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ROI Based Medical Image Compression for Telemedicine Using IWT & SPIHT

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Abstract: ***In Medical imaging, telemedicine has been proved as a boon for patients located in rural areas. Its objective is to enhance health care services together with the integration of telecommunication technology. But due to high demanding resolution factor the amount of data associated with medical images such as X-ray, CT-scan, MRI is large enough and hence occupies considerable storage capacity which in turn requires a large bandwidth to be transmitted over the network. To solve this problem image compression is a well known technique from many years, which is presented in this paper via a Region of Interest (ROI) based concept. Here, ROI part is compressed via Integer wavelet transform in a lossless manner and SPIHT is used for efficient lossy compression for rest of the regions. Implementation of algorithm is done on MATLAB and parameters such as CR & PSNR are used for evaluating the performance of the system. The results shows that ROI based compression have better performance in terms of image quality, PSNR and bandwidth requirement with preserving the critical information as compare to compression result on the whole image.***

Keywords: compression ratio; image compression, integer wavelet transform, region of interest, SPIHT

I. INTRODUCTION

World health organization has defined Telemedicine as; “The delivery of healthcare services, where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for continuing education of healthcare providers, all in the interest of advancing the health of individuals and their communities” [1]. To get a successful real time application of this definition along with an efficient archiving and faithful transmission, in telemedicine application, Medical Image Compression has been proved as a very important mean by many researchers. The exploitation of redundancies present in an image, so that it requires lesser number of bits to represent certain information is termed as Compression. For medical image this degree of compression should be such that it decreases file size substantially, but produces a degree of image distortion which is not clinically significant. For telemedicine- teleradiology application, Compression is not just about the storage costs, it is also about imaging apparatus utilization, convenience/comfort of the patient, required bandwidth and hence the transmission time over the network. An intelligent Compression technique can reduce file size and transmission time, i.e. improving overall care.

In general two techniques of image compression can be used: Lossy and Lossless. Although Lossy compression schemes results in higher compression ratio, yet they are not acceptable to be used for both clinical and legal reasons. However Lossless compression algorithms such as JPEG2000 and wavelet-based compression can produce images statistically identical diagnostic results compared with the original images without any loss [2, 3], therefore lossless image compression is important and more suitable for medical image because any information loss or error caused by the image compression process could affect the clinical diagnostic process [4]. But, as previously mentioned, high compression ratio is strongly recommended. So, the aim of

this paper is to present a novel approach which provide a good CR but with maintaining all essential information i.e. high PSNR.

II. Medical Image Compression

A medical image for Compression can be a single image or sequence of images. The diagnostic data produced by hospitals has geometrically increased. Table I shows typical sizes of some medical images which indicates that a compression technique is needed that results with greater data reductions and hence transmission speed. In medical cases, a lossy compression method that preserves the diagnostic information is necessary. Visually indistinguishable resultant images at high quality can be obtained using lossy compression techniques, for compression rates much greater than those obtained by lossless compression techniques. Recently ROI based coding has also been proved as a good approach for medical image compression especially in telemedicine applications. Region of interests (ROI) are those regions which can be given more importance in any given image.

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. Since all regions of medical images do not have equal importance. Special consideration is given only to a few item(s) of the image [5]. Such as for brain MRI, instead of scanning the whole image the section of image that contains the tumor is examined. Which results in high reconstruction quality over user specified spatial regions in a limited time. Lossless compression, Progressive transmission and region of interest (ROI) are necessary requirements for a medical image compression scheme.

TABLE I
Typical Matrix Sizes for Different Types of Digital Diagnostic Images

Digital Imaging Modality	Matrix Size and Typical Bit Depth
Nuclear Medicine	128 x 128 x 12
Magnetic Resonance Imaging	256 x 256 x 12
Computed Tomography	512 x 512 x 12
Digital Subtraction Angiography	1024 x 1024 x 10
Computed Radiography	2048 x 2048 x 12
Digital Radiography	2048 x 2048 x 12
Digital Mammography	4096 x 4096 x 12

III. Review of Related Research

To study and analyze more about the Medical image compression techniques, in this section discussion has been done with the help of many researchers work. To avoid risk of diagnostically lossed data and also because of legal issues lossless compression scheme is most popular so focus has been made over this approach.

