A New Lossless Medical Image Compression Technique using Hybrid Prediction Model

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Abstract

Medical image compression presents the best solution as hospitals move towards filmless imaging and go completely digital. Due to the large size of images; image compression is required to reduce the redundancies in image and represents it shortly with efficient archiving and transmission of images. When the information is critical and losing of this information is not acceptable; the lossless technique is the best image compression method for that purpose. But this technique has a big problem which is the compression rate is very low compared with a lossy compression technique. Many lossless compression techniques such as LPC-Huffman and DWT-Huffman were presented to enhance the compression rate, but these techniques still suffering from low compression rate. In this paper, a new hybrid lossless image compression technique which named LPC-DWT-Huffman (LPCDH) technique is proposed to maximize compression. The image firstly passed through the LPC transformation. The waveform transformation is then applied to the LPC output. Finally, the wavelet coefficients are encoded by the Huffman coding. Compared with both Huffman and DWT-Huffman (DH) techniques; our new model is as maximum compression ratio as that before.

Keywords: Medical Image Compression, LPC-Huffman, DWT-Huffman, LPCDH Technique.

1. INTRODUCTION

Image compression is an important research issue. The difficulty in several applications lies on the desired high compression rates. There are a number of techniques and methods that have been approved and proposed in this regard. These techniques can be classified into two categories, lossless and lossy compression techniques. Lossless techniques are applied when data are critical and loss of information is not acceptable. Hence, many medical images should be compressed by lossless techniques. On the other hand, Lossy compression techniques are more efficient in terms of storage and transmission needs but there is no warranty that they can preserve the characteristics needed in medical image processing and diagnosis. [1].

Image compression methods are based on either redundancy reduction or irrelevancy reduction while most compression methods exploit both. The parts of a coder that process redundancy and irrelevancy are separate in some methods; while in other methods they cannot be easily separated [1]. Several image compression techniques encode transformed image data instead of the original images [2]-[3]. An efficient method for medical images is based on two processes of transformation of quantized medical images prior to Huffman encoding, so that threefold compression can be obtained.

The overall organization of the paper is as follows. The main idea is presented in section II, we provide a brief review of the related work in section III, The main idea of Huffman encoding, Linear Predictive Coding, Discrete Wavelet Transform and performance measures equations is discussed in section IV, we describes the proposed methodology used, the mathematical model, the simulation results and the discussion and performance evaluation provided by the three techniques, Huffman, DH and the proposed, LPCDH in section V. Finally, the conclusions drawn are elaborated in section VI.

2. MOTIVATION AND CONTRIBUTION

2.1 Motivation

Most hospitals store medical image data in digital form using picture archiving and communication systems due to extensive digitization of data and increasing telemedicine use. However, the need for data storage capacity and transmission bandwidth continues to exceed the capability of available technologies. Medical image processing and compression have become an important tool for diagnosis and treatment of many diseases so we need a hybrid technique to compress medical image without any loss in image information which important for medical diagnosis.

2.2 Contribution

Image compression plays a critical role in telemedicine. It is desired that either single images or sequences of images be transmitted over computer networks at large distances that they could be used in a multitude of purposes.so The main contribution of the research is aim to compress medical image to be small size, reliable, improved and fast to facilitate medical diagnosis performed by many medical centers.

3. RELATED WORK

JAGADISH H. PUJAR proposed the Lossless method of image compression and decompression using Huffman coding this technique is simple in implementation and utilizes less memory, the decompressed image is approximately equal to the input image. The compression ratio is low [16]. Neelesh Kumar Sahu, et al are merging the Huffman encoding technique along with LPC for the enhancement of compression ratio but it still low [17]. Harjeetpal Singh , Sakshi Rana present hybrid model which is the combination of DWT, DCT and Huffman which applied to normal image not medical ones [13]. Vaishali G. Dubey, Jaspal Singh 3D image is divided into smaller nonoverlapping tiles on which 2D DWT is applied. Thereafter, Hard Thresholding and Huffman coding are respectively applied on each of the tiles to get compressed image [14]. Mohamed Abo-Zahhad , et al compare DWT-Huffman and DPCM-DWT-Huffman with other ones and the compression ratio of the methods is lower than our proposed [15].

