ROI BASED IMAGE COMPRESSION ON MEDICAL IMAGES USING HAAR WAVELET

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Abstract- **The goal of medical image compression in this paper is to maintain the superiority of the regions which are critical for diagnose. This could be maintained when both ROI and background region of medical images undergo different compression i.e. ROI with lossless compression so that important information and space memory both will be sustained and background with lossy compression because some loss in background is tolerated. Basically, discrete wavelet transform (DWT) with haar wavelet is acquired for compression in this paper. Compression ensued two times i.e. with ROI and without ROI on same four types of medical images which are MRI, CT- scan, ultrasound and X- ray. Five parameters named compression ratio, correlation coefficient, peak signal to noise ratio, mean square error and structural similarity index have been used to perceive how much the proposed method is efficacious with the help of MATLAB software. All the five factors are computed with ROI, background and without ROI of medical images. With ROI and without ROI are compared on the basis of compression ratio and peak signal to noise ratio from which it is evaluated that with ROI compression is better than without ROI.**

Index terms-**DWT, haar wavelet, ROI, medical images, compression ratio, PSNR, MSE, SSIM, correlation coefficient**

1. INTRODUCTION

Multimedia information and digital nature data has increased drastically within few span of years tend to make a necessity of image compression as it reduces the irrelevant and redundant data for the transmission. Firstly, image compression has started in 1970's in which encoding techniques were used to compress an image. To use least number of bits for the representation of an image is the main motive of this technique with distortion minimization which rooted during compressing of an image [1]. Loss of imperative information is not endured during compression. Compression is classified as lossy and lossless compression; the reorganized data is perceptual good quality that is lossy compression whereas reorganized data that is replica of original data is called lossless compression [2, 3].

Signal is represented in coordinate system. The mathematical tool which is used to change the coordinate system is known as wavelets. Domain which is best for the system is also decided by the wavelet. Coding which are based on wavelets is most effective with errors in decoding and transmission. Wavelets are adjustable and have inherent multi resolution nature. When degradation is tolerable then this is used [4]. When we need signals in increasing resolutions hierarchy then wavelets play important role of decomposing them and also multi resolution of every image is formed by them. High and low pass channels' arrangement is used to form wavelet transformation. Compression which comes as the low pass channel output can be used. Digital computer is one application in which wavelets of DWT are generated and calculated [5]. Compression with haar wavelet which is one of the techniques of DWT is proposed in this paper. This compression is procured by selecting a particular ROI. Proposed technique is experimentally tested on medical images. Four types of medical images are used which are MRI, CT- scan, X- ray and ultrasound. With ROI and without ROI both are used for compression and then compared on the basis of five parameters which are MSE, PSNR, SSIM, correlation coefficient and compression ratio.

Many researchers recommended different methods for selection of ROI. Manpreet Kaur and Vikas Wasson in 2015 had proposed a method for both ROI and non- ROI part of medical images. Compression of ROI is done with context weighting lossless and that of non- ROI is with fractal lossy compression and results of scalable RBC and integer wavelet transform is used for comparison purpose. Khushpreet Kaur and Sheenam Malhotra in 2015 used discrete cosine transform for selecting ROI from medical images and then applied filters for clarification of image. Results are examined with the help of MATLAB software. In 2018, K Vidhya, T R G Babu and S S Devi introduced a method in which abnormalities from medical images were extracted using threshold based technique so that diagnostically significant information was preserved within the edges of images. Area within these edges was known as ROI region.

2. PROPOSED TECHNIQUE

Proposed technique for image compression is braked up in three parts. First part is discrete wavelet transform for distinction of an image, second is haar wavelet for decomposition of an image and last is ROI in which particular region of interest is selected for compression. All are discussed in detail in below sections.

2.1 Discrete Wavelet Transform

Transform used for distinction of image into pixels is known as discrete wavelet transforms (DWT). This comes under the lossless image compression.

