

1 An Enhanced Wavelet based Image Compression Technique

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5

6 **Abstract**

7 With the fast expansion of multimedia technologies, the compression of multimedia data has
8 become an important aspect. Image compression is important for efficient storage and
9 transmission of images. The limitation in bandwidth of wireless channels has made data
10 compression a necessity. Wireless channels are bandwidth limited and due to this constraint of
11 wireless channels, progressive image transmission has gained much popularity and acceptance.
12 The Embedded Zerotree Wavelet algorithm (EZW) is based on progressive encoding, in which
13 bits in the bit stream are generated in order of importance. The EZW algorithm, code all the
14 frequency band of wavelet coefficients as the same importance without considering the amount
15 of information in each frequency band. This paper presents an enhanced wavelet based
16 approach to overcome the limitation of the Embedded Zerotree Wavelet (EZW) algorithm.
17 This method divides the image into some sub-blocks.

18

19 *Index terms*— MEZW, wavelet, image compression methods, run length encoding, PSNR, entropy.

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22 an important aspect. Image compression is important for efficient storage and transmission of images. The
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24 bandwidth limited and due to this constraint of wireless channels, progressive image transmission has gained
25 much popularity and acceptance.

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27 bit stream are generated in order of importance. The EZW algorithm, code all the frequency band of wavelet
28 coefficients as the same importance without considering the amount of information in each frequency band.
29 This paper presents an enhanced wavelet based approach to overcome the limitation of the Embedded Zerotree
30 Wavelet (EZW) algorithm. This method divides the image into some sub-blocks. The sub image with low
31 frequency, containing higher amount of information is compressed lossless by DPCM method, and the modified
32 EZW (MEZW) coding and Run Length Encoding (RLE) methods are used to compress the sub-images with high
33 frequency. Higher information part is compressed by a lossless method can result in the improved PSNR. The
34 high frequency content of the image is less important, compressed using lossy method MEZW. The Modified
35 EZW algorithm generates less Zerotree root symbol (Z) in comparing to EZW. Run Length Encoding (RLE)
36 is used, to use the correlation in the coded symbols. This method can ensure that makes the best use of the
37 hierarchical relationship of wavelet coefficients and can also improve the PSNR.

38 **2 Introduction**

39 Looking back through the previous years, we can see the marvelous advancement in digital media. This kind of
40 environment gives birth to attractive applications in multimedia. Fast and instant availability of images shows
41 the achievements of technology in the field of multimedia. Data compression is necessary in every field where
42 data travels across the network. Today's massive use of images, generates a significant volume of data. It is
43 required to compress these digital images, so that their transmission and storage can be simplified. Techniques

5 B) SIGNIFICANCE TEST

44 to compress the image can be lossy and lossless. Lossless techniques reconstruct the actual image at the receiver
45 side, i.e. no loss of the information. Lossless compression ??21] is required in medical images, technical writing
46 or in clip arts. The second technique is the lossy one. In this, the image at receiver side is not the same as sender
47 side. There is always some loss of information. Lossy compression tends to increase the compression ratio while
48 somehow compromising the quality of the image.

49 For still image compression, popular and well adapted algorithm is JPEG [17] standard. Similarly, MPEG
50 ??18] standard is used for video compression. Both JPEG and MPEG make use of transform coding, i.e. DCT
51 [8] Discrete Transform. In this type of transforming only spatial correlation of the pixels inside the single 2D
52 block is considered and the correlation from the pixels of neighboring blocks is neglected. It is extremely difficult
53 to décor relate the blocks at their boundaries using DCT. Undesirable blocking artifacts affect the reconstructed
54 images of video frames.

55 An alternative of DCT is Discrete Wavelet Transform (DWT) [1]. This wavelet transform is able to remove
56 the artifacts of DCT and still producing the compression ratios compatible to DCT.

57 Wavelets are being used in many compression algorithms. Most widely used wavelet based image compression
58 algorithms are Shapiro's EZW [2], SPIHT (Set Partitioning in Hierarchical Trees) [11], SPECK (Set Partitioning
59 Embedded Block) ??19]. These algorithms which are based on embedded coding create an embedded binary
60 flow, a progressive data transmission that allows the image to be reconstructed using various compression ratios,
61 allowing the algorithm to be either lossy or lossless ??20].