4. DEFINITIONS

This section represent the main concepts used for proposed method.

4.1 Huffman

Figure 1 shows a schematic block diagram for image compression using Huffman encoding method. The Huffman encoding starts with calculating the probability of each symbol in the image. The symbols probabilities are arranged in a descending order forming leaf nodes of a tree. When the symbols are coded individually, the Huffman code is designed by merging the lowest probable symbols and this process is repeated until only two probabilities of two compound symbols are left. Thus a code tree is generated and Huffman codes are obtained from labelling of the code tree. The minimal length binary code for a two-symbol source, of course, is the symbols 0 and 1. The Huffman codes for the symbols are obtained by reading the branch digits sequentially from the root node to the respective terminal node or leaf. Huffman coding is the most popular technique for removing coding redundancy [4], [18].

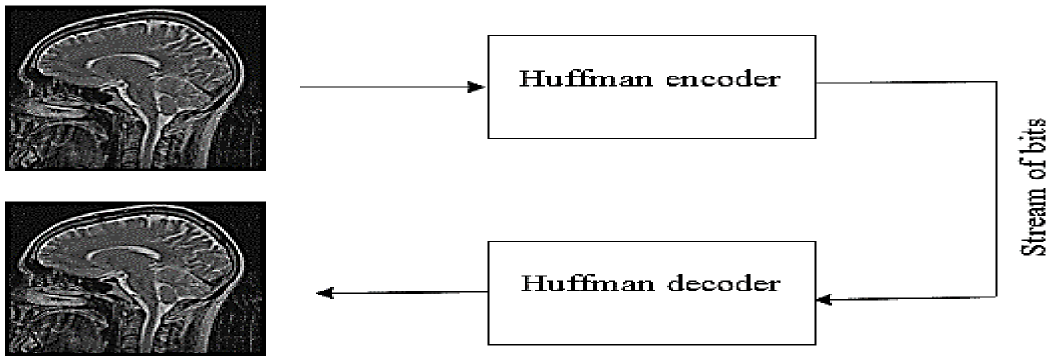

FIGURE 1: Schematic diagram of image compression using Huffman encoding.

Huffman code procedure is based on the following two observations:
a. More frequently occurred symbols will have shorter code words than symbol that occur less frequently.
b. The two symbols that occur least frequently will have the same length.
The average length of the code is given by the average of the product of probability of the symbol and number of bits used to encode it. More information can found in [5-6].

4.2 Linear Predictive Coding (LPC)

The techniques of linear prediction have been applied with great success in many problems of speech processing. The success in processing speech signals suggests that similar techniques might be useful in modelling and coding of 2-D image signals. Due to the extensive computation required for its implementation in two dimensions, only the simplest forms of linear prediction have received much attention in image coding [7]. The schemes of one dimensional predictors make predictions based only on the value of the previous pixel on the current line as shown in equation (1).

$$Z = X - D \tag{1}$$

Z denotes as output predictor and X is the considered pixel and D is the adjacent pixels.

The other schemes are called two dimensional prediction schemes. The schemes make predictions based on the values of previous pixels in a left-to-right, top-to-bottom scan of an image as given by equation (2) and shown in figure 2. In this figure X denotes the considered pixel and A, B, C and D are the adjacent pixels located on the north, northwest and west direction respectively [8].

$$Z = X - (D + B) \tag{2}$$

A	B	C
D	X	

FIGURE 2: Neighbour pixels for predicting X.

The residual error (E), which is the difference between the actual value of the current pixel (X) and the predicted one (Z) is given by the following equation.

$$E = X - Z \tag{3}$$

The residual errors are then encoded, usually by an encoding scheme like Huffman encoding, to generate a compressed data stream.