Compression in DWT

To compress an image in Discrete Wavelet Transform (DWT) following steps should be followed:

- Firstly, two filters i.e. low pass and high pass filter are fitted on each row through which input image is passed.
- Then, L1 and H1 are used to represent outputs of low pass and high pass filters respectively.
- L1 and H1 are combined as A1 which is [L1, H1] because filters are in rows. Then down sample by 2 is applied on A1.
- After this both filters are fitted in column and A1 is processed through them and output of this is named as A2 which is a combination of H2 and L2.

$$A2 = \begin{bmatrix} L2 \\ H2 \end{bmatrix}$$

- The same process of down sampling is again carried out and we will get the compressed image as the output. This is one level of decomposition in which we get an input in four versions.

Above steps should be followed as much time as we want until we get the desired compression ratio [20- 23].

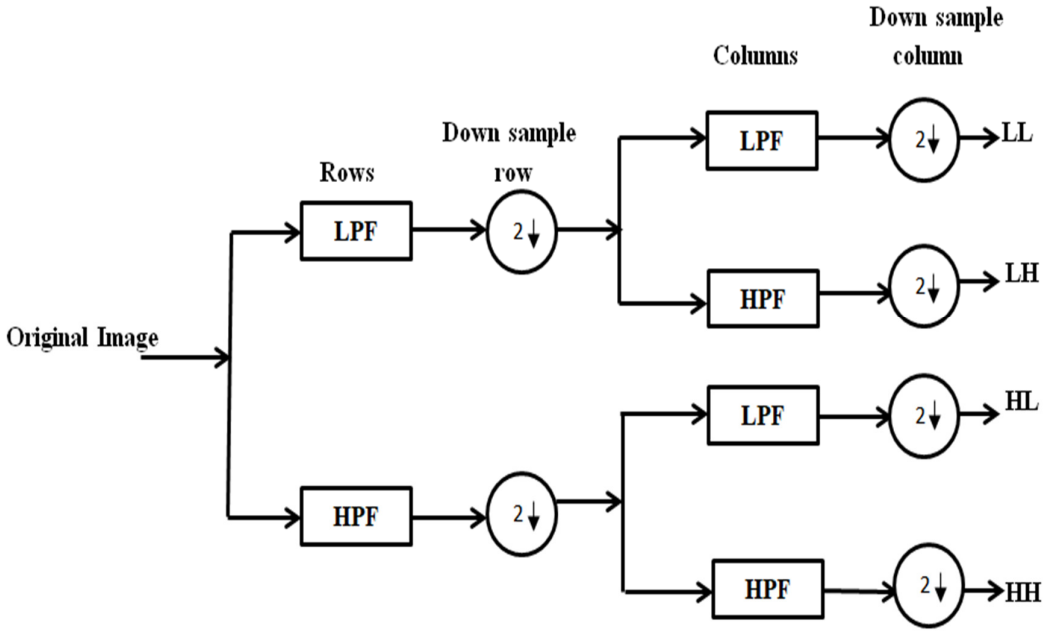

Figure 1:3-D decomposition

2.2 Haar Wavelet

Haar wavelet is the uncomplicated and basic among all wavelet techniques (DCT, KLT, DFT, DST etc.). The decomposition of signal by haar wavelet gives two components as the result. These components are difference and average [7].

2.3 ROI

The motive of image compression is not to lose any important information during compressing an image. To accomplish this motive, compression of only region of interest (ROI) is proposed. Shape of the ROI's depends on our points which we have fixed [8- 12]. Required compression mainly depends on the geometry of ROI's in medical images. Very few researchers have done work on the variation of compression ration by using different ROI's in medical images. In this paper, ROI and background region are selected separately for compression. Grayscale medical images are used as the input from which the any region of our interest is selected [13].

