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Lossless Image Compression Schemes: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. Author IM managed and compile the literature searches under the supervision of author EJG, as major supervisor and author ASA, as co-supervisor. All authors read and approved the final manuscript.

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Systematic Review

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ABSTRACT

Data compression refers to the process of representation of data using fewer number of bits. Data compression can be lossless or lossy. There are many schemes developed and used to perform either lossless or lossy compression. Lossless data compression allows the original data be conveniently reconstructed from the compressed data while lossy compression allow only an approximate of the original data to be constructed. The type of data to compressed can be classified as image data, textual data, audio data or even video content. Various researches are being carried out in the area of image compression. This paper presents various literatures in field of data compression and the techniques used to compress image using lossless type of compression. In conclusion, the paper reviewed some schemes used to compress an image using a single schemes or combination of two or more schemes methods.

Keywords: Lossless; image compression data; scheme.

1. INTRODUCTION

The growth and development of modern information and communication technologies, has led the demand for data compression to increase rapidly. Recent development in the field of Computer Science and information has led to the generation of large amount of data

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always. According to Parkinson's First Law (Parkinson, 1957), the need for storage and transmission increases at least double as storage and transmission capabilities increases. The breakthrough of multimedia technologies has made digital libraries a reality.

Digital images are usually encoded using lossy compression scheme because of their memory size and bandwidth requirements. The lossy compression scheme leads to high compression ratio while the image experiences lost in quality. However, there are many cases where the loss of image quality or information due to compression needs to be avoided, such as medical, artistic and scientific images. Therefore, efficient lossless compression become paramount, although the lossy compressed images are usually satisfactory in divers' cases. In most cases, common characteristics of most images is that the neighboring pixels are highly correlated and therefore contain highly redundant data or information.

According to Singh, Kuma, Singh and Shrivastava [1], some importance of image compression schemes may include the following:

It leads to sending less amount data on the network, it decreases the amount for storage and decrease the entire time of execution, reduces the chances of the errors during transmission as some bits have got transferred and enable a level of the security against monitoring the unlawful activities.

Data compression refers to the process of representing or encoding a file, image, video or audio using fewer numbers of bits. The major aim of lossless image compression is to reduce the redundancy and irreverence of image data for better storage and transmission of data in the better form. According to Bindu, Ganpadi and Sharma [2], compression is the means by which the description of digitized information is modified so that the storage capability or the bit rate required for transmission is reduced. Image compression is briefly the process that is used to operate on the image and hence perform modification on the element of the image to perfectly reduce its size to visual appealing level. By performing data compression on image, it is absolutely possible to reduce the size of the data and also the bandwidth for image transmission. Many real time applications depend largely on a huge number of images for their smooth processing. Data compression has two major essential components. They are the redundancy and the irrelevancy. Redundant data can be found in almost any type of image. Duplications of data in an image are termed as redundancy. It may be seen as repeated pixel across the image, which is most of the time and more frequently repeated in the image. Redundant information in the image mostly can be used in saving the storage space of that image [3].

Generally, data can be compressed by removing irrelevancy and redundancy present in the original data before compression. There are two major levels to compress data: They are modelling and coding. In the modelling level, the data to be compressed is analyzed first for any redundant information if available then extract it to develop a working model. In the next level, the difference between model and actual data which is called the residual is now computed and is encoded by an encoding scheme. There are various ways to characterize a data and these characterization leads to the development of series of data compression methods or schemes. Since various data compression technique have been developed, there is need to review the existing methods which will be fine helpful for researchers who have interest in data compression to approximately choose the required algorithms in a particular situation.

2 LITERATURE REVIEW

Data compression refers to the process of representation of data using fewer number of bits. Data compression can be lossless or lossy. There are many researches carried out and is being carried out in the area depending on the type of data to be compressed. The data files that can be compressed can compressed include image data files, video data files, textual data files or even sound data files. For the purpose of this survey, image data file is considered.

Different data compression schemes have been developed and deployed to use throughout the years. Some of these compressions are used for general used which means it can be used to compress files of different types and others are developed to compress a particular type of file.

Generally, lossless data compression seeks to reduce the number of bits required to show content of an image, video, file without affecting the quality of that data. It also lowers the quantity of bits that is needed to save and send the digital media [1].

