



# Subband Thresholding For Near-Lossless Medical Image Compression

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**Abstract:** Medical images play a prominent role in diagnostic and treatment planning in the medical arena. Medical images are acquired using several medical imaging modalities like Computed Tomography (CT), Magnetic Resonance Imaging (MRI), UltraSound (US), Positron Emission Tomography (PET), and X-Ray. These are used as an image acquisition tool to capture the medical images. Numerous volumes of medical data are produced for processing, storing and transmission over the network for telemedicine services every day. Those images are in the form of multidimensional data with high resolution. Hence, it certainly yields higher bandwidth and storage. Thus, it is very essential for medical image applications to reduce storage and to solve transmission problems. Every information it holds is a matter of human lives. The fast and safe transmission of these data will decrease the mortality rate. Lossy type of image compression technique achieves better compression rate than image quality where lossless compression can only retain the image quality. Therefore, there is an existing need for near-lossless compression which compromises both the compression rate and image quality. In this paper, we have proposed a near-lossless medical image compression technique that thresholds the sub-bands to increase the number of zero coefficients. And as an entropy encoder run-length encoding is applied to compress the medical image to retain the diagnostic information with high compression efficiency with better image quality. Compression Ratio (CR), Peak Signal to Noise Ratio (PSNR), Time Complexity and Bits Per Pixel (BPP) were used as assessment parameters to examine the performance of our proposed method. We achieved an average of 2 BPP and PSNR of 42.43 dB which is higher than the existing methods.

**Keywords:** Medical Image Compression, Wavelet based Method, Subband Thresholding, Run Length Coding

## 1. INTRODUCTION

Now, we are living in the world of a visually and digitally enchanted era which explores features like intensity, colors, texture, and motions. In this digital eon, image processing and digital images are playing a prominent role in various applications like Space and Satellite imaging, Web-related applications, Multimedia services and Medical Imaging etc. In recent years, the utilization of medical imaging tools are tremendously increasing, and it is a process used to examine or view the interior organs of the human body for diagnostic and treatment purposes. Accordingly, it achieves the main objective of medical imaging evolution by decreasing the number of mortality, fewer hospital admissions, and reducing the need for exploratory [1]. As aforementioned, medical images are produced from different imaging modalities based on the requirement of treatment. Therefore, huge voluminous of medical data are acquired, processed, stored, and may be transmitted for diagnostic reasons. In every momentum, medical images are necessary for a precise diagnostic that could be transmitted or stored with low distortion and not by distressing the image quality [2]. It leads to insufficient storage of memory and bandwidth of the

network. Medical data carries valuable information than the other text or document files. Consequently, it needs an additional demand for memory and bandwidth to travel over different types of network [3]. Hence, there is a requirement for reducing the image file size before it is going to be stored or transmitted. Thus, this instigates the need for medical image compression. Compression techniques are categorized into Lossless or Near-lossless compression and Lossy compression. Whereas in lossless compression, the decoded image is identical to the original image without any loss of information, but in the event of lossy compression, it is an irreversible process and loss of data can occur [4]. In the situation of medical image compression, lossless manner compression is most desirable because it holds significant information. By this method we could not achieve more compression. In the case of lossy compression, we lose the significant data on the image. Hence, the near lossless method may attain superior compression rate and good image quality by taking the characteristics of lossy and lossless compression methods. Our Human Visual System (HVS) has less concentration on high frequency signals. By reducing the pixel values at those portions may increase the compression rate. We can access the high frequency



signals through wavelet decomposition. It decomposed the image into different frequency subband. By thresholding those subband we increase the performance of compression technique. Hence, we have develop a wavelet based subband thresholding technique to compress the medical images.

Left over, the paper is arranged as follows: Section 2 list some existing works on the literature. Need for compression is discussed in section 3. The proposed method is described in section 4. In section 5, we discussed the evaluation parameters used in our method. The results of our proposed scheme are evaluated and discussed in section 6. Lastly, the future work and main conclusions of the paper are stated in section 7.

## 2. RELATED WORK

There are several compression methods available in spatial domain based techniques as well as frequency domain or transform based techniques [5]. Wavelets have a unique feature that they are able to drive the fine details in an image. They can split-up the data and can be examined separately [6]. In medical images, every pixel holds significant information, hence, with the wavelet decomposition, we can easily get the most significant details and local features of the image by applying low and high pass filters on rows and columns of the image.

Many wavelet based image compression techniques and algorithms are available in the past literature. The most notable techniques are described below. An adaptive subband thresholding compression method for medical image compression proposed in [7] employs different thresholds for each subband to increase the compression ratio. They choose the maximum occurring coefficient as a threshold in each subband. They mainly focused on escalating the Peak Signal to Noise Ratio (PSNR) value to greater than 36 dB and updating the threshold value recurrently until to reach the desired level of PSNR. They use arithmetic encoders to encode the coefficients. Kalavathi and Boopathiraja [8] develop an image compression method using wavelets for medical images. They use 2D-DWT for wavelet decomposition and RLE as an entropy encoder. They evaluate their method using Structure Similarity Index (SSIM), PSNR, Bits Per Pixel (BPP), and Compression Ratio (CR) for different sizes of images obtained from various modalities. For larger size images their method provides better results than the small size images. A medical image compression method which works based on wavelet and RLC encoder developed in [9] uses bior1.1 as a basis function with level four decomposition. They applied hard thresholding to increase the amount of presented zero coefficients in the image. And, the quality of the reconstructed image was analyzed in terms of different bit rates. Improvement of Human Visual System (HVS) image compression procedure using wavelets is developed by Taujuddin et al [10]., they use DWT for wavelet decomposition of the image. To increase the zero coefficients, they used the standard deviation of each subband as a threshold value.