3. IMPLEMENTATION WORK

The proposed technique for compression is implemented in following parts; one is with ROI, second is background and third time compression is implemented without selecting any ROI region. Third time compression is implemented to differentiate the performance of with ROI and without ROI compression. Steps followed in compressing the medical images are as follows:

- Medical images are uploaded for compression which is segmented into ROI and background region.
- ROI compression happens with lossless while background compression occurs with lossy compression because no loss is tolerated in ROI region.
- Compressed images turn out as a result in both cases.
- In this step, image is transmitted to other side which is decompression one for decompressing the compressed image.
- Lossless ROI helps in acquiring the original image.

4. EXPERIMENTS AND RESULTS

Four categories of medical images are used in this paper for compression. MRI, CT- scan, ultrasound and X- ray is the medical images each of which has five images [18].

- MRI – MRI images comprises of brain, ankle, shoulder, knee and spine images.
- Ultrasound- Ultrasound has thyroid, kidney stone, fatty liver, breast and normal liver images.
- X- ray- X- ray includes images of foot, hands, knee, lungs and spine.
- CT- scan- Brain, chest, elbow, spine and neck are the five CT-scan images used in this paper.

The parameters which will be discussed below shows how much the proposed method is efficacious. Five parameters named compression ratio, correlation coefficient, peak signal to noise ratio, mean square error and structural similarity index have been used in this paper.

- *Mean Square Error (MSE):* The mean of the square of errors is measured by MSE. The difference between the original image and the compressed image is described by this parameter. Less MSE indicated good compression or good quality of an image.

$$MSE = \frac{1}{P*Q} \sum_{m=1}^{P} \sum_{n=1}^{Q} (I[m,n] - J[m,n])^2 \quad (1)$$

  Where P*Q are dimensions of an image and I is the original image and J is the compressed image.

- *Compression Ratio (CR):* Compression ratio is the ratio of the size of compressed image and size of original image.

$$CR = \frac{Original\ \ size\ of\ an\ image}{Compressed\ size\ of\ an\ image} \quad (2)$$

If compression ratio comes out to be higher than it means image quality is less reconstructed [14].

- *Peak Signal To Noise Ratio (PSNR):* Evaluation of peak error is known as PSNR. As the value of PSNR and noise are inversely proportional so PSNR should always be as high as possible. But with increase in compression ratio, PSNR should decrease [14].

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

- *Correlation coefficient*: In word correlation, co means 'together' and whole word describes the relationship between two images. How the two images are related to each other.

$$CC = \frac{\sum_j (\mu_j - \mu_n)(z_j - z_n)}{\sqrt{\sum_j (\mu_j - \mu_n)^2} \sqrt{\sum_j (z_j - z_n)^2}} \quad (4)$$

  Where,

  μ_j and z_j = Intensity of 1st and 2nd image's j^{th} pixel

  μ_n and z_n = Mean intensity of 1st and 2nd image

  Value of correlation lies between 1 and -1.

- *Structural Similarity Index* (SSIM): To measure the similarity between two images, structural similarity index is used. Estimation of image quality is done with the help of uncompressed image. SSIM is more consistent and accurate than PSNR and MSE. Luminance distortion, loss of correlation and contrast distortion are the three factors used in image distortion modelling which plays important in evaluating SSIM [15].

Compression of medical images is attained in two parts which are with ROI and without ROI.

4.1 With ROI

ROI and background are further two partitions of with ROI compression. Both are separately compressed because our aim is to conserve the area which is diagnostically more sensitive. We mark this sensitive area as ROI so that it undergoes lossless compression and imperative information will be saved [16].

Results

1. *MRI*- Evaluated values of compression ratio (CR), peak signal o noise ratio (PSNR), correlation coefficient (CC), mean square error (MSE) and SSIM are shown below in table.

Table 1- Values of different parameters of all MRI images with ROI

Images	CR	MSE	CC	SSIM	PSNR
Brain	5.64	0.03	0.999994	0.998	63.18
Knee	3.50	0.05	0.999992	0.997	61.12
Shoulder	4.07	0.04	0.999992	0.998	61.81
Spine	4.53	0.04	0.999982	0.994	62.21
Ankle	3.77	0.05	0.999979	0.994	61.35

This table defines the five parametric values to compare the MRI images when a particular region of interest is selected. As the value of compression ratio is less so it means ROI area is compressed less and no important information is lost.

