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Image Compression for Telemedicine using New Wavelets and Modified EZW

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Abstract*: *With the invent of better signal processing operations unveiled by the research community of both communication and signal processing, the Telemedicine is becoming more and more prominent all over the world. Communicating the data captured from the patient to the clinicians in non-recognizable seconds of time is crucial in many cases so as to take a right decision at right time. Then the processing of the data sent to clinicians is the second part of telemedicine where extensive processing capabilities are required. In this paper, the first part of telemedicine is answered by devising diversified schemes using wavelet and modification of standard coding scheme embedded zero tree wavelet (EZW). First, coding by EZW and Set partitioning in Hierarchical tree (SPIHT) was implemented. Then, new wavelets and their lifting versions are designed. Finally, two variations of standard EZW scheme were proposed. The simulation results suggest that the techniques presented in this paper provide better compression performance at different levels of compression ratio (CR) and peak signal to noise ratio (PSNR). In addition to CR and PSNR, bit error rate and output bandwidths are calculated.

Index Terms*: *EZW, isolated zero, subband, telemedicine, zerotree

I. INTRODUCTION

Today, all multi-specialty hospitals massively rely on digital images and uses efficient scanner technologies for capturing the digital images of different diseases. The size of the medical images is in terms of Mega Bytes (MB). However, it is important to store the images with less storage space and transmit the images with less bandwidth. This is the purpose of image compression [1]-[4]. Telemedicine is a communication technology, which is used widely in the treatment of diseases. Telemedicine technology means even doctor away from the hospital can also monitor the health status of their critical patients. Therefore, image compression plays an important role in telemedicine for transmission of medical images with low bandwidth [5]. Generally, images are compressed in two ways. They are lossy and lossless. In lossy compression, the reconstructed image appears like the original image with maximal loss of data and is not identical. However, in lossless image compression, the reconstructed image appears like the original image and is identical [6,7,17,18]. Applications include medical image transmission inside and among medical service organizations using public networks.

Further, along with data compression, it also needs security, when handling with sensitive medical images [8]-[10]. Medical image compression includes high image compression ratio and the ability to decode the medical image into unknown form. In this paper, a number of techniques are presented, which are wavelet based image compression schemes for telemedicine [11]-[14].

II. NEW WAVELETS AND LIFTING VERSION

In this work, two new wavelets are presented: newwa1, newwa2, newwa3, newwa4 [15]. Sample signals are generated with a sight to use them as basic functions of proposed wavelets. The generated wavelets are loaded with image compression and the coefficients of the wavelet transform filters are learned based on the compression performance. All the four wavelets are orthogonal wavelets. The scaling and wavelet functions connected with the new wavelets are plotted in Fig.1. All the proposed wavelets are of short duration. Compared to the other wavelets, the wavelet NewWa4 has sharp edges and irregular peaks. The smooth version of NewWa4 is NewWa2. Among the four wavelets, the NewWa4 is the only one which has significant negative values. The short waves shown in Fig.1 will be dilated and translated to produce the required resolution in time and frequency. The wavelet and scaling functions are generally described using the scaling and wavelet relation. But the relation will be common for all the wavelets except for the number of coefficients and the coefficient values. Hence, pictorial representation of wavelet function gives more insight in the respective wavelet. The lifting scheme for these wavelets is presented in [16]. The polyphase matrix with lifting steps is given below.

$$P(z)=\begin{bmatrix} A_4+A_5z^{-1} & H_o^{New}(z) \\ A_6+A_7z^{-1} & G_o^{New}(z) \end{bmatrix}\begin{bmatrix} 1 & 0 \\ A_1z+A_2+A_3z^{-1} & 1 \end{bmatrix} \times\begin{bmatrix} 1 & C_1z^{-1}+C_2z^{-2}+C_3z^{-3} \\ 0 & 1 \end{bmatrix} \quad (1)$$