4.3 Discrete Wavelet transform (DWT)

Wavelet analysis have been known as an efficient approach to representing data (signal or image) by approximation and detailed coefficients. In one level image analysis the approximation wavelet coefficient shows the general direction of the pixel value and three detailed coefficients shows vertical, horizontal and diagonal details as shown in figure 3 – figure 4. Compression ratio increases when the number of wavelet coefficient that are equal zeroes increase [9], [19-21]. Fortunately, in practice, it has been found that many images can be represented by fewer number of wavelet coefficients. DWT has families such as Haar and Daupachies (db) the compression ratio can vary from wavelet type to another depending which one can represented the signal in fewer number coefficients.

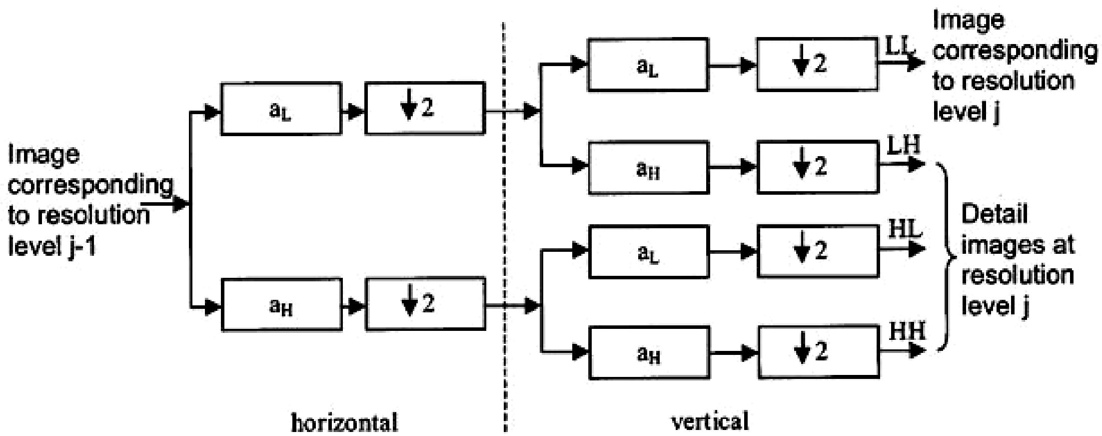

FIGURE 3: filter stage in 2D DWT [15].

There are two types of filters:
a. High pass filter: keep high frequency information, lose low frequency information.
b. Low pass filter: keep low frequency information, lose high frequency information.

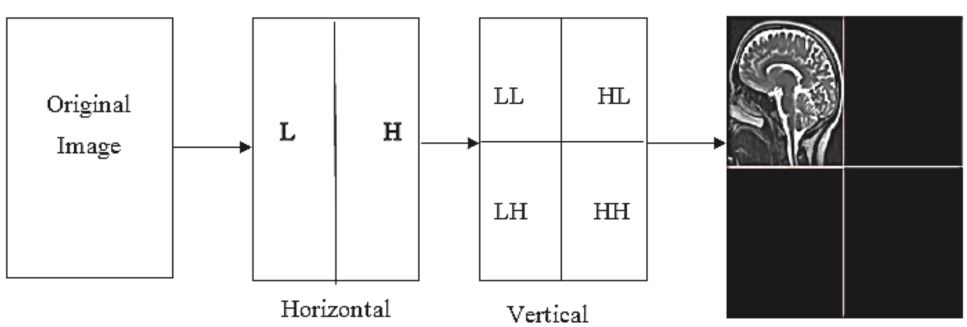

FIGURE 4: Wavelet Decomposition applied on an image.

