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ENHANCED IMAGE CODING SCHEME BASED ON MODIFIED EMBEDDED ZEROTREE WAVELET TRANSFORM (DMEZW)

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ABSTRACT:
In this paper the proposed scheme uses different processing methods by applying Integer Lifting Wavelet Transform (ILWT) on gray scale image generating four subband is presented. The low frequency subbands is compressed losslessly by the Developed Modified Embedded Zerotree Wavelet Transform (DMEZW) directly. The high and middle frequency subbands are compressed lossyly by applying first to single stage Vector Quantization (VQ) then to DMEZW, finally generating two vectors ready for entropy coding and it is presented as Arithmetic Coding (AC) to produce a bit stream to be stored or transmitted. The main improvements of DMEZW is done by modifying the scanning strategy of the wavelet coefficients and the quantization threshold. The high and low frequency subbands are manipulated separately. The experimental results show that the developed method can improve the quality of the recovered image and the encoding efficiency. The proposed scheme programming code has achieved high Compression Ratio (CR) and remarkable Peak Signal to Noise Ratio (PSNR).

KEYWORDS: Image Compression; Shapiro's EZW algorithm; MEZW; DMEZW; PSNR; Compression Ratio.

1. INTRODUCTION

Demand for communication of multimedia data through the telecommunications network and accessing the multimedia data through Internet is growing explosively. In order to handle this pervasive multimedia data usage, it is essential that the data representation and encoding of multimedia data be compressed across different platforms and applications (Acharya & Tsai, 2005). This is important particularly in Image compression which is a process of storing an image in a more compact form while maintaining a desirable image quality. There are two major families of compression techniques, *lossless* and *lossy* compression. A compression approach is lossless only if it is possible to exactly reconstruct the original data from the compressed version. There is no loss of any information during the compression process (Pu, 2006). Information that is produced and analyzed in real-life situations is discrete (Ghanbari, 2011). Transformation a signal is just another form of representing this signal, it does not change the information content present in it (Misiti, *et al*., 2003). Wavelet transform is used to provide a multi-resolution image representation fitting human visual system which has excellent energy compaction property suitable to exploit redundancy in an image to achieve compression (Channa & Hussain, 2005).
Quantization is a necessary component in lossy coding and has direct impact on the bit rate (Shi & Sun, 2008). The amplitude values obtained after Wavelet may be long real numbers which are usually rounded to the nearest predefined discrete values. This process of converting the real numbers to the predefined discrete numbers is called quantization (Pu, 2006).
Embedded Zerotree Wavelet Transform (EZW) algorithm is an effective image compression algorithm produced by Shapiro J.M. (1993), it is a simple, yet remarkably effective image compression algorithm, having the property that the bits in the bit stream are generated in order of importance. This technique produces a fully embedded bit stream for image coding (Janaki & Tamilarasi, 2011). The combination of the wavelet transform and quantization then Embedded algorithms forms a coding method which has become extremely attractive for image compression (Hawkes, 2001).
The proposed DMEZW coding algorithm is a new modification of the original EZW which uses the main EZW rules to encode wavelet decomposed coefficients, in addition to the new coding rules and modifications.

2. EMBEDDED ZEROTREE WAVELET TRANSFORM

Embedded Zerotree Wavelet Transform (EZW) algorithm was originally proposed by Shapiro, (1993), it is a simple, yet remarkably effective, image compression algorithm, having the property that the bits in the bit stream are generated in order of importance, yielding a fully embedded code. The embedded code represents a sequence of binary decisions that distinguish an image from the “null” image. Using an embedded coding algorithm, an encoder can terminate the encoding at any point thereby allowing a target rate or target distortion metric to be met exactly, it is also given a bit stream, the decoder can cease decoding at any point in the bit stream and still produce exactly the same image that would have been encoded at the bit rate corresponding to the truncated bit stream. In addition to produce a fully embedded bit stream, EZW consistently produces compression results that are competitive with virtually all known compression algorithms (Shapiro, 1993).
The basic process flow of EZW algorithm can be described as follows: Operate the image through wavelet transform and quantizing the coefficients. Given a series of threshold values which are sorted from high to low, sort all the coefficients and maintain the important coefficients and discard the important coefficients according to this threshold. It would generate four symbols, respectively named positive important coefficient (POS), negative important coefficient (NEG), isolated zero (IZ) and zero-tree root (ZTR). Then gradually decrease the threshold and find the important coefficients due to a peculiar scan order. This would form a sequence of important coefficients through this method (Xiaoping, 2005).

