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Lossless Image Compression of Medical Images Using Golomb Rice Coding Technique

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Abstract—*Medical Science Applications generate a huge amount of sequential images for medical diagnosis, such as Magnetic Resonance Images (MRI), Computed Tomography (CT) scan, and Fluoroscopy. Fluorography is a continuous form of X-Ray. These images take up a large amount of storage and also takes large time and cost in transmission. To maintain the good quality of medical images, lossless compression is preferred, because it is very difficult to diagnose a problem in blurred or poor quality images.*
The existing algorithm for still image compression such as Run Length Encoding (RLE), Huffman coding and Block Truncation Coding (BTC) were developed by considering the compression efficiency parameter by giving least importance to the visual quality of images. Hence we introduce a new lossless image compression technique based on Golomb-Rice Coding, which efficiently maintain the compression ratio up to 8.7 for good visual quality in the reconstruction process and enhanced Peak Signal to Noise Ratio (PSNR) up to 34.525627 for test image im_3 and 35.526205 for test image im_10 in medical images. The Proposed work of this technique is simulated and tested in MATLAB.

Keywords: *Fluoroscopy; ROI; Lossless image compression; Huffman Coding; Golomb-Rice Coding.*

1. INTRODUCTION

Digital images have become very popular in the present scenario, especially in Medical science application, electronic industries and other organizations like satellite imaging, and multimedia applications. In the last few years medical images have been increased tremendously in terms of generation, transmission and storage. This has brought the attraction of many researchers in developing novel techniques for compressing medical images.

Image compression is the process of minimizing the size in bytes of an image file without degrading the visual quality of the image to an unacceptable level. The compact file size allows to store more images in a fixed amount of disk or memory space. It also reduces the transmission time required for images to be sent over the Internet or downloaded from Web pages.

Compression techniques can be classified into Lossy and Lossless compression.

Lossy compression reduces the size of an image by permanently eliminating certain information, especially redundant information. Lossy compression reduces the accuracy of medical images, and which makes doctors unable to diagnose the case of the patient. JPEG, DCT and DWT are some common examples of lossy image compression techniques.

All the original data can be reconstructed when the file is uncompressed. By implementing lossless compression, every single bit of data that was present in the original file remains as it is after the file is uncompressed. All of the information is completely restored. So it is specially used for Medical image compression. JPEG-LS, PNG, TIFF are some lossless image compression file formats. Lossy image compression techniques provide a high compression ratio while the lossless image compression techniques give an improved visual quality of images after reconstruction process[1][2].

The Haar wavelet, which is the simplest of all the 2D DWT, along with thresholding has been applied on a JPEG image. After that Run Length Entropy Coding has been adopted. This approach is used for compression of image using parameter CR (Compression Ratio) without losing the parameter PSNR, the quality of image, using less bandwidth [3]. Run length coding is the standard coding technique for compressing the images. This method counts the number of repeated zeros which is represented as RUN and appends the non-zero coefficient represented as LEVEL following the sequence of zeros. Then it was observed that for the occurrence of consecutive non-zero sequence the value of RUN is zero for most of the time, so this redundancy was removed by encoding the nonzero coefficient (LEVEL) only, instead of an ordered pair of RUN (= 0)/ LEVEL. According to this scheme the single zero present between two non zero coefficients would be encoded as (1,0) .The proposed work aims at removing the unintended RUN, LEVEL (1,0) pair used for a single zero present between the two non-zero characters. So instead of using (1, 0) pair for the zero between non-zero characters, a single ’0’ will be encoded [4].

Huffman coding is a variable length coding that assigns longer codes to symbols with low probabilities and shorter codes to symbols with higher probabilities. This coding scheme is efficient to compress differential data[5].The RLE is one of the most popular and simplest method that is applied to the repeated data or code pattern in a single code[6]. The combination of two effective compression methods that is RLE and Huffman was proposed to reduce the data volume, pattern delivery time and save power in scan applications[7]. In medical images the combination of run length and Huffman coding was implemented on MRI images and X-Ray angiograms to achieve maximum compression [8]. Lossless compression of Fluoroscopy medical images using correlation and Huffman coding was done in [9][10]

A new method for lossless compression of pharynx and esophagus fluoroscopy images, using correlation and combination of Run Length and Huffman coding on the difference pairs of images classified by correlation. From the experimental results obtained, the proposed method achieved improved performance [11]. A hint for the application of Golomb Rice encoding for compressing Fluoroscopic medical images was given in [11].