4.4 Performance Measures Equations

The most common objective performance measures used are Maximum Absolute Error (MAE), Mean Square Error (MSE), Root Mean Square Error (RMSE), Signal-to-Noise Ratio (SNR), Peak Signal-to-Noise Ratio (PSNR), Compression Ratio (CR). The error function between the reconstructed and original images is given by

$$e(i,j) = f(i,j) - f^*(i,j) \tag{4}$$

where f(i,j) is the original image and f^* (i,j) is the reconstructed image generated form the compressed image data. The MAE is given by

$$MAE = \max\left(\left|e(i,j)\right|\right) \tag{5}$$

The MSE is the second moment of the error function between the reconstructed and original images, given by [10], [22].

$$MSE = \frac{1}{MN}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left(e\left(i,j\right)\right)^2 \tag{6}$$

Where, MxN is the image size, The RMSE is simply the square root of the MSE given by (6).
The Signal to noise ratio (SNR) in dB is given by

$$SNR = 10\log\left\{\frac{\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left[f\left(i,j\right)^2\right]}{\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left[\left|f\left(i,j\right)-f^*\left(i,j\right)\right|^2\right]}\right\} \tag{7}$$

Where the numerator is the power of the original image and denominator is the additive noise corrupting the reconstructed image. The PSNR measure the ratio the maximum pixel intensity 2B-1 (where B is number of bits) to MSE given by [10].

$$PSNR = 20\log\left(\frac{2^B-1}{MSE}\right)dB \tag{8}$$

Therefor a higher value of PSNR offers better performance. The CR is often computed by dividing the size of the original image in bits over the size of the compressed image data. Thus it is given by [11].

$$CR = \frac{Size \text{ of original image data}}{Size\ of\ \text{ compressed image data}} \tag{9}$$

The four methods, Huffman, LH, DH and the proposed LPCDH, have been applied to three CT medical images with different sizes.

5. PROPOSED SCHEME

5.1 LPC-DWT-Huffman (LPCDH)

DWT has been incorporated with LPC and Huffman, the LPC is applied to input image, then the Haar wavelet transform is applied to the prediction error which generated by LPC to obtain the approximation and detailed coefficients representing the error signal. Then the Huffman encoding applied to the nonzero coefficients producing a stream of bits. Theses bits are applied to Huffman decoder, the out of decoder is inversed transform by Invers-DWT (IDWT) then the output is applied to Inverse –LPC (ILPC) to get reconstructed image as shown in figure 5. Thus the compression ratio (CR) can be threefold of the Huffman algorithm.

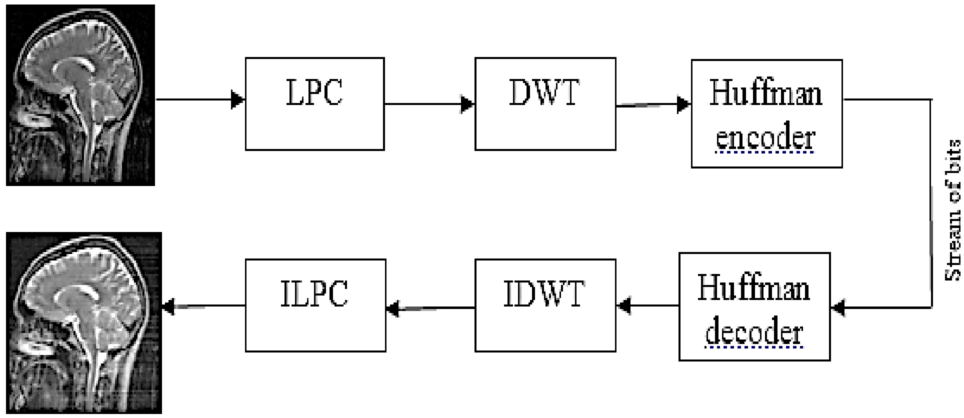

FIGURE 5: a schematic diagram for the image compression algorithm using LPC-DWT-Huffman encoding.