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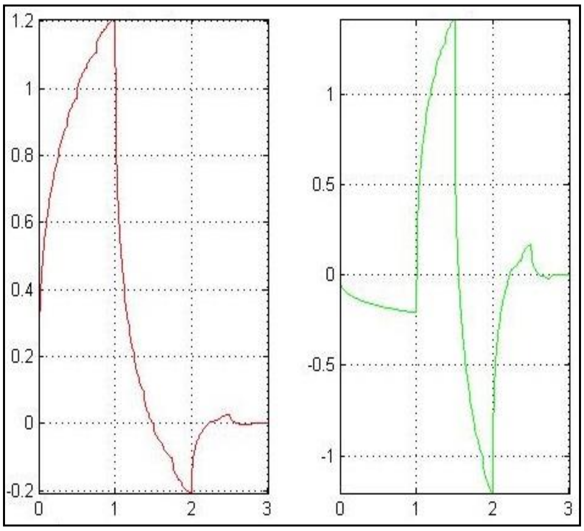
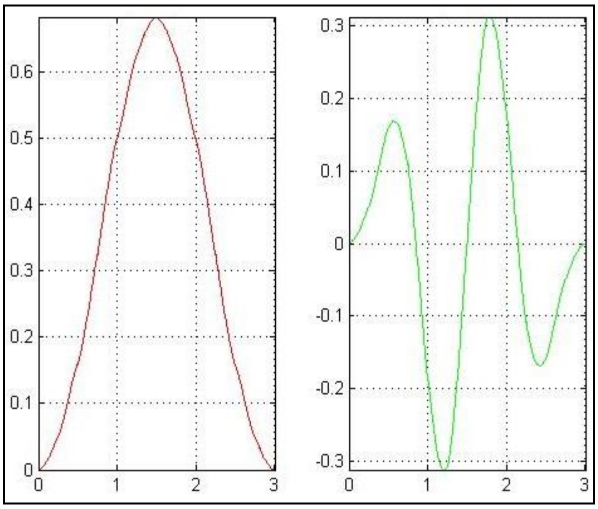
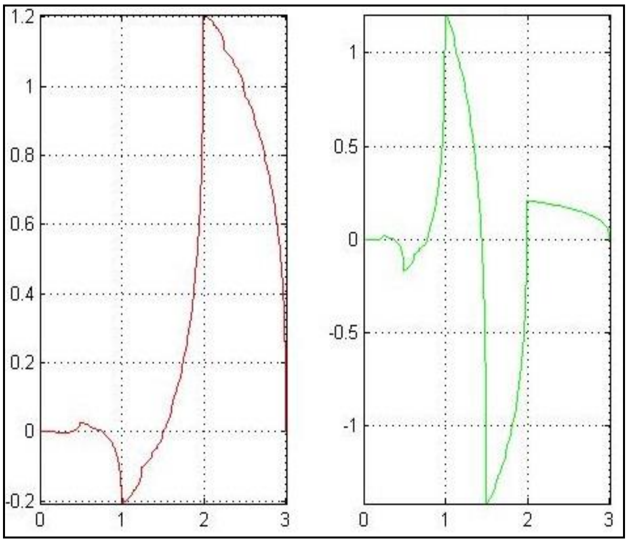






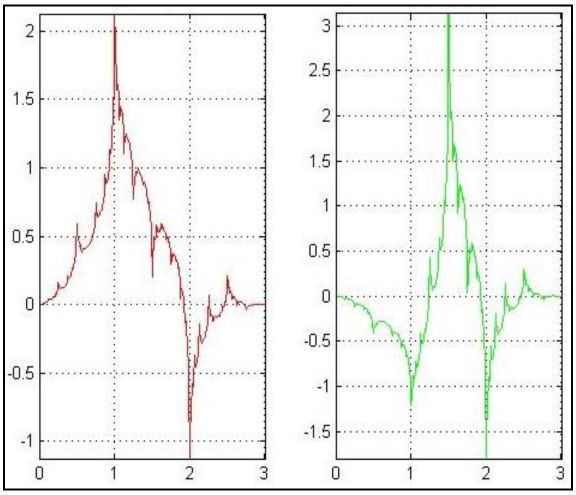
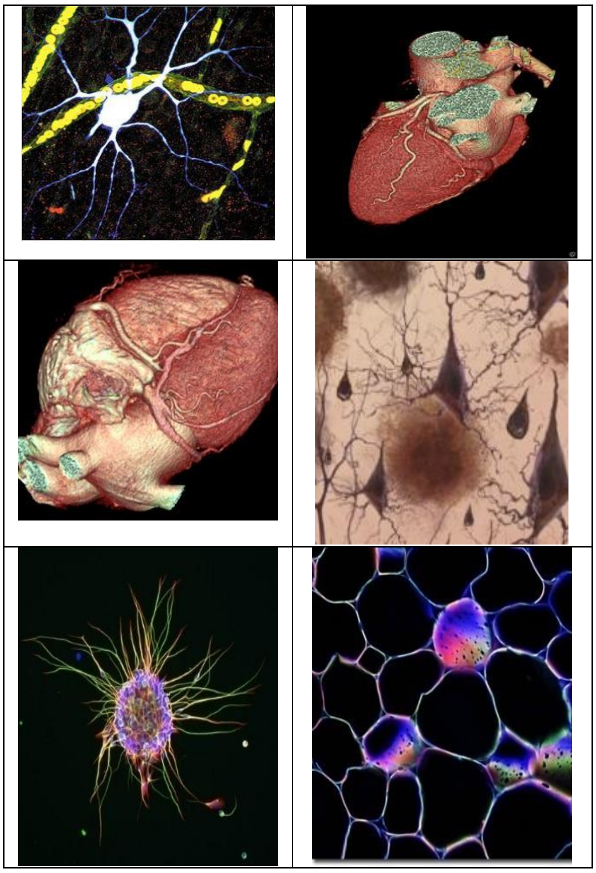


