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Lossless Medical Image Compression

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Abstract
Image compression has become an important process in today's world of information exchange. Image compression helps in effective utilization of high speed network resources. Medical Image Compression is very important in the present world for efficient archiving and transmission of images. In this paper two different approaches for lossless image compression is proposed. One uses the combination of 2D-DWT & FELICS algorithm for lossy to lossless Image Compression and another uses combination of prediction algorithm and Integer wavelet Transform (IWT). To show the effectiveness of the methodology used, different image quality parameters are measured and shown the comparison of both the approaches. We observed the increased compression ratio and higher PSNR values.
Keywords: Lossy Image Compression, Lossless Image Compression, 2D-DWT, IWT, FELICS, Image Quality Parameter

I. Introduction

During last decade there has been enormous increase in digital images. This type of information gives rise to high transmission and storage cost. To store these images or make them available over networks, compression techniques are needed. The objective of image compression technique is to reduce redundancy of the image data in order to be able to store or transmit data in an efficient form. Image compression is of two types: lossy and lossless compression. In lossy compression, the original signal cannot be exactly reconstructed from the compressed data. The reason is that, much of the detail in an image can be discarded without greatly changing the appearance of the image. The lossless image compression can remove redundant information and guarantee that the reconstructed image is without any loss to original image. For lossy compression technique, many sophisticated standards have been developed such as JPEG and JPEG 2000 for still image, and MPEG-4 and H.264 for multimedia communications and high-end video applications, respectively. FELICS algorithm used in this system is prediction based algorithm. Prediction-based algorithms apply prediction technique to generate the residual, and utilize the entropy coding tool to encode it.

II. Wavelet Transform

Wavelets are small waves (unlike sine and cosine waves with infinite duration) with finite duration having finite energy and an average value of zero. The wavelets can be used to attain information from any type of data that is not limited to only signals and images. A wavelet transform is the representation of a function using wavelets called the daughter wavelets which are scaled and translated copies of the main oscillating waveform called the mother wavelet. Wavelet transforms have become increasingly important in image compression since wavelets allow both time and frequency analysis simultaneously. Here we have used Discrete Wavelet Transform & Integer Wavelet Transform.

III. Discrete Wavelet Transform

In Discrete Wavelet Transform (DWT) the wavelets are discretely sampled. The DWT of a signal is calculated by passing the signal through series of filters called filter bank. The sample x is simultaneously passed through a high pass filter and a low pass filter with impulse response g resulting in a convolution. $y[n]$ is the convolution of input signal x with the impulse response g.

$$y[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k]g[n-k] \qquad (1)$$

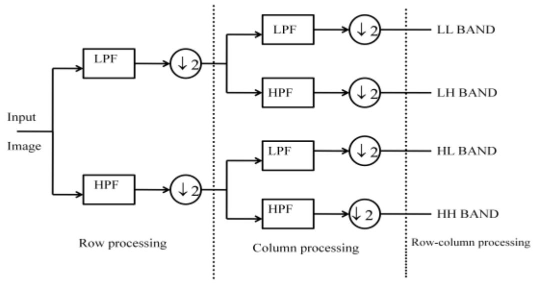

Fig.1: Wavelet decomposition

IV. Integer Wavelet Transform

Integer wavelet transform maps an integer data set into other integer data set. This transform is perfectly invertible and gives exactly the original data set. If the input data consist of sequences of integers, then the resulting filtered outputs no longer consist of integers, which do not allow perfect reconstruction of the original image. However, with the introduction of Wavelet transforms that map integers to integers we are able to characterize the output completely with integers.The image is transformed in different sub bands.