62 Several modifications of Shapiro's EZW [2] algorithm have been proposed till now. The authors in [9], gives
63 some improvements in the implementation, they used four symbols, different than the original EZW [2]. In [10],
64 the same coefficients used by [9] and compression scheme adopted for video compression are proposed. In [12], a
65 degree-k model, in order to quantify the coding power of zero trees in wavelet based image coding is introduced,
66 [12] deduced that the EZW [2] is degree 0 zero tree and the SPIHT is degree 2 zero tree. It is concluded that
67 the higher degree zero tree coder is more powerful. In [3], author presents a modification of EZW [2] algorithm.
68 It uses six symbols to encode the wavelet coefficients instead of four symbols, which are used in the original one.
69 It further includes binary regrouping of elements to optimize the coding.

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71 ? Following the inspiration from [2], the principle of the Shapiro algorithm is reviewed (Sect. 2). In Sect. 3, the
72 Modified EZW (MEZW) [3] algorithm is described in detail. In Sect. 4, the proposed algorithm is described in
73 detail. In Sect. 5, results obtained with the proposed algorithm are analyzed and compared with results from
74 MEZW [3] algorithm and DPCM [5] algorithm. II.

75 4 Shapiro's Ezw Algorithm

76 The Embedded Zero tree Wavelet (EZW) [2] algorithm is based on embedded encoding. Embedded encoding
77 is also called as progressive encoding. This means that when more bits are added to the bit stream, the image
78 will contain more detail. The EZW algorithm uses embedded encoder, an embedded encoder can terminate the
79 encoding at any point, thereby allowing a target rate or target accuracy to be met exactly. The EZW algorithm
80 [2] has the following features. 1. Discrete wavelet transform [1] 2. Zero tree coding of wavelet coefficients 3.
81 Successive-approximation quantization (SAQ) 4. Adaptive arithmetic coding [14] The EZW encoder is based
82 on these two important observations: 1. Natural images in general have a low pass spectrum. When an image
83 is wavelet transform, the energy in the sub-bands decreases with the scale goes lower (low scale means high
84 resolution), so the wavelet coefficient will, on average, be smaller in the lower levels than in the higher levels.
85 2. Large wavelet coefficients are more important than small wavelet coefficients. These two observations are
86 utilized by encoding the wavelet coefficients in several passes as EZW algorithm is a multiple pass algorithm. For
87 every pass or iteration a threshold is chosen against which significance of all the wavelet coefficients is measured.
88 Shapiro's encoder exploited possible dependence protocols between the different sub bands in order to create the
89 zero trees. A zero tree is a data structure, composed of a parent and its descendants. In zero tree, for each
90 parent at the scale i, there are four descendants at scale i-1 (Fig. 1). To make the "zero tree" effective, the
91 wavelet coefficients are scanned for the path presented in Fig. 2. No child node is scanned before its parent node.
92 Coding of wavelet coefficients is performed by determining the two lists of coefficients, i.e. dominant pass list
93 and a subordinate list (fig. 4). Let us consider the matrix test (Fig. 3) in terms of the steps of EZW algorithm
94 [2]. The wavelet transform is applied to the image and initial threshold is calculated. T_0 , the initial threshold
95 is calculated using $()_{\max} 2 0 \log 2 c T =$

96 Where c_{\max} is a maximum wavelet coefficient. For the test matrix, in fig. 3, initial threshold calculated is
97 32 and c_{\max} is 63.

98 5 b) Significance Test

99 The wavelet coefficients are scanned for the path presented in Fig. 2. Each coefficient is assigned a significance
100 symbol (P, N, Z or T), by comparing each coefficient with the actual thres hold $j T$, where j is the iteration
101 count):

102 ? P (Positive and Significant): If a coefficient is greater than the threshold then it is called significant. If
103 the sign of the significant coefficient is positive, then this coefficient will be coded as P. This is the case for the
104 coefficients {63, 49 and 47} in the matrix test (Fig. 3)

105 ? N (Negative and Significant): If a coefficient is significant with a negative sign, then it is coded with N
106 symbol. This is the case for the coefficient {?34} in the matrix test (Fig. 3).

107 ? T (Zero tree): If the coefficient is insignificant and has only insignificant descendants. Like coefficient {24}
108 in matrix test. The descendants of this type of coefficients will not be coded.

109 ? Z (Isolated Zero): The coefficient is insignificant but has some significant descendants then it is coded
110 isolated zero Z symbol. This is the case for the coefficients {-31 and 14} (Fig. 3).