Fig. 1. New Wavelets: phi and psi functions of NewWa1, NewWa2, NewWa3 and NewWa4

III. TEST IMAGES AND TELEMEDICINE DESIGN PARAMETERS

The compression results in medical images using standard EZW and bior4.4 wavelet are given below. Before presenting the compression results, the test images and the input bandwidth (IPBW) associated with the test images are given in Fig. 2 and Table 1 respectively.



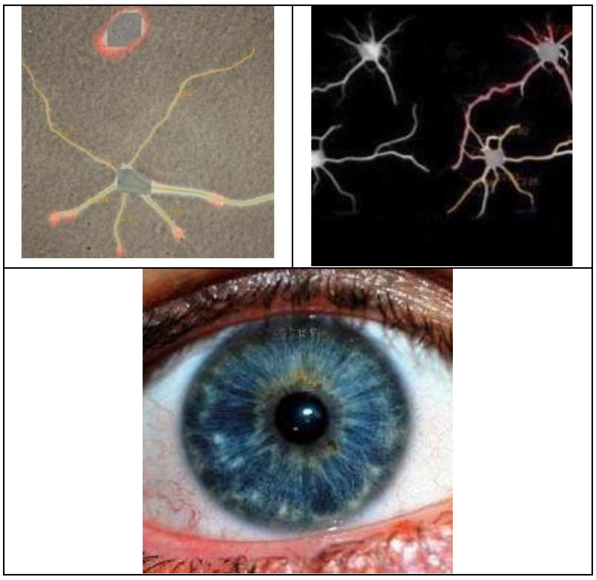


Fig. 2 Test Images

A set of 9 medical images whose input bandwidths are given in Table 1. The images were chosen to cover a general set with varied intensity groups ranging from light to dark. Compression results using bior4.4 wavelets are presented in Table 2 and that using new wavelets in Table 3. Output bandwidth (OPBW) in KHz, Compression ratio, Bit error rate (BER) in KB and Peak signal to noise ratio (PSNR) in decibels are calculated and tabulated below.

Table 1. Input Bandwidths of Test Images

Images	IPBW (KHz)
1	133.60
2	84.38
3	108.38
4	97.51
5	241.46
6	198.38
7	153.77
8	59.77
9	64.60

Table 2. Compression Results with EZW using bior4.4

Images	Standard EZW - bior4.4			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	11.5	4.4	117.7	20.8
2	3.7	8.6	68.5	23
3	4.9	8.3	103.3	22.1
4	4.9	7.5	95.4	19.7
5	11.5	7.9	188.6	24
6	21.1	3.5	149.9	23.5
7	1.3	44.2	158.6	18.4
8	3.5	6.5	41.5	24.6
9	4.2	5.8	62.6	20.5

