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Influence of Golomb Rice and Run-length Encoding in Image Compression – An Analysis

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Abstract: An image is worth more than thousand words. In the present world, the use of digital images in communication has drastically increased. Raw images that are captured by digital cameras or created digitally have excess of redundant information that are not processed by the human eye and that does not hamper visual perception of image upon their elimination. Image compression technique removes this excess of information to make the images less in size and easily transferrable. Image compression is categorized as lossy and lossless compression. In lossless compression there is an absence of loss of data. Whereas, lossy compression-reduces a data by permanently eliminating certain information especially redundant data. The existing methods uses combination of various lossy compression techniques for compression that are applicable for tiff format images that are already reduced in their size [1]. The proposed method also uses combination of compression techniques along with frequency-based transformations on any uncompressed images by satisfying various performance parameters such as Compression ratio, SNR, PSNR and MSE.

Index Terms: Compression, Lossy image compression, Lossless image compression.

I. INTRODUCTION

Digital Image Processing

Digital image processing is processing of images by utilized a digital computer. The principle advantage of Digital Image Processing methods is its versatility, repeatability and the preservation of original data precision. Digital image processing contains varies algorithms to process the image. Digital image processing contains varies processing methodology that is

- Image representation: converting an image into representation of pixels in the form of matrix
- Image pre-processing: processing of image so that an image can be utilized for digital image processing.
- Image enhancement: increasing the quality of the image.
- Image restoration: restoration of image which is damaged or destroyed under various circumstances.
- Image analysis: analysis the image to obtain the information which is present with in image.
- Image reconstruction: conversion of images from one dimension to another dimension.
- Image compression: minimizing the capacity require to store or transmit the image.

A image contains [2] a significant amount of information. For this purpose, storing of image require a lot of memory capacity to not to lose this information. The image compression become mandatory to minimize the size of which will be helpful in storing and transmission of image.

Image Compression

Image compression is a method that is utilized to minimize the storage consumption of images, videos that leads to increase storage and transmission process's performance. Image compression do not only focus on minimization of storage capacity of image but also concentrate on processing it without diminishing the quality and without depriving the dominant information of image. Images contain large amounts of information that have necessity of large storage space, large transmission bandwidths and long transmission time. Therefore, it is essential to compress the image by retaining the dominant and essential information needed to reconstruct the image. An image can be thought of as a matrix of pixel (or intensity) values. In order to compress the image, redundancies must be exploited, for example, areas where there is little or no change within pixel values. Therefore, images having large areas of uniform color will have large redundancies and simple to compress, and conversely images that have frequent and large changes in color will be less redundant and harder to compress. For the compression of images there exist large No of methods are available which can be utilized for a simple to a most sophisticated image. The nature of compression technique to utilize depends on the complexity of the image. Image compression technique is mainly implemented by reducing the storage require to store the redundancy present in the images. Image compression technique are categorized into two types that's lossy and lossless compression.

Lossy Image Compression

Lossy image compression is a image compression type in which the process discard some of the data from the image file and minimize the actual file size. This process is irreversible, that is once it is implemented the data which is lost cannot be retrieved. Some of the algorithms that is utilized to implement lossy compression include the transform encryption, discrete wavelet transform and fractal compression.

- Advantages:
  - Reduce the size considerable
- Disadvantages:
  - Reduce the quality of the of image
  - Loss of data is irreversible

Lossless Image Compression

Lossless image compression is a image compression type in which the minimization occur by removing additional, non-essential information and also by reducing the spatial redundancy. Some of the algorithms that are utilized to implement lossless image compression include run-length encoding, Huffman coding and arithmetic encoding.

- Advantages:
  - No loss of data
  - Data is retrievable
  - No reduction in image quality
- Disadvantages:
  - Least minimization capacity

Process of image compression

First an image is pre-processed with the help of digital image pre-processing techniques. Various pre-processing techniques were denoising, grey scale conversion, normalization etc. After pre-processing an image will be ready for feature extraction. Features extraction will be done by digital image feature extraction techniques. Various feature extraction techniques are PCA, GLCM, canny edge detection etc. After features extraction is done, these features were utilized to know the information present in the image. Later this information is exploited for image compression. Image compression will be done with various algorithms based on the requirement.