5.2 Mathematical Model

i LPC Equation:

$$E = X - Z \tag{10}$$

The residual error (E), which is the difference between the actual value of the current pixel (X) and the predicted one (Z) is given by the following equation.

ii DWT-IDWT Equations

- For DWT equation:

$$W_Q^i\left(j, K_1, K_2\right) = \frac{1}{\sqrt{N_1 N_2}} \sum_{n_1=0}^{N_1-1} \sum_{n_2=0}^{N_2-1} E\left(n_1, n_2\right) Q_{j,K_1,K_2}\left(n_1, n_2\right) \tag{11}$$

$$W_\mu^i\left(j, K_1, K_2\right) = \frac{1}{\sqrt{N_1 N_2}} \sum_{n_1=0}^{N_1-1} \sum_{n_2=0}^{N_2-1} E\left(n_1, n_2\right) \mu_{j,K_1,K_2}\left(n_1, n_2\right) \tag{12}$$

Where $Q\left(n_1, n_2\right)$ is approximated signal, $E\left(n_1, n_2\right)$ the output of LPC, $W_Q\left(j, K_1, K_2\right)$ is the approximation DWT and $W_Q^i\left(j, K_1, K_2\right)$ is the detailed DWT where i represent the direction index (vertical V, horizontal H, diagonal D) [12].

- For IDWT equation:

$$\begin{aligned} E(n_1, n_2) = {} & \frac{1}{\sqrt{N_1 N_2}} \sum_{K_1} \sum_{K_2} W_Q\left(j, K_1, K_2\right) Q_{j,K_1,K_2}\left(n_1, n_2\right) \\ & + \frac{1}{\sqrt{N_1 N_2}} \sum_{i} \sum_{j=0}^{\infty} \sum_{K_1} \sum_{K_2} W_\mu^i\left(j, K_1, K_2\right) \mu_{j,K_1,K_2}\left(n_1, n_2\right) \end{aligned} \tag{13}$$

iii Huffman Equations

- Entropy:

$$H = \sum_{K=1}^{L} p(i) \log \frac{1}{p(i)} \tag{14}$$

It is the mean information provided by the source per outcome or symbol. It is measured in bits/symbol. Where $p(i)$ is the probability of the symbol [15].

- The Average code word length:

$$L_{av} = \sum_{k=0}^{k-1} p_k l_k \tag{15}$$

where l_k is the Code word length.

- The Efficiency of an information is:

$$\eta = \frac{H}{L_{av}} \tag{16}$$

5.3 Simulation Model

To show the rational of incorporating the wavelet transform between the LPC and Huffman coding, we have executed the following simulation using Matlab 2014 by applying mathematical model in previous section. For an exemplary image shown in figure 6(a), we have computed the histogram of an exemplary image, figure 6(b), histogram of wavelet transform (approximation and details coefficient) as shown in figure 6(c)-(d) respectively. We have computed the LPC of the image shown in figure 6(e), its histogram, shown in figure 6(f), and the histogram of wavelet transform (approximation and details coefficient) of LPC image shown in figure 6(g)-(h) respectively. It is apparent that the wavelet transform after the LPC provides denser histogram than the histogram of wavelet transform directly of the image. This dense in the distribution leads to small number of Huffman coding.