The coefficients which are all underneath to the threshold value are suppressed to zero value. Setia and Kumar [11] presented an image compression method using RLE and Huffman coding as an encoder. They used a Haar wavelet as a decomposer with three levels of DWT. They compared their method with some existing techniques in respect of BPP and PSNR.

Sahoo et al.,[12] developed an image compression method which uses two dimensional Haar Wavelet Transform and RLE for encoding. At first, they specified zigzag scan ordering in RLE. For decomposition they used 2D HWT on the image and applied a hard thresholding on wavelet coefficients. They test their method with different types of RLE methods, such as Optimized Run Length Encoding (ORLE), Conventional Run Length Encoding (CRLE), and Enhanced Run Length Encoding (ERLE). Their technique achieves better performance outputs regarding PSNR when compared with different RLE methods and JPEG. A lossless medical image compression method proposed in [13] incorporates Kronecker delta mask for preprocessing and used Brige-Massart and Parity Strategy methods based on wavelets, which includes unimodal thresholding for compression. CT, MRI and other standard images are used as test images. Their proposed method is out performed over MRI images and the resultant CR is also better when compared with existing methods.

A hybrid medical image compression method was by Aree and Jamal [14] presented a compression technique which is based on hybrid medical image compression. To achieve the higher compression ratio, they applied DWT on LL and HH bands and DCT on HL and LH to preserve the decompressed image quality. They used variable shift coding as an entropy encoder. They evaluated their method using different quantization factors. They observed that, when the quantization factor increases, the CR and PSNR values decrease. They concluded that their method preserved the image quality when the quantization factor is less than 0.5. Wavelet transform and threshold based compression technique proposed in [15] used DWT transform with Haar wavelet as a basis of transformation function. To reduce the redundancy, thresholding is used and, for further reduction Huffman encoding was applied. CR and PSNR metrics are used for the evaluation, and it shows that their proposed method produced a higher compression ratio compared with other thresholding methods.

Yao et al.,[16] proposed an adaptive predictive based lossless medical image compression technique with the help of wavelets. To find out the proper basis function, they first analyze the correlation between the coefficients of wavelets. Then the decomposition is performed using lifting IWT on an identified basis function. Then construct the prediction equation using detailed coefficients of the decomposed image. Then using those predicted equations they figure out the error between the original value and predicted values. Finally, to encode the difference they exploited adaptive

arithmetic coding. Their method overcomes the problem of multicollinearity. Selection of basis function and predictor variable helps them to achieve high accuracy of prediction.

An object based hybrid lossless three dimensional medical image compression algorithm proposed in [17], this method compresses a selected portion i.e VOI on the medical image which produces a better compression ratio and bit rate is also reduced. To extract the VOI they used a selective bounding volume method because it reduces the reconstruction complexity of 3D images and it needs only fewer amounts of reconstruction details. For encoding it uses the LZW followed by arithmetic coding on the image. Their proposed method was analysed with the existing techniques and it increases the compression ratio as well as it decreases the computational time. Taujuddin et al developed an compression algorithm based on threshold. [18]. To produce new efficient coefficients the given image is separated into two regions as ROI and ROB (Region of Background). Then the quantization based prediction method is used for quantization. The resultant coefficients are encoded using RLE encoder. Finally hard and soft thresholds are applied to evaluate the compression algorithm.

Hosseini et al [19] develop a compression technique to achieve a good compression ratio by segmenting the image as Contextual Region of Interest (CROI) first later it segments the Background (BG). To segment the image CVQ (Contextual vector Quantization) method they used a region growing approach. To retain the image quality of ultrasound images CROI and BG are compressed with Low as well as High compression ratio respectively. Then for the encoding process Contextual Quantization method is applied. Various weights are used for different regions. They compared their method with conventional methods like JPEG, SPIHT and also compared with ROI based methods like Maxshift, EBCOT etc. And they achieve 3 dB better PSNR than the other methods.

Lossless Adaptive Prediction grounded medical image compression technique represented by Baware et al.,[20] Here the adaptive prediction is set towards gradients in the image in four directions. To achieve more compression maximum prediction value is set to the lowest gradient valued pixels in the image. To enhance the coding efficiency the obtained residual errors are grouped using maxplane coding. The resultant groups are encoded with the help of Huffman or Arithmetic encoding. And the performance is evaluated with the standard methods like CALIC and DPCM and it provides better compression ratio and bit rates than the aforementioned methods. In [21] the author presented a predictor based near-lossless image compression for MRI medical images. It incorporates the lossless and lossy codings for low coding efficiency and low image quality respectively. Proposed Resolution Independent Gradient Edge Detector (RIGED) is used to fix the optimal threshold at optimum q-level of quantization. Their method removes

the psycho-visual redundancy and inter-pixel redundancy in the image. With the help of block based coding the coding redundancy is also removed from image as block by block. They evaluated their method with existing standard techniques like LOCO-I, DPCM and CALIC; it outperforms these methods in terms of BPP.