II. Literature survey

Many researchers and scholars done work and proposed various methodologies to improve the image compression techniques.

Murat Alparslan Gungor and Kenan Gencol [3] done a work to find the optimal operating point between image compression and image visual quantity. In this work an optimal compression methodology based on transform coding which is utilized for noisy images. This work combines a wavelet dependent JPEG2000 compression algorithm with wavelet dependent denoising algorithms. In this work proposed method is applied on the medical images if the noise is present with in an image, then denoising algorithm were implemented before compression. If noise is less or least, then directly proposed compression algorithm is applied to minimize the computation time. This work states that proposed methodology can achieve the optimal result. Maximum compression can also be obtained when visual quantity is minimized.

Mu Li et al proposed a [4] strategy by utilizing context based convolutional networks to develop an entropy model. Probabilistic structure of digital images plays a dominant role in image compression. In this work developed entropy model is utilized for both lossy and losses image compression algorithms which leads to favorable outcome. This work states that developed entropy model by utilizing the convolutional networks leads to better compression in lossless image compression algorithms whereas in lossy image compression technique better visual quality can be maintained.

Cheonshik Kim et al developed a [5] methodology to hide the data in image compression. In this methodology Adaptive BTC Edge Quantization along with optimal pixel adjustment process were utilized to optimize two quantization levels that are embedding capacity and quality of the compressed image. DH method depend on Adaptive BTC Edge Quantization algorithm which is proposed in this methodology is utilized for embedding the data present in the image and optimal pixel adjustment process is utilized to ensure the quality of compressed image. This works stated that the proposed methodology gives a satisfactory result in both embedding capacity and quality of compressed image. It is stated that this process in done on a cover page that results in large embedded capacity without reducing the quality of a cover image.

A strategy [6] developed by P. Chitra and M. Mary Shanthi Rani for digital image compression which is done on medical images. This strategy contains two levels to get the image compression that are vector quantization and thresholding. Haar Wavelet Transformation is applied on image to obtain one Approximation Co-efficient matrix and three Detailed Coefficient matrices. AC matrix is again decompressed by vector quantization and thresholding is implemented on DC matrices. After thresholding DC matrices were compressed by run-length coding. This works states that this strategy led to obtain compressed image with no reduction of quality of image.

Roman Starosolski [7] introduced a methodology for lossless image compression. Hybrid Adaptive Lossless Image Compression which depends on Discrete Wavelet Transform is proposed in this work. In this method sub-bands of images obtained from DWT were processed using RDLS algorithm with step skipping and new wavelets are developed by utilizing heuristics and entropy along with predictions. This method is applied on wide range of images. This work states that the efficiency of this compression is almost twice when comparted to standard JPEG2000 and all result were better compared to other algorithms

A. Sathesh developed [8] a methodology involves a hybrid data representation utilizing the light field coding. In this work a hybrid data representation which traverse four major redundancies. In this work a new hybrid light field data representation by utilizing light field coding is introduced. The work stated that the Life code images are compressed efficaciously by utilizing codec (HEVC).

Sandor Piros, Peter Korondi developed [9] a method that is entropy dependent adaptive compression method. The main features of this method is hierarchical schema and entropy dependent compression. In this method wavelet transform of a dataset is rearranged to a binary tree like schema. Based on schema the importance of compression will be considered in this method. This work states that this method can be utilized both on lossy and lossless algorithms.

III. EXISTING METHOD

Run-Length Coding

Run Length technique is an unadorned configuration of lossless image compression technique where the sequences in which likewise data value occurs consecutively are accumulated as a combined data value and count rather than as the original run is accommodated [10]. Run alludes to a pixel sequence having same values and the length of run alludes to the number of pixels accommodate likewise values. This technique is preferred where the image has many same pixel values run. But this method is not much useful for images with short or a smaller number of runs. An essential role of Run-length (RL) is in the application of maps in Internet. The performance of RL encoding exhibits better results than raster-based processing. The advantage of Run-length encoding (RLE) is that single data value and count accommodate the run. This technique is utilized for the image that contains data of such runs.