Pai, Cheng, Lu and Ruan [4], proposed that a compression technique by the use of two lossless technologies Huffman coding and Lempel-Ziv-Welch coding for image compression. At first stage of the scheme, an image is get compressed with the Huffman coding that is resulting in the Huffman – tree and a generated code-words. In their work, a technique has been proposed which is called the “sub-trees modification of Huffman Coding for stuffing Bits Reduction and Efficient NRZI Data Transmission”. The authors basically targeted on transmission of the data and multimedia compression and also handling the issue as encoding of compression and transmission to come up with the low-bit rate of transmission model which depends on Huffman encoding scheme. The suggested scheme balances the 1 bit and 0 bit by measuring the chances of mismatch found in the traditional Huffman-tree. More so, the suggested techniques also get modified with the transitional –tree within the same compressional ratio [5].

The Lempel-Ziv-Welch (LZW) algorithm was introduced in 1984 by Terry Welch. It removes redundant characters in the output and includes every character in the dictionary before starting compression and employs other techniques to improve the compression (Sharma and Kaur, 2014).

The Huffman coding algorithm named after its inventor, David Huffman, who developed the method as a student in a class on information theory at MIT in 1950. Huffman code procedure is based on the two observations. More frequently occurred symbols will have shorter code words than symbol that occur less frequently. The two symbols that occur less frequently will have the same length. 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 and thus a code tree is generated and Huffman codes are obtained from labelling of the code tree

Suresh, Nair and Kutty [6] in their research presented, a vector quantization technique of image compression. In their work, they adjusted the encoding for the difference in map between the actual images and then after that it got restored in the VQ compressed variation. It is the experimental results that show that their model which is required to enable the original data, it may considerably enhance the VQ images compression and also be compromised based on the difference in map from the lossy schemes to the lossless compression scheme.

Jassin and Qassim [7], presented an ideal image compression scheme known as the Five Module Method (FMM). The scheme transforms every pixel value in the 8x8 blocks into the multiple of five for every array of RBG. After which the value may be fragmented by 5 to generate the new values that are bit of length for every pixel and which is less in the storage area as compared to the actual values that is of 8 bits.

Unlike the existing approaches, the method of Alarabeyyat et al., [8] encodes information of edge line obtained using the modified edge tracking method instead of directly encoding image data. The second is compressing the encoded image Huffman and Lempel-Ziv-Welch. Alarabeyyat, et al., [8] proposed a numerous number of existing schemes. In the approach, LZW algorithm was applied first on the image at hand for encoding and later BCH for error detection and correction. This is to improve the compression ratio. The result of the scheme indicates that the algorithm achieves an excellent compression ratio without data loss when compared with standard compression algorithms.

Pujar and Kadlaskar [9] used a lossless method of image compression and decompression was proposed. It uses a simple coding technique called Huffman coding. A software algorithm has been developed and implemented to compress and decompress the given image using Huffman coding techniques in a MATLAB platform. Their major concern is to compress images by reducing the number of bits per pixel required to present it, and to decrease the transmission time for images transmission. The image is reconstructed back by decoding it using Huffman codes.

Kaur and Kaur [10] proposed a new lossless compression scheme and name it Huffman based LZW lossless image compression using Retinex algorithm which consist of three stages: In the first stage, a Huffman coding is used to compress the image, in the second stage all Huffman code words are concatenated together and then compressed with LZW coding and decoding. In the final stage, the Retinax algorithm are used on compressed image to enhance the contrast of image and improve the quality of image. This proposed scheme is used to increase the compression ratio (CR), peak signal to noise ratio (PSNR), and mean square error (MSE) in the MATLAB software.

Hasan [11], presented an algorithm for image compression consisting of a combination of lossy and lossless methods which is based on a discrete wavelet transform and apply entropy coding as lossless compression with using quantization and thresholding techniques to produce a high compression ratio and high quality of image.

Smith, [12] presented one of the most vital research in data compression. In his work, he explained DC from mathematical level to coding level. The study of [13] pointed out that theories are the starting point of any latest technology. The author theoretically explained namely Shannon's theory, Huffman code, Lempel Ziv (LZ) code and self-learning autopsy data trees. The work did not include many lossless DC schemes and reviewed only few schemes. Hosseini, (2012) tried to explained many DC techniques with their performance evaluation and applications. The work exploit Huffman algorithm, Run length encoding (RLE), LZ algorithm, arithmetic coding, JPEG and MPEG with their various applications. Cheng and Ang (2008) employed some image compression algorithms and classify them into first and second-generation image compression algorithms. A comparison is also done on several features such as preprocessing, post processing, code book, memory complexity, size and compression quality. Sangeetha and Betta [14] presented a dynamic image compression using an improved LZW encoding algorithm. The objective of their research is to present a comparative measure of present techniques of image processing in accounts by using an image compression technique which are used in bio-metric data. The performance measure reveals that LZW compression algorithm have better accuracy over other predictive methods like Run-length encoding, Huffman encoding, delta encoding, JPEG (Transform Compression and MPEG algorithms because they perform less.