### 3. NEED FOR MEDICAL IMAGE COMPRESSION

Although these kinds of techniques were on hand, still there exists a huge demand on compression especially in telemedicine services. In recent days, every treatment needs a huge volume of images or clinical data for prediction and accurate diagnosis. The identification and treatment procedure was done in online. Thus, it is very essential to keep or send all that data in a safe manner for a long time. Nowadays Picture Archiving and Communications Systems (PACS) is mostly used as a systematic approach to handle the patient details. It utilizes the one of highly accepted standards of medical image format Digital imaging and Communication (DICOM) it incorporates the compression technique and transmission protocol for the transmission of medical image. Even though it is widely used in medical practice still the quality of image is less in high compression rate. Thus, it shows that there exists a special need for compression of medical images. Therefore, the compression technique must hold the capacity to accommodate the following constraints to achieve better compression ratio, transmission speed and must maintain the image quality. The existing methods only rely either on lossy or lossless means of compression. Those schemes, which are not compromising the above constraints consequently. Therefore the near-lossless compression method may achieve a better compression rate and image quality than the lossy and lossless methods.

Here, we proposed a subband thresholding technique for medical image compression with the help of wavelets, which incorporates the Discrete Wavelet Transform (DWT) for wavelet decomposition and RLE as an entropy encoder to achieve a higher compression ratio. This proposed compression method compromise between the quality and the compression ratio in the decompressed images and hence, it is classified as one of the near lossless compression techniques. And the proposed scheme is analyzed with some existing techniques in terms of lossy and also in lossless compression.

### 4. METHODOLOGY

The working procedure of the proposed method is depicted with the flow diagram given in Figure 1. The steps involved in our proposed method are i) Wavelet decomposition, ii) Separation of coefficients, iii) Thresholding coefficients iv) Encoding sub-bands using RLE and v) Decompression process. Each of these steps is explained in detail in the following sections.

#### A. Wavelet Decomposition

The input medical image is decomposed using wavelet transform to get the significant details and local features.

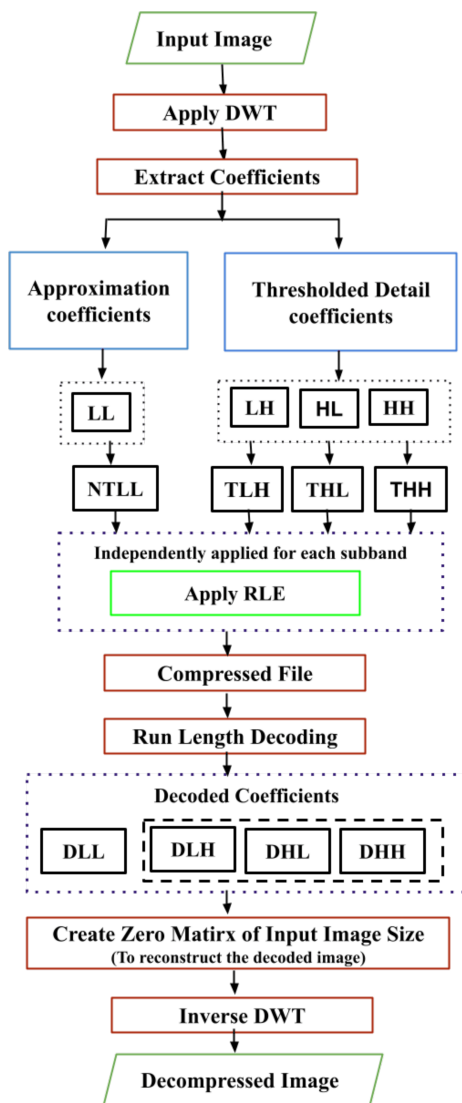


Figure 1. Flow chart of the proposed method

In our method, we performed single level wavelet decomposition by Discrete Wavelet Transform using db1 wavelet. Figure 2 shows the single level decomposition of MRI images. The decomposed approximation and detail subbands are given as an input for the next step of the compression process of medical images

### B. Separation of Coefficients

As a result of wavelet decomposition, we get four subbands LL, LH, HL, and HH from the given input image. From this, we extract the approximation (LL) and detailed coefficients (LH, HL, HH) separately and give them as an input for the next step of proposed compression technique