Coefficients with coordinates on the dominant list are compared to the threshold, to determine their significance, and to show their sign (Ouafi, *et al.*, 2006), as explained below:

- POS: a positive coefficient is greater than the current threshold.
- NEG: a negative coefficient is greater than the current threshold.
- ZTR (zerotree): a zero-tree root, this coefficient and all of its descendants are below the current threshold.
- IZ (isolated zero): an isolated zero or a coefficient that is below the current threshold but is not a zerotree root.

2.1 General Steps of EZW

Original algorithms of (EZW) by Shapiro are consisting of the following steps:

1. Image should be read and converted to grayscale.
2. The wavelet transform is applied.
3. Quantization of the Coefficients should be made.
4. The encoding wavelet coefficients using EZW algorithm - Raster Scan is used for scanning wavelet coefficients (Figure 1).
5. The encoding is stop when the final threshold is achieved (Shapiro, 1993).

The general flowchart of EZW encoding is shown in Figure 1.

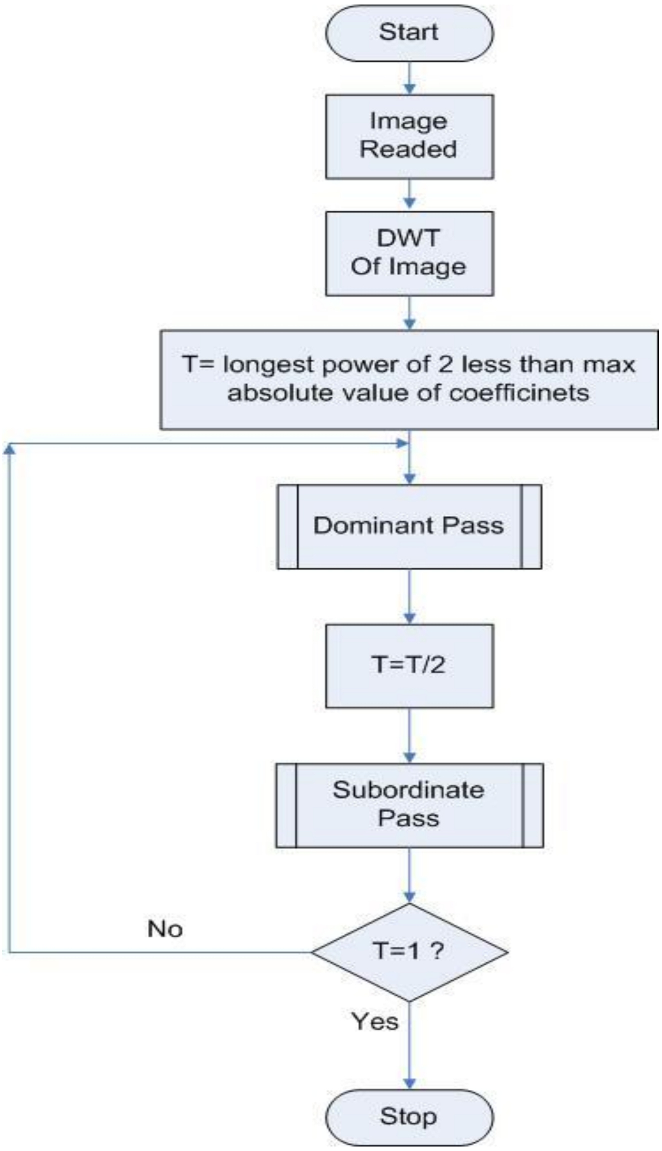

Figure 1. Flow Chart for Encoding a Coefficient of the Significant Map

2.2 Dominant Pass

The flow chart for the dominant pass procedure, shown in Figure 2 demonstrates how the dominant pass selects which symbol to output. The first step is to check if the coefficient has become significant at the current threshold. Then the absolute value of the coefficient minus the current threshold value is appended to the subordinate list and either the positive significant (P) or negative significant (N) symbol is outputted. The subordinate list ultimately records all the significant coefficients. On the other hand, if the coefficient is not significant, the next step is to check if the insignificant coefficient is a child of an already discovered zerotree, in this case no symbol is outputted. If the coefficient is not part of an already discovered zerotree, it must either be a root of a new zerotree or an isolated zero and the appropriate symbol (Z or T) is outputted (Shapiro, 1996).

