 ISSN : 2230-7109 (Online) | ISSN : 2230-9543 (Print)

# Medical Image Compression using Improved EZW and New Lifting Based Wavelets

[1]A. Hazarathaiah, [2]Dr. B. Prabhakara Rao
[1]Professor, Dept. of ECE, SV College of Engg., Tirupati, INDIA
[2]Rector, JNTUK, Kakinada, INDIA

**Abstract**
Embedded Zerotree Wavelet (EZW) coding was proved to be one of the best schemes for compressing wavelet decomposed image data. The symbols were generated systematically by defining a scanning pattern and predetermined symbols. These symbols are then coded by using any symbol coder. In this paper, the standard EZW algorithm was modified in three ways. First, the HH band of wavelet decomposition was ignored. Second, HH, HL and LH bands are ignored. In third, two newly added symbols are used each for positive and negative coefficients with zerotrees as descendants. These three schemes are used on 'bior4.4' wavelet decomposed data as was done with original EZW algorithm and on new lifting based wavelet decomposed data. The code sequence and outcomes of subordinate passes are presented by taking an example for the standard EZW coding and proposed schemes. The simulation results shows that the proposed algorithms exhibit better results compared to most of the works available in the literature.

**Keywords**
EZW, Wavelet, Compression, Subband, Zerotree

## I. Introduction

Wavelet based image compression schemes prove to be more prominent since the inception of wavelet in one form or other. On the direct spatial form of image data, a number of coding algorithms are proposed in the literature. But the wavelet domain of image data for that matter some kinds of hierarchical tree based representation eases the coding operation as it shifts down all the correlation or redundancy in to a single block. The embedded zerotree wavelet coding [1], proposed in 1993, was modified in a number of works.

Ouafi. A, et. al, proposed a new study to image compression based on the principle of Shapiro's EZW [2]. The proposed EZW distributes entropy differently than Shapiro's and also optimizes the coding. This work has produced results that are a significant improvement on PSNR and compression ratio obtained in standard EZW. Nizar Mohammed Ameen Ahmed et. al, in [3] exploited the main classification rules used in EZW and Modified EZW (MEZW) presented in 2008. The new modification distributes the entropy among eight symbols instead of four in EZW and six in MEZW. Also, the generated symbols are binary regrouped before entropy coding, which is an additional pass implemented in MEZW too. NMEZW Image coding results are compared to those obtained by EZW, MEZW, SPIHT and SPIKE algorithms.

Ganesh D. Bhokare et. al, in [4], extended the standard EZW to M-band wavelet transform. Through this scheme the efficiency of the embedded zero wavelet tree coding, that finds extensive application as a variable bit-rate coder. Aiswarya S, Dr. S. Veni in [5], described the hardware implementation of EZW encoding algorithm along with Huffman encoding and decoding architectures. After performing lifting based DWT technique and EZW algorithm, Huffman coding was used to ensure further compression of the image. In Huffman coding no bit string is a prefix of any other bit string. Hence each code is uniquely decodable. T. Celine Therese Jenny et.al, proposed a vector quantization as a post processing step to reduce the coded file size [6]. Vector Quantization method can reduce redundancy of the image data in order to be able to store or transmit data in an efficient form. It is demonstrated by experimental results that the proposed method outperforms several well-known lossless image compression techniques for still images that contain 256 colors or less.

Venkata Sainath Gupta et.al's [7] deals with the image security along with compression. An algorithm using chaos on EZW compression technique was proposed to provide security along with image compression. The process of providing image security starts with compressing the image using EZW. The output sequence of EZW is converted to 2-D data and on this 2-D data row and column scrambling algorithm based on chaos was applied.

Ktata. S, Mahjoubi. H in [8] evaluated the compression performance and characteristics of zerotree coding compression schemes of ECG applications. Modified EZW and SPIHT algorithms are proposed for compression of ECG data. Both methodologies were evaluated using the percent root mean square difference (PRD) and the Compression Ratio (CR). Theoretical results are contrasted with a simulation study with actual ECG signals from MIT-BIH arrhythmia database. The simulation results show that the both methods achieve a very significant improvement in the performances of compression ratio and error measurement for ECG, as compared with some other compression methods.

Zhang Wei proposed an EZW and Huffman joint encoding algorithm In order to reduce the desired number of digits used in coding [9]. The experimental results shows, compared with the independent EZW algorithm, the joint encoding algorithm can improve the efficiency of image compression and coding. Kancelkis. D, Kančelkis. D proposed a new approach to the analysis of quad-trees in the discrete wavelet spectrum of a digital image [10]. The developed scheme can be applied to any iterative zero-tree based image coding procedure, i.e. to the EZW algorithm, to the SPIHT algorithm, etc. The key point of the proposal - on each iteration, the scheme generates information bitwise variable values for the whole set of quad-tree roots and gathers data on the significance of respective descendants. Exceptionally high-performance of the proposed approach is demonstrated using the EZW algorithm and the reversible Le Gall wavelet transform.

Some of the modifications of EZW, implementations of EZW and similar algorithms and application of EZW and modified EZW in different fields are presented in [11]-[19]. While this paper presents modification of EZW and application of EZW and modification of EZW on the image decomposition using new wavelet proposed. The rest of the paper is organized as follows.