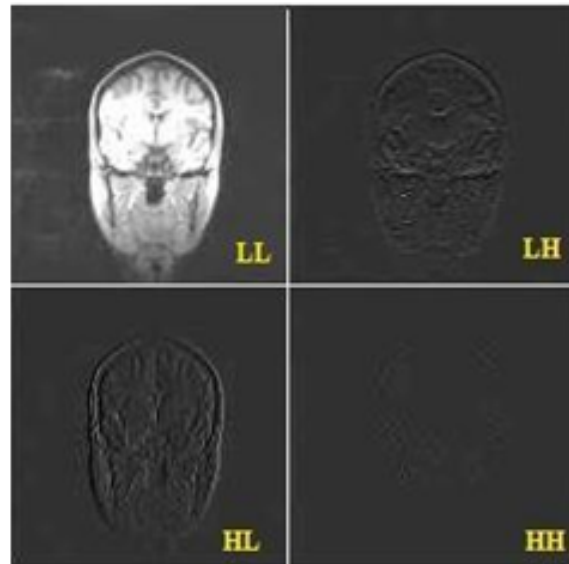


Figure 2. Single Level Wavelet Decomposition

### C. Thresholding Coefficients

Thresholding is a process used to isolate the objects or other relevant information on the image. There are different methods available for calculating threshold. A proper mathematical technique is to be used for computing the threshold value. In the image unwanted noise is present then the calculated threshold value is small. At the same time, high threshold values will disturb the significant values in the image and it leads to loss of image quality. Therefore, the selection of threshold value is very decisive in medical image compression because in medical images every pixel carries important information. In our proposed method, we use thresholding for the purpose of increasing the number of zero coefficients presented on the image is ultimately reduces the size of the image. In our method, the detail coefficients (LH, HL, HH) of the given image alone are applied for thresholding. We did not apply any threshold operation on the approximation coefficient (LL) subband because most of the energy coefficients [22] are isolated in this band, so we keep these coefficients as it is. For the detailed coefficients, we calculate the Standard Deviation (SD) for each subband (LH, HL, HH) separately and set SD as a threshold value. The reason for selecting SD as a threshold is, it is a reliable measure to find the amount of variations in the set of values. Here the coefficients which are all lesser than the threshold are suppressing coefficients and are considered as zero value coefficients. When the number of zero coefficients are increased, it obviously increases the CR of the image. The SD can be calculated using Equation 1 as follows.

$$SD = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n}} \quad (1)$$



Where,  $\bar{x}$  is the mean and it is represented as

$$\bar{x} = \frac{\sum_{i=1}^n (x_i)}{n} \quad (2)$$

#### D. Encoding of Subband using RLE

RLE is a lossless encoding process used to compress the image. Since, the proposed method deals with medical image compression, we applied RLE as an encoding technique. In medical image, every pixel carries significant details and thus, the selection of encoder is very important. In RLE, the encoder transmits only the ordered pair of values which have pixel intensity value and count of each pixel values in the images [19], hence it does not require larger memory to store these two values but at the same time it helps us to increase the compression ratio. In this proposed method, the detailed coefficients which are thresholded are denoted as Threshold-LH band (TLH), Threshold-HL band (THL) and, Threshold-HH band (THH). The significant LL subband coefficient which is not thresholded (NTLL) is transmitted through this encoder. Then, the RLE is applied on each of these subband coefficients (NTLL, TLH, THL, and THH) individually. By doing this we can attain more number of zero coefficients in detail subbands which are used to reduce the memory, at the same time we can preserve the most important details in the significant subband which will maintain the image quality with less information loss achieve the near lossless scenario.

#### E. Decompression

##### 1) Decoding of Subbands

At the receiver side, decompression or RLE decoding is to be performed on each compressed subband file and we get two types of decompressed coefficients namely decoded LL (DLL) band and group of DLH, DHL and DHH decoded detail coefficients.

##### 2) Reconstruction of Decoded Image

After decoding the subbands, we get decoded coefficients as an output. To merge the individual coefficients, we create a zero matrix and map all the subbands on it to get the final decoded image.

#### F. Inverse DWT

In order to obtain the reconstructed image we perform the Inverse DWT (IDWT) on the resultant decoded image.

## 5. EVALUATION PARAMETERS AND DATASETS USED

Performance of the compression method mostly relies on reducing the redundant data from the image. The enactment of compression technique is decided based on two important factors; time and space complexity [1]. In our method, to estimate the performance of compression techniques, we use the following metrics as evaluation parameters.

##### 1) Compression Ratio (CR)

It calculates the ratio between the number of bits in the original image and compressed image is known as Compression Ratio. It is calculated by using the expression

$$CR = \frac{\text{No.ofbitsinoriginalimage}}{\text{Noofbitsforcompressedfile}} \quad (3)$$

##### 2) Compression Percentage

It is used to find the percentage of compression achieved by compression algorithm. It is calculated using the following equation 4.

$$CR(\%) = \left[ 1 - \frac{\text{No.ofbitsinoriginalimage}}{\text{Noofbitsforcompressedfile}} \right] * 100 \quad (4)$$

##### 3) Peak Signal to Noise Ratio

PSNR is one of the image quality measurement metrics. It is calculated as the ratio between the maximum intensity value and error on the image.

$$PSNR = 10 \log_{10} \frac{(2^n - 1)}{\sqrt{MSE}} \quad (5)$$

Where, MSE is obtained using

$$MSE = \frac{1}{MN} \sum_{y=1}^M \sum_{x=1}^N I(x, y) - I'(x, y)^2 \quad (6)$$

Where, M and N represents the size of the image, I represents the given input image and I' represents the reconstructed image

##### 4) Bits Per Pixel (BPP)

Number of bits required to accumulate a single pixel is represented as BPP. It is calculated by using the following equation 7.

$$BPP = \frac{\text{Compressedfilesize}}{\text{Bitdepth}} \quad (7)$$

#### A. Datasets Used

Image compression algorithms are applied for both general purpose images and medical images in different cases. In this work we have focused on compression of 2D medical images of various medical imaging modalities. To assess the performance of our proposed method we have taken images from different online medical image repositories like IBSR (Internet Brain Segmentation Repository) [23] and Radiopaedia [24] and also the images collected by our research team for different research works.