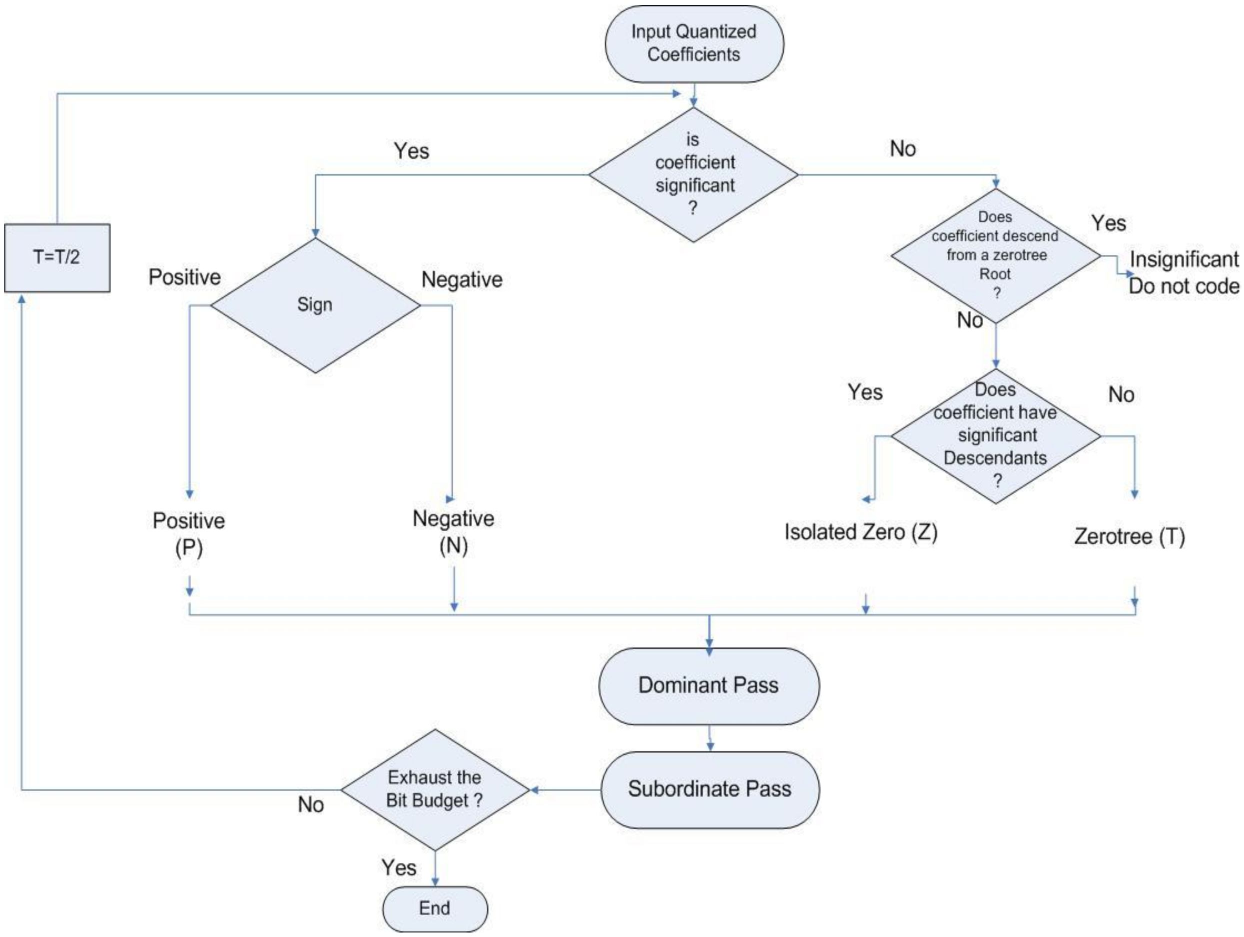

Figure 2. Flow Chart for Dominant Pass

2.3 Subordinate Pass

The flow chart for the subordinate pass procedure is shown in Figure 3. The Subordinate Pass, sometimes called the Refinement Pass, 'refines' the value of each significant coefficient. For each coefficient in the subordinate list (coefficients are added by the dominate pass when they are found to be significant), the subordinate pass checks if their current value is larger or smaller than the current threshold value. If it is larger, a '1' is sent to the entropy encoder and the current threshold is subtracted from the coefficient value in the subordinate list. If the coefficient is smaller than the threshold, a '0' is sent to the entropy encoder (Xiaoping, 2005).