- Ex: AAAABBCCCAA
  - Sol: A3B2C3A2

Huffman Coding

The most exploited technique for removing coding redundancy is by the virtue of Huffman. When coding the characters individually, Huffman coding yields the least feasible numbers of code characters per original characters. In phrase of noiseless coding theorem, the derived code is optimal for a predetermined value of n, concern to the constraint that original characters to be coded each one at a time.

The initial step in Huffman's approach is to generate a series of original minimization by ordering the probabilities of the characters under cogitation and amalgamate the lowest probability characters into a single character that reinstate them in the preceding original minimization.

In the following step Huffman's procced towards to code for every minimized original, starting with the least original and functioning back to the original origin. The minimal length binary code for two characters origins, of course, is the characters 0&1.

Huffman coding is one of the entropy coding which is lossless and is utilized in various images and video standards. This technique is a standard prefix code generated from the character occurrence probabilities. These codes consisting of variable code length. Depending on the probabilities, bits are assigned to each character. In this the higher probability characters gets a smaller number of bits and least probability characters get a greater number of bits which aggregates in the reduction of the average code length that leads to storage capacity of the compressed data is lesser than the original. Huffman coding gives a great deal of compression gain with in digital images.

Table.1 The Variable Length Code Obtained from Huffman Coding

Original Source			Reduction Source					
Characters	Probability	Code	1		2		3	
a1	0.4	1	0.4	1	0.4	1	0.4	1
a2	0.3	10	0.3	10	0.3	10	0.6	0
a3	0.15	101	0.15	101	0.3	11		
a4	0.075	1101	0.15	111				
a5	0.075	1011						

Lavg=0.4*1+0.3*2+.15*3+0.075*4+0.075*4=2.05 bits/character.

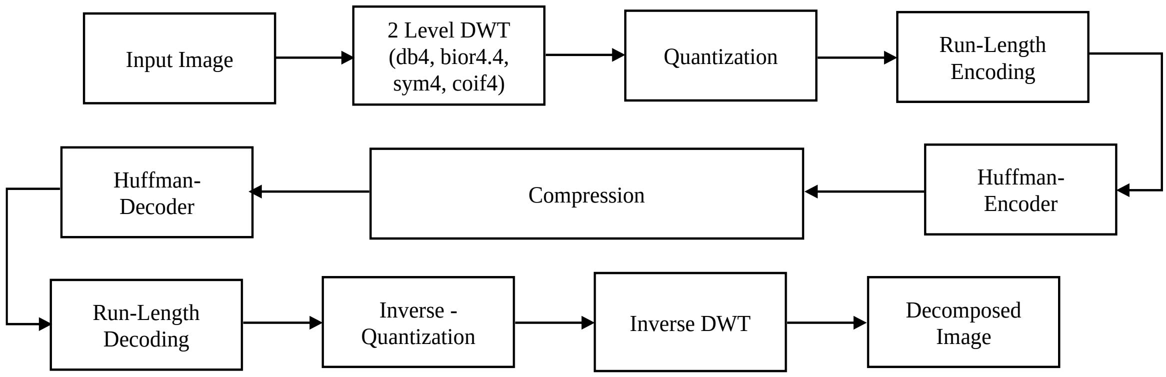

Figure.1 RH Compression Model

RH Compression Pseudo Code
Input: Grayscale image.
Output: Compressed .dat file.
Step1: Read input grayscale image.
Step2: Implement 2-level DWT on input grayscale image to obtain wavelet sub-bands (LL, LH, HH, HL sub-bands).
Step3: Load the image which is obtained from 2-level DWT.
Step4: Apply Quantization on the sub-bands of the image to obtain quantized image.
Step5: Identify the storage capacity of the quantized image after quantization.
Step6: Process the data of quantized image by run length encoding to minimize the storage capacity of image to a certain extent.
Step7: Implement Huffman encoding on the data obtained from the run length coding.
Step8: Compressed .dat file is obtained.

RH Decompression Pseudo Code
Input: Compressed .dat file.
Output: Decompressed image.
Step1: Read the input compressed .dat file.
Step2: Implement Huffman decoding on the .dat file to decode the Huffman encoding to obtain data.
Step3: Implement Run length decoding to obtain the quantized image.
Step4: Apply inverse quantization on quantized image this will leads to obtain the wavelet sub-bands of image.
Step5: Implement inverse DWT on wavelet sub-bands of image to obtain original decompressed image.
Step6: Decompressed image is obtained.