For the evaluation, we have chosen the medical images which are in the size of 256×256 with 8 bit depth. Medical data sets which are used to test our algorithm are taken from each of the following imaging modalities: MRI, CT image, X-ray, PET and US. Figure 3 shows the outcomes of the proposed technique for the selected sample images

from our image dataset, in this figure column 1 is Image ID and column 2 represents the original image used for compression and column 3 represents the decompressed image obtained after the decompression process. Here, the first two images are MRI images, Image ID 3-4 represents the CT images, X-Ray images are depicted with ID of 5 and 6, Image ID 7-8 are PET images, and last two images are UltraSound images. For the evaluation of our proposed method, we compared our method with two Lossless compression techniques such as RLE and Huffman and two Lossy compression techniques Block Truncation Coding (BTC) and JPEG.

Table I demonstrates the results of proposed method with lossless compression methods (RLE and Huffman) in terms of Compression Ratio (CR) and Compression Percentage  $CR\%$ . Thus, proposed method produced CR with an average of 5.67, and it yields 29%, 36% more compression rate than the RLE and Huffman respectively.

The comparison of the proposed method with lossy compression techniques such as, BTC and JPEG in respect of CR, Compression Percentage and PSNR are illustrated in Table II. In BTC, to maintain the medical image quality we have chosen  $2 \times 2$  as a block size for the compression process. It shows that the proposed method outperformed against BTC, at the same time when compared with JPEG, the proposed method has lesser compression rate but it retains the image quality. Because image quality is one of the prominent attributes in the case of medical images. And in terms of CR and PSNR, the PET images achieve a better rate of compression when compared with other modality images.

Figure 3 depicts the performance comparison of the proposed method with lossy and lossless compression methods in terms of compression ratio. It shows that our proposed method yields higher CR than RLE, Huffman and BTC methods, whereas JPEG achieves more CR than the proposed method. It reveals the fact that the performance of our method lies between the lossless and lossy compression techniques. Thus, we claim that our method achieves the property of near lossless compression techniques.

Figure 4 represents the performance comparison of our proposed technique with Lossless and Lossy compression methods in terms of BPP. It shows that our method achieves less BPP when compared with RLE, Huffman, and BTC with an average of 2 bits per pixel. But, the JPEG compression achieves less BPP than the proposed method. When considering the image quality, the proposed method retains the better image quality than the JPEG. In case of compression ratio and image quality the proposed method meets both the constraints.

Figure 5 represents the performance comparison of the proposed technique with lossy compression methods in terms of PSNR

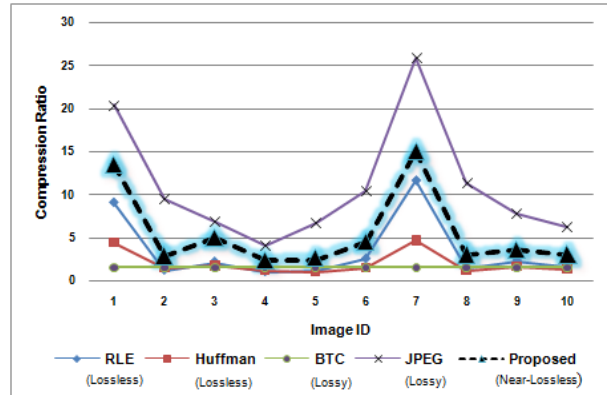


Figure 3. Compression Results of the proposed method with Lossless and Lossy compression methods in terms of CR

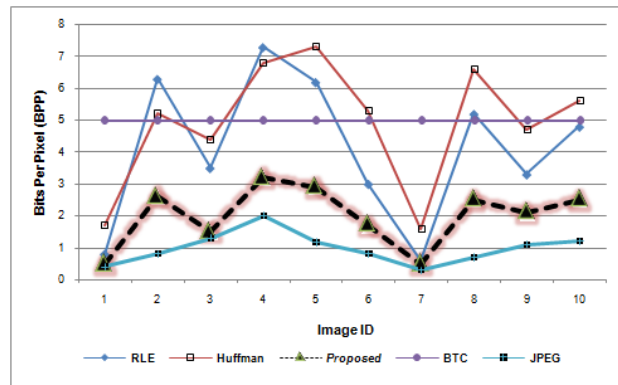


Figure 4. Compression Results of the proposed method with Lossless and Lossy compression methods in terms of BPP

respect to PSNR and it shows that our method gives better PSNR with the average of 42.43 dB against BTC and JPEG.