In the next section, new wavelet and the corresponding lifting schemes are presented. In section III, the standard EZW algorithm was present with examples. Section IV presents the modified EZW with an illustrated example. Section V presents the simulation results. Section VI concludes the paper.

## II. New Wavelet & Lifting Scheme

The main intension of this paper is to improve the compression performance of EZW coding algorithm, and it was achieved and implemented on existing traditional wavelets and lifting version of new wavelet proposed in [20-21]. The new wavelet proposed in [20] was described below for convenience. The phi(Φ) and psi(Ψ) functions and the four filters associated with new wavelets are plotted in the fig. 1.

The lifting scheme proposed in [21], was presented here again for convenience.

**Forward Wavelet Transform:**

Split :

$$\lambda_k \leftarrow x(2k),\ \ \gamma_k \leftarrow x(2k+1)$$

Dual Lifting (Predict):

$$\gamma_k \leftarrow \gamma_k + [A_1\, \gamma_{k-1} + A_2\, \gamma_k + A_3\, \gamma_{k+1}]$$

Primal Lifting (Update):

$$\lambda_k \leftarrow \lambda_k + [C_1\, \lambda_{k+1} + C_2\, \lambda_{k+2} + C_3\, \lambda_{k+3}]$$

**Inverse Wavelet Transform:**

Inverse Primal Lifting (Update):

$$\lambda_k \leftarrow \lambda_k - [C_1\, \lambda_{k+1} + C_2\, \lambda_{k+2} + C_3\, \lambda_{k+3}]$$

Inverse Dual Lifting (Predict):

$$\gamma_k \leftarrow \gamma_k + [A_1\, \gamma_{k-1} + A_2\, \gamma_k + A_3\, \gamma_{k+1}]$$

Merge : $x(2k) \leftarrow \lambda_k$

$x(2k+1) \leftarrow \gamma_k$

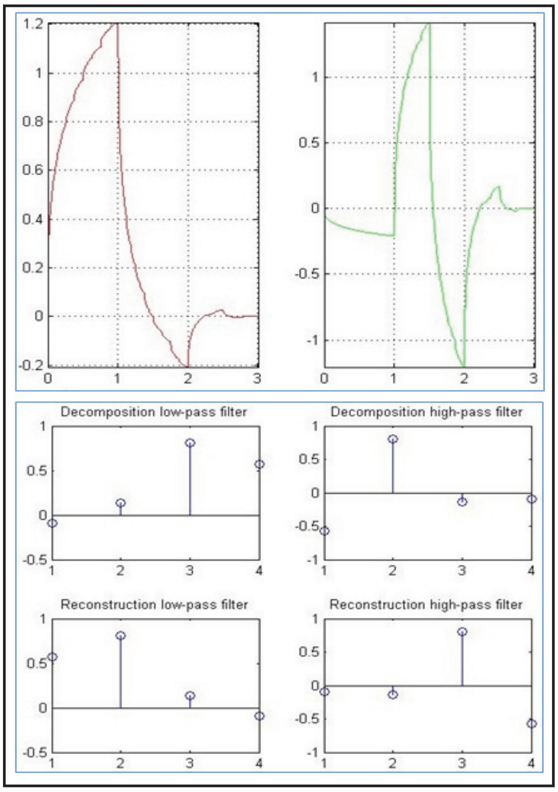


Fig. 1: Phi, Psi Functions and Filter Banks Associated With New Wavelet

Refer [21] for the details of the constants $A_1$, $A_2$, $A_3$, $C_1$, $C_2$, and $C_3$.

## III. EZW

The embedded zerotree wavelet coding was impressed by the properties of subband coding of wavelet transform. The wavelet transformed coefficients will have less energy as the decomposition level increases. But as the decomposition level increases the complexity associated with working with minute details increases. The transmission of wavelet coefficients, some form of generic coding of raw data as well as subband coefficients through the channel was considered in a number of previous works.

If the value of the coefficient is equal to that of its neighbor, it is said to possess a property by on which a coding scheme may be developed, as is a Run-length coding. But, if the run value is zero or insignificant and if a mechanism to intimate that a coefficient is insignificant or vice versa then it is possible to reduce the cost of transmission of the image data. At times the message of insignificant map or significant map may be higher than the data itself. The embedded zerotree wavelet coding was designed to track the significant map by using a hierarchical structure. The EZW uses the wavelet domain data of an image, a scanning pattern and an algorithm which designate a particular coefficient as either significant or not. In this paper the wavelet domain was obtained from different kinds of wavelets as mentioned previously. The scanning pattern is shown in fig. 2 below.