2. *ULTRASOUND*- All ultrasound images undergo processing of compression by selecting particular ROI and gave us following results.

Table 2- Values of different parameters of all ultrasound images with ROI

Images	CR	MSE	CC	SSIM	PSNR
Kidney stone	4.0	0.04	0.999993	0.997	61.84
Fatty liver	8.5	0.02	0.999981	0.998	65.07
Breast	4.2	0.04	0.999975	0.997	61.93
Liver	8.0	0.02	0.999988	0.998	64.94
Thyroid	4.1	0.04	0.999982	0.992	61.68

All five ultrasound images discussed above the table had given us the parametric values written in table 7. This table defines the results of compression with ROI. Different images have different values depending on their selected ROI. Image with highest CR has highest PSNR value.

3. *X- RAY*- Compressing the x- ray images gives us the values of five parameters which are discussed below. This table shows the values of parameters used in this work for x- ray images with ROI. Foot has the highest value of compression ratio and least t hatof MSE while lung has the least compression ration and highest MSE.

Table 3- Values of different parameters of all x- ray images with ROI

Images	CR	MSE	CC	SSIM	PSNR
Knee	5.5	0.04	0.999992	0.993	62.65
Lungs	3.2	0.06	0.999993	0.997	60.54
Sidespine	4.6	0.04	0.999995	0.997	62.26
Hand	6.6	0.03	0.999996	0.995	63.85
Foot	7.1	0.02	0.99997	0.993	64.21

4. *CT- SCAN*- Compression after selecting the particular ROI from CT- scan images gives us the results written below in the table.

Table 4- Values of different parameters of all CT- scan images with ROI

Images	CR	MSE	CC	SSIM	PSNR
Brain	4.1	0.04	0.999995	0.996	61.96
Neck	7.5	0.02	0.999997	0.996	64.61
Spine	4.6	0.04	0.999982	0.988	62.24
Chest	4.5	0.04	0.999997	0.998	62.31
Elbow	4.7	0.04	0.999997	0.997	62.53

After compression with ROI the system give us the values of five parameters i.e CR, PSNR, MSE, CC and SSIM. Values for different CT- scan images for all these parameters are shown in table 4. MSE value of CT- scan images are same except neck and also neck has highest CR. These values depend on the selected ROI. Values of all CT- scan images except naeck are same.

4.2 Without ROI

Without ROI connote that we are not selecting any ROI i.e. whole image is compressed only once and each part of an image is compressed equally.

1. *MRI*- Results of images when no ROI is selected are analyzed in table. CR, MSE, CC, SSIM and PSNR are discussed in table 5.

Table 5- Values of all MRI images without ROI

Images	CR	MSE	CC	SSIM	PSNR
Knee	0.5	0.11	0.99998	0.992	57.57
Shoulder	0.6	0.09	0.99998	0.997	58.73
Spine	0.5	0.12	0.99996	0.987	57.52
Ankle	0.6	0.11	0.99996	0.977	57.82
Brain	0.5	0.09	0.99998	0.967	58.85

The same MRI images are again compressed but this time without ROI i.e. whole image is compressed equally. This compression gives us the values summed up in table 5.

2. *ULTRASOUND*- Five parameters which were evaluated from the compression of ultrasound images are studied.

Table 6- Values of all Ultrasound images without ROI

Images	CR	MSE	CC	SSIM	PSNR
Kidney stone	0.83	0.07	0.99999	0.992	59.68
Fatty liver	0.57	0.11	0.99997	0.988	57.88
Breast	0.74	0.08	0.99995	0.990	58.99
Liver	0.73	0.09	0.99998	0.967	58.85
Thyroid	0.66	0.09	0.99998	0.985	58.42

In this table, each image is treated as on image i.e. not divided into two parts (ROI and background) and are then compressed. This compression gives us the results which are shown in table 6.