Rupinder Kaur et al. [6] has performed comparative analysis of different compression techniques such as Wavelet Transform, SPIHT, JPEG 2000 and RLE i.e. Run Length Coding using parameter of compression ratio along with image quality. To show the result different medical images have been used. In the result it has been found that SPIHT i.e. Set Partitioning in Hierarchical Tress provides higher CR for images of MRI, Ultrasound, and CT scan. Also they observe that as compare to JPEG method, wavelet transform result in higher CR and good PSNR value for MRI image has higher compression ratio and has good PSNR value for iris image. For CT scan image JPEG compression method outperforms the PSNR and degree of compression than wavelet compression method [6]. A wavelet based coding system featuring object based 3D encoding with 2D decoding capabilities was proposed in [8]. The implementation of the DWT via lifting steps scheme in the non linear integer version and the embedding of the encoded information allow reconstructing each object of each image at a progressive up lossless quality.

As mentioned earlier, lossless methods are preferred in the medical community. Among them, JPEG and Wavelet are most widely used. These two compression methods actually gained widespread acceptance as lossy methods. However, each can be made lossless which is the preferred style in medical imaging. JPEG 2000 is a wavelet based coding scheme. Research on JPEG coding [9] has proved that JPEG-LS is simple and easy to implement. It consumes less memory and is faster than JPEG 2000 though JPEG 2000 supports progressive transmission. A scheme based on the three-dimensional (3-D) discrete cosine transform (DCT) has been proposed for volumetric data coding [10]. But Medical applications immensely require a technique which is coupled with both quality as well as resolution scalability, the above techniques are nearly fail to provide such facility.

Based on the concept of self similarity the fractal compression technique relies on the fact that in certain images, parts of the image resemble other parts of the same image. Many algorithms have been proposed to compress 3D meshes efficiently since early 1990s. Fractal image compression methods exploit the self similarity among image elements among various scales to implement compression through formation of a partitioned iterated function system. some authors have addressed the task of object based coding for medical images [11]-[13], In object based coding different objects that are present in a scene are assigned priorities in the encoding process, based on their importance in the framework of the considered application [14]. A prior knowledge about the image contents makes such approaches particularly suitable for medical images.

In 1994, Chen et al. [7] made use of regions of interest using subband analysis and synthesis or volumetric datasets using wavelets. They followed up this work with (Chen et al., 1995) by using structure preserving adaptive quantization methods as a means of improving quality for compression rates in the regions of interest. But all of their effort was on lossy approaches. In the most relevant work, [15] developed a region based coding approach. They discussed two approaches: one uses different compression methods in each region such as ‘contour-texture’ coding and subband decomposition coding, and the other uses the same compression method in each region such as the discrete cosine transform but with varying compression quality in each region such as by using different quantization tables. They used two multi-resolution coding schemes: wavelet zerotree coding and the S-transform, and considered only 8 bit images. In their implementation, the regions of interest were selected manually.

IV. PROPOSED WORK

The proposed work can be obtained by integer wavelet transform followed by SPIHT algorithm.Fig.1 Shows the general architecture of the proposed system. The proposed image compression and reconstruction architecture addressed in this paper involves the following steps.