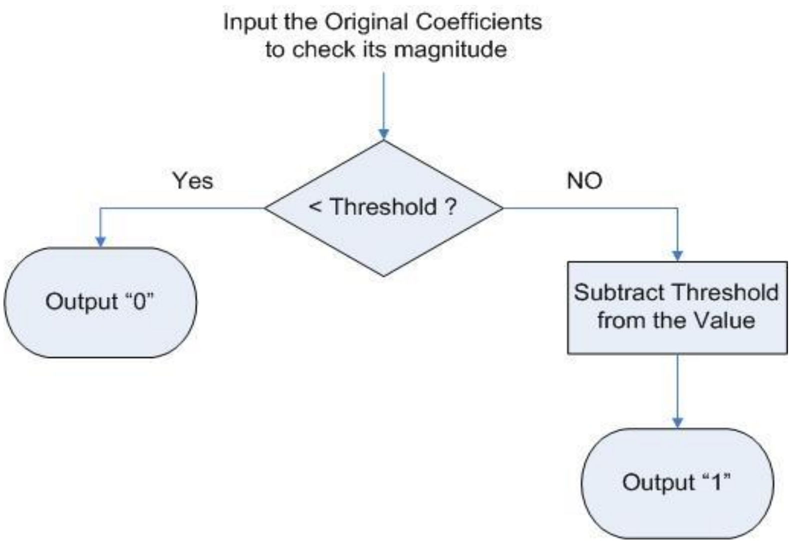

Figure 3. Flow chart for Subordinate Pass

Coding the wavelet coefficients is performed by determining two lists of coefficients as follows (Ouafi, et al., 2006):

• Dominant List (DL): it contains information concerning the significance of coefficients, which were coded using arithmetic coding.

- Significant List (SL): it contains the amplitude values of the significant coefficients, which were coded using arithmetic coding.

2.4 EZW Encoder Example Results

Let us consider the following simple example shown in Figure 4.

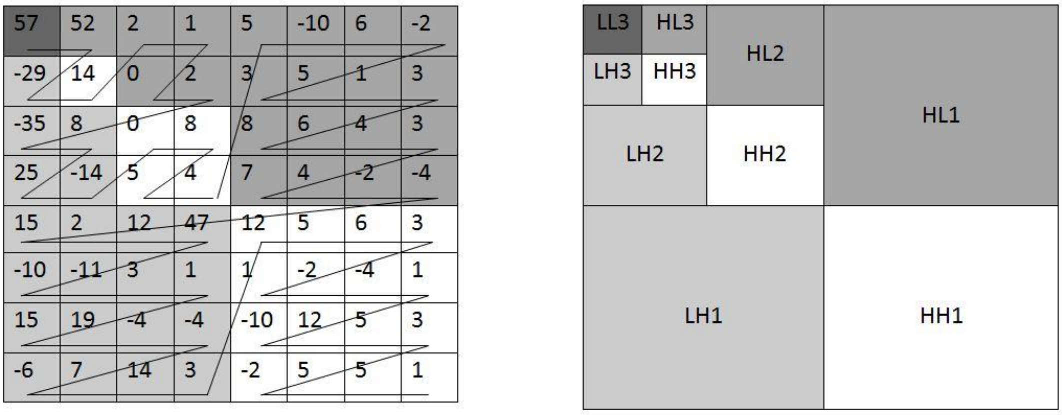

Figure 4. (a) Raster scan order of 8*8 matrix (b) Three level wavelet decomposition