3. *X- RAY*- Compression without ROI compress the every part of the image equalyy whether that part is important or not.

Table 7- Values of all X- ray images without ROI

Images	CR	MSE	CC	SSIM	PSNR
Knee	0.73	0.09	0.99997	0.962	58.41
Lungs	0.60	0.11	0.99998	0.995	57.90
Side spine	0.58	0.11	0.99998	0.993	57.64
Hand	0.68	0.10	0.99998	0.955	58.32
Foot	1.18	0.05	0.99999	0.986	61.02

After compressing all x- ray images without ROI the system shows us the results shown in table 7. In this foot is at number one by scoring the highest compression ratio, PSNR, CC. Foot has the least MSE value as compared to other x- ray's.

4. *CT- SCAN*- Values of all five factors are evaluated for all CT- scan images. Results are scrutinized in table 8.

Table 8- Values of all CT- scan images without ROI

Images	CR	MSE	CC	SSIM	PSNR
Brain	0.77	0.08	0.999995	0.9927	59.38
Neck	0.94	0.06	0.999996	0.9926	60.34
Spine	0.82	0.08	0.999982	0.9780	59.31
Chest	0.60	0.10	0.999994	0.9970	58.29
Elbow	0.89	0.06	0.999995	0.9961	60.60

Table 8 defines the results of CT- scan images without ROI. For this also all the five parameters are evaluated i.e. CR, PSNR, MSE, CC and SSIM. These values give us the idea about the compression of an image and on the basis of this we can compare the images with any other images.

4.3 Comparison between ROI and without ROI

Comparison of performance of images with ROI and images without ROI is covered in this section. Two performance factors are used for comparison which are compression ratio (CR) and peak signal to noise ratio (PSNR).

1. *MRI*- Knee, shoulder, spine, ankle and brain all images are used for comparison purpose. Table 9 consists of values of CR and PSNR for both ROI and without ROI.

Table 9- Comparison of MRI images with ROI and without ROI

Images	ROI		Without ROI	
	CR	PSNR	CR	PSNR
Knee	3.50	61.1190	0.55	57.5737
Shoulder	4.07	61.8117	0.68	58.7312
Spine	4.53	62.2075	0.55	57.5163
Ankle	3.77	61.3544	0.59	57.8209
Brain	5.64	63.1803	0.53	58.8450

Table 9 defines the difference between compressing the images with ROI and compressing without ROI. Compression ratio changes drastically when we select the ROI. As in Knee when we select the ROI and compress an image then compression ratio is 3.50 and PSNR is 61.11901017 but when we compress an image without selecting ROI then compression ratio is just 0.55 and PSNR is 57.5737776.

Figure 2 graph implies that compression ratio of with ROI images are more as compared to without ROI images. Compression ratio is appraised in percentage which is below 1% for without ROI and above 3% for with ROI.

Figure 3 graph indicates that PSNR value for all MRI images with ROI is more than that of MRI images without ROI. PSNR is calculated in decibles. With ROI PSNR is above 55 for all images while for without ROI it is below 59.

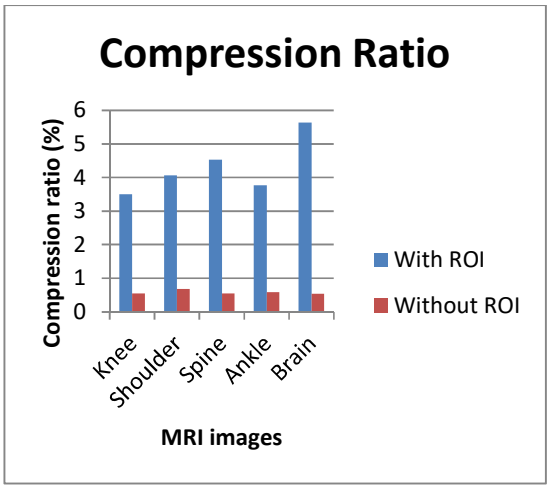

Figure 2- Comparison of with ROI and without ROI MRI images on the basis of compression ratio