111 The dominant list D contains information concerning the significance of coefficients, which will be coded using
112 arithmetic coding. The significant list S contains the amplitude values of the significant coefficients, which will
113 undergo uniform scalar quantization followed by arithmetic coding.

114 **6 c) Successive Approximation Quantization and Refinement**

115 The significant values {63,-34,49 and 47} from the matrix test (fig. 3) are quantized by the bits "1 0 1 0" [2].
116 Then, step B of the algorithm is repeated by incrementing j by 1 and dividing threshold by 2. This process is
117 reiterated until the desired quality of the reconstructed image is reached orbit budget is exhausted. [2].

118 **7 III.**

119 **8 Modified EZW [3]**

120 A modified version of traditional Embedded Zero tree Wavelet encoding names MEZW [3]. In general [3] modified
121 the EZW [2] in the following manner: 1. Symbols were added in the significance test step (step B). More symbols
122 allow a better redistribution of the entropy. 2. Coding of the dominant list D elements and subordinate list S
123 quantization bits was optimized by the binary regrouping of elements.

124 Let us consider the matrix test shown in Fig. 3, in terms of the steps of MEZW algorithm. Initialization step
125 will be same as the EZW [2] algorithm, initializing the threshold by T0

126 **9 a) Significance Test**

127 The wavelet coefficients are scanned for the path presented in Fig. 2. Each coefficient is assigned a significance
128 symbol (P, N, Z, T, P t and N t), by comparing each coefficient with the actual thres hold () j o j T T 2 =
129 , where j is the iteration count):

130 ? If a coefficient is greater than the threshold then it is called significant. If a coefficient is tested and found
131 to be significant, its descendants must also be tested. If at least one descendant is significant the it

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135 H is encoded as P or N symbol. If the sign of the significant coefficient is positive, then this coefficient will be
136 coded as P.

137 ? This is the case for the coefficients {63, 49 and 47} in the matrix test (Fig. 4).

138 ? If the coefficient is greater than the threshold and its sign is negative then this is coded as N. This is the
139 case for the coefficient {?34} in the matrix test (Fig. 4).

140 ? If a coefficient is less than its threshold value, then it will be considered as insignificant coefficient. If a
141 coefficient is insignificant, then its descendent must be tested. If all of its descendants are insignificant, then it
142 is encoded as a Pt or Nt symbols. If the symbol is positive, then the coefficient is coded as Pt symbol. This is
143 the case for the coefficient {49} in the matrix test (Fig. 4).

144 ? If the symbol is positive, then the coefficient is not coded as a symbol.

145 ? If a wavelet coefficient is insignificant and all of its descendants are also insignificant, then it is coded as a
146 zero tree T symbol. Like coefficient {23} in the matrix test (Fig. 4)

147 ? The coefficient is insignificant but has some significant descendants then it is coded isolated zero Z symbol.
148 This is the case for the coefficients {-31 and 14} (Fig. 4). By applying the MEZW to the matrix in Fig. 4 IV.

149 **12 Proposed Method**

150 As we know, after the wavelet transform of the image [1], the energy is concentrated in the low frequency part of
151 the image. Most of the information is present in the low frequency part only. The traditional Embedded Zerotree
152 Wavelet [2] coding approach, code all the frequency band of wavelet coefficients as the same importance without
153 considering the amount of information in each frequency band. There is no difference if the sub band is a low
154 frequency band or a high frequency band. Our proposed technique overcomes this limitation of EZW algorithm.
155 This method divides the image into some sub-blocks. The sub image with low frequency, containing higher

15 CONCLUSION

156 amount of information is compressed lossless by DPCM method. Lossless compression of the lower frequency
157 sub band will increase the Peak Signal to Noise Ratio (PSNR). The modified EZW (MEZW) [3] coding and Run
158 Length Encoding (RLE) [6] methods are used to compress the sub-images with high frequency (fig. 5). The
159 high frequency content is less important, compressed using lossy method MEZW. The Modified EZW algorithm
160 generates less Zero tree root symbol (Z) in comparing to EZW. RLE [6] coding for the use of this kind of relevance
161 precisely.