The results show that in stage five it is not necessary to send signs list to the encoder because it is the same as in stage four. This is also because stage five is the last stage when the threshold reached to 1. Table 1 shows that the number of symbols obtained for each of the stages of this example.

Table 1. Results for Encoding process of EZW for 8*8 matrix

Stage	Symbols	Total Symbols	Signs List	Total Signs
1	16	16	4	4
2	12	28	7	11
3	52	80	22	33
4	56	136	42	75
5	58	194		

3. MODIFIED EMBEDDED ZEROTREE WAVELET TRANSFORM (MEZW)

Since 1993 many improvements have been made on original Shapiro's algorithm which used four symbols (POS, NEG, ZTR, IZ). Those modifications include either reading the coefficients for the image as (Raster or Morton) scan order or handling image's subbands or the number of symbols used to represent the coefficients, as shown in Figure 5.

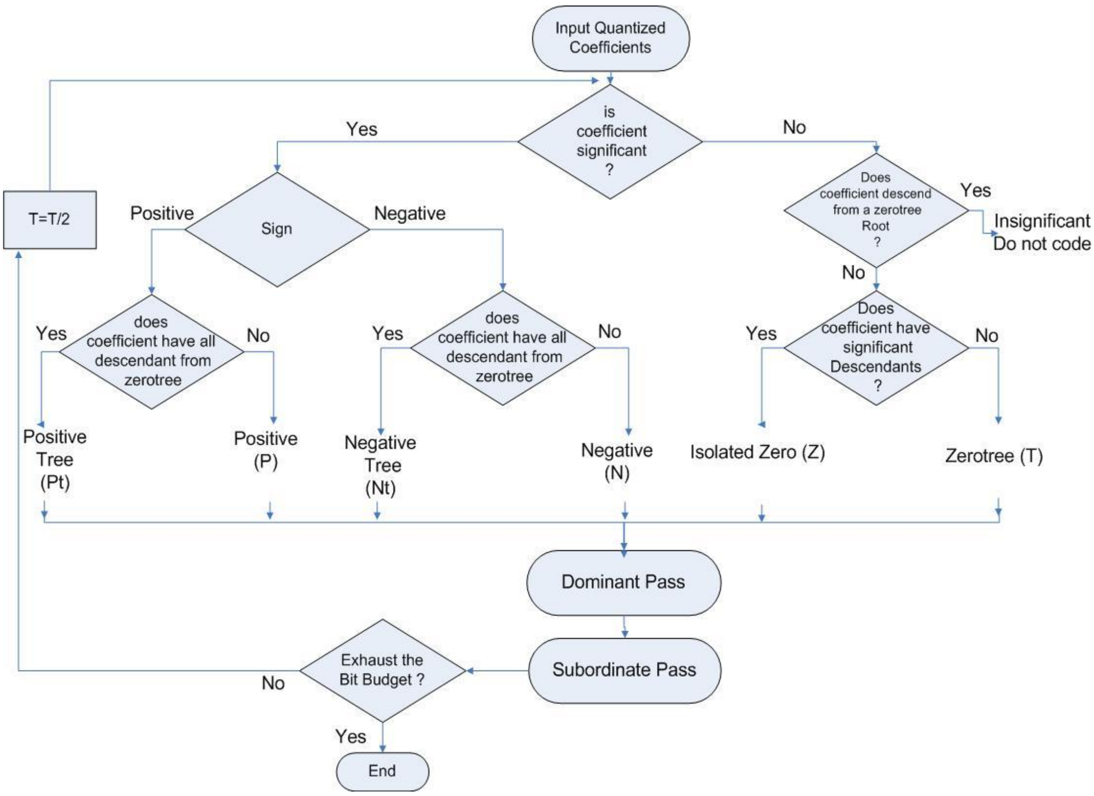

Figure 5. Flow Chart for Dominant Pass of MEZW

In 2008, Ouafi, et al., (2006) introduced (MEZW) which distributes entropy differently than Shapiro's by using six symbols $(POS, NEG, ZTR, IZ, P_t, N_t)$ instead of four symbols used in Shapiro's algorithm and also it optimizes the coding by a binary grouping of elements before coding.

The objective of Shapiro's algorithm and all modification encoder is to exploit possible dependence protocols between the wavelet coefficients of different sub-bands in order to successfully create zero-trees.

3.1 MEZW Encoder

All coefficients are tested and if founded to be significant, its descendants must also be tested. If at least one descendant is significant, then the coefficients are coded according to the rules of Shapiro's algorithm. However, if all the descendants are judged insignificant, the coefficients are coded according to MEZW algorithm's coding rules, using the symbols P_t for positive coefficients and N_t for negative coefficients as follows:

- If the significant coefficient is in the root of the matrix, then a symbol P_t, (or N_t), in MEZW algorithm, represents four symbols "PTTT' (or "NTTT') in EZW algorithm.
- If the significant coefficient is not in the root of the matrix, P_t (or N_t), in MEZW algorithm, represents five symbols "PTTTT' (or "NTTTT') in EZW algorithm.

3.2 MEZW Encoder Example Results

Let us consider the same example of Figure 4. The main difference between EZW and MEZW can be shown as follows: PP_tZT NTTT TTTT (MEZW) instead of PPZT TTTT NTTT TTTT (EZW), as shown in Table 2.

Table 2. Results for Encoding process of MEZW for 8*8 matrix

Stage	Symbols	Total Symbols	Signs List	Total Signs
1	12	12	4	4
2	12	24	7	11
3	48	72	22	33
4	56	128	42	75
5	60	188		

4. DEVELOPED MODIFIED EMBEDDED ZEROTREE WAVELET TRANSFORM (DMEZW)

Many improvements have been made on original Shapiro's algorithm since 1993 which is used four symbols (POS, NEG, ZTR, IZ), and that modification include either reading the coefficients for the image as (Raster or Morton) scan order, also handling image's subband or the number of symbols used to represent the coefficients.

The current development on MEZW can be explained by using Morton scanning order for the coefficients for better optimizing the coding and reordering the coefficient from the most important to the less one. The main difference between the current development and MEZW is in handling the subband of the image because in MEZW and EZW the coding process is ignored (LL_n) subband because it contains the most significant information of the image and any little loss of information will defect the entire image quality. Figure 6 shows the difference between the current development and the original and modified version of (EZW).

