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Wavelet Transform and Polynomial Approximation Model for Lossless Medical Image Compression

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Abstract: In this paper, a simple lossless image compression method is introduced for compressing medical images, it is based on efficiently exploiting the polynomial representation model along with wavelet transform according to the block nature whether edge or non-edge block. The test shown high compression performance achieved with fully grunted reconstruction, its flexibility of use leads to smaller amount of compressed information required.

Keywords: Entropy Encoder, Entropy decoder and wavelet transform

1. Introduction

Data compression is a serious issue in computer storage and transmission. Today, Teleradiology (transmission of radiological patient images), has become an alternative essential way to provide patient services because its cuts costs and saves time. Teleradiology is unfortunately required network technology which limited with the bandwidth. Medical image compression of lossless based that characterized by preserving image quality as the original without any degradation, at the expense of compression performance. However, some efforts go beyond this and have constructed hybrid techniques based on combining various coding techniques, which represent a challenge in order to increase the compression performance. Reviews of different medical image compression techniques can be found in [1-9]. Polynomial representation model constitutes one of the new promising image compression techniques alternative to predictive coding method, due to simplicity and highly compression performance which adopted by a number of researchers [10-13]. On the other hand, the utilizing of efficient wavelet transform paved the way for implementing effective international standard for medical images, namely jpeg2000 [14].

In this paper, a simple lossless combined method for compressing medical images is introduced that based on exploited the polynomial approximation model of linear based along with the wavelet transform for each non-overlapped blocks. The rest of paper organized as follows, section 2 contains comprehensive clarification of the proposed system; the results for the proposed system, is given in section 3.

2- Proposed System

The scheme characterized by simplicity and efficiency based on incorporate polynomial model with wavelet transform. Figure (1) shown the proposed system and the implementation are explained in the following steps:

Step 1: Load the input uncompressed image I of size $N\times N$.

Step 2: Partition the image I into nonoverlapped blocks of fixed size $n\times n$ (i.e., $n<<N$). In general, fixed partitioning method in which the blocks are partitioned based on the size of the region, adopted in international standard coding, such as JPEG, where the ease of implementation play a critical role in use over the techniques of variable block sizes (i.e., Quadtree, Horizontal-Vertical, Triangular).

Step 3: Classify the partitioned nonoverlapped blocks into edge and non-edge regions depending on edge threshold value that corresponds to number of edge pixels in each block after applying the sobel operator on the input image I.

Step 4: Perform the combined suggested method of polynomial approximation model and wavelet transform, to encode the $n\times n$ blocks depending on its nature, the following steps are applied:

a) For non-edge blocks, use only the a_0 coefficients of polynomial approximation model that corresponds to mean value of the blocks.

$$a_0 = \frac{1}{n\times n}\sum_{i=0}^{n-1}\sum_{j=0}^{n-1} I(i,j) \quad \text{..........(1)}$$

b) For edge blocks, integrate both techniques by first exploiting the wavelet transform that characterized by high image quality with high compression ratios by decomposing each block of size $n\times n$ into approximation and detail sub bands (LL, LH, HL and HH) each of size ($n/2\times n/2$), and then perform the polynomial representation approximation model on only the approximation sub-band (LL) of low resolution size according to equations (2,3,4) [10].

$$a_0 = \frac{1}{(n/2\times n/2)}\sum_{i=0}^{(n/2)-1}\sum_{j=0}^{(n/2)-1} LL(i,j) \quad \text{..........(2)}$$

$$a_1 = \frac{\sum_{i=0}^{(n/2)-1}\sum_{j=0}^{(n/2)-1} LL(i,j)\times(j-x_c)}{\sum_{i=0}^{(n/2)-1}\sum_{j=0}^{(n/2)-1}(j-x_c)^2} \quad \text{...........(3)}$$

$$a_2 = \frac{\sum_{i=0}^{(n/2)-1}\sum_{j=0}^{(n/2)-1} LL(i,j)\times(i-y_c)}{\sum_{i=0}^{(n/2)-1}\sum_{j=0}^{(n/2)-1}(i-y_c)^2} \quad \text{..........(4)}$$

Where *LL (i,j)* is the low resolution approximation sub-band of original image block of size (*n/2*×*n/2*) and

$$xc = yc = \frac{(n/2)-1}{2} \quad \text{.............................(5)}$$

Step 5: Create the approximated or predicted image value $\tilde{I}$ using the estimated polynomial coefficients for each block representation depending on block nature, namely either by using 1 coefficient or 3 coefficients.

$$\tilde{I} = a_0 + a_1(j-x_c) + a_2(i-y_c) \text{.....(6)}$$

Step 6: Find the residual or prediction error as difference between the original *I* and the predicted one $\tilde{I}$.

$$R(i,j) = I(i,j) - \tilde{I}(i,j) \text{........(7)}$$

Step 7: Apply efficient simple symbol encoder of Arithmetic coding to code the compressed information that composed of the residual image values, the polynomial representation coefficients and the approximation and detail sub bands.