Golomb coding is a lossless data compression technique using data compression codes invented by Solomon W. Golomb in the 1960s. Alphabets following a geometric distribution will have a Golomb code as an optimal prefix code, making Golomb coding highly suitable for situations in which the occurrence of small values in the input stream is significantly more likely than large values. Rice coding is invented by Robert F. Rice. It denotes using a subset of the family of Golomb codes to produce a simpler (but possibly suboptimal) prefix code; Rice used this in an adaptive coding scheme, although "Rice coding" can refer to either that scheme or merely using that subset of Golomb codes. Whereas a Golomb code has a tuneable parameter that can be any positive value, Rice codes are those in which the tuneable parameter is a power of two. This makes Rice codes convenient for use on a computer, since multiplication and division by 2 can be implemented more efficiently in binary arithmetic. Rice coding is used as the entropy encoding stage in a number of lossless image compression and audio data compression methods [12]. Golomb-Rice coding, is introduced also for improve the JPEG standard. Since the coding scheme is not based on frequency analysis from certain of images to gain a codebook, the decoded images that are encoded with this scheme are assured in average quality. The standard JPEG compression scheme can import these two for higher compression rates or wider application fields [13]. Hierarchical interpolating prediction and adaptive Golomb-Rice coding, and achieves 7-35 times faster compression than existing methods such as JPEG2000 and JPEG-LS, at similar compression ratios [14].

2. GOLOMB-RICE CODING

In this Rice–Golomb encoding, the remainder code uses simple truncated binary encoding, also named "Rice coding" (other varying-length binary encodings, like arithmetic or Huffman encodings, are possible for the remainder codes, if the statistic distribution of remainder codes is not flat, and notably when not all possible remainders after the division are used). In this algorithm, if the M parameter is a power of 2, it becomes equivalent to the simpler Rice encoding.

1. Fix the parameter M to an integer value.
2. For N, the number to be encoded, find
   quotient = q = int[N/M]
   remainder = r = N modulo M

3. Generate Codeword
1. The Code format: <Quotient Code><Remainder Code>, where
2. Quotient Code (in unary coding)
   1. Write a q-length string of 1 bits
   2. Write a 0 bit
   3. Remainder Code (in truncated binary encoding)
      1. If M is power of 2, code remainder as binary format. So $\log_2(M)$ bits are needed. (Ricecode)
      2. If M is not a power of 2, set b=$\lceil \log_2(M) \rceil$
      1. If r<2^b-M code r as plain binary using b-1 bits.
      2. If r>=2^b-M code the number r+2^b-M in plain binary representation using b bits.

Example

Set M = 10. Thus b=$\lceil \log_2(10) \rceil$ =4

The cutoff is 2^b-M=16 10=6

Table 1(a): Results of Golomb Coding for M=10 and b=4

Encoding of Quotient Part	
Q	**Output bits**
0	0
1	10
2	110
3	1110
4	11110
5	111110
6	1111110
…..	………….
N	111…….1110

Table 1(b): Results of Golomb Coding for M=10 and b=4

Encoding of remainder part			
R	**Offset**	**Binary**	**Output**
0	0	0000	000
1	1	0001	001
2	2	0010	010

3	3	0011	011
4	4	0100	100
5	5	0101	101
6	12	1100	1100
7	13	1101	1101
8	14	1110	1110
9	15	1111	1111

3. PROPOSED METHOD

The proposed method is to implement Golomb-Rice coding to provide lossless image compression in sequential medical images used in modern era such as MRI, CT Scan and Fluoroscopy, to decrease the transmission time and enhance the storage capacity. The work enhances the compression ratio by testing the two sequential images to examine the shifting existence. This is to ensure that our proposed method is robust to the shifting cases. Identifying and Extracting accurately the ROI, as shown in Fig. 1, is an essential step before coding and compressing the image data for efficient transition or storage. The proposed method is divided into two main phases: the first is preprocessing and the final phase is encoding. To restore the series of images, the process is reversed.