- Load the Medical image as input.
- Using a Global thresholding method, Apply threshold to remove background i.e. the ROI & Non-ROI regions are separated from background (BG).
- Select ROI, and separate out ROI and Non-ROI.
- ROI region is encoded using IWT with high bpp.
- Non-ROI region is encoded using SPIHT with low bpp.
- Merge the two encoded regions (ROI and Non-ROI) to get the ROI based compressed image.
- To perform Non-ROI compression i.e. compression without any particular selection of Region applies SPIHT on the binary image, obtained in step (ii).
- Get the Non-ROI based compressed image.
- Compare the quality of ROI based compressed image with Non-ROI based compressed image obtained in previous steps in terms of PSNR and compression ratio.

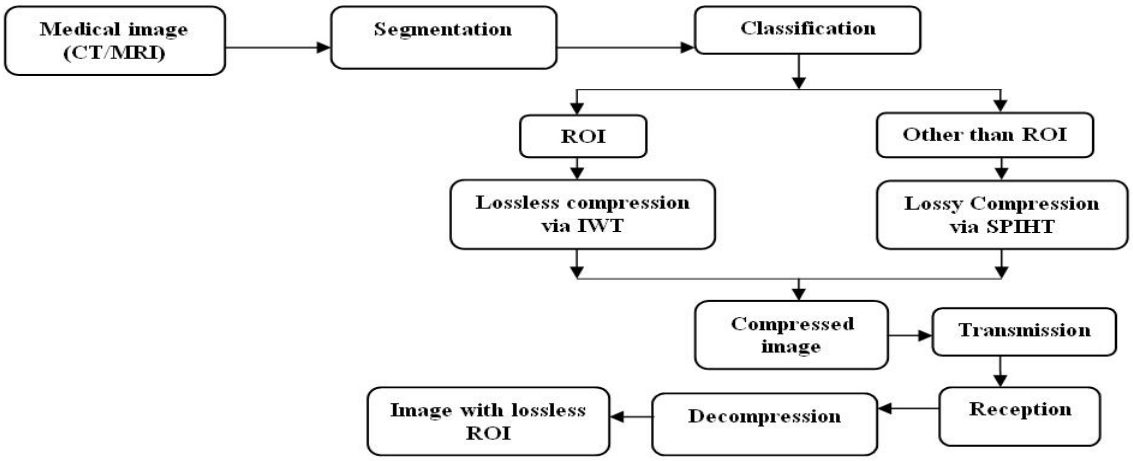


Fig.1 Flowchart of proposed system

a) Region of Interest

Those regions of an image which are given more consideration as compare to other regions are called region of interest i.e. ROI. It is a general observation that in some real image or medical image all the regions do not show equal importance for examination point of view. Considering this fact, attention is paid only to selected parts of the image [16].For example in Fig.2, of a brain MRI image, region containing tumor is examined instead of scanning the whole image, because actual information exists here.