Boopathiraja et al., [15] proposed a hybrid lossless method using Lempel-Ziv-Welch (LZW) and Arithmetic Coding for compressing the multispectral Images. The performance of the method is compared with existing lossless compression methods such as Huffman Coding, Run Length Coding (RLE), LZW and Arithmetic Coding. This leads to conception of several compression methods for these multispectral images. Moreover, every tiny information from multispectral image is very important for efficient processing and so the lossless encoding is always preferable. improved compression technique is proposed by Naeven ,Jagadale and Bhat [16] using wavelet transform and discrete fractional cosine transform to achieve high quality of reconstruction of an image at high compression rate. The algorithm adopted uses wavelet transform to decompose image into frequency spectrum with low and high frequency sub bands. Application of quantization process for both sub bands at two levels increases the number of zeroes, however rich zeroes from high frequency sub bands are eliminated by creating the blocks and then storing only non-zero values and kill all blocks with zero values to form reduced array. The arithmetic coding method is used to encode the sub bands. The Experimental results of proposed method are compared with its primitive two-dimensional fractional cosine and fractional Fourier compression algorithms and some significant improvements can be observed in peak signal to noise ratio and self-similarity index mode at high compassion ratio. Ravikumar and Arulmozhi, [17], outlined some of the applications of digital image processing which includes: image sharpening and restoration, colour processing, pattern recognition, hurdle detection and video processing. They also outlined the techniques for digital image processing which includes: image editing, independent component analysis, image restoration, anisotropic diffusion, linear filtering and pixilation, principal component analysis, neural networks and partial differential equations.

3. PROPOSED METHODOLOGY

Arora and Shukla [27] basically describes the usual steps involved in compressing an image data are:

Table 1. Reviewed summary with authors contributions

S/No	Author/Year	Problem identified	Title/Solution
1.	Kamal and Al-hashemi, [18].	Separation of invalid code words from the valid codewords.	A New Lossless Image Compression Technique Based on Bose, Chandhuri and Hocquengham Codes.
2.	Alarabeyyat et al. [8].	Image coding, image decoding and error detection.	Lossless Image Compression Using Combination Methods.
3.	Kaur, [10].	Improving Image Compression ratio and Image enhancement.	Huffman Based LZW Lossless Image Compression Using Retinex Algorithm.
4.	Hassan, [11].	How to improve image Compression Ratio why retaining image quality by Combining compression schemes	Combination of lossy and lossless data compression shames.
5.	Sharma and Kaur , (2014).	Improvement of image compression	Review on lossless Image Compression.
6.	Fathima, Kavitha and Ahmed, [19]	Formulating active learning problem into PR minimization problem.	Machine learning Approach to Image compression Technique.
7.	Kaur, Sethi and Singh, [20].	Comparison of different compression scheme based on Compression Ratio, Bit rate and Bits Per Pixel	Review on Data Compression Techniques.
8.	Kumar and Deepika, [21].	How to achieve high transmission rate while reducing the errors	Block estimation and distortion to optimize the compression ratio
9.	Pabi et al ,(2016).	Code optimization	Image compression based on butterfly Particle Swarm Optimization
10.	Kabbai et al., [22].	How to enhance an Image.	FPGA Implementation of an Image Using 2D Gaussian Filter.
11.	Surbhi and Gupta, [23].	Compression and decompression of grayscale images.	A JPEG Image Compression and Decompression based on Huffman Coding.
12.	Ray and Sharma, [24].	How to achieve high compression ratio while retaining image quality.	Image Compression Based on three block transform method.
13.	Dalal, [25].	Review on the effective image compression Schemes.	Review on lossless image compression using lossless and lossy algorithms.
14.	Kumar and Vaish, (2017).	Compression of encrypted images.	An efficient encryption-then-compression technique for encrypted images using SVD. Digit. Signal Process.
15.	Kumar and Sharma, (2018)	Inter pixel redundancies in an image.	Image Compression For Different Block Pixel Algorithm For Random Image
16.	Ravikumar and Arulmozhi, [17]	Image sharpening and restoration, colour processing and pattern recognition in an image	Digital Image Processing. A quick review.
17.	Uthayakumar, [26].	Problem of coding schemes and application	A survey of data compression Schemes: From the perspective, coding schemes, data types and application.