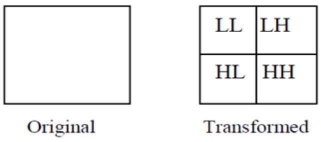

Fig.2.Image after applying DWT and IWT

The LL Sub-band contains a rough description of the image and hence called the approximation Sub-band. The HH Sub-band contains the high-frequency components along the diagonals. The HL and LH images result from low-pass filtering in one direction and high-pass filtering in the other direction. LH contains mostly the vertical detail information, which corresponds to horizontal edges. HL represents the horizontal detail information from the vertical edges. The sub-bands HL, LH and HH are called the detail sub-bands since they add the high-frequency detail to the approximation image.

V. FELICS Algorithm

The FELICS, proposed by P. G. Howard and J. S. Vitter in 1993, is a lossless compression algorithm with the advantage of fast and efficient coding principle. FELICS presents competitive coding efficiency in comparison with other sophisticated lossless compression algorithms.

In FELICS, three primary techniques, including intensity distribution model, adjusted binary code and Golomb-Rice code, are incorporated to construct a complete coding flow. The FELICS encoding flow is summarized as following steps:

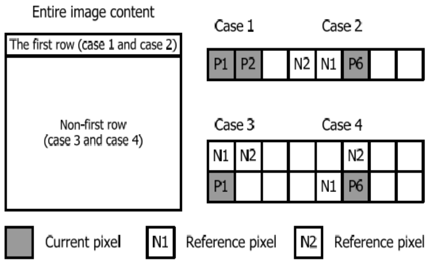

Fig.3: Illustration of Prediction Template in FELICS.

1. The first two pixels at first row are directly packed into bit stream without any encoding procedure.
2. According to the prediction template in Fig.3 find the corresponding two reference pixels, N1 and N2.
3. Assign, L= min (N 1, N 2), H = max (N 1, N 2) and delta=H –L. Apply adjusted binary code for P-L in range, Golomb–Rice code for L-P-1 in below range, and Golomb–Rice code for P-H -1 in above range as shown in Fig.4 .Except first two pixels at first row, the others are directly started from step 2 to step 4. The decoding flow can by approximately obtained by inversion of encoding data flow. The prefix code is utilized to decide the decoding mode, and thus the image samples can be recovered in decoding procedure.

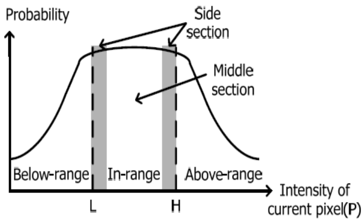

Fig.4: Illustration of Intensity Distribution Model

VI. Predictive Coding

Lossless predictive coding predicts the value of each pixel by using the values of its neighboring pixels. Therefore, every pixel is encoded with a prediction error rather than its original value. Typically, the errors are much smaller compared with the original value so that fewer bits are required to store them. Integer addition of the current sample and a constant is one-to-one under some amplitude constraints on all computer architectures. Integer addition can be expressed as,

$$e(n) = f_{of}(X(n) + S(n)) \tag{2}$$

Where f_{of} is the overflow operator, *x* (n) is the current sample, *s* (n) an integer value which defines the transformation at time *n,* and *e* (n) is the current filter output.

The reverse operation is given by the equation

$$X(n) = f_{of}(e(n) - S(n)) \tag{3}$$

This process always leads to an increase in number of bits required. To overcome this, rounding operation on the predictor output is performed making the predictor lossless. The lossless predictive encoder and decoder are shown in Figure.

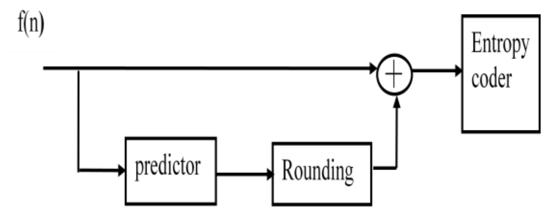

Fig.5: Block Diagram of Predictive Encoder

In the process of predictive coding input image is passed through a predictor where it is predicted with its two previous values.

$$\hat{f}(n) = \overset{*}{\alpha}\, f(n-1)\, \overset{*}{\beta}\, f(n-2) \quad (4)$$