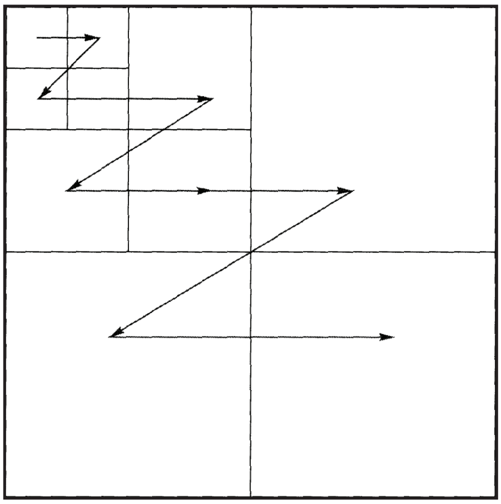

Fig. 2: Scanning Pattern in EZW

The coefficients are related in a hierarchical manner and a coefficient is designated as root, and some coefficients are designated as descendants or children of the root as shown in the fig. 3. As shown in the fig. 3, $a_1$, $a_2$ and $a_3$ are the children of a. $a_{11}$, $a_{12}$, $a_{13}$ and $a_{14}$ are the children of $a_1$ and so on. As shown in the scanning pattern, the children will be scanned only after their root was scanned. It is also assumed that all the children of a root will have lesser value than that of root. Based on the values of the wavelet coefficients a threshold will be defined. Then, based on this threshold the coefficients will be verified and coded as and when required according to the following algorithm. First, a coefficient (beginning from the top leftmost coefficient as shown in the scanning pattern) will be compared with the threshold.

If the coefficient is significant with respect to the threshold in that iteration, based on the sign of the coefficient, a positive/negative (p/n) symbol will be coded. On the other hand, if the coefficient is insignificant with respect to the threshold, then it will be verified whether it is a descendant from a zerotree root. If it is so, then the coefficient will not be coded with any symbol, otherwise the descendants of this coefficient will be compared against the threshold. If all the descendants are insignificant then a zerotree root symbol will be coded for the coefficient. Otherwise, an isolated symbol will be coded for the coefficient. Likewise all the coefficients will be scanned according to the scanning pattern and will be coded. This process is called dominant pass (because it is the first pass, it is called first dominant pass). Following the dominant pass is a subordinate pass. In the subordinate pass will refine the magnitudes and makes the coefficient chart ready for second dominant pass. Following example gives better idea of EZW. Consider the wavelet decomposition shown in fig. 4.

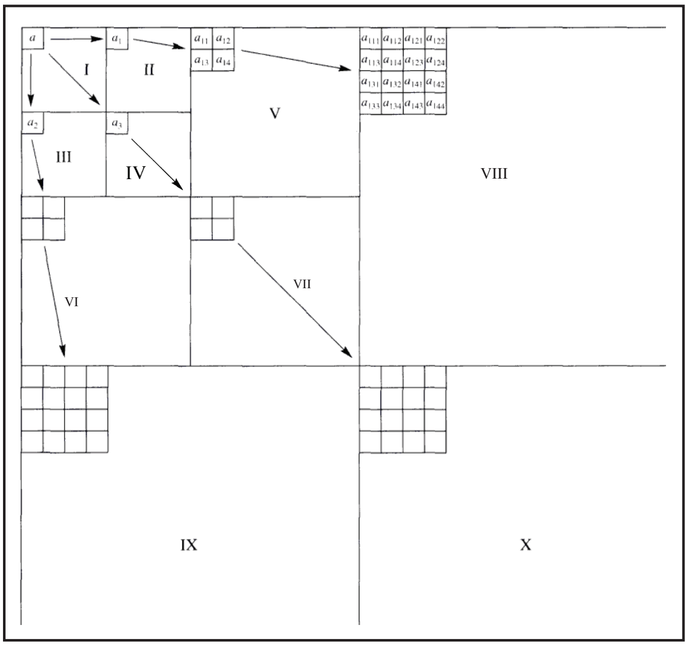


Fig. 3: Hierarchical relation among the wavelet coefficients in a 10 – band wavelet decomposition

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 59 | -26 | 36 | 17 | 5 | 13 | -12 | 7 |
| 15 | 33 | 12 | -16 | 3 | 4 | 6 | -1 |
| 16 | 17 | 13 | -16 | 8 | 17 | -3 | 5 |
| -7 | 3 | -14 | 18 | 14 | 2 | -3 | 21 |
| -2 | -3 | -6 | 7 | 56 | 17 | -3 | 6 |
| -5 | 3 | 4 | 8 | 6 | 3 | 8 | 6 |
| 21 | -39 | 7 | -6 | 3 | 9 | 8 | -2 |
| -3 | 8 | 6 | -6 | 2 | -2 | -8 | 5 |

Fig. 4: Sample Wavelet Decomposition

The initial threshold is 32. The codes allotted to the image data with different thresholds in different passes is given in the table 1 [22].

Table 1: Results of Dominant Pass

| T | Codes |
|---|---|
| 32 | pzzppttttztztttttttttnttpttt |
| 16 | znzztpznppztzntpttttpttttptttttttttpttttpttttttttt |
| 8 | zzpzzzpttzztpznztpttntttptpttttptttptttttpttpttptnt |
| 4 | zzzzzztzzznzzztzpttptppttptttntnppttttpnpnttp ttptpttp |
| 2 | zzzzztzzztzpzzzzttpttttpntntnntpttnttttttttpntttpt pntntt |
| 1 | zztttzttttn |

Results of subordinate passes are shown in figure 5. In the standard EZW coding scheme, adaptive arithmetic coding was used to code the coded symbols. This is because the symbol sequence may have redundancy.

## IV. Modified EZW

The EZW can be improved (or modified) by incorporating some modification in the standard algorithm. First consider the value of threshold. The initial threshold was calculated based on the initial wavelet coefficients of the input image. In the subsequent dominant passes, the threshold was simply factored by 2 and not considered the remaining coefficients in the decomposition.