IV. PROPOSED METHODOLOGY

Golomb Coding

Golomb coding is a lossless data compression technique which utilize a family of data compression codes [11] introduced and developed by Solomon W. Golomb in the 1960s. Alphabets which consists a geometric distribution possess a Golomb code will be considered as an optimal prefix code, this leads to Golomb coding highly compactable for circumstances in which the contingency of least values within the input stream is notable greater than large values.

Rice Coding

Rice coding is a lossless data compression technique introduced by Robert F. Rice which utilize a subset of the family of Golomb codes to generate an uncomplicated prefix code but it is mostly a sub optimal code. This method utilizes this set of codes in a robust coding scheme. This method is proposed to make Golomb coding to uncomplicated to generate a subset due to the fact that geometric distributions changes frequently with time period which is not known exactly due this reason adapting to seemingly optimal code might not be very dominant in various circumstances. Rice coding is utilized in entropy encoding stage in various lossless audio data compression and lossless image compression methodologies.

Consider constant P, any character T can be expressed as a quotient U and remainder V, where: $T = U \times P + V$. If T is less with respective to P then U will also consist at least value. Rice encoding is constructed to minimize the number of bits essential to express characters where U is least value. Instead expressing both U and V as binary values, Rice encoding express U as a unary value and V as a binary value.

Example: 7 = 11111110 and 10 = 111111111110.

Encoding

Rice coding is uncomplicated methodology.
Consider a bit length, Z. Calculate the modulus, O by utilizing the equation O = 2Z. Repeat following for every character P:

1. Writing P& (O - 1) in binary.
2. Writing P >>Z in unary.

Example:

Encoding the 8-bit value 18 (0000010010) where Z = 4 implies O = 16

1. P& (O - 1) = 18 & (16 - 1) = 0000010010 & 001111 = 000010
2. P>>Z = 18 >> 4 = 0000010010 >> 4 = 000001 that is 10 in unary

From this the encoded value obtained is 100010, which saves 2 bits storage.

Decoding

Decoding is also uncomplicated as encoding.

Like encoding, consider a bit length Z. Calculate the modulus, O by utilizing the equation O = 2Z. Repeat the process for each encoded character P:

1. Identify U by counting the number of 1s preceded by the first 0.
2. Identify V by reading the succeeding Z bits as a binary value.
3. Write P as U × O + V.

Example:

Decoding the encoded value 100010 where Z = 4 and O = 16

1. U = 1
2. V = 000010 = 2
3. P = U × O + V = 1 × 16 + 2 = 18

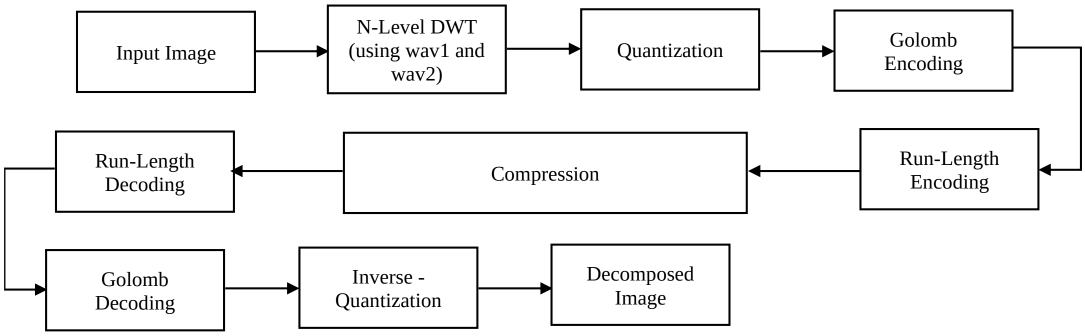

Figure.2 Proposed Flow Model

GR Image Compression Pseudo code

Input: Digital image.

Output: Compressed .dat file.

Step1: Reading a digital image of either grayscale or RGB image.

Step2: If the input image is RGB type then convert the RGB digital image into grayscale digital image.

Step3: Now grayscale image is decomposed by utilizing wavelets for N-level DWT to obtain sub-bands (LL, LH, HH, HL).