Table 3. Compression results with EZW using new wavelets

Images	Standard EZW with New Wavelets							
	newwave1				newwave2			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	10.1	5.0	112.6	27.3	3.8	13.3	115.4	23.3
2	2.7	11.5	69.3	32.9	2.1	15.3	71.4	26.2
3	3.8	10.8	102.9	30.0	3.0	13.4	106.5	24.9
4	3.8	9.7	96.0	24.9	2.6	14.0	95.8	21.7
5	7.8	11.5	147.3	35.8	5.4	16.9	160.4	27.7
6	19.3	3.8	131.3	34.0	5.8	12.9	151.6	26.9
7	4.4	13.0	159.3	22.8	3.1	18.4	158.7	20.2
8	3.3	6.9	33.2	38.1	1.4	15.8	42.1	27.7
9	3.7	6.5	61.9	26.5	2.1	11.5	62.2	22.8

The compression results of SPIHT using new wavelets are presented in Table 4.

Table 4. Compression results of SPIHT coding using new wavelets

Images	SPIHT Coding – New wavelets							
	newwave1				newwave2			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	11.1	11.8	90.0	37.6	10.3	12.8	96.6	38.5
2	7.4	11.4	37.1	42.2	7.2	11.7	39.3	40.3
3	9.3	11.7	61.7	41.0	8.4	12.9	62.8	40.4
4	8.9	10.7	63.5	39.6	8.3	11.4	67.2	39.6
5	12.5	19.3	129.6	39.7	11.6	20.8	95.6	39.9
6	11.5	17.3	70.5	40.0	10.6	18.7	80.6	39.8
7	10.2	14.7	102.9	41.4	9.2	16.4	150.7	39.9
8	6.1	9.7	19.9	40.6	5.8	10.1	18.5	40.4
9	7.3	8.8	43.8	42.4	6.5	9.9	41.8	41.3

IV. EZW WITH SIGNIFICANT WAVELET DOMAIN

If it is conceivable to decrease the number of codes produced in the dominant pass without losing considerable amount of the image information, then the memory needed can be condensed radically. The wavelet transformation achieves sub-band coding by excruciating the signal/image into different bands. The LL band is said to comprise the maximum of image data, while the HH band is said to have no or very less image data. Sample wavelet decomposition is shown in Fig.3.

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. 3 Sample wavelet decomposition

The codes allotted to the coefficients are given in Table 5.

Table 5. Results of Dominant pass when HH is ignored

Threshold	Codes
32	p z z p p t t t t t z t t t t t t t t t t n t t
16	z n z z t p z n p p z t t n t p t t t t t p t t t t t p t t t t t t t t p t t t t t t t t t t t
8	z z p z z z p t t z z t p t n t t p t t n t t t p t p t t t t p t t t p t t t t t t t t
4	z z z t z z t z z z n z p t t p t p p t t p t t t t n t n p p t t t t t p n p n
2	z z z t z t z z z t z p t t p t t t t p n t n t n n t p t t n t t t t t
1	z z t t t z t t t t t n

The strength of the coefficients that are present in HH band is very less. Correspondingly, they constitute very less in reconstruction of the original image back. In special domain watermarking schemes, least significant bits are used to hold the bits of original image or data, as the least significant bits constitute very less to the pixel value of a pixel. Similarly, the wavelet based watermarking schemes HH band is used to hold some information regarding the watermark. It has also been established that, in cases, the HL/LH bands will have less information than HH band. Consequently, if all these three sub-bands 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. Table 6 shows the coding sequence which is the outcome of dominant passes.

Table 6. Results of Dominant pass when HH, HL and LH are ignored

Threshold	Codes
32	p z t p p t t t t t t t t t t
16	z n z z t p t n p p t t t n t p t t t t t t t t t t t t t t t t t t t t t t t
8	z z p z t t p t t t t t p t n t t t t t t t t t t t t t
4	z t z t t t n t t t t t
2	z t z t t t t p t t t t
1	z t t t

The above two techniques ignore some of the coefficients in wavelet domain of the input image. This makes EZW more efficient with respect to the compression ratio. These techniques make the symbols generated short and the structure of the symbols is also very much suitable to the further run-length coding. The compression results, when bands other than LL are ignored are presented in the rest of the section. Table 7 presents the compression results with bior4.4 wavelet. Table 8 and 9 present the compression results with HH ignored and HH, HL and LH ignored correspondingly.