If one considers the present (remaining) coefficients and then evaluate the new threshold, it better quantizes and approximates the coefficient values. The convergence rate will also be higher. But a question arises. How the decoder knows the threshold value? To inform the new threshold value every time some bits need to be spent. In [1], it was already mentioned that factoring by 3 may give better results. However it is observed that for different initial thresholds, the compression results are different. Also, if the threshold value is less then, in the application of compressing images, high quality is obtained and at higher initial thresholds, high compression was achieved. If it is possible to reduce the number of codes generated in the dominant pass without losing much of the image information then the memory required can be reduced drastically.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 48 | 0 | 32 | 0 | 0 | 0 | 0 | 0 |
| 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | -32 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 56 | -24 | 32 | 16 | 0 | 0 | 0 | 0 |
| 0 | 32 | 0 | -16 | 0 | 0 | 0 | 0 |
| 16 | 16 | 0 | -16 | 0 | 16 | 0 | 0 |
| 0 | 0 | 0 | 16 | 0 | 0 | 0 | 16 |
| 0 | 0 | 0 | 0 | 56 | 16 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | -32 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 56 | -24 | 32 | 16 | 0 | 12 | -12 | 0 |
| 12 | 32 | 12 | -16 | 0 | 0 | 0 | 0 |
| 16 | 16 | 12 | -16 | 8 | 16 | 0 | 0 |
| 0 | 0 | -12 | 16 | 12 | 0 | 0 | 20 |
| 0 | 0 | 0 | 0 | 56 | 16 | 0 | 0 |
| 0 | 0 | 0 | 8 | 0 | 0 | 8 | 0 |
| 20 | -36 | 0 | 0 | 0 | 8 | 8 | 0 |
| 0 | 8 | 0 | 0 | 0 | 0 | -8 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 58 | -26 | 36 | 16 | 4 | 12 | -12 | 6 |
| 14 | 32 | 12 | -16 | 0 | 4 | 6 | 0 |
| 16 | 16 | 12 | -16 | 8 | 16 | 0 | 4 |
| -6 | 0 | -14 | 18 | 14 | 0 | 0 | 20 |
| 0 | 0 | -6 | 6 | 56 | 16 | 0 | 6 |
| -4 | 0 | 4 | 8 | 6 | 0 | 8 | 6 |
| 20 | -38 | 6 | -6 | 0 | 8 | 8 | 0 |
| 0 | 8 | 6 | -6 | 0 | 0 | -8 | 4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 59 | -26 | 36 | 17 | 5 | 13 | -12 | 7 |
| 15 | 33 | 12 | -16 | 3 | 4 | 6 | 0 |
| 16 | 17 | 13 | -16 | 8 | 17 | -3 | 5 |
| -7 | 3 | -14 | 18 | 14 | 2 | -3 | 21 |
| -2 | -3 | -6 | 7 | 56 | 17 | -3 | 6 |
| -5 | 3 | 4 | 8 | 6 | 3 | 8 | 6 |
| 21 | -39 | 7 | -6 | 3 | 9 | 8 | -2 |
| -3 | 8 | 6 | -6 | 2 | -2 | -8 | 5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 59 | -26 | 36 | 17 | 5 | 13 | -12 | 7 |
| 15 | 33 | 12 | -16 | 3 | 4 | 6 | -1 |
| 16 | 17 | 13 | -16 | 8 | 17 | -3 | 5 |
| -7 | 3 | -14 | 18 | 14 | 2 | -3 | 21 |
| -2 | -3 | -6 | 7 | 56 | 17 | -3 | 6 |
| -5 | 3 | 4 | 8 | 6 | 3 | 8 | 6 |
| 21 | -39 | 7 | -6 | 3 | 9 | 8 | -2 |
| -3 | 8 | 6 | -6 | 2 | -2 | -8 | 5 |

Fig. 5: Results of Subordinate Passes of Standard EZW

The wavelet transformation performs subband coding by splitting the signal/image into different bands. The LL band is said to contain the maximum of image data, while the HH band is said to have no or very less image data. The plan here is to check the number of the codes generated if the HH band was nullified or ignored.

The following example gives more information regarding the application of the above said plan. Consider the same example as it was considered in the previous section. But make the HH band coefficients a zero. The resulting set of coefficients is given in fig. 6, the codes allotted to the coefficients are given in Table 2 and the results of subordinate passes are given in fig. 7.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 59 | -26 | 36 | 17 | 5 | 13 | -12 | 7 |
| 15 | 33 | 12 | -16 | 3 | 4 | 6 | -1 |
| 16 | 17 | 13 | -16 | 8 | 17 | -3 | 5 |
| -7 | 3 | -14 | 18 | 14 | 2 | -3 | 21 |
| -2 | -3 | -6 | 7 | 0 | 0 | 0 | 0 |
| -5 | 3 | 4 | 8 | 0 | 0 | 0 | 0 |
| 21 | -39 | 7 | -6 | 0 | 0 | 0 | 0 |
| -3 | 8 | 6 | -6 | 0 | 0 | 0 | 0 |