$\hat{f}(n)$ is the rounded output of the predictor, f(n-1) and f(n-2) are the previous values, α and β are the coefficients of the second order predictor ranging from 0 to 1. The output of the predictor is rounded and is subtracted from the original input. This difference is given by

$$d(n) = f(n) - \hat{f}(n) \quad (5)$$

Now this difference is given as an input to the decoder part of the predictive coding technique. In the decoding part the difference is added with the f^ (n) to give the original data.

$$f(n) = d(n) + \hat{f}(n) \quad (6)$$

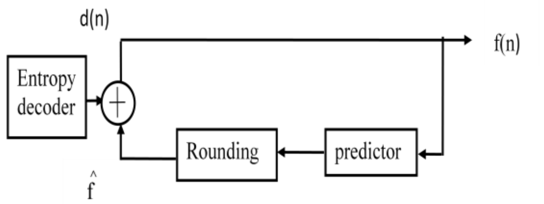

Fig.6: Block Diagram of Predictive Decoder

VII. Lifting Scheme

To implement Integer Wavelet Transform forward lifting scheme is used & for implementation of inverse Integer Wavelet Transform Reverse lifting scheme is used. In this lifting we have used the Haar filter of the order one and also one level decomposition. Filter coefficients are given for,

Type I h1= [-1 9 9 1] / (16)
h2= [0 0 1 1] / (-4)

Where h1 is the prediction filter coefficient and h2 is update filter coefficient in the lifting scheme.

The filter coefficients of reduction are given by,

Type II h1= [-1 9 9 1] / (16*1.5)
h2= [0 0 1 1] / (-4*1.5)

7.1 Forward Lifting Scheme

Lifting scheme consists of three steps:

1. Split: It splits the signal into two disjoint set of samples. One consists of even indexed samples and other odd indexed samples. Splitting into even and odd samples is called lazy wavelet transform

$(Odd_{j-1}, Even_{j-1}) = Split(S_j)$

2. Predict: By using Haar an odd sample will use left neighboring even sample as its predictor. We then let the detail be the difference between odd sample and its prediction.

$d_{j-1} = Odd_{j-1} - P(Even_{j-1})$

3.Update : average is calculated by using the difference value and even value

$S_{j-1} = Even_{j-1} + U(d_{j-1})$

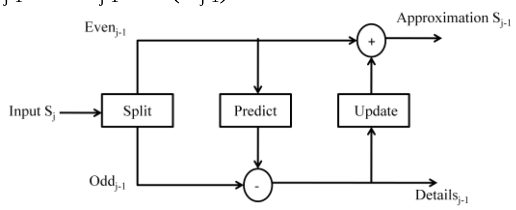

Fig.7: Block Diagram of Forward Lifting Scheme

7.2 Reverse Lifting Scheme

Inverse transform gets back to original signal by exactly reversing operation with a merger operation to split. Even sample can be recovered by subtracting update information.

$$Even_{j-1} = S_{j-1} - U(d_{j-1}) \quad (7)$$

Odd sample can be recovered by adding prediction.

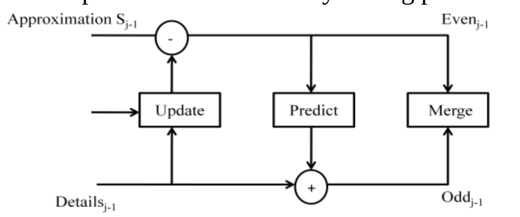

Fig.8: Block Diagram of Reverse Lifting Scheme

VIII. System Model of Approach – 1

8.1 Encoder

When the input image is passed through 2D-DWT block, image is decomposed to a desired level to obtain four sub bands viz. LL, LH, HL and HH. Since LL band contains approximate information it is further compressed losslessly using FELICS algorithm and other bands are made zero. 2D-DWT is implemented using Haar Wavelet and Daubechies Wavelet.