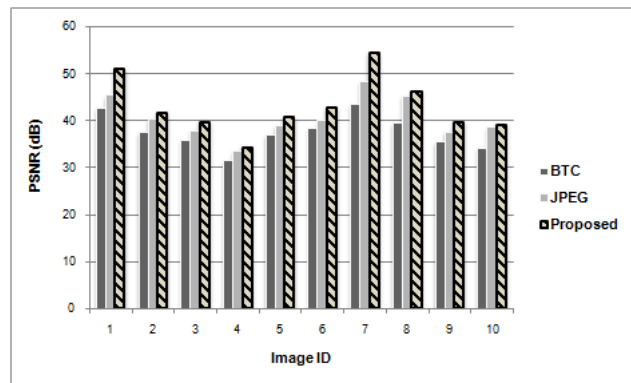


Figure 5. Compression Results of the proposed method with Lossy compression methods in terms of PSNR



TABLE I. COMPARISON OF PROPOSED TECHNIQUE WITH EXISTING LOSSLESS COMPRESSION METHODS

Image ID	RLE	Huffman	Proposed	RLE	Huffman	Proposed
1	9.14	4.54	13.63	89.05	77.97	92.66
2	1.27	1.53	03.01	21.28	34.44	66.82
3	2.24	1.80	05.13	55.46	45.81	80.53
4	1.09	1.17	02.48	08.18	15.21	59.73
5	1.29	1.09	02.73	22.87	08.50	63.35
6	2.59	1.50	04.61	61.50	33.58	78.32
7	11.69	4.80	15.18	91.45	79.17	93.41
8	1.52	1.21	03.17	34.31	17.04	68.45
9	2.36	1.70	03.70	57.77	41.28	73.00
10	1.66	1.41	03.13	40.05	29.57	68.13
Average	3.48	2.07	05.67	48.19	38.25	74.44

TABLE II. COMPARISON OF PROPOSED TECHNIQUE WITH EXISTING LOSSY COMPRESSION METHODS

Image ID	Compression Ratio			Compression Percentage			PSNR		
	BTC	JPEG	Proposed	BTC	JPEG	Proposed	BTC	JPEG	Proposed
1	1.6	20.40	13.63	37.5	95.09	92.66	42.81	45.51	51.10
2	1.6	9.53	3.01	37.5	89.50	66.82	37.60	40.45	41.86
3	1.6	6.89	5.13	37.5	85.48	80.53	35.84	38.04	39.93
4	1.6	4.10	2.48	37.5	75.60	59.73	31.57	33.64	34.46
5	1.6	6.80	2.73	37.5	85.29	63.35	37.12	39.12	40.83
6	1.6	10.45	4.61	37.5	90.43	78.32	38.56	40.33	42.93
7	1.6	25.87	15.18	37.5	96.13	93.41	43.54	48.44	54.64
8	1.6	11.36	3.17	37.5	91.19	68.45	39.66	45.47	46.30
9	1.6	7.87	3.70	37.5	87.29	73.00	35.54	37.73	39.83
10	1.6	6.27	3.13	37.5	84.05	68.13	34.30	38.73	39.32
Average	1.6	10.9	5.6	37.5	88.00	74.44	37.65	40.74	42.43

TABLE III. COMPARISON OF PROPOSED METHOD WITH EXISTING NEAR-LOSSLESS COMPRESSION METHODS

Images	Devadoss et al[25]	Song et al[26]	Sharma et al[21]	Proposed
MRI	34.69	47.31	46.62	51.10
CT	33.97	48.20	38.13	39.93
Ultrasound	38.73	–	–	39.83
X-Ray	40.43	–	–	42.93
PET	–	–	–	54.64