Fig. 6: The Wavelet Decomposition With HH Nullified

Table 2: Results of Dominant Pass in Technique 1

| T | Codes |
|---|---|
| 32 | pzzppttttztttttttttttntt |
| 16 | znzztpznppzttntpttttptttttpttttttttptttttttttt |
| 8 | zzpzzzpttzztptnttpttntttptptttptttpttttttt |
| 4 | zzztzztzzznzpttptppttpttttntnpptttttpnpn |
| 2 | zzztztzzztzpttpttttpntntnntpttnttttt |
| 1 | zztttzttttn |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 48 | 0 | 32 | 0 | 0 | 0 | 0 | 0 |
| 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | -32 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 56 | -24 | 32 | 16 | 0 | 0 | 0 | 0 |
| 0 | 32 | 0 | -16 | 0 | 0 | 0 | 0 |
| 16 | 16 | 0 | -16 | 0 | 16 | 0 | 0 |
| 0 | 0 | 0 | 16 | 0 | 0 | 0 | 16 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | -32 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 56 | -24 | 36 | 16 | 0 | 12 | -12 | 0 |
| 12 | 32 | 12 | -16 | 0 | 0 | 0 | 0 |
| 16 | 16 | 12 | -16 | 8 | 16 | 0 | 0 |
| 0 | 0 | -12 | 16 | 12 | 0 | 0 | 20 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 |
| 20 | -36 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 58 | -26 | 36 | 16 | 4 | 12 | -12 | 6 |
| 14 | 32 | 12 | -16 | 0 | 4 | 6 | 0 |
| 16 | 16 | 12 | -16 | 8 | 16 | 0 | 4 |
| -6 | 0 | -14 | 18 | 14 | 0 | 0 | 20 |
| 0 | 0 | -6 | 6 | 0 | 0 | 0 | 0 |
| -4 | 0 | 4 | 8 | 0 | 0 | 0 | 0 |
| 20 | -38 | 6 | -6 | 0 | 0 | 0 | 0 |
| 0 | 8 | 6 | -6 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 59 | -26 | 36 | 17 | 5 | 13 | -12 | 7 |
| 15 | 33 | 12 | -16 | 3 | 4 | 6 | 0 |
| 16 | 17 | 13 | -16 | 8 | 17 | -3 | 5 |
| -7 | 3 | -14 | 18 | 14 | 2 | -3 | 21 |
| -2 | -3 | -6 | 7 | 0 | 0 | 0 | 0 |
| -5 | 3 | 4 | 8 | 0 | 0 | 0 | 0 |
| 21 | -39 | 7 | -6 | 0 | 0 | 0 | 0 |
| -3 | 8 | 6 | -6 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 59 | -26 | 36 | 17 | 5 | 13 | -12 | 7 |
| 15 | 33 | 12 | -16 | 3 | 4 | 6 | -1 |
| 16 | 17 | 13 | -16 | 8 | 17 | -3 | 5 |
| -7 | 3 | -14 | 18 | 14 | 2 | -3 | 21 |
| -2 | -3 | -6 | 7 | 0 | 0 | 0 | 0 |
| -5 | 3 | 4 | 8 | 0 | 0 | 0 | 0 |
| 21 | -39 | 7 | -6 | 0 | 0 | 0 | 0 |
| -3 | 8 | 6 | -6 | 0 | 0 | 0 | 0 |

Fig. 7: Results of Subordinate Passes of Technique-1

In wavelet based image watermarking schemes, the watermark will be somehow embedded into HH band ass it contains almost no useful data in reconstruction. The above technique is analogous to these. In watermarking field, in recent times, a number of works are being carried out on finding the subband with less useful information. It has also been established that, in cases, the HL/LH bands will have less information than HH band. Consequently, if all these three subbands are ignored, then the length of the coding sequence will be less giving high compression ratio at the cost of quality. This technique was extended for the above example. Fig. 8 gives the wavelet coefficients with HH=HL=LH=0, table 3 shows the coding sequence which is the outcome of dominant passes and fig. 9 shows the results of subordinate passes.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 59 | -26 | 36 | 17 | 0 | 0 | 0 | 0 |
| 15 | 33 | 12 | -16 | 0 | 0 | 0 | 0 |
| 16 | 17 | 13 | -16 | 0 | 0 | 0 | 0 |
| -7 | 3 | -14 | 18 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Fig. 8: The Wavelet Decomposition With HH, HL and LH Nullified

Table 3: Results of Dominant Pass in Technique 2

| T | Codes |
|---|---|
| 32 | pztppttttttttt |
| 16 | znzztptnppttntptttttttttttttttttttttt |
| 8 | zzpzttpttttptnttttttttttt |
| 4 | ztztttnttttt |
| 2 | ztzttttptttt |
| 1 | zttt |

In the above two techniques, in addition to reducing the number of codes in coding sequence, the pattern of the sequence is also very much suitable for run length or adaptive arithmetic coder, for that matter, for any coder. From Table 3, one can observe that the length of the sequences is very less compared to that of standard EZW scheme. In the standard EZW scheme, a total of four codes are used, a positive significant (p), a negative significant (n), an isolated zero (z) and a zerotree root (t). To code these four codes a maximum of 2 bits are required. In the coefficient map there exists isolated zerotrees also. If one tries to code these separately, the length of the tree has to be informed because significant coefficients may follow the tree. This isolated zerotree will consume one extra code also.