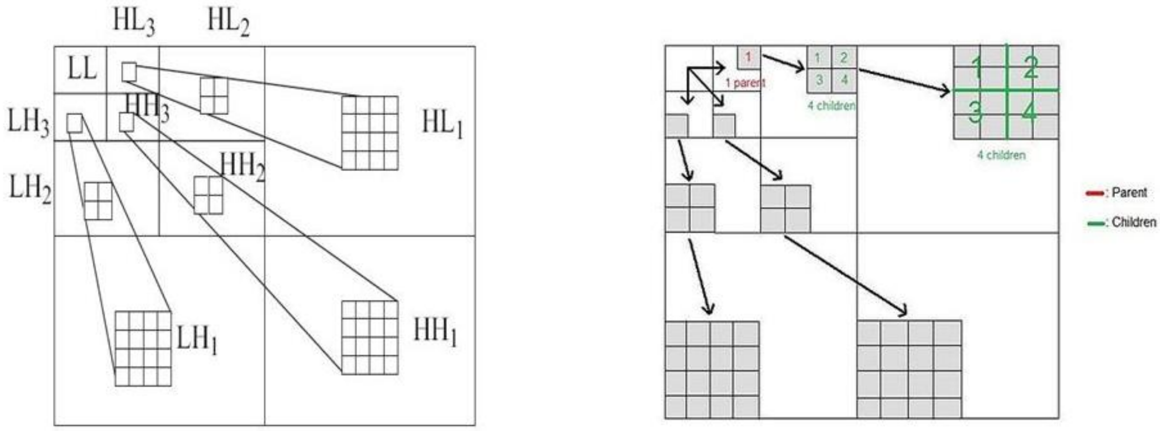

Figure 6. a) Parent-Descendant Dependencies b) Proposed Parent-Descendant Dependencies

For example, in image size 512*512 of three level wavelet decomposition after applying Morton scan, the (LL_3) has size of 64*64, so from coefficient number 1 to (64*64=4096) each of these coefficients are parent for one descendant in (LH, HL, HH). This makes them together three descendants for one parent, and after that each descendant of them are parent of four descendant like in the original EZW.

4.1 DMEZW Encoder Example Results

Let us consider the same example shown in Figure 4

Table 3. Results for Encoding process of DMEZW for 8*8 matrix

Stage	Symbols	Total Symbols	Signs List	Total Signs
1	12	12	4	4
2	12	24	7	11
3	48	72	22	33
4	56	128	42	75
5	56	184		

The results show that using different scanning order leads to obtain better ordering for the coefficient and thus obtaining less number of symbols in stage 5 as shown in Table 3. This is compression with those obtained by MEZW in Table 2 and also with those obtained by EZW shown in Table 1. For five steps of EZW it is generated 194 symbols as total, for five steps of MEZW it is generated 188 symbols as total and for five steps of DMEZW it is generated 184 symbols as total, as shown in Table 4.

Table 4. Compression Between Different Algorithms from Number of Symbols Generated.

	Algorithm	Total Symbols for 5 stage decompression
1	EZW	194
2	MEZW	188
3	DMEZW	184

4.2 Experimental Results

From Table 5, it can be seen that the results obtained are better in terms of PSNR and CR (bpp) than standard shapiro's EZW for all images for the iteration starting from 1 until almost iteration 8, when (bpp) became close to 1

Table 5. Comparison Among Proposed Algorithms with Several Well-known Algorithms

Image	Coding algorithm	PSNR (dB)		
		0.25 bpp	0.5 bpp	**1 bpp**
Lena (512*512)	**proposed**	**33.87**	**36.44**	**38.20**
	MEZW	33.20	36.93	**40.64**
	EZW	33.17	36.28	**39.55**
	SPIHT	34.11	37.21	**40.44**
	SPECK	34.03	37.10	**40.25**
Barbara (512*512)	**proposed**	**30.58**	**32.61**	**35.81**
	MEZW	27.23	31.41	**36.77**
	EZW	26.77	30.53	**35.14**
	SPIHT	27.58	31.40	**36.41**
	SPECK	27.76	31.54	**36.49**
Goldhill (512*512)	**proposed**	**32.45**	**33.90**	**36.10**
	MEZW	29.91	32.92	**36.86**
	EZW	30.31	32.87	**36.20**
	SPIHT	30.56	33.13	**36.55**
	SPECK	**30.50**	**33.03**	**36.36**

5. CONCLUSION

An image compression scheme DMEZW based on the same principle as Shapiro's algorithm was developed. This algorithm is able to improve the performance of the EZW and MEZW algorithms it is used six symbols to represent the image coefficients instead of four used by Shapiro's EZW and also used binary regrouping of these symbols generated by DMEZW by 3-bits for dominant list and 8-bits for subordinate list for better optimizes the coding, it is also used Morton scan order for reordering the coefficients of image instead of using raster scan order used in Shapiro's algorithm. All its modified versions have ultimately been tested differently with last low frequently subbands (LL_n) by having three descendants from each coefficient in it than all other subbands. This proposed scheme and programming code has achieved high Compression Ratio (CR) and remarkable Peak Signal to Noise Ratio (PSNR).

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