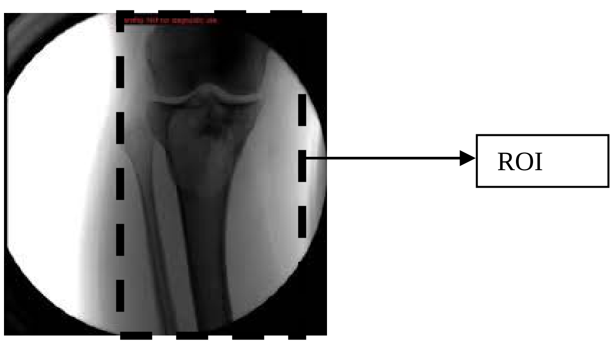

Fig. 1: Important area in fluoroscopy images

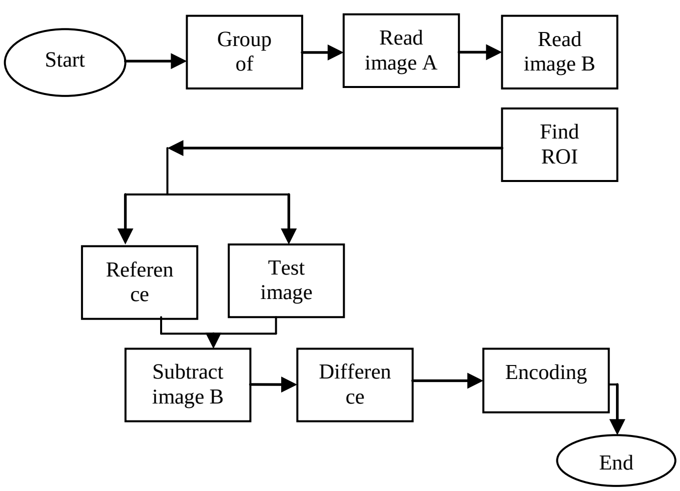

Fig. 2: Finding process of ROI

Compute the difference between images by subtracting the test image from the reference image, as most images taken from the same view are mostly similar. Therefore, we can use the first image as the base pattern (reference image) and store only the difference results as a vector. The process outlines are shown in Fig. 2.

4. RESULTS AND DISCUSSIONS

The fluoroscopic images of lungs are subtracted with a reference image and the resulting difference vector is then encoded using Golomb-Rice Encoding Method. The procedure is repeated for every image being sent to the destination. The size of the encoded difference vector is found to be smaller then the original images. Let the reference image vector be im_ref, the test image vector be im_test. The difference vector found according to the rule given below:

[Im_diff] = [im_ref]-[im_test]

Now the im_diff vector is encoded using Golomb-Rice encoder and transmitted to the destination. The process is shown in Fig. 3.

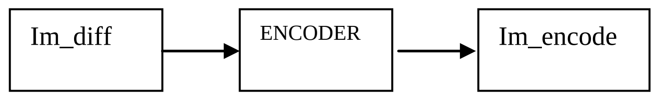

Fig. 3: Encoding process of difference vector

At the destination a reverse process for restoration of the original image is done as shown in Fig. 4.

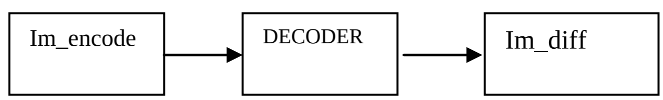

Fig. 4: Decoding process of encoded vector

The decoded images are checked for the MSE and PSNR values. The simulation and the verification of the results are done in MATLAB environment. The results of the encoded image is compared with the result of Huffman coding and RLHM (Run length-Huffman) coding in terms of compression Ratio, MSE and PSNR values.

The comparison of the proposed method with Huffman Encoding and RLHM coding in terms of CR is shown in Table 2(a).

Table 2(a): Comparative results in terms of Compression Ratio

Encoding Method	**File Name**	**Size of difference vector**	**Size of coded difference vector**	**Size of Restored image**
Golomb Rice Coding	Ref1-Im1.tif	18726	3040	18882
	Ref1-Im2.tif	18514	2128	17638
	Ref2-Im3.tif	7862	2628	7877