As mentioned in [1], two additional symbols, each for significant positive and negative but with zerotree following. If these two new symbols are added, once say a positive significant coefficient is found then it may be coded as either 'p' or '$\tilde{p}$', 'p' indicating a positive significant with either a significant or isolated zero following and '$\tilde{p}$' indicating a zerotree following. This kind of coding is somehow analogous to piggybacking of computer networks whereby the information related to the following zerotree is embedded in the present significant coefficient's code itself. It may appear at first look that the number of different codes increases. Yes, but the number of bits to represent will not increase as one may use entropy coding as is the case with the present work. But in practice it was identified, when used along with the above two techniques, that the effect of these new codes are not that much significant because the appearance of zerotrees is more, but the effect is countable on the standard wavelet decompositions. These three techniques are implemented and the simulation results are presented in the next section.

ISSN : 2230-7109 (Online) | ISSN : 2230-9543 (Print)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 48 | 0 | 32 | 0 | 0 | 0 | 0 | 0 |
| 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 56 | -24 | 32 | 16 | 0 | 0 | 0 | 0 |
| 0 | 32 | 0 | -16 | 0 | 0 | 0 | 0 |
| 16 | 16 | 0 | -16 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 56 | -24 | 36 | 16 | 0 | 0 | 0 | 0 |
| 12 | 32 | 12 | -16 | 0 | 0 | 0 | 0 |
| 16 | 16 | 12 | -16 | 0 | 0 | 0 | 0 |
| 0 | 0 | -12 | 16 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 58 | -24 | 36 | 16 | 0 | 0 | 0 | 0 |
| 14 | 32 | 12 | -16 | 0 | 0 | 0 | 0 |
| 16 | 16 | 12 | -16 | 0 | 0 | 0 | 0 |
| -6 | 0 | -14 | 18 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 59 | -26 | 36 | 17 | 0 | 0 | 0 | 0 |
| 15 | 33 | 12 | -16 | 0 | 0 | 0 | 0 |
| 16 | 17 | 13 | -16 | 0 | 0 | 0 | 0 |
| -7 | 3 | -14 | 18 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 59 | -26 | 36 | 17 | 0 | 0 | 0 | 0 |
| 15 | 33 | 12 | -16 | 0 | 0 | 0 | 0 |
| 16 | 17 | 13 | -16 | 0 | 0 | 0 | 0 |
| -7 | 3 | -14 | 18 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Fig. 9: Results of Subordinate Passes of Technique-2

## V. Results & Discussion

For comparison, consider the tables IV and V, which give the compression performance of various techniques on 'HeartCT2' image. At the threshold of 10, the standard EZW with 'bior4.4' wavelet produces a PSNR of 28.58dB with compression ratio of 7.14bpp. The same standard EZW with new wavelet produces a PSNR of 30.38dB with a compression ratio of 6.61bpp. The technique-1 with 'bior4.4' wavelet produces 28.69dB of PSNR and 7.48bpp of compression ratio. While with new wavelet, the technique-1 produces 30.16dB of PSNR and 7.02bpp of compression ratio. The technique-2 with 'bior4.4' wavelet produces 30.45dB of PSNR and 10bpp of compression ratio. While with new wavelet, the technique-2 produces 29.06dB of PSNR and 10bpp of compression ratio. The technique-3 with 'bior4.4' wavelet along with technique-2 produces 31.73dB of PNSR at 10bpp of compression ratio, while with new wavelet these are 44.45dB at 10bpp.

Table 4: Simulation Results of all the Techniques on 'HeartCT2' Image

| Threshold | EZW, Technique 1 and 2 with 'bior4.4' | | | | | | Technique 3 with 'bior4.4' | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Normal (EZW)** | | **HH=0** | | **HH=HL=LH=0** | | **Normal** | | **HH=0** | | **HH=HL=LH=0** | |
| | **CR** | **PSNR** | **CR** | **PSNR** | **CR** | **PSNR** | **CR** | **PSNR** | **CR** | **PSNR** | **CR** | **PSNR** |
| 10 | 7.14 | 28.58 | 7.48 | 28.69 | 10.00 | 30.45 | 7.14 | 29.37 | 7.48 | 29.50 | 10.00 | 31.73 |
| 20 | 16.00 | 28.72 | 16.00 | 28.74 | 18.60 | 29.44 | 16.00 | 29.53 | 16.00 | 29.56 | 18.60 | 30.42 |
| 30 | 16.00 | 28.72 | 16.00 | 28.74 | 18.60 | 29.44 | 16.00 | 29.53 | 16.00 | 29.56 | 18.60 | 30.42 |
| 40 | 44.44 | 27.54 | 44.44 | 27.54 | 47.06 | 27.46 | 44.44 | 28.15 | 44.44 | 28.15 | 47.06 | 28.06 |
| 50 | 44.44 | 27.54 | 44.44 | 27.54 | 47.06 | 27.46 | 44.44 | 28.15 | 44.44 | 28.15 | 47.06 | 28.06 |
| 75 | 133 | 25.14 | 133 | 25.14 | 133 | 25.14 | 133 | 25.48 | 133 | 25.48 | 133 | 25.48 |
| 100 | 133 | 25.14 | 133 | 25.14 | 133 | 25.14 | 133 | 25.48 | 133 | 25.48 | 133 | 25.48 |
| 200 | 400 | 23.09 | 400 | 23.09 | 400 | 23.09 | 400 | 23.30 | 400 | 23.30 | 400 | 23.30 |
| 300 | 800 | 21.13 | 800 | 21.13 | 800 | 21.13 | 800 | 21.26 | 800 | 21.26 | 800 | 21.26 |