i. Specifying the rate (bits available) and distortion (tolerable error) parameters for the target image.
ii. Dividing the chunk image data into various classes, based on their importance
iii. Dividing the bit available among those classes, such that the distortion in the data is reduced to the barest minimum.
iv. Quantize each class separately using the bit allocation information derived from step.
v. Encode each class separately using an entropy coder and write to the file. Reconstructing the image from the compressed data is usually a faster process than compression. The steps involved are:
vi. Read in the quantized data from the file, using an entropy decoder. (Reverse of step v)
vii. Dequantize the data. (Reverse of step iv).
viii. Rebuild the image. (Reverse of step ii).

Two important structures used in image compression model are:

Encoder and Decoder.

Encoder: In this structure, an input image *f(x,y)* is fed into the encoder and this creates the set of symbol from the input data.

Decoder: Here, the encoded information is sent to the decoder where the required reconstructed output image is generated *f(x,y)*

The general compression system model is shown in Fig. 1.

Three Source encoder consist of three encoding stages which are:

The mapper, quantizer and the symbol encoder.

The mapper translates the input data format required to reduce interpixel redundancies present in the image. Reversible operation may or may not reduce the size of data requires to represent the image. The quantizer process reduces the accuracy of mappers output and psychovisual redundancies of the input image and the operation is not reversible. This must be omitted when error free in lossless compression is desired. The third and the final stage is the symbol encoder which creates a fixed and variable length code to represent the quantizers output and maps the output image in accordance with the code. Variable length code is used and the operation is reversible.

The source decoder contains two components. These are the symbol decoder and the inverse mapper. The operation performed by the inverse mapper is in reverse order.

For the purpose of this research, a combination of existing algorithm was used. Improved Bose Chaudhuri and Hocquenghem (BCH), for image encoding and LZW for dynamic compression. Standard research images were used. The algorithm was implemented using JAVA programming language. Twelve different research images were used and their compression ratio were compared against the existing compression method.