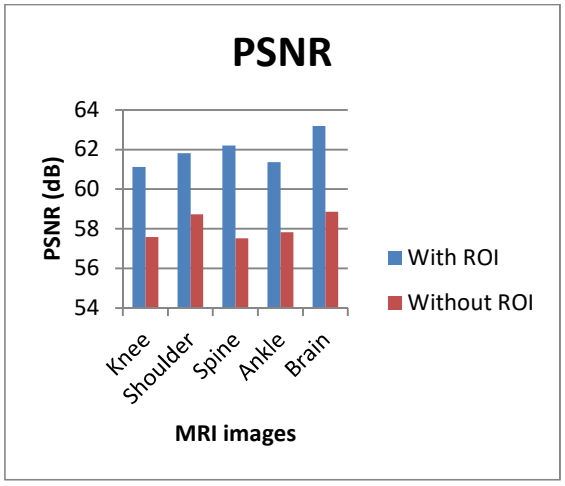

Figure 3- Comparison of with ROI and without ROI MRI images on the basis of PSNR

2. *ULTRASOUND*- Without ROI results of ultrasound images are analyzed in this segment. Same five ultrasound images are used for compression. The comparison is made on the basis of PSNR and compression ratio.

Table 10- Comparison of Ultrasound images with ROI and without ROI

Images	ROI		Without ROI	
	CR	PSNR	CR	PSNR
Kidney stone	4.03	61.8475	0.83	59.6897
Fatty liver	8.52	65.0707	0.57	57.8839
Breast	4.24	61.9279	0.74	58.9988
Liver	8.03	64.9434	0.73	58.8450
Thyroid	4.11	61.6813	0.66	58.4249

Above table indicates that compression ratio declines when compression is done without selecting an ROI due to which image quality also declines. For example in thyroid compression ratio decreases from 4.11 to 0.66.

Figure 4 Percentage compression ratio of kidney stone, fatty liver, breast, liver and thyroid when no ROI is selected is between 0 and 1 while that of with ROI is above 4 for all images. Compression ratio of all ultrasound images are higher which is the main aim of our experiment.

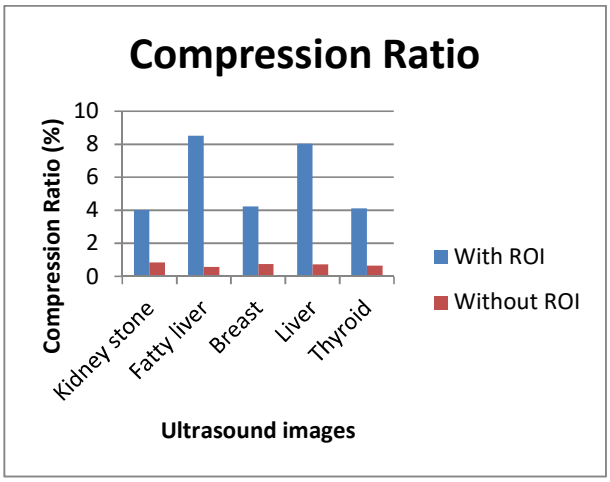

Figure 4- Comparison of with and without ROI ultrasound images on the basis of compression ratio