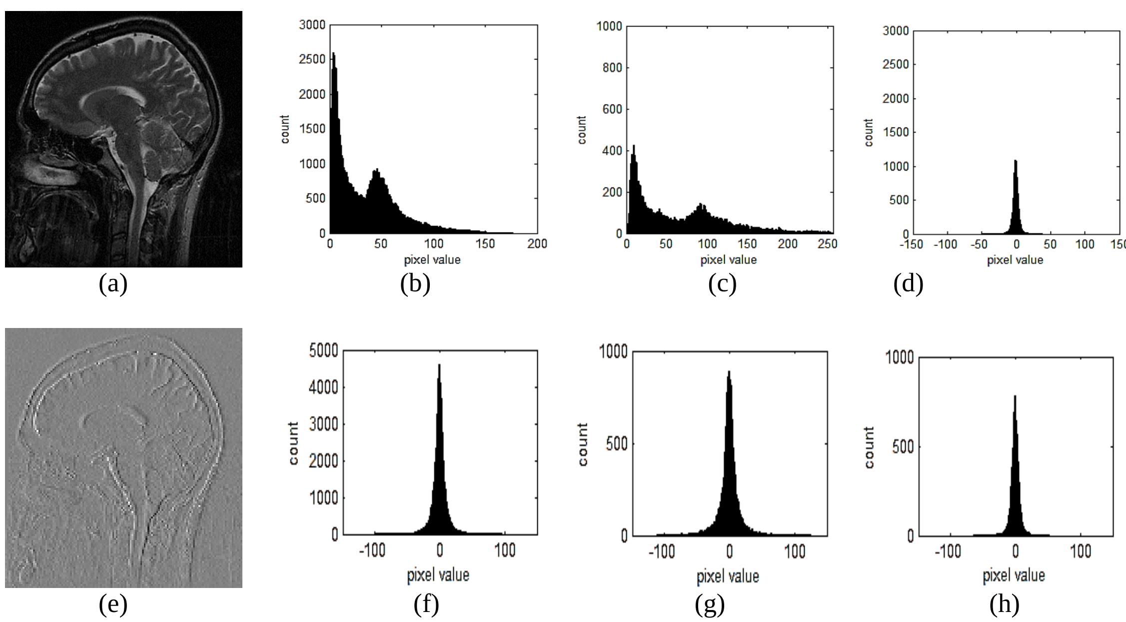

FIGURE 6: (a) Original image (b) original image histogram (c) DWT of original image (approximation coefficient) histogram (d) DWT of original image (Details coefficient) histogram (e) LPC output (f) LPC output histogram (g) DWT of LPC output (approximation coefficient) histogram (h) DWT of LPC output (Details coefficient) histogram.

5.4 Discussion and Performance Evaluation

In this section the comparison between the outputs of Huffman, DWT-Huffman and proposed LPCDH is applied on medical image shown in figure 7. Tables 1, provides the performance measures such as SNR, MES, RMSE, PSNR, CR and estimated time in seconds of the LPCDH in comparison with Huffman and DWT-Huffman. The CR is 7.78, 1.2 and 4.32 respectively and the estimated time is 17, 143, 62 sec respectively this illustrates that the proposed method is faster and higher CR than other methods.

Methods	Metrics					
	SNR	MSE	RMSE	PSNR	CR	Estimated Time (s)
Huffman	Inf	0.00	0.00	Inf	1.235	143
DWT (haar) +Huffman	11.80	61.63	7.85	30.23	4.321	62
Proposed method(LPCDH)	11.5	95.57	9.78	28.33	7.783	17

TABLE 1: Comparison between our method and other ones.

