.

If value '1' is chosen for the foreground and a value '0' for the background, then the generated mask is logically AND-ed with the image. This will help to separate-out ROI part (IMG_ROI) and Non-ROI image part as shown in equation 2.

$$ROI\_mask \&\& simg = IMG\_ROI. \qquad (2)$$

Where ROI_mask is the mask generated and IMG_ROI is the ROI part to be separated.

2. ROI and Non-ROI processing

As per the requirement, the two separated parts can be processed separately i.e., ROI part will be processed by lossless technique such as Huffman, Arithmetic, RLE, LZW etc. while with accepted lossy compression methods such as Transformation coding (FT/DCT/Wavelets), Vector quantization, Fractal coding compression technique Non-ROI will be processed.

Different techniques can be used for Non-ROI part to compress it. One question may arise that if the ROI is the only important part, then why to encode and transmit Non-ROI part? It is important to encode this part, because it gives the position of ROI in the image. Also this image is carrying the patient's other information in the text format, which is needed exclusively at the time of decoding the image. Also when ROI based coding is used, it is not faithful to use conventional objective quality analysis measures [2].

Following are the two steps to be applied on the image for Adaptive SPIHT coding.

a) Energy efficient SPIHT on non-ROI

To achieve the desired energy efficient medical image compression, the region that must be exploited is Non–ROI region. SPIHT is a very effective technique in this concern, which will provide a fully embedded bit stream with the maximum value coefficients at first and the minimum value coefficients at the end of the stream, making this scheme applicable on the non- ROI image. Fig.3 shows, Firstly DWT (Discrete Wavelet Transform) is applied on the sample image. Out of four subbands, all the high frequency bands can be completely eliminated and only the low frequency components of the transform level be sent further, because this part of the medical image is of no diagnostic importance. Benefit of this process is the reduced compression time, reconstruction time and peak signal to noise ratio, along with an enhanced compression ratio.

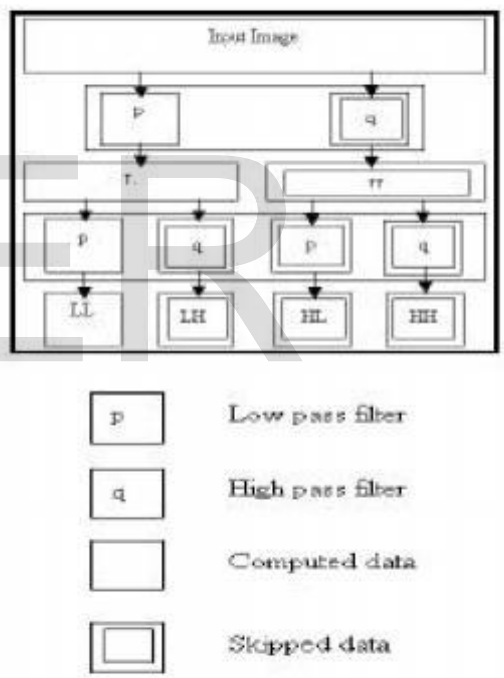

Fig. 3. Application of DWT on input image

b) JPEG2000 on the ROI

The Region of interest contains most important information. In outmost importance. The JPEG algorithm [13], [14] ensures quality. But an energy efficient compression cannot be afforded as this will lead to loss of detailing information. As the ROI selected is very small in size, in that case, instead of partitioning the bits into blocks, as for Embedded block code for optimized truncation (EBCOT), the bits are Huffman [16] or Run length coded directly, after the discrete wavelet transform has been applied. Decrease in bit rate on account of this for the sake of quality is affordable which is compromised by blocking artifacts whenever we go for splitting the image

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into blocks for any computation. As these are extremely simple methods of encoding, the encoding and decoding computational complexities are drastically reduced.

6 Performance Measures and Comparative Analysis

Some of the most desirable properties of any compression method for 3D medical images include:

1. High lossless compression ratios, along with high PSNR.
2. High correlation between original and reconstructed image.
3. Resolution scalability, which refers to the ability to decode the compressed image data at various resolutions.