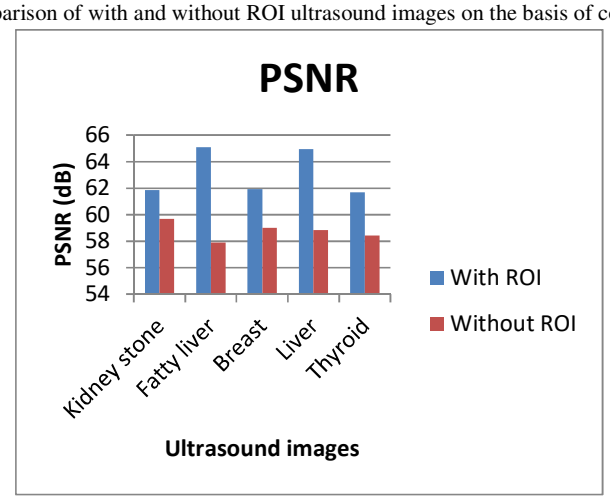

Figure 5- Comparison of with and without ROI ultrasound images on the basis of PSNR

PSNR value of without ROI ultrasound images is less as compared to with ROI images.

3. *X-RAY*- Same five x-ray images which are knee, lungs, side spine, hand and foot are compressed for without ROI also. Results of with ROI and without ROI compression are as follows

Table 11- Comparison of X– ray images with ROI and without ROI

Images	ROI		Without ROI	
	CR	PSNR	CR	PSNR
Knee	5.54	62.6528	0.73	58.4169
Lungs	3.16	60.5423	0.60	57.9006
Side spine	4.66	62.2586	0.58	57.6473
Hand	6.64	63.8474	0.68	58.3216
Foot	7.15	64.2056	1.18	61.0234

Table 11 fulfills the motive of this paper by comparing the parametric values of all x- ray images with ROI and without ROI. When image is compressed with ROI then compression ratio of all images is from 3- 7 but when same images are compressed without ROI then compression ratio declines near to 0. There is a huge difference in compression ratio of X- ray images. Without ROI compression ratio is in the range of 0- 2 due to which image quality degrades.

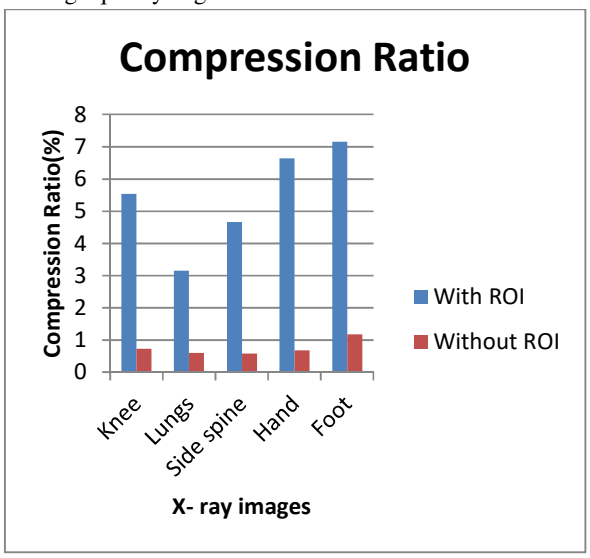

Figure 6- Comparison of with and without ROI X- ray images on the basis of compression ratio

PSNR values of all X- ray images is evaluated in figure 10. Foot has the highest PSNR for both with and without ROI images.

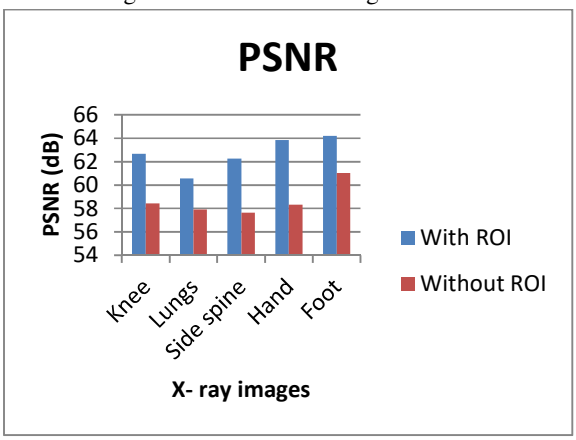

Figure 7- Comparison of with and without ROI X- ray images on the basis of PSNR

4. *CT-SCAN*- This segment defines the results of CT- scan images without ROI. For this also all the five parameters are evaluated i.e. CR, PSNR, MSE, CC and SSIM ut only two are discussed here. These values give us the idea about the compression of an image and on the basis of this we can compare the images with any other images. Table 12 defines the comparison of same CT- scan images. Clear difference can be seen between the compression ratio and PSNR of compression with ROI and without ROI. Compression ratio rises from 0.77 to 4.11 in case of brain when compressed by selecting a particular ROI.