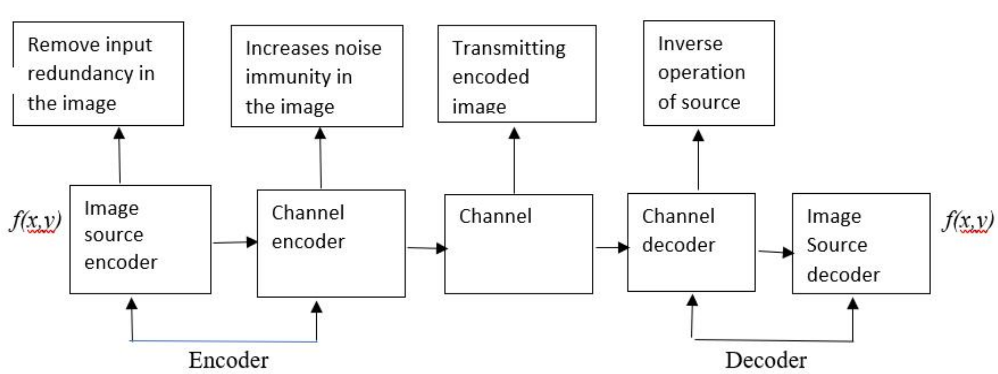

Fig. 1. Generalized image compression system

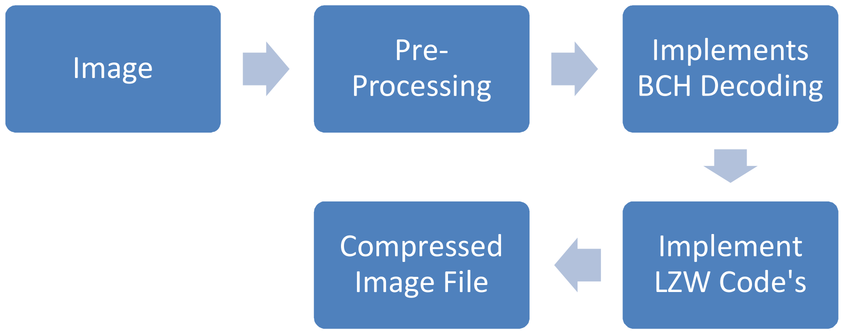

Fig. 2. Basic compression steps for the proposed scheme

4. RESULTS AND DISCUSSION

Table 2 shows the compression ratio result of the test images in which the obtained results depends on the size of the original to the size of the image compressed. In the table, the column two presents the compression ratio result from compressed image by the RLE algorithm and the next two columns present the compression ration results from compress LZW and Huffman respectively. The last column presents the compression ratio of the new scheme. The average compression ratio of each of the methods after applying the test images are RLE 1.2017, LZW 1.4808, Huffman 1.191957882 and the new scheme's average compression ratio is 1.6489 respectively. Based on the new method, the average compression ratio achieved so far is higher than the average compression ratio of RLE, LZW and Huffman algorithm which means that is the best compared to the three algorithms. This mean that is reduced higher when combination method BCH and LZW are used compared to the standard of lossless data compression.

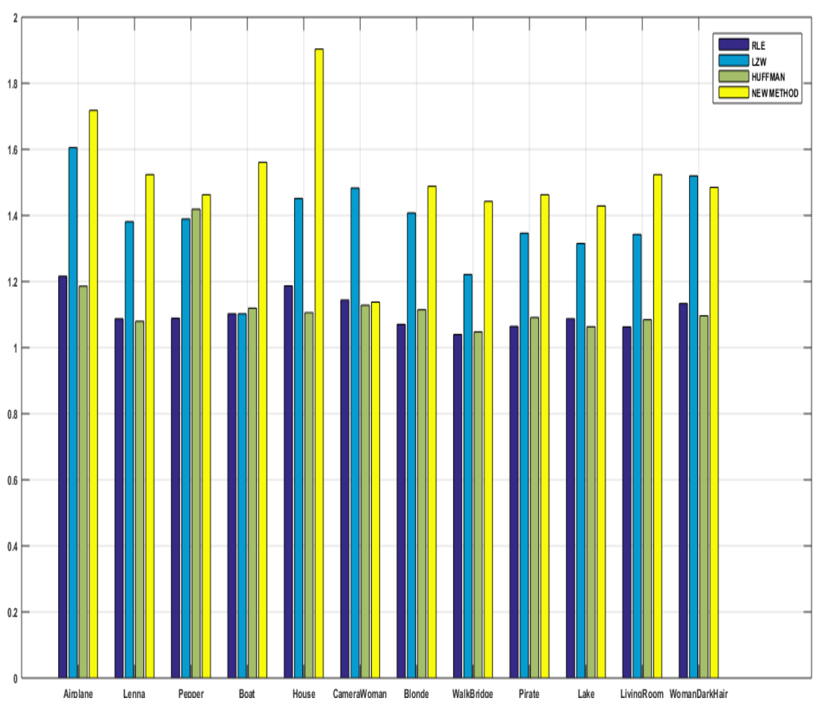

Fig. 3. Bar chart showing compression ratio of the new method against the existing method

Table 2. Compression ratio Comparison Table

IMAGE	RLE	LZW	HUFFMAN	NEW METHOD
Airplane	1.2162	1.6052	1.1857	1.7181
Lenna	1.0871	1.3811	1.0795	1.5238
Peppars	1.0892	1.3893	1.4187	1.4629
Boat	1.1023	1.1023	1.1192	1.561
House	1.1867	1.4515	1.1059	1.9033
Camera	11441	1.483	1.1285	1.1378
Woman Blonde	1.0701	1.4074	1.1145	1.4884
WalkBridge	1.0398	1.2212	1.0475	1.4423
Pirate	1.064	1.3462	1.0911	1.4629
Lake	1.0875	1.3151	1.0633	1.429
Living Room	1.0629	1.3425	1.0845	1.5237
WomanDarkhair	1.1333	1.5197	1.0964	1.4848

5. CONCLUSION

Over the years, image compression has become very important area of research. In previous years, many researchers came up with different compression techniques. In this paper, different compression techniques and how they were applied to solve many image compressions were reviewed. In the proposed methodology, there was an improvement in the compression ratio compared to LZW, Huffman and other methods when used individually compared to combining the methods In conclusion, in lossless image compression, image quality is maintained as original after decompression but little compression ratio is realized. This is because neighboring pixels are highly correlated and contain redundant information. Other researches can be carryout by combining other existing methods to compare compression ratio, bit per pixel and other parameters and the research should be carried out on large data set .

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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