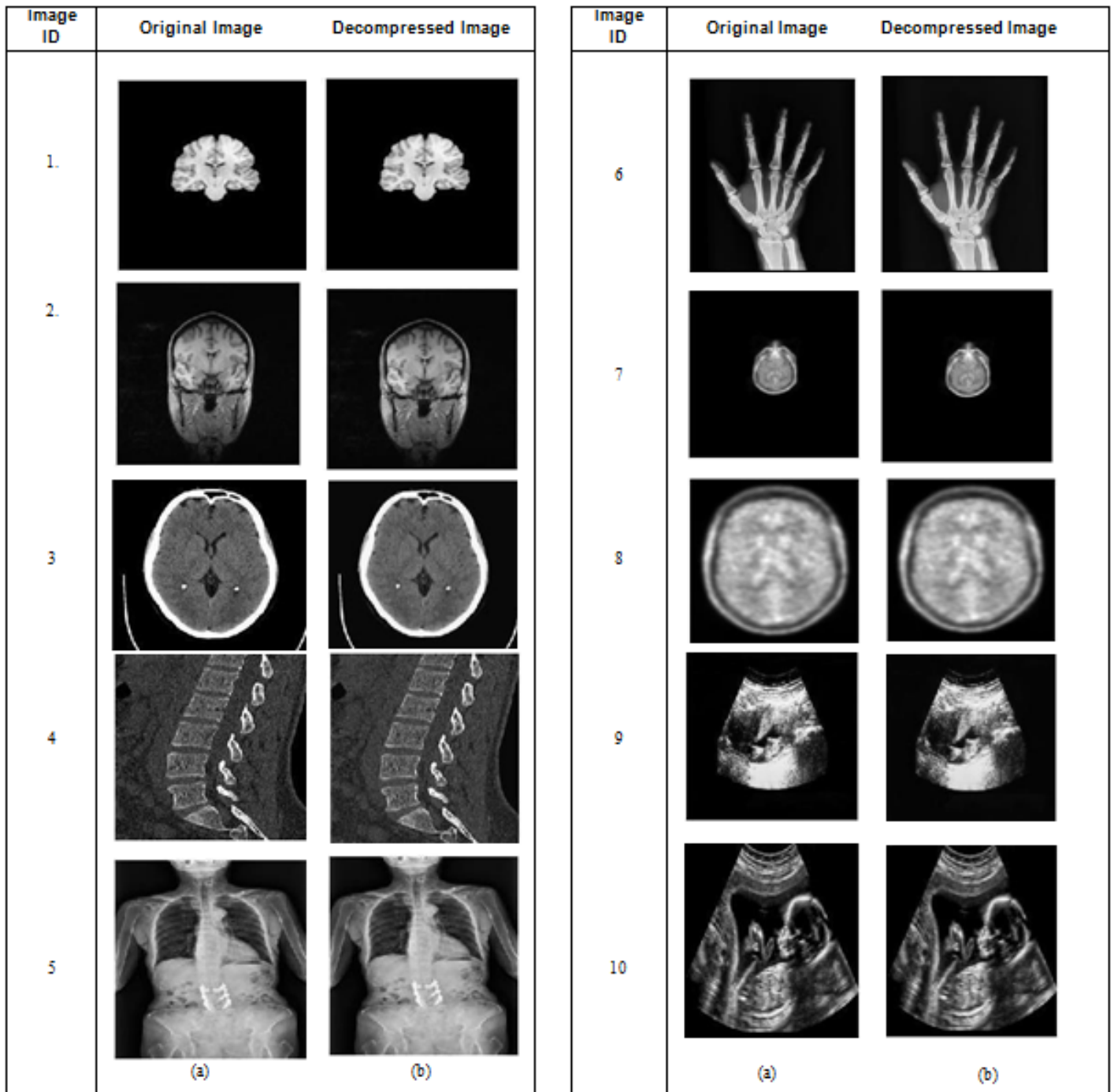


Figure 6. Compression Results of the proposed method: (a) Original Image (b) Decompressed Image



Table III illustrates the comparison of the proposed method with existing near-lossless compression techniques in terms of PSNR. From that we understand that the method achieves better results than the other methods. Moreover the existing methods work only on MRI and CT medical images. But our proposed method also works on other imaging modalities such as Ultrasound, X-Ray, PET etc.,. The limitation of the proposed method is, for CT medical images it gives lesser PSNR than the existing methods.

Figure 6 depicts the results of the compression scheme. Column (a) refers the original image and Column (b) shows the reconstructed image. Figure 7 Shows the average time complexity of the proposed method. When compared with lossless methods RLE and Huffman the proposed methods consume less time and whereas when comparing with lossy JPEG and BTC, it consumes more time. Hence our method consumes a little bit more time but it achieves better image quality than the lossy methods. In the case of medical images we could not compromise the image quality other than the time constraints. Thus, the proposed method lies in between the lossy and lossless methods ensuring the near-lossless scenario in terms of average time complexity also.

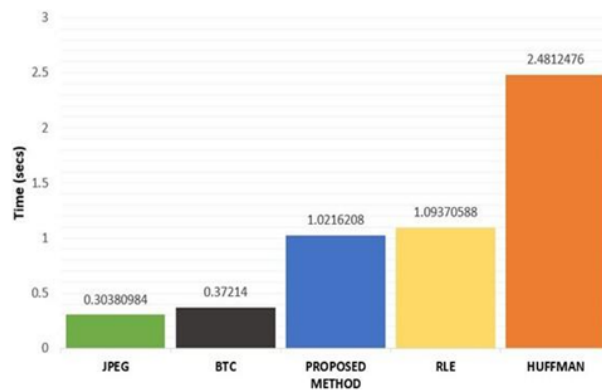


Figure 7. Performance comparison of proposed method with Existing Compression Methods in terms of average Time Complexity

## 6. CONCLUSION AND FUTURE WORK

In the need of medical image compression especially in case of telemedicine services we must have a consideration on both storage and quality. In this article, we developed a wavelet subband based thresholding for medical image compression with the help of RLE lossless encoder. The Lossy method of wavelet and lossless method of RLE makes the working process of our algorithm more efficient and makes our method as near-lossless. From the comparisons, with the existing methods, it is shown that our proposed technique is well performed counter to both lossy and lossless compression techniques in terms of CR, BPP and PSNR. This proposed method satisfies the near-lossless scheme of compression because it gives higher compression ratio than the lossless methods and achieves nearer to original image quality than the lossy methods. It also consumed lesser

time complexity when compared to other existing lossless methods. The execution of this proposed method encourages further development of medical image compression methods on 3D medical images in near-lossless manner with higher compression efficiency and fidelity for telemedicine related applications.