Table 7. Compression results of EZW coding using bior4.4 with HH=HL=LH=0

Images	EZW with bior4.4 & HH=0, HH=HL=LH = 0							
	EZW HH=0				EZW HH=HL=LH = 0			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	8.9	5.6	118.8	20.0	5.6	9.0	119.5	19.4
2	2.1	15.2	73.4	21.9	1.1	28.9	80.5	21.2
3	2.9	14.1	106.1	21.1	1.7	24.4	104.7	20.4
4	3.0	12.0	95.5	18.9	1.9	19.4	95.2	18.4
5	6.9	13.1	193.7	22.8	2.8	32.1	195.4	22.1
6	17.3	4.3	159.0	22.3	12.4	6.0	167.5	21.6
7	4.2	13.8	157.0	17.8	3.3	17.4	156.8	17.3
8	2.3	9.6	42.8	23.0	1.4	15.7	44.4	22.4
9	2.9	8.2	62.6	19.7	2.3	10.5	62.7	19.1

Table 8. Compression results of EZW coding new wavelets with HH=0

Images	EZW with New Wavelets - HH=0							
	newwavelet1				newwavelet2			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	9.8	5.1	113.6	25.7	2.9	17.2	116.4	22.3
2	2.6	12.3	65.9	29.8	1.5	20.6	80.2	24.9
3	3.6	11.4	101.7	27.9	2.3	17.4	99.9	23.8
4	3.6	10.2	95.9	23.6	2.0	18.3	95.7	20.9
5	7.3	12.4	148.7	32.1	3.8	23.6	177.8	26.2
6	18.8	4.0	135.0	30.9	4.5	16.5	163.9	25.5
7	2.4	24.0	159.0	21.8	2.2	26.8	158.7	19.5
8	3.6	16.2	159.0	21.8	1.0	21.5	42.8	26.9
9	3.2	7.1	37.6	33.6	1.7	14.4	62.2	21.9

Table 9. Compression results of EZW coding using new wavelets with HH=HL=LH=0

Images	EZW with New Wavelets - HH=HL=LH =0							
	newwavelet1				newwavelet2			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	6.3	7.9	114.2	24.7	2.1	24.4	117.0	21.7
2	1.6	20.1	65.6	28.3	1.1	28.9	67.2	24.0
3	2.3	17.9	101.8	26.7	1.5	27.8	102.0	23.0
4	2.4	15.0	95.9	22.9	1.7	21.5	95.5	20.3
5	4.2	21.7	149.6	30.3	2.4	38.2	188.1	25.2
6	13.5	5.5	142.8	29.2	3.9	19.2	148.8	24.6
7	2.2	26.6	158.9	21.2	2.0	29.3	158.2	19.1
8	1.8	12.7	40.8	31.4	1.0	22.9	44.7	25.8
9	2.7	9.1	62.1	24.2	1.6	15.4	62.4	21.3

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 [12], two additional symbols, each for significant positive and negative but with zerotree are 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. 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, the effect of these new codes is 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. The simulation results are presented below. Tables 10, 11 and 12 present the compression performance of modified EZW with bior4.4 wavelet with regular wavelet decomposition, HH=0 and HH=LH=HL=0 respectively. Tables 13, 14 and 15 present the compression performance of modified EZW using new wavelets with regular wavelet decomposition, HH=0 and HH=LH=HL=0 respectively.

Table 10. Compression results of modified EZW coding using bior4.4

Images	Modified EZW with bior4.4			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	10.0	5.0	115.8	22.8
2	2.7	11.6	78.2	25.5
3	3.7	11.0	101.9	24.3
4	3.8	9.7	95.7	21.3
5	8.8	10.3	173.0	26.5
6	18.9	3.9	160.3	26.1
7	3.6	16.0	159.3	19.8
8	2.8	8.0	41.2	27.6
9	3.4	7.1	62.3	22.3

Table 11. Compression results of modified EZW coding using bior4.4 with HH=0

Images	Modified EZW with bior4.4 with HH=0			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	8.1	6.2	117.2	21.3
2	1.6	19.7	74.3	23.5
3	2.3	17.8	103.5	22.5
4	2.5	14.7	95.5	20.0
5	5.6	16.2	186.3	24.6
6	16.2	4.6	148.1	23.7
7	2.7	21.0	158.2	18.7
8	2.0	11.1	49.7	18.6
9	2.6	9.4	62.4	20.9