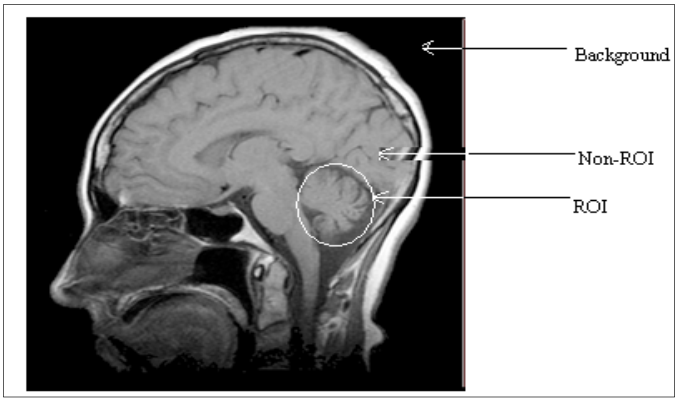


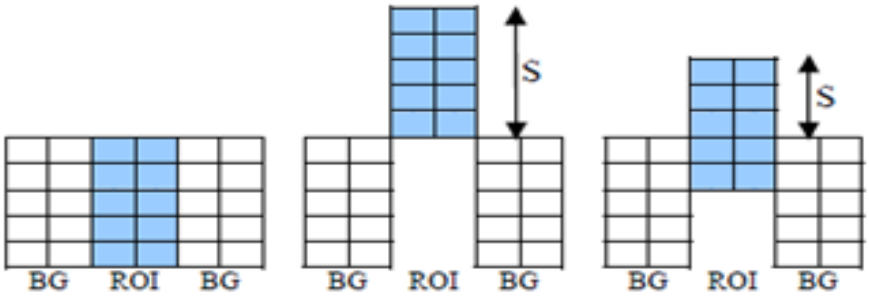
Fig.2 Different parts of Medical Image

In medical diagnosis, the Region of Interest (ROI) concept is important because of the limitation and hampering of medical images due to lossy and lossless compression techniques. The compression ratio of lossless compression techniques result into 25% of original size, while for the lossy encoder's compression ratio is much greater, but both of these compressions causes loss in the data [17]. This loss in data may cramp the important part of medical image. So to get rid from this problem, a better compression technique is needed which provide a better compression ratio by taking care of the important part (ROI) of the medical images.

b) *ROI Based Coding*

To fulfill the need of high compression rate, another approach for lossy compression may be ROI (Region of Interest) based coding. In this approach instead of transforming the whole image, the same transformation can be separately applied to the diagnostically important regions and background. In a medical image ROI is selected according to a predetermined characteristic or as per users need. The goal of such compression method is to maximize the overall CR i.e. compressing each region separately with its own CR, depending on its significance, so as to preserve the diagnostically important characteristics. Hence, such a strategy that exploits the feature of ROI is becoming beneficial and compact, providing better CRs and fast processing especially on a low bandwidth media. Further, ROI coding provides an excellent trade-off between image quality

and CR. Most of the ROI coding methods are based on the wavelet coding techniques of JPEG2000 like EBCOT, Maxshift, general scaling, implicit and few other modified methods. Fig. 3 shows some of them.



a) No Shift **b) Maxshift** **c) Scaling Based**

Fig.3 Comparison of Promotion between several ROI bits plane

c) Integer Wavelet Transform

By many research works it has been proved that the Discrete Wavelet Transform (DWT) is a versatile signal processing tool for many applications. It is an important step of JPEG 2000 based image compression. Further enhancement in wavelet transform is achieved via the technique of lifting. Traditional implementation of wavelet transforms was based on convolution, as compare to that, lifting scheme can be implemented in more efficient way. With the help of this scheme new types of nonlinear wavelet transforms may be implemented. The Integer Wavelet Transforms (IWT) maps integers to integers and allows for perfect invariability with finite precision arithmetic [18]. Thus, Integer Wavelet Transform can be used for lossless compression of medical images, for that firstly the traditional DWT is reconstructed into a form of lifting steps. After that at each step rounding operation is performed.

d) SPIHT Coding Algorithm

SPIHT is compression technique based on wavelet based image compression. Main features of SPIHT are high quality of image, simpler quantization algorithm, progressive transmission of image, fully coded file, efficient coding and decoding, fully adaptive, lossless compression, Exact bit rate coding and Error protection[19][20]. For the compression process, SPIHT makes use of three lists which are nothing but, coefficient location lists containing their co-ordinates. Name of lists are-

» List of Significant Pixels (LSP),

» List of Insignificant Pixels (LIP)

» List of Insignificant Sets (LIS).

Following the initialization process, for each level of threshold the SPIHT algorithm takes – the sorting pass (in which lists are organized) and the refinement pass (which does the actual progressive coding transmission). Both stages together results in code stream or bit stream. It is capable of recovering the image perfectly (every single bit of it) by coding all bits of the transform. As a small preamble to SPIHT [21] method, it involves,

1. Exploitation of the hierarchical structure of the wavelet transform, by using a tree-based organization of the coefficients;
2. Partial ordering of the transformed coefficients by magnitude, with the ordering data not explicitly transmitted but recalculated by the decoder.
3. Ordered bit plane transmission of refinement bits for the coefficient values.