	Ref2-Im4.tif	7856	2368	7886
	Ref2-Im5.tif	7784	2385	7793
	Ref2-Im6.tif	7968	2584	7964
	Ref2-Im7.tif	7657	2538	7685
	Ref2-Im8.tif	7456	2653	7565
	Ref2-Im9.tif	7665	2638	7686
	Ref2-Im10.tif	7454	2453	7484
Huffman Encoding	Ref1-Im1.tif	18726	5770	18786
	Ref1-Im2.tif	18514	6182	18820
	Ref2-Im3.tif	7862	5680	7874
	Ref2-Im4.tif	7856	4986	7867
	Ref2-Im5.tif	7784	5588	7798
	Ref2-Im6.tif	7968	5984	7986
	Ref2-Im7.tif	7657	5830	7699
	Ref2-Im8.tif	7456	5417	7552
	Ref2-Im9.tif	7858	5081	7872
	Ref2-Im10.tif	7827	4467	7863
RLHM Coding	Ref1-Im1.tif	18726	3454	18786
	Ref1-Im2.tif	18514	2862	18820
	Ref2-Im3.tif	7862	3455	7868
	Ref2-Im4.tif	7856	3546	7876
	Ref2-Im5.tif	7784	3350	7789
	Ref2-Im6.tif	7968	3559	7976
	Ref2-Im7.tif	7657	3245	7657
	Ref2-Im8.tif	7456	3127	7472
	Ref2-Im9.tif	7233	3273	7283
	Ref2-Im10.tif	7468	3529	7477

The comparison of the proposed method with Huffman Encoding and RLHM coding in terms of MSE & PSNR is shown in Table 2(b).

Table 2 (b): Comparative Results in terms of MSE & PSNRThe graphical comparison of the proposed method with Huffman Encoding and RLHM coding in terms of compression Ratio (CR) is shown in Fig. 5.

Encoding Method	File Name	MSE	PSNR
Golomb Rice Encoding	Im1.tif	28.639636	33.595124
	Im2.tif	42.948235	31.835346
	Im3.tif	28.234761	34.525627
	Im4.tif	64.154267	29.535246
	Im5.tif	48.725367	33.352566
	Im6.tif	63.763782	28.562662
	Im7.tif	52.377263	32.367457
	Im8.tif	62.637263	28.536666
	Im9.tif	43.635626	31.525625
	Im10.tif	53.635526	35.526205
Huffman Coding	Im1.tif	74.658577	29.400007
	Im2.tif	170.606866	25.810839
	Im3.tif	92.426246	27.326635
	Im4.tif	53.943453	23.762187
	Im5.tif	74.637609	28.612736
	Im6.tif	64.154267	25.712678
	Im7.tif	48.725367	27.672321
	Im8.tif	63.763782	21.672377
	Im9.tif	52.377263	24.763278
	Im10.tif	62.637263	25.712672
RLHM Coding	Im1.tif	74.658577	29.434002
	Im2.tif	170.606866	25.844834
	Im3.tif	92.427372	28.657574
	Im4.tif	53.327678	23.546647
	Im5.tif	74.732684	28.356577
	Im6.tif	64.326478	25.765648
	Im7.tif	48.322387	27.567475
	Im8.tif	63.132891	22.676576
	Im9.tif	52.873242	24.576437
	Im10.tif	62.328974	25.654564

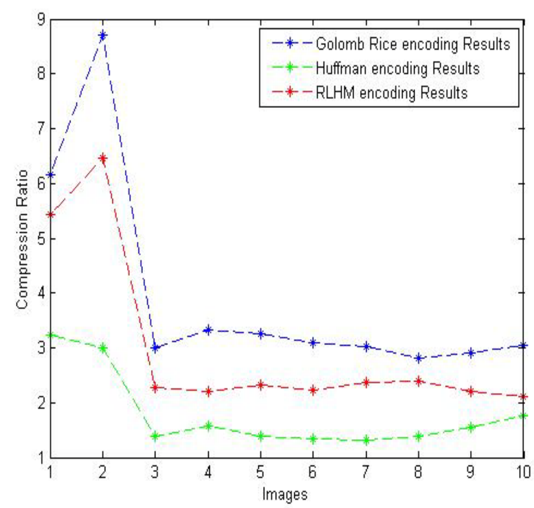

Fig. 5: Comparative analysis with experimental results for different encoding scheme in terms of compression ratio (CR).

5. CONCLUSION

The research work in this thesis describes that the Golomb rice encoding method improves the compression ratio and maintains visual quality in case of shifted images to the other method like Huffman coding and Run length Huffman coding. The experimental results in this thesis validate the research work. According to the results calculated, the Golomb Rice coding method achieves better compression ratio up to 8.7 for test image (im2) as the size of difference vector reduces from 18514 to 2128 in this method , the values of MSE is 28.639636 and PSNR value is 33.595124 and for difference vector of test image im1 and the values of MSE is 42.948235and PSNR value is 31.835346 for test image im2 which is better than Huffman coding and Run length Huffman (RLHM) coding methods.

The Compression Ratio enhances the storage capacity and the MSE & PSNR values improve the visual quality of restored image.

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