Step 8: Reconstruct the decoded or compressed image which identical to the original image *I* without any degradation or distortion, using the following steps:

a) Perform Arithmetic decoding to reconstruct the coded compressed information of residual, polynomial approximation model coefficients, and wavelet transform details.

b) Utilize the reconstructed coefficients values along with the wavelet transform information to rebuilt the predicted image value according to equation (6)

c) Apply the inverse polynomial representation model by adding the residual values to the predicted image resultant from the above step, such that:

$$I(i,j) = R(i,j) + \tilde{I}(i,j) \text{........(8)}$$

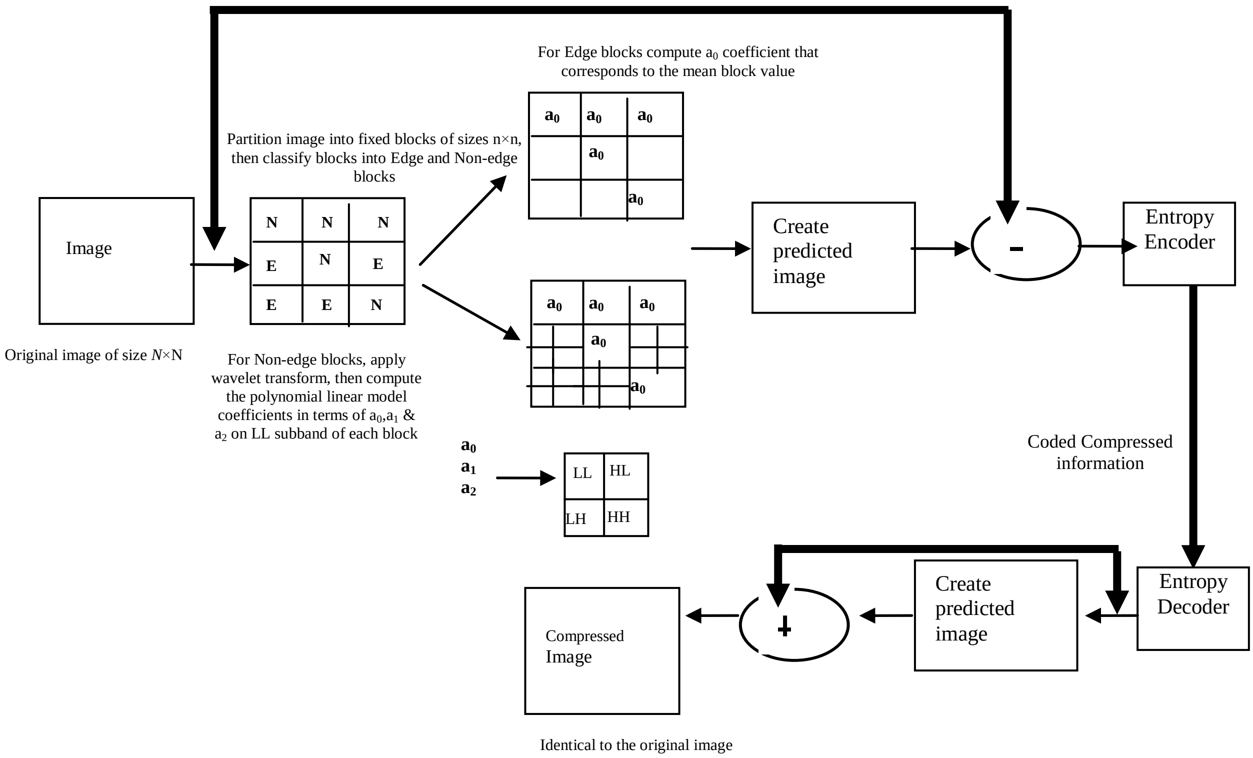

Fig. (1): Proposed compression system

Brain MR Knee-1 MR Knee-2 MR Echo-US

Fig. (2): Medical tested images

Table 1: Compression ratio on the tested medical images

Tested image	Size in bytes of Original image	No. Edge Pixels	Block Size 4×4	
			Size in bytes compressed information	Comp. Ratio
Brain	65536	2	9288	7.0560
	65536	5	6970	9.4026
	65536	7	6458	10.4180
	65536	10	5780	11.3385
Knee1	65536	2	11340	5.7792
	65536	5	8644	7.5817
	65536	7	8208	7.9844
Knee2	65536	10	8078	8.1129
	65536	2	9210	7.1157
	65536	5	6822	9.6066
	65536	7	6434	10.1859
	65536	10	6102	10.7400
echo	65536	2	8632	7.5922
	65536	5	7372	8.8899
	65536	7	7208	9.0921
	65536	10	7059	9.2840

3- Experimental Results

Experiments were done to evaluate the performance of the proposed lossless medical image compression system using a block size of 4×4 with the number edge pixel threshold value was selected to be between 2 and 10, applied on a number of medical gray square images of different types (i.e., 8bits/pixel) of size 256×256 pixels (see Figure 2 for an overview).

In order to test the lossless compression system efficiency, the common compression ratio quantitative objective criteria selected, based on measuring the size of the coded or compressed information to the size of the original uncompressed information, such as:

$$CompressionRatio = \frac{SizeofOriginalImage}{SizeofCompressedInformation} \quad \ldots\ldots\ldots\ldots\ldots(9)$$

The experimental results are listed in Table 1, showed that the compression ratio is directly affected by the image's characteristics or details. In knee1 there is highly detailed image with small background size. While other images of small/low or medium details, with large background size. These results generally imply that there is a lower/smaller compression ratio for large detailed images compared to images with small and moderate details.

Also the result illustrates clearly that the compression ratio of the tested images generally varies according to the number edge pixels threshold value which used to classify the blocks into edge or non-edge block, where for small values has a smaller compression ratio (i.e., 3 coefficients required in terns of a_0,a_1 & a_2), and as the values gets bigger the compression ratio increases, implicitly meaning a large number of blocks considered as non-edge blocks that means the use of only one coefficient (i.e., a_0) that leads decrease the size of compressed information.

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