Table 12. Compression results of modified EZW coding using bior4.4 with HH=0, HH=HL=LH=0

Images	Modified EZW HH=HL=LH =0			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	5.8	8.7	117.6	20.9
2	1.2	25.6	68.7	23.0
3	1.8	22.0	102.8	22.1
4	2.0	17.8	95.4	19.7
5	3.2	28.0	189.2	23.8
6	12.8	5.8	146.1	23.5

7	2.5	23.5	157.7	18.4
8	1.5	14.7	50.6	18.4
9	2.4	10.1	62.5	20.5

Table 13. Compression results of modified EZW coding using new wavelets

Images	Modified EZW with New Wavelets							
	newwavelet1				newwavelet2			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	9.6	5.2	111.8	29.0	7.0	7.1	114.5	24.3
2	2.5	12.8	65.7	35.8	4.1	7.7	71.1	27.7
3	3.4	11.9	100.9	32.4	5.7	7.2	103.4	26.2
4	3.5	10.6	96.0	26.2	5.0	7.3	95.9	22.6
5	7.1	12.8	153.4	41.1	11.3	8.0	149.6	29.5
6	18.7	4.0	121.4	38.1	10.6	7.0	145.4	28.6
7	3.2	18.1	159.4	23.8	7.5	7.7	158.9	20.9
8	3.1	7.3	31.6	44.6	2.9	7.8	39.0	30.6
9	3.5	6.9	61.8	28.1	3.7	6.6	62.1	23.8

Table 14. Compression results of modified EZW coding using new wavelets with HH=0

Images	Modified EZW with New Wavelets - HH=0							
	newwavelet1				newwavelet2			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	9.1	5.5	112.8	27.1	6.0	8.3	115.4	23.3
2	2.1	15.1	69.4	32.1	3.5	9.0	71.4	26.2
3	3.0	13.7	100.2	29.8	4.9	8.4	106.5	24.9
4	3.0	12.0	96.0	24.7	4.3	8.6	95.8	21.7
5	5.9	15.3	148.5	35.4	9.4	9.6	160.4	27.7
6	17.7	4.2	135.4	33.6	9.1	8.2	151.6	26.9
7	2.6	22.1	159.2	22.7	6.6	8.7	158.7	20.2
8	2.8	8.0	34.6	37.6	2.4	9.2	39.9	28.6
9	3.2	7.6	61.9	26.5	3.2	7.6	62.2	22.8

Table 15. Compression results of modified EZW coding using new wavelets with HH=HL=LH=0

Images	Modified EZW with New Wavelets - HH=HL=LH=0							
	newwavelet1				newwavelet2			
	OPBW (KHz)	CR	BER (KB)	PSNR (dB)	OPBW (KHz)	CR	BER (KB)	PSNR (dB)
1	5.5	9.2	114.2	24.7	5.4	9.2	117.0	21.7
2	1.0	30.7	65.6	28.3	1.0	31.5	67.2	24.0
3	1.6	25.7	101.8	26.7	1.5	26.2	102.0	23.0
4	1.8	20.2	95.9	22.9	1.8	20.5	95.5	20.3
5	2.6	34.4	149.6	30.3	2.6	35.3	188.1	25.2
6	12.3	6.1	142.8	29.2	12.2	6.1	148.8	24.6
7	2.0	28.5	158.9	21.2	6.6	8.7	158.4	19.0
8	1.4	16.2	40.8	31.4	1.4	16.4	44.7	25.8
9	2.3	10.8	62.1	24.2	2.2	10.9	62.4	21.3

V. CONCLUSIONS

In this paper, effective medical image compression was implemented using different techniques. New wavelets are devised by choosing the wavelet filter coefficients with certain properties using trail error method. Trial and error was so chosen as even the transforms with perfect reconstruction gives only a nominal performance in many cases. A simplified lifting scheme was presented and used to arrive at the lifting version of the newly proposed wavelets. The EZW and SPIHT coding techniques are used to code the wavelet domain obtained with new wavelets. The EZW coding was explored and proposed two variations. The first one was achieved by identifying that the HH, HL and LH bands contain less information and ignoring them will yield better compression and quality will be lessen very little. The second, by introducing new symbol of coding, it was identified that the coding as well as reconstruction performance will be improved. The simulation results proved the estimations.

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