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Various Image Compression Techniques: A Review

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Abstract—**Digital image compression technology is of special significance for the fast transmission and real-time processing of digital image information on the internet.A digital image in its original form carries a large amount of information in it which needs a huge amount of memory for its storage. . The basic approach of image compression is to reduce the number of the image pixel elements without affecting the original quality of image. It is basically achieved by removing the redundancy present in the image. The two most important techniques are lossy and