162 13 Simulation Results

163 Lena image [2] is used as the test image. The Lena image of resolution 256 * 256. The bit depth of the image is 8
164 bits per pixel. First of all, using Haar wavelet for lifting decomposition of the image and then using the proposed
165 method of compression. The quality of reconstruction image is calculated in terms of a parameter called peak
166 signal to noise ratio (PSNR). PSNR (dB) performance and compression ratio (CR) performance is calculated
167 using the following formulae.
168 Here, the mean square is:
$$\text{MSE} = \frac{1}{n \times m} \sum_{i=1}^n \sum_{j=1}^m (x_{ij} - y_{ij})^2$$

169 Where n, m is the image size, x_{ij} the initial image and y_{ij} the reconstructed image. m n bits coded of number
170 bpp $CR = \frac{m \times n}{\text{MSE}}$

171 Compression results of the proposed approach are compared with the MEZW [3] approach and DPCM [5]
172 algorithm. The results obtained by proposing algorithm indicate that the use of sub band decomposition and
173 different compression methods for different sub band of the image results in a significant increase in the signal
174 to noise ratio of the image. The proposed algorithm is compared with MEZW [3] algorithm (fig. ??). With each
175 iteration or scan pass the PSNR is increasing. For each scan pass proposed algorithm results in an approximate
176 20 dB large PSNR in comparing to MEZW [3]. Comparison of PSNR of different sub bands and MEZW [3]
177 algorithm is presented in fig. ???. When comparing to DPCM [5] algorithm (fig. ??), there also increases in the
178 PSNR value, but is less in comparison to previous comparison.

179 Compression ratio is large for the proposed technique. After each pass, value of compression ratio increase, so
180 as the PSNR.

181 14 VI.

182 15 Conclusion

183 As the amount of information content is different for each frequency sub band of the image, in this paper, we
184 proposed an image compression algorithm based on the high and low frequency distribution of wavelet coefficients.
185 The results are compared to conventional DPCM and MEZW [3] approach for PSNR, resulting in improved PSNR.
186 So we conclude that we use a different compression technique for each sub band, according to the amount of
187 valuable information in the particular band. This will allow us to use the lossless technique for a crucial part of
188 the image, results in an increased PSNR. We also find an approximated range, between twelve to fourteen, there
189 is a negligible change in the PSNR of different sub bands. ^{1 2 3}

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Figure 1: Figure 1 :

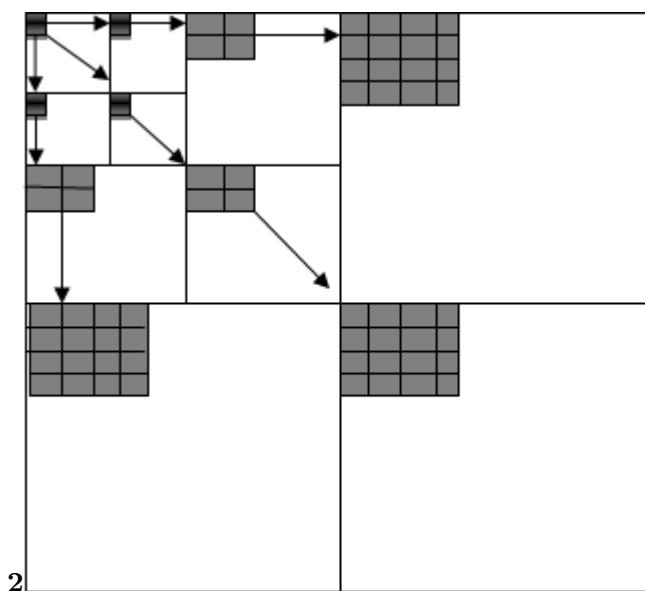


Figure 2: Figure 2 :