6.1 Comparison of PSNR on the ROI and Non-ROI

This is used to measure objective performance of reconstructed image.

PSNR measured in decibels (dB) is given by:

$$PSNR=20*\log10\ [(255/\mathrm{sqrt}\ (MSE)] \qquad (3)$$

where the value 255 is the maximum possible value that can be attained by the image signal. Mean square error (MSE) is defined as

$$MSE = 1/MN \sum_{i=1}^{M}\sum_{j=1}^{N}(A_{i,j} - B_{i,j})^2 \qquad (4)$$

.

6.2 Comparison of correlation on the ROI and Non-ROI

The Correlation between the reconstructed image and the original image is measured by the formula:

$$r_{xy} = \frac{\sum x_i y_i - n x' y'}{(n-1)\, s_x s_y} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{[n\sum x_i^2 - (\sum x_i)^2]^{1/2}[n\sum y_i^2 - (\sum y_i)^2]^{1/2}} \qquad (5)$$

Where x and y are the images, x′ and y′ are the mean of the images, s_x and s_y are the standard deviations of x and y. The coefficient r_{xy} is scaled in the range -1 to 1[18].

Fig. 4 shows that an adaptive SPIHT technique leads to strong correlation between original and reconstructed image.

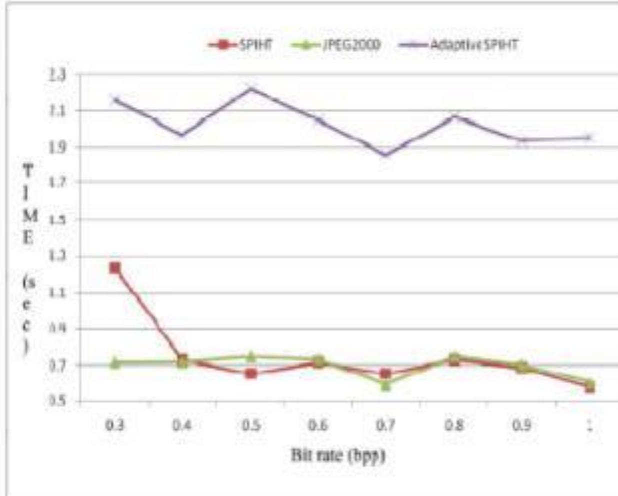

Fig. 4. Bit rate vs. Time for different ROI coding schemes

6.3 Compression Ratio (CR)

It is a measure of the reduction of detail coefficient of data.

$$CR = (\text{Discarded Data}) / (\text{Original Data}) \qquad (6)$$

In the process of image compression, it is important to know how much important coefficient one can discard from input data in order to preserve critical information of the original data.

6.4 Variance

Variance is another tool to calculate the performance of image compression algorithm. Variance describes how far certain value deviates from the mean. It's the measure of variability from an average. In signal processing, the variances, σ_k^2 (k=1, 2…N), are represented by the eigen values of the transformed coefficient [9]. N is the size of N input data block. The lower the variance, higher will be the energy compaction property. Higher the energy compaction property, the better is the compression algorithm.

7 Conclusion

From the report, it is clear that some extent of loss is necessary and helpful in the longer term for medical images. Compression schemes produce high compression rates if loss of quality is acceptable. However, in most cases physicians may not afford any deficiency in diagnostically high compression rate with good quality in the ROI is thus necessary. Considering all these, in this paper, various medical image compression techniques such as JPEG2000 scaling based ROI coding, JPEG2000 MAXSHIFT ROI coding, Shape

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Adaptive SPIHT ROI, are reviewed. Emphasis has been made on the hybrid scheme adaptive SPIHT, which is appropriate for efficient and accurate compression of 3D medical images. The model uses lossless compression in the region of interest, and very high-rate, lossy compression in the other. These techniques propose a unique characteristic which is used to compress medical image but there are some drawbacks present in these schemes. Therefore the research is going on to overcome these drawbacks and also to enhance the reconstructed quality of compressed image with high compression rate for medical image.

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