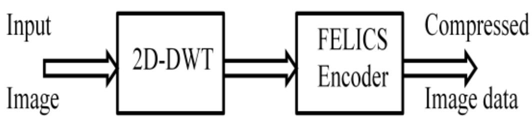

Fig.9: Block diagram of encoder

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8.2 Decoder

Fig.10 shows that decoder has 2 blocks FELICS decoder and 2D-IDWT.The compressed image output obtained at the transmitter is given as input to the FELICS decoder, at the output of FELICS decoder we get LL band of compressed image .This LL band along with three other bands which were made zero during encoding are now given to the 2D-IDWT block we get the reconstructed image.

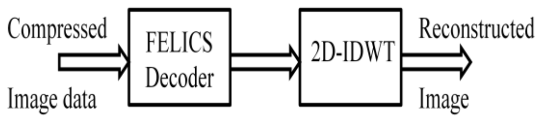


Fig.10: Block diagram of Decoder

IX. System Model of Approach – 2

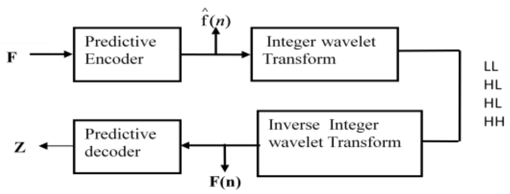


Fig.11: Block diagram of Approach-2

In this method the original image 'F' is first applied to the predictive encoder to give encoded image denoted as $\hat{f}(n)$ and then to integer wavelet transform which divides the image into four sub-bands as LL, LH, HL, and HH. In the decoding part of the design these four sub-bands undergo inverse integer wavelet transform to get the decoded image denoted as F (n) and then predictive decoding is done to get the reconstructed image represented as 'Z'. To verify perfect reconstruction the Original and reconstructed images are subtracted and the output is a dark image with maximum values as zero.

X. Image Quality Parameters

Image quality parameters such as compression ratio (CR), Mean squared error (MSE), Peak-signal to noise ratio (PSNR) et .al. are measured. I1 (m, n) indicates an element of original image matrix and I2 (m, n) indicates an element from compressed image matrix. Also M and N indicate the number of rows and columns of image matrix. For calculating the image quality parameters the dimensions of original and compressed images must be same.

10.1 Compression Ratio (CR)

Compression ratio is defined as,

$$\frac{\text{Original Image File size}}{\text{Compressed Image File size}}$$

Higher the compression ratio, reconstructed image is more compressed and the quality of image degrades.

10.2 Peak signal to noise ratio (PSNR)

PSNR is defined as,

$$\text{PSNR}=10\log_{10}\left(\frac{255^2}{MSE}\right)$$

PSNR should be as high as possible, low value of PSNR means the quality of image is poor

10.3 Mean Squared Error (MSE)

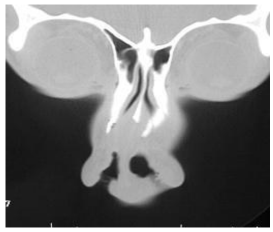
Mean squared error is defined as,

$$\text{MSE} = \frac{\sum_{M,N}[I_1(m,n)-I_2(m,n)]^2}{M*N}$$

The large value of MSE indicates that image is of poor quality.

XI. IMAGES USED FOR TESTING

Ribcage Image, 256x256 resolution, BMP File type



Nasal fract Image, 256x256 resolution, BMP File type

XII. Results

Here in this paper two medical images are compressed using both approach – 1 and approach – 2 and measured image quality parameters like Compression ratio(CR), Peak signal to noise ratio (PSNR), Mean Squared Error (MSE).