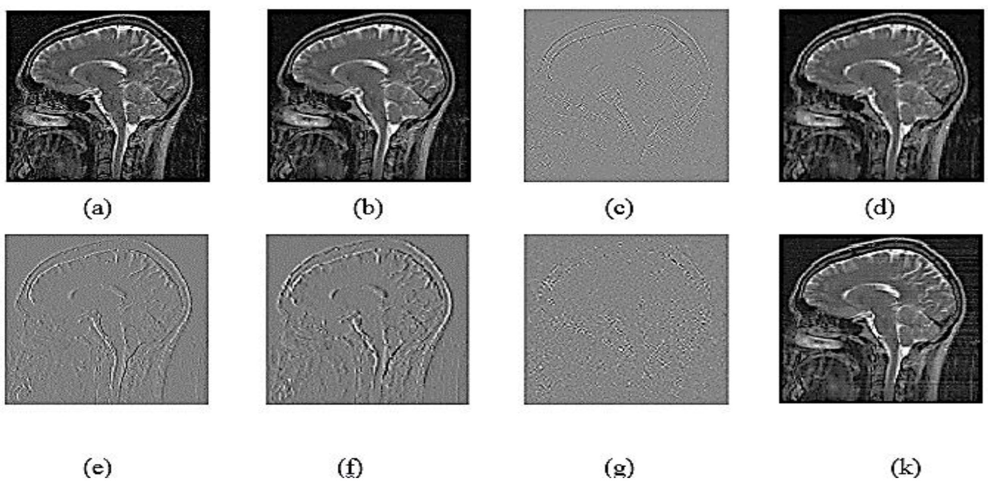

FIGURE 7: (a) Reconstructed image from Huffman compression (b) wavelet approximation coefficient from DWT-Huffman (c) wavlet details coeffient from DWT-Huffman (d) reonstructed image from DWT-Huffman (e) LPC output from LPC-DWT-Huffman (f) wavelet approximation coefficient from LPC-DWT-Huffman (haar) (g) wavelet details coefficient from LPC-DWT-Huffman (haar) (k) reconstructed image from LPC-DWT-Huffman (haar).

The time of the proposed method is very low compared with Huffman and DWT-Huffman as shown in figure 8.

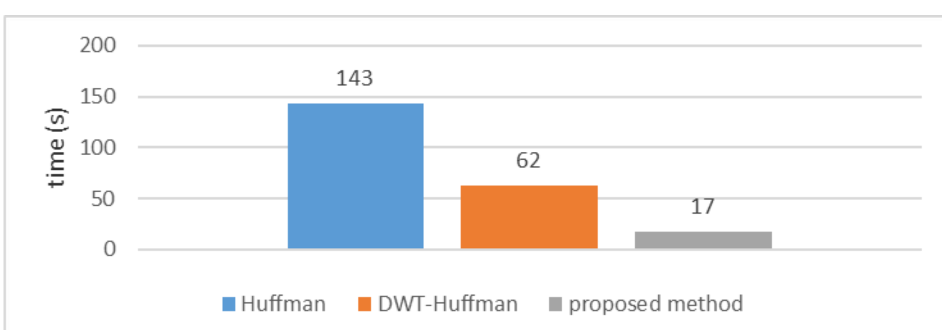

FIGURE 8: Compare between methods for taken time.

The CR of the proposed method is the highest one between the three methods as shown in figure 9.

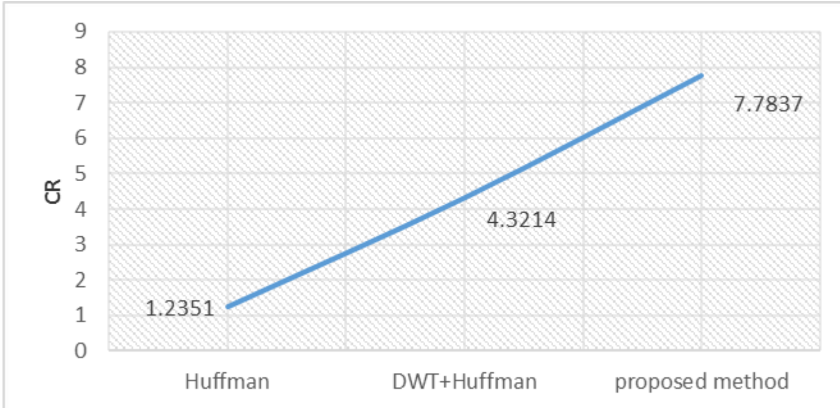

FIGURE 9: compare between methods for CR.

6. CONCLUSION

In this paper, we have presented a new image compression technique consisting of the association of the LPC, the DWT and the Huffman coding. In this technique, the image is first passed through the LPC transformation, the wavelet transformation is applied to the LPC output and finally the wavelet coefficients are encoded by the Huffman coding. So the wavelet transformation reduces the redundancy and spatial reputation in the image data, which make the compression more efficiently. Simulation results have shown that the proposed LPCDH outperforms the DWT-Huffman and Huffman methods. The three methods provide CR of 7.78, 4.32 and 1.2 respectively.

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