Table 5: Simulation Results of all the Techniques on 'HeartCT2' image (Contd..)

| **Threshold** | EZW, Technique 1 and 2 with new wavelet | | | | | | Technique 3 with new wavelet | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Normal** | | **HH=0** | | **HH=HL=LH=0** | | **Normal** | | **HH=0** | | **HH=HL=LH=0** | |
| | **CR** | **PSNR** | **CR** | **PSNR** | **CR** | **PSNR** | **CR** | **PSNR** | **CR** | **PSNR** | **CR** | **PSNR** |
| 10 | 6.61 | 30.38 | 7.02 | 30.16 | 10 | 29.06 | 6.61 | 44.26 | 7.02 | 44.41 | 10.00 | 44.45 |
| 20 | 14.55 | 29.97 | 14.81 | 29.91 | 18 | 29.89 | 14.55 | 42.72 | 14.81 | 46.79 | 18.18 | 36.01 |
| 30 | 14.55 | 29.97 | 14.81 | 29.91 | 18 | 29.89 | 14.55 | 42.72 | 14.81 | 46.79 | 18.18 | 36.01 |
| 40 | 38.10 | 33.46 | 38.10 | 33.43 | 40 | 33.71 | 38.10 | 32.99 | 38.10 | 32.63 | 40 | 30.7 |
| 50 | 38.10 | 33.46 | 38.10 | 33.43 | 40 | 33.71 | 38.10 | 32.99 | 38.10 | 32.63 | 40 | 30.7 |
| 75 | 100 | 31.43 | 100 | 31.43 | 100 | 31.43 | 100 | 27.76 | 100 | 27.65 | 100 | 27 |
| 100 | 100 | 31.43 | 100 | 31.43 | 100 | 31.43 | 100 | 27.76 | 100 | 27.65 | 100 | 27 |
| 200 | 267 | 25.94 | 267 | 25.94 | 267 | 25.94 | 267 | 24.56 | 267 | 24.50 | 267 | 24.18 |
| 300 | 800 | 22.63 | 800 | 22.63 | 800 | 22.63 | 800 | 21.93 | 800 | 21.90 | 800 | 21.72 |

Table 6: Average CR and PSNR Values with SPIHT Coding with Different Medical Images [21]

| | CR | PSNR |
|---|---|---|
| **Haar** | 3.62 | 23.10 |
| **Daubechies** | 3.48 | 23.74 |
| **Biorthogonal** | 3.53 | 24.07 |
| **Demeyer** | 2.12 | 23.77 |
| **Coiflet** | 3.20 | 40.00 |
| **Symlet** | 3.57 | 23.70 |
| **NewWa1** | 2.88 | 34.73 |
| **NewWa2** | 3.32 | 25.83 |
| **NewWa3** | 2.88 | 34.68 |
| **NewWa4** | 2.70 | 30.88 |

For a comparison, table VI shows the average Compression ratio and PSNR values when SPIHT coding used on different medical images [21].

## VI. Conclusion

The paper presents the modified EZW and applied on existing and new lifting based wavelets. The wavelet decomposition transforms the image raw data to a structured manner by dividing into a number of subbands. The decomposition is usually iterative. The wavelet decomposition first divides the data into two bands, then again decomposes one of the bands into two more bands and continues in the same manner. The resulting structure will perfectly reconstructs the original image. But the left over bands in early stages will involve only a part in the reconstruction process and in the EZW coding these subbands incurs same computational complexity as the useful bands. Hence, in this paper these insignificant bands are neglected. Secondly, two more symbols are used in addition to the four symbols originally used in standard EZW. Because of the property of wavelet decomposition and ignoring some of the bands the total number of symbols produced was reduced by a significant margin. Along with this, the usage of entropy coding has compensated the extra symbol burden. The simulation results show that these techniques outperform all the existing techniques.

## References


[1] Shapiro J.M.,"Embedded image coding using zerotrees of wavelet coefficients", IEEE Trans. Signal Proc., Vol. 41, No. 12, pp. 3445–3462, 1993.

[2] Ouafi A, Z.E.Baarir, A Taleb Ahmed, N. Doghmane,"A new approach based on Shapiro's Embedded Zerotree Wavelet (EZW) Algorithm for Image Compression", Asian Journal of Information Technology 5(8): 893-900, 2006.

[3] Nizar Mohammed Ameen Ahmed, Adnan Mohsin Abdulazeez Brifcani, "A New Modified Embedded Zerotree Wavelet Approach for Image Coding (NMEZW)", International Journal Of Scientific & Engineering Research, Volume 4, Issue 9, September-2013.

[4] Ganesh D. Bhokare, Raghuram J Karthik, Vikram M. Gadre, "Modified EZW Coding For The M-Band Wavelet Transform and its Application to Image Compression", IEEE, 2005.

[5] Aiswarya S, Dr. S. Veni, "Hardware Implementation of EZW based Image Compression with Huffman coding", International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 5, September 2013.

[6] T. Celine Therese Jenny, G. MuthuLakshmi, "A Modified Embedded Zero-Tree Wavelet Method for Medical Image Compression", ICTACT Journal on Image and Video Processing, November 2010, Issue: 02.