Table 1: Results of Ribcage Image for approach – 1

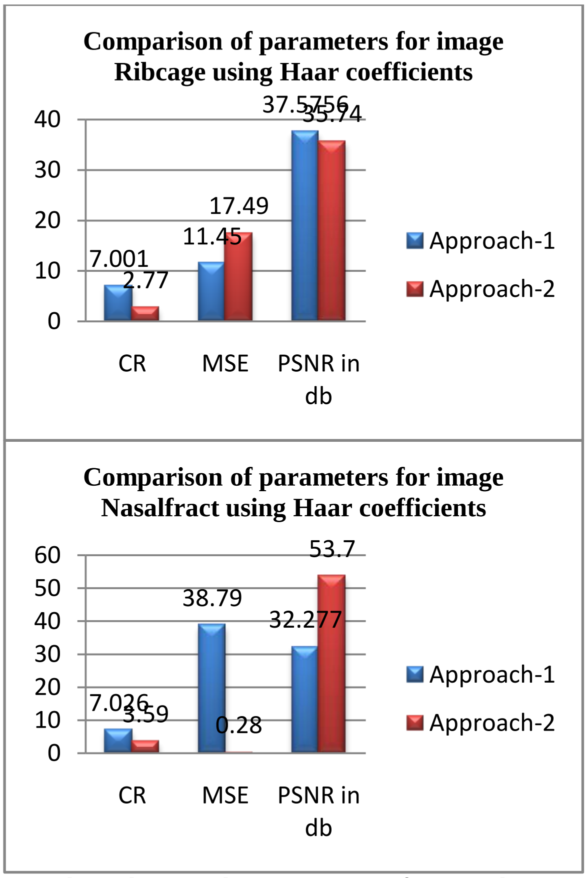
Ribcage Image	**Compression technique**	
	1-Level DWT(Haar)+FELICS	**1-Level DWT(db2)+FELICS**
CR	7.001	6.868
Encoded time	32.1429s	31.8034s
MSE	11.45	3.32
PSNR in db	37.5756	45.9483

Table 2: Results of Nasal fract Image for approach – 1

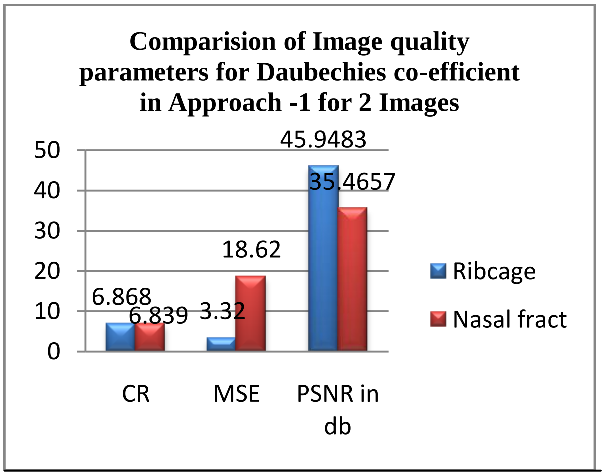
Nasal fract Image	**Compression technique**	
	1-Level DWT(Haar) +FELICS	**1-Level DWT(db2)+FELICS**
CR	7.026	6.839
Encoded time	13.6416s	12.4457s
MSE	38.79	18.62
PSNR in db	32.277	35.4657

Table 3: Results for approach – 2

Image	CR	PSNR in db	MSE	Encoding Time
Ribcage Image	2.77	35.74	17.49	0.587360s
Nasal fract	3.59	53.70	0.28	0.48437s



Graph 1: Showing the comparison of approach-1 & approach-2 for Haar co-efficient for two Images



Graph 2: Showing the comparison of Image quality parameters for Daubechies co-efficient in approach-1 for two Images

XIII. Conclusion

The methodology used in approach - 1 is 2D-DWT & Felics algorithm, where only LL band is taken into consideration for the processing after DWT. Approach II is Prediction and IWT where all four bands are processed and reconstructed. As shown in the result table, we have achieved higher compression ratios and also maintaining the quality of image for both Haar and Daubechies filter coefficients for one level decomposition in approach I compared to approach II, Better PSNR values are achieved in approach II. In approach-1, Image quality is good in 1-Level DWT (db2) + FELICS compare to 1-Level DWT (Haar) + FELICS.

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