Table 12- Comparison of CT- scan images with ROI and without ROI

Images	ROI		Background	
	CR	PSNR	CR	PSNR
Brain	4.11	61.9566	0.77	59.3879
Neck	7.51	64.6089	0.94	60.3389
Spine	4.66	62.2392	0.82	59.3139
Chest	4.45	62.3014	0.6	58.2950
Elbow	4.74	62.5296	0.89	60.6025

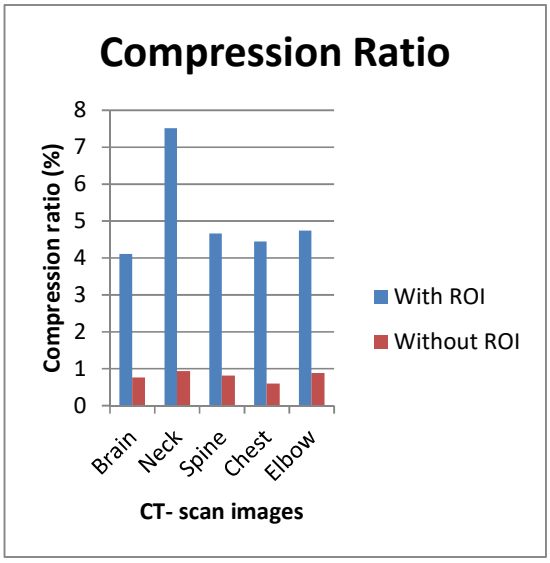

Figure 8- Comparison of with and without ROI CT- scan images on the basis of compression ratio

Above graph evaluates that there is a huge difference in compression ratio of with and without ROI. With ROI images compression ratio for neck is 7.5% which is highest.

PSNR of all CT- scan images with ROI is higher than without ROI images and is also above than 62 but that of without ROI is below 61

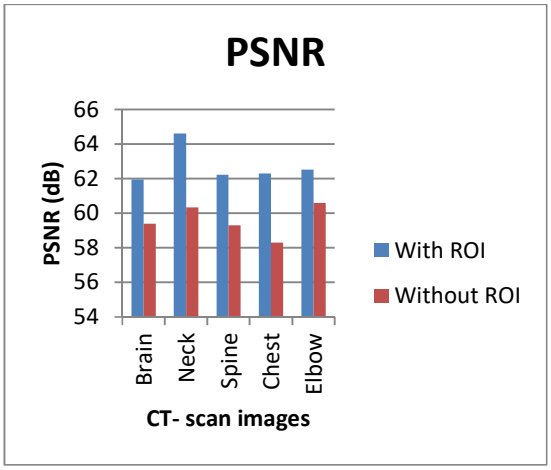

Figure 9- Comparison of with and without ROI CT- scan images on the basis of PSNR.

5. CONCLUSION AND FUTURE WORK

Discrete wavelet transform with haar wavelet is proposed for image compression in this paper. Here a particular ROI is selected for procuring compression and images used for compression are medical images. Medical images used are of four types which are MRI, CT- scan, ultrasound and X- ray each having five images of different body parts. Analysis is done in two segments i.e. with ROI and without ROI. Results of both are compared from which is it clear that compression ratio of with ROI image is better as compared to without ROI which implies that compressed images have very good quality. But still there is some place for improvement i.e. compression ratio will be improved more to have more good quality. Also, multiple ROI would also be selected with same algorithm and instead of images video would be used.

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