[7] Venkata Sainath Gupta, T. Naveen, C., Satpute, V.R., Gandhi, A.S., "Image security using chaos and EZW compression", 2014 Students Conference on Engineering and Systems (SCES), pp. 1 – 6, 28-30 May 2014.

[8] Ktata. S, Mahjoubi. H, "A zerotree coding for compression of ECG signal using EZW and SPIHT", IECON 2012 - 38th Annual Conference on IEEE Industrial Electronics Society, pp. 1458 – 1464, 25-28 Oct. 2012.

[9] Zhang Wei, "An Improved Image Encoding Algorithm Based on EZW and Huffman Joint Encoding", 2014 Ninth International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC), , pp. 217 – 220, 8-10 Nov. 2014.

[10] Kancelkis. D, Kančelkis. D, "A new approch to quad-tree analysis in EZW algorithm", 2012 19th International Conference on Systems, Signals and Image Processing (IWSSIP), pp. 600 – 603, 11-13 April 2012.

[11] Singh, R, Srivastava V.K., "Performance comparison of arithmetic and Huffman coder applied to EZW codec", 2012 2nd International Conference on Power, Control and Embedded Systems (ICPCES), pp. 1 – 6, 17-19 Dec. 2012.

[12] Pooja. B, Kulkami. P, Sneha. J, Madhuri. K.L., "Comparison of algorithms for image compression", 3rd International Conference on Advances in Recent Technologies in Communication and Computing (ARTCom 2011), pp. 259 – 261, 14-15 Nov. 2011.

[13] Strahl. S, Hansen. H, Mertins. A, "A Dynamic Fine-Grain Scalable Compression Scheme With Application to Progressive Audio Coding", IEEE Transactions on Audio, Speech, and Language Processing, Vol.19, Iss.1, pp. 14 – 23, Jan. 2011.

[14] Dehkordi V.R, Daou H, Labeau. F, "A Channel Differential EZW Coding Scheme for EEG Data Compression", IEEE Transactions on Information Technology in Biomedicine, Vol. 15, Iss. 6, pp. 831 – 838, Nov. 2011.

[15] Kai-jen Cheng, Dill. J, "Lossless to Lossy Dual-Tree BEZW Compression for Hyperspectral Images", IEEE Transactions on Geoscience and Remote Sensing, Vol. 52, Iss. 9, pp. 5765 – 5770, Sept. 2014.

[16] Chopra G., Pal A.K, "An Improved Image Compression Algorithm Using Binary Space Partition Scheme and Geometric Wavelets", IEEE Transactions on Image Processing, Vol. 20, Iss.1, pp. 270 – 275, Jan. 2011.

[17] Strahl S, Hansen H, Mertins. A, "A Dynamic Fine-Grain Scalable Compression Scheme With Application to Progressive Audio Coding", IEEE Transactions on Audio, Speech, and Language Processing, Vol. 19, Iss. 1, pp. 14 – 23, Jan. 2011.

[18] Janaki. R, Dr.Tamilarasi.A, "Visually Improved Image Compression by using Embedded Zero-tree Wavelet Coding", IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 2, March 2011.

[19] Janaki. R, Dr.Tamilarasi.A, "Still Image Compression by Combining EZW Encoding with Huffman Encoder", International Journal of Computer Application), Volume 13– No.7, January 2011.

[20] A. Hazarathaiah, Dr.B. PrabhakaRao, "A Novel Medical Image Compression using New Traditional Orthogonal Wavelets", CiiT International Journal on Digital Image Processing, Vol 5, No 11, 2013.
[21] A. Hazarathaiah, Dr.B. Prabhaka Rao, "Nonlinear Lifting based New Wavelet Transforms for Improved Medical Image Compression", International Journal of Scientific & Engineering Research, Volume 5, Issue 7, July-2014.
[22] Clemens Valen, [Online] Available: http://polyvalens.pagesperso-orange.fr/clemens/clemens.html

A. Hazarathaiah received Engineering Graduation from Institution of Engineers, Kolkatta. He received Master Degree M.Tech (Instrumentation and Control) from JNT University, Kakinada, Andrapradesh in the year 2005. Currently he is pursuing Ph.D in JNTU, Kakinada. He has more than 15 years teaching Experience. Presently he is working as a professor in Dept of ECE in SV College of Engineering, Tirupati. His research interest is in Image processing .He is a life member of ISTE, IE, and member of IEEE.

Dr. B.Prabhakara Rao obtained B.Tech., & M.Tech from S.V. University, Tirupathi with Specializations in Electronics & Communications Engineering, Electronic Instrumentation & Communications Systems in the years 1979 and 1981 respectively. He received the Doctoral degree from Indian Institute of Science, Bangalore in1995. He has more than 31 years of Experience in Teaching & Research. He held different positions in his career such as Head of the Dept. & Vice Principal, Director (Institute of Science & Technology), Director of Evaluation, Director of Foreign Universities Relations, Director –Admissions during in the years 2001 to 2013. Presently he is working as Rector and Director-Admissions from July 2013 in JNT University, Kakinada. He is Senior IEEE (USA) member, Fellow of IE, IETE, Life Member of ISTE, (EMC) Association, and Indian Science Congress Association (Kolkatta). He was honored with the "State Best Teacher Award" for the year 2010 by the Government of Andhra Pradesh.