Step4: Select wavelet sub-bands of image then assign the sub-bands for quantization.

Step5: Implement Quantization for the input grayscale image which is decomposed by the N- level DWT to obtain quantized image.

Step6: Implement Golomb Encoding on the quantized image to obtain data.

Step7: Implement Run length Encoding on the data obtained from the Golomb Encoding to obtain final compressed data.

Step8: After implementation of run length encoding now compute the encoded data to view the resultant compressed image.

Step9: The compressed data is stored as .dat file.

GR Image Decompression Pseudo code

Input: Compressed .dat file.

Output: decompressed digital image.

Step1: Read compressed .dat file.

Step2: Read the data present within the compressed .dat file.

Step3: Implement the run length decoding on the data obtained from .dat file.

Step4: Implement the Golomb decoding on the data obtain from the run length encoding to obtain the quantized image.

Step5: Implement dequantization on the quantized image to obtain the decomposed image.

Step6: Execute Inverse DWT on the decomposed image to produce decompressed image.

Step7: Decompressed image is acquired.

V. TABLES AND GRAPHS

The results of the proposed and existing are compared and tabulated along with respective graphs:

Table.2 PSNR Comparison between existing method and proposed method

S.No	Image Name	PSNR	
		Existing method	Proposed method
1	Rice	20.1433	26.4187
2	Coins	19.1241	28.4187
3	Pears	21.6128	28.1087
4	Lena	20.1531	27.467
5	Tree	23.1211	25.6854

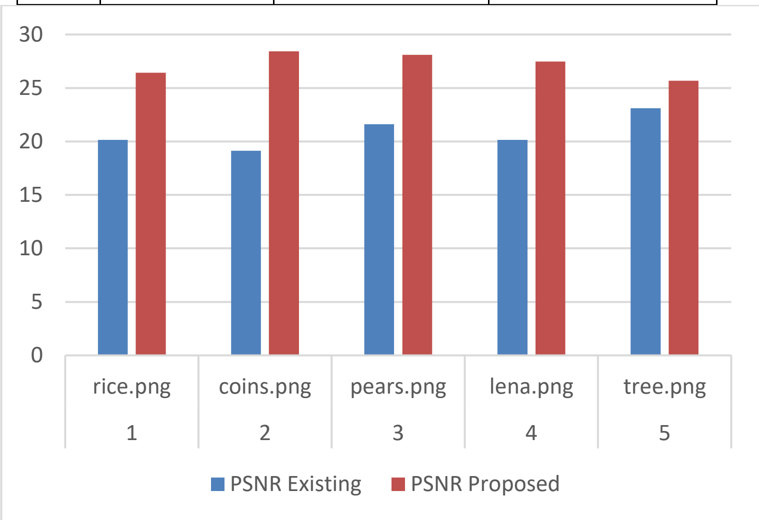

Figure.3 PSNR Comparison between Existing method and proposed method

Table.3 MSE Comparison between existing method and proposed method

S.No	Image Name	MSE	
		Existing method	Proposed method
1	Rice	150.8112	137.8751
2	Coins	101.2171	99.583
3	Pears	109.6123	100.509
4	Lena	121.9136	116.509
5	Tree	180.1121	175.6071

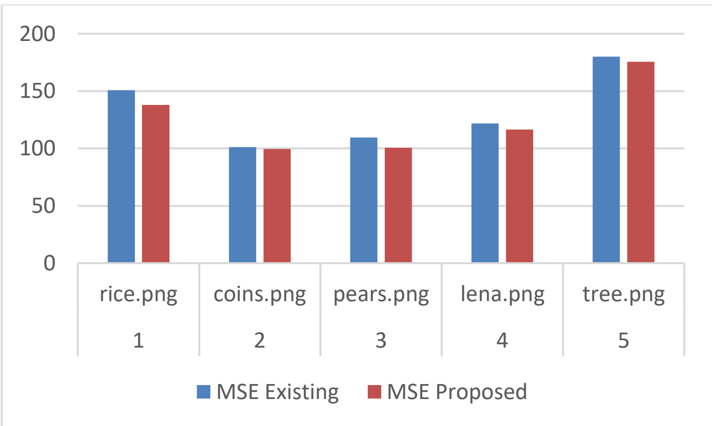

Figure.4. MSE Comparison between existing method and proposed method

Table 4 Compression Ratio comparison between existing method and proposed method

S.No	Image Name	COMPRESSION RATIO	
		Existing method	Proposed method
1	Rice	2.3593	4.8494
2	Coins	3.0254	5.3857
3	Pears	5.2543	5.7407
4	Lena	5.0625	5.2684
5	Tree	3.609	5.7096