4. The major advantage of using SPIHT coding technique is that, it supports embedded coding along with progressive transmission, which is suitable for telemedicine.

Such scheme of embedded coding results in a facility to arrange the coefficients in order from maximum to minimum value i.e. fully embedded bit stream. So this scheme is applicable as a lossy compression scheme, which makes the compression energy efficient.

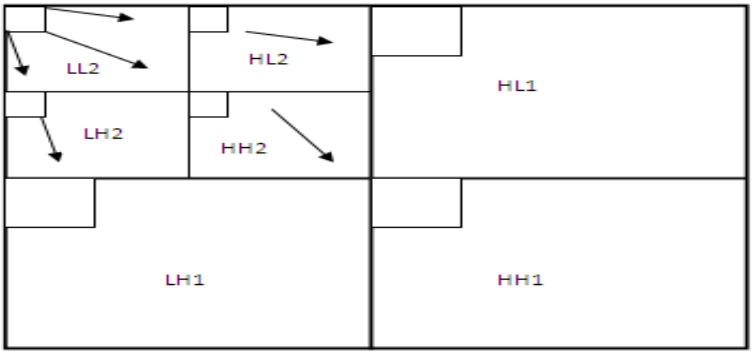
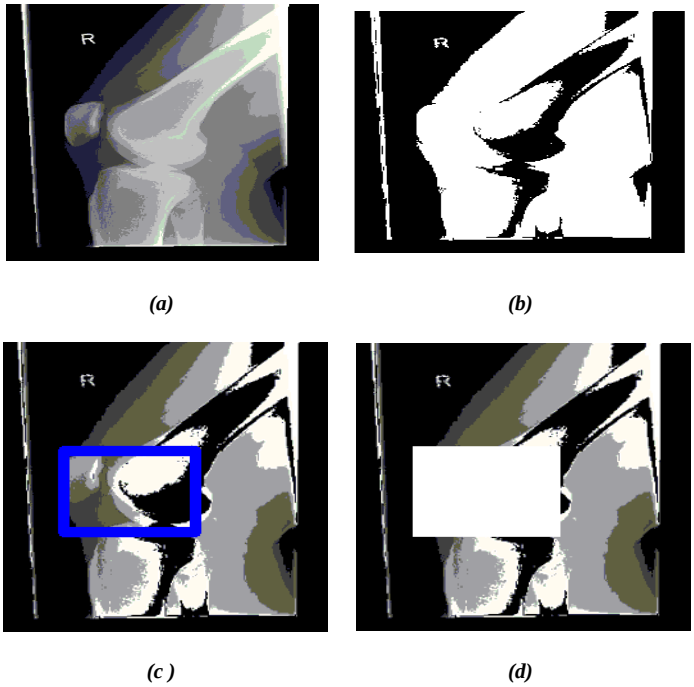


Fig. 4 Tree Structure of SPIHT

V. EXPERIMENT RESULTS

a) Extraction:

The first step in the proposed work is segmenting the image into two regions. One approach is suggested for this. One is the selection of the region of interest by hand and then superimposing the selected pixel matrix on an m*n matrix of zeroes, where m and n refer to the number of horizontal and vertical pixels in the image respectively. The background is left as such with zero values for the selected region. This is shown by fig. (5). Coming to the advantages of the method, a great degree of freedom to choose the ROI is experienced. Secondly, not much computation energy is involved in the process. The extraction by hand is illustrated below.