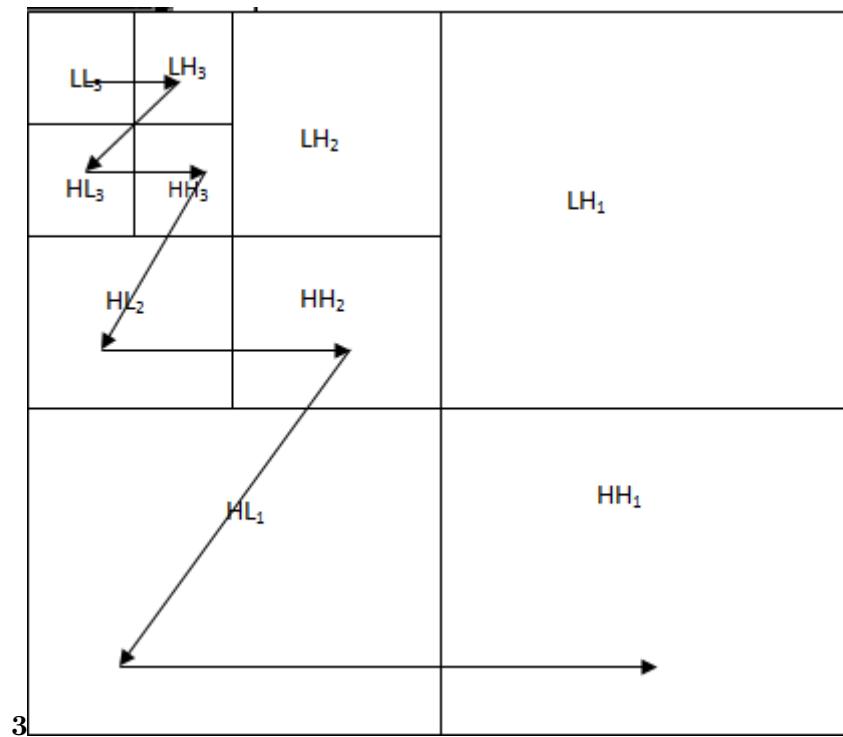


Figure 3: Figure 3 :

63	-34	9	10	7	-13	12	7
-31	23	-14	-13	3	4	6	1
15	14	3	-12	5	-7	3	9
-9	-7	-17	8	4	-2	3	9
-5	9	-1	47	4	-6	-2	2
3	0	-3	2	2	-2	0	4
2	-3	6	4	3	6	3	6
5	11	5	6	0	3	-4	4

Figure 4: Figure 4 :

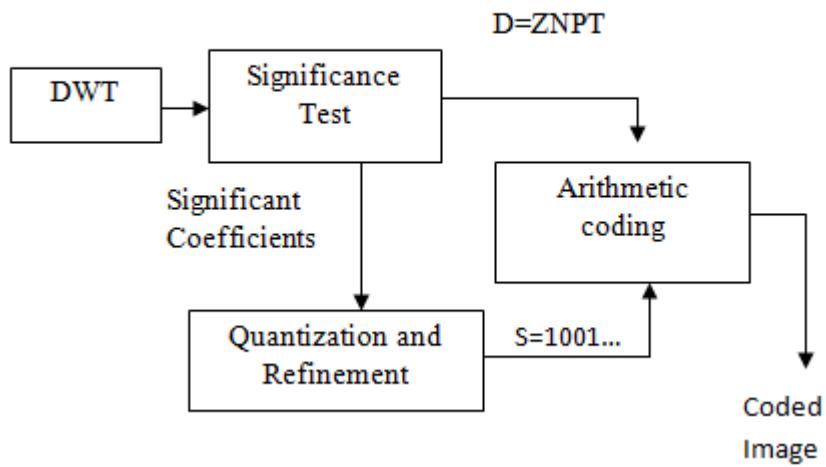


Figure 5:

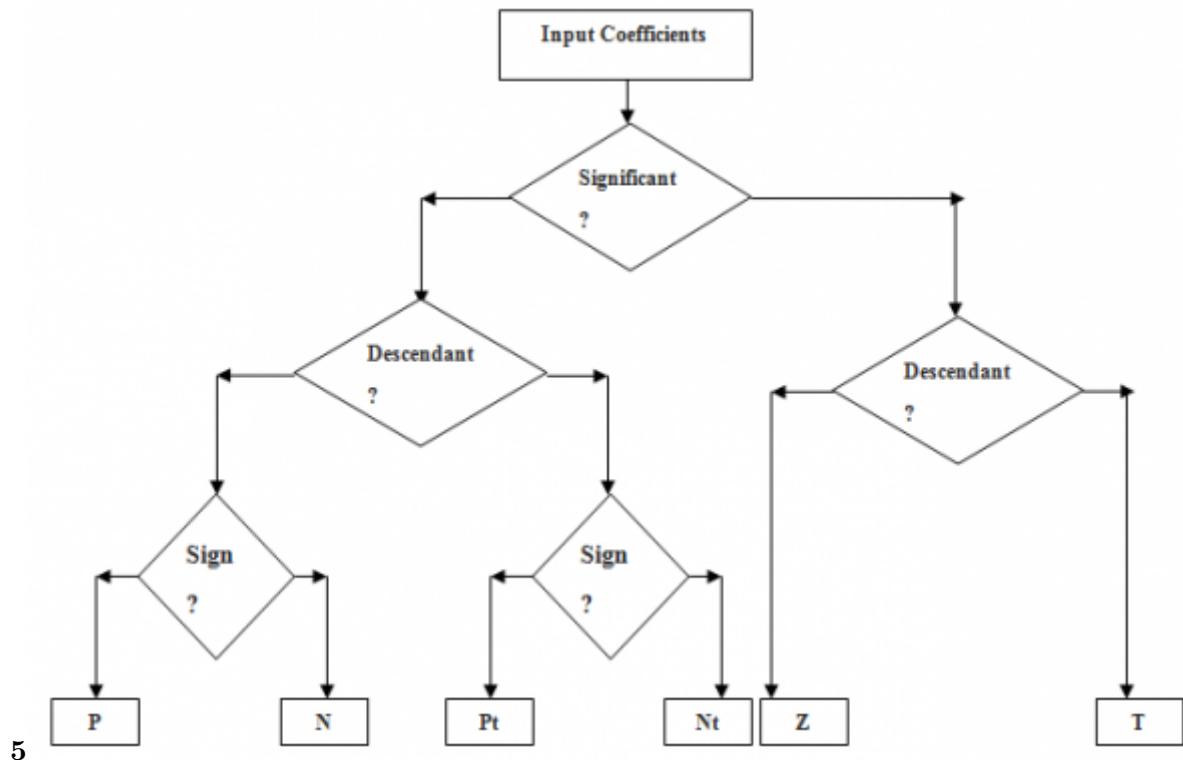
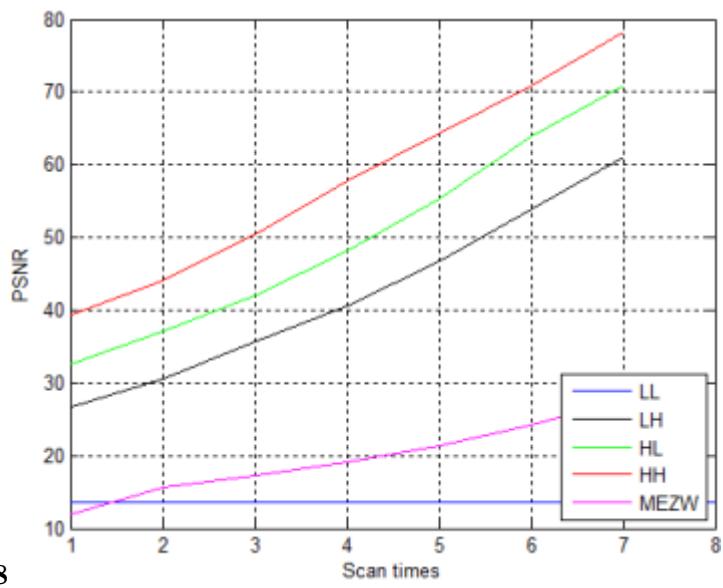


Figure 6: Figure 5 :



78

Figure 7: Figure 7 :Figure 8 :

I

An Enhanced Wavelet based Image Compression Technique												
63	-30	9	10	0	0	0	0	7	-	13	12	7
-	23	-	13	0	0	0	0	3	4	6	1	
31		14										
		0	0	0	0	0	0	5	-7	3	9	
15	14	3	-									
		12										
		0	0	0	0	0	0	4	-2	3	9	
-9	-7	-	8									
		14										
		-	9	-1		7		4	-6	-2	2	
		5										
		3	0	-3		2		2	-2	0	4	
		2	-3	6		4		3	6	3	6	
		5	11	5		6		0	3	-4	4	
DPCM Encoding				Scan	MEZW	MEZW	+ Run Length Encoding	Proposed				

Times Algorithm PSNR(dB) PSNR(dB)
 5 7 9 Scan Times 5 LL 13.48 37.65 46.71 62.41 HL LH HH Average 40.06 13.48 42.0

7 18.61 17.83 19.92 24.49 28
 9 18.61 22.00 19.92 24.49 28

Comparison of DPCM and H approach in terms of PSNR

[Note: H Figure 6 : Basics of Proposed algorithm]

Figure 8: Table I .

Year
 ()

[Note: HFigure 9]

Figure 9: :

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