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## REFERENCES

- [1] V. Punitha and P. Kalavathi, "Analysis of file formats and lossless compression techniques for medical images," *International Journal of Scientific Research in Computing*, vol. 2, 2020.
- [2] S. Boopathiraja and P. Kalavathi, "A near lossless multispectral image compression using 3d-dwt with application to landsat images," *Int J Comput Sci Eng*, vol. 6, no. 4, pp. 332–336, 2018.
- [3] M. Hasan and K. Nur, "A lossless image compression technique using location based approach," *International Journal of Scientific Technology Research Volume*, vol. 1, 04 2012.
- [4] S. Boopathiraja, P. Kalavathi, and C. Dhanalakshmi, "Significance of image compression and its upshots-a survey," *Int. J. Sci. Res. Comput. Sci. Eng. Inf. Technol*, vol. 5, no. 2, pp. 1203–1208, 2019.
- [5] S. Saha, "Image compression—from dct to wavelets: A review," *RADS*, vol. 6, no. 3, p. 12–21, mar 2000. [Online]. Available: <https://doi.org/10.1145/331624.331630>
- [6] S. Boopathiraja, V. Punitha, P. Kalavathi, and V. S. Prasath, "Computational 2d and 3d medical image data compression models," *Archives of Computational Methods in Engineering*, vol. 29, no. 2, pp. 975–1007, 2022.
- [7] K. Vidhya, "Medical image compression using adaptive subband threshold," *Journal of Electrical Engineering and Technology*, vol. 2, no. 2, Mar 2016. [Online]. Available: <http://dx.doi.org/10.5370/JEET.2016.11.2.499>
- [8] S. Boopathiraja and P. Kalavathi, "A medical image compression technique using 2d-dwt with run length encoding," *Global Journal of Pure and Applied Mathematics*, vol. 13, pp. 87–96, 09 2017.
- [9] P. Kalavathi and S. Boopathiraja, "A wavelet based image compression with rlc encoder," in *National Conference on Computational Methods, Communication Techniques and Informatics*, 2017, pp. 289–292.
- [10] N. S. A. M. Taujuddin, S. Sari, R. Ibrahim, and S. A. Lashari, "Image compression using wavelet-based thresholding technique for human visual system (hvs) improvement," in *2017 6th International Conference on Electrical Engineering and Informatics (ICEEI)*, 2017, pp. 1–6.
- [11] V. Setia and V. Kumar, "Coding of DWT Coefficients using Run-length Coding and Huffman Coding for the Purpose of Color Image Compression," Feb. 2012. [Online]. Available: <https://doi.org/10.5281/zenodo.1079516>

- [12] R. Sahooinst, S. Roy, and S. S. Chaudhuri, "Haar wavelet transform image compression using various run length encoding schemes," in *Proceedings of the 3rd International Conference on Frontiers of Intelligent Computing: Theory and Applications (FICTA) 2014*. Cham: Springer International Publishing, 2015, pp. 37–42.
- [13] Chithra and Tamilmathi, "Image preservation using wavelet based on kronecker mask, birge - massart and parity strategy." [Online]. Available: <http://dx.doi.org/10.35940/ijitee.K1598.0881119>
- [14] A. A. Mohammed and J. A. Hussein, "Hybrid transform coding scheme for medical image application," in *The 10th IEEE International Symposium on Signal Processing and Information Technology*, 2010, pp. 237–240.
- [15] A. A. Nashat and N. Hussain Hassan, "Image compression based upon wavelet transform and a statistical threshold," in *2016 International Conference on Optoelectronics and Image Processing (ICOIP)*, 2016, pp. 20–24.
- [16] Y.-T. Chen and D.-C. Tseng, "Wavelet-based medical image compression with adaptive prediction," *Computerized Medical Imaging and Graphics*, vol. 31, no. 1, pp. 1–8, 2007. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0895611106001054>
- [17] B. Subramanian, K. Palanisamy, and V. S. Prasath, "On a hybrid lossless compression technique for three-dimensional medical images," *Journal of applied clinical medical physics*, vol. 22, no. 8, pp. 191–203, 2021.
- [18] R. Taujuddin, N. S. A. M. and Ibrahim, "Enhancement of medical image compression by using threshold predicting wavelet-based algorithm," in *Advanced Computer and Communication Engineering Technology*. Cham: Springer International Publishing, 2015, pp. 755–765.
- [19] S. M. Hosseini and A.-R. Naghsh-Nilchi, "Medical ultrasound image compression using contextual vector quantization," *Computers in Biology and Medicine*, vol. 42, no. 7, pp. 743–750, 2012. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0010482512000728>
- [20] J. S. Ashok Ekta Baware and, "Medical image compression using adaptive prediction and block based entropy coding," *International Journal of Computer Applications*, vol. 153, pp. 28–33, 11 2016.
- [21] U. Sharma, M. Sood, and E. Puthooran, "A block adaptive near-lossless compression algorithm for medical image sequences and diagnostic quality assessment," *Journal of Digital Imaging*, vol. 33, 10 2019.
- [22] S. Boopathiraja and P. Kalavathi, "A near lossless three-dimensional medical image compression technique using 3d-discrete wavelet transform," *International Journal of Biomedical Engineering and Technology*, vol. 35, no. 3, pp. 191–206, 2021.
- [23] Ibsr dataset. [Online]. Available: <https://www.nitrc.org/projects/ibsr>, (n.d.).
- [24] Radiopaedia dataset. [Online]. Available: <https://radiopaedia.org/articles/imaging-data-sets>
- [25] P. Chamberlin and S. Balasubramanian, "Near lossless medical image compression using block bwt–mtf and hybrid fractal compression techniques," *Cluster Computing*, vol. 22, 09 2019.
- [26] X. Song, Q. Huang, S. Chang, J. He, and H. Wang, "Novel near-lossless compression algorithm for medical sequence images with adaptive block-based spatial prediction," *Journal of Digital Imaging*, vol. 29, 07 2016.



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