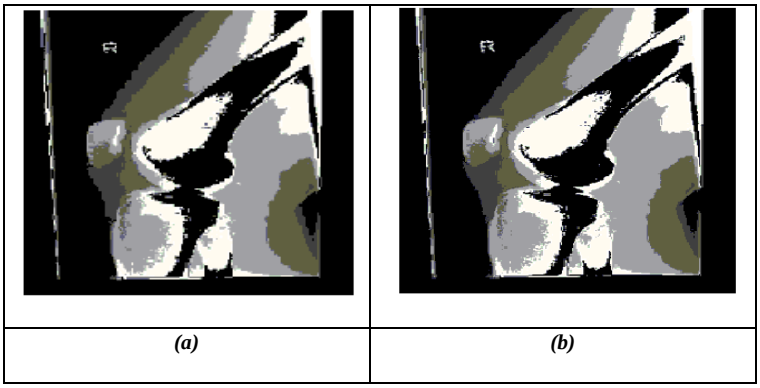
(a) *(b)*

(c) *(d)*

Fig. 5 (a) original X-ray image of size 256 x 256; (b) ROI_mask (Binary image); (c) selected Region of interest (ROI-part); (d) Non-ROI part of original image

b) Encoding:

Integer Wavelet Transform (IWT) is used as lossless scheme for ROI part, and Set Partitioning in Hierarchical Trees (SPIHT) is used as lossy techniques for rest of the part which are discussed in previous.



(a) *(b)*

Fig. 6 (a) Reconstructed image without ROI (PSNR =54.15 dB at bpp 4.0) (b) Reconstructed image with ROI (PSNR of 64.15 dB at bpp 4.0) (proposed work)

The same algorithm has been performed on MRI image and also on the natural image, Lena. The result shows that that the present work is suitable for both of them long with the X-ray image, for which compression is discussed above. All the simulated results are shown in following tables.

TABLE II

Conventional Method (Spiht On The Whole Image, Without Any Roi Selection)

Image	PSNR	MSE	CR
X-ray	24.2134	2.896	16.6519
MRI	34.1263	2.981	16.9113
LENA (Natural Image)	37.2027	2.995	16.8594

TABLE III

Proposed System

Image	PSNR	MSE	CR
X-ray	35.6891	1.20	21.2021
MRI	36.7398	1.15	16.0004
LENA (Natural Image)	43.6323	1.05	16.8503

c) Comparison Graph:

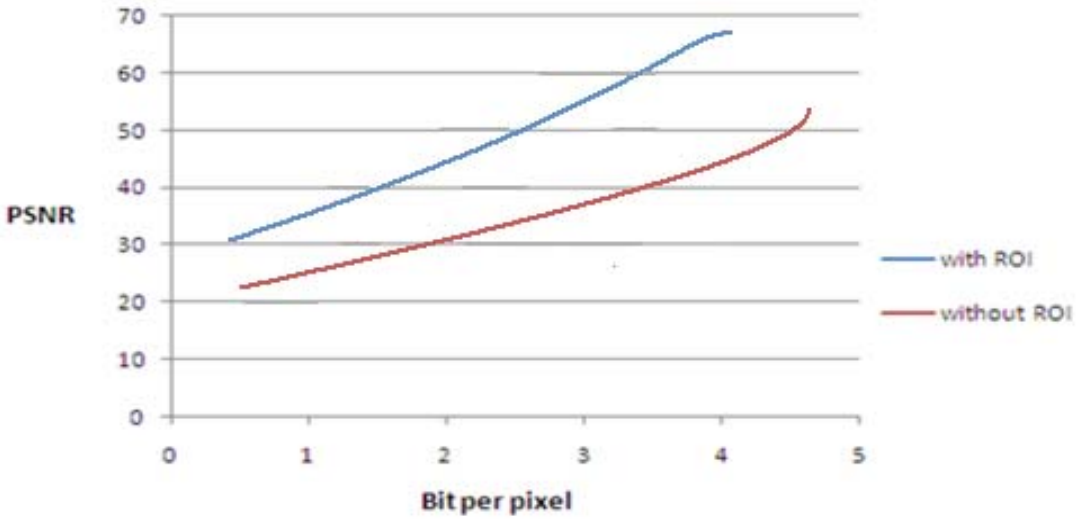


Fig.7 PSNR vs. Bit per pixel for X-ray image

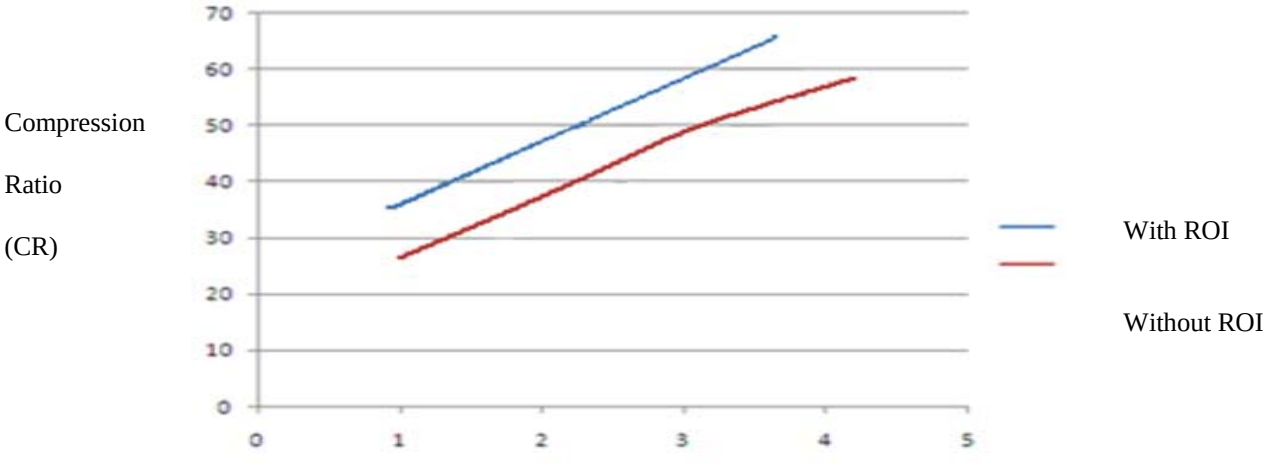


Fig. 8 CR vs. Bit per pixel for X-ray image

VI. CONCLUSION

From the presented work in this paper, it can be concluded that Region Based Coding Technique is significant for telemedicine application i.e. medical image compression and their transmission over the network. Concerning the medical imaging, only a small portion of any particular image might be diagnostically important. So this fact is utilized in the present work, i.e. in selected regions, lossless compression can helps to achieve high efficiency performance. The easier MATLAB simulation & corresponding results prove it, a very efficient and low complexity compression method for medical images. Manual identification of ROI is done here and further combined with effect of Integer Wavelet Transform (IWT), also SPIHT has many advantages, such as good image quality, high PSNR and good progressive image transmission which has been used for lossy compression in the proposed work. Evaluation has been done with the help of X-ray, MRI Brain image and it shows that both techniques are useful to reconstruct the original image, reversibly with desired quality, especially in limited bandwidth over a telemedicine application. The work shows a good result for natural image also.

The proposed work can be extended with automatic selection of ROI rather than manual and also on the basis of information contents present in the image. The most demanding area is the need for a system which automatically extracts the region of interest and proceeds as stated above.

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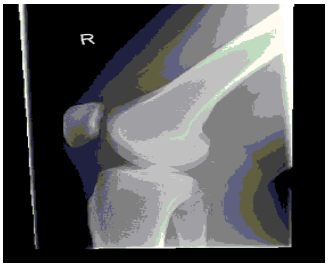
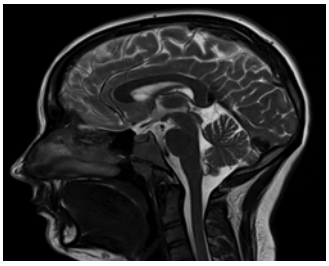
Appendix A

Sample Images used in the Experiment



X-Ray Image



MRI Image

Natural Image (Lena)