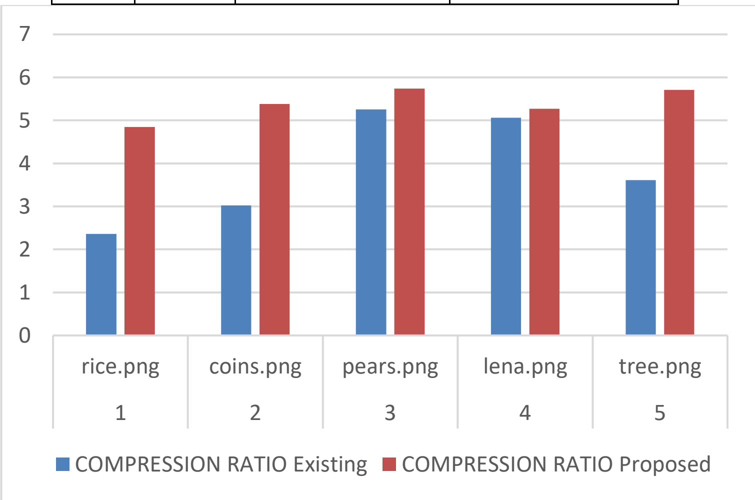

Figure.5 Compression Ratio comparison between existing method and proposed method

Table.6 Space Saving Comparison between existing method and proposed method

S.No	Image Name	SPACE SAVINGS	
		Existing method	Proposed method
1	Rice	26.43	79.37
2	Coins	27.02	81.43
3	Pears	20.27	82.58
4	Lena	75.38	81.01
5	Tree	43.58	82.48

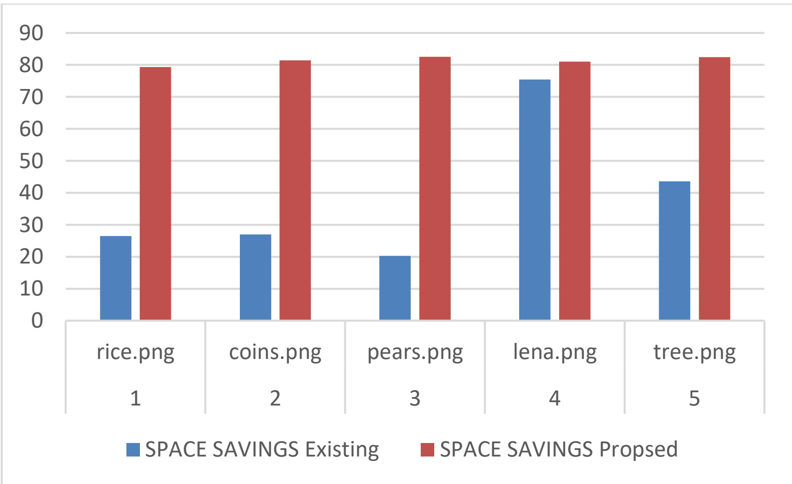

Figure.7 Space Saving Comparison between existing method and proposed method

VI. CONCLUSION

Compression is the process that reduces the size of an image file without affecting and degrading its quality to a greater extent. The proposed work uses various compression techniques such as Discrete Wavelet Transformations (DWT) followed by Golomb and Run length coding to get better results. The results are evaluated against various compression performance metrics such as Entropy, MSE, RMSE, PSNR, SNR, Compression Ratio, saving storage etc. From the results it's clear that the proposed work is showing good performance compared to existing method. The present research mainly focused on the effective image compression techniques using various approaches. The performance requirements of image processing especially in image compression applications increase the computing power of implementation platforms, especially when they are executed under real time constraints. In near future this work can be extended by using various other compression and frequency transformation techniques to achieve more enhancement. The proposed work may also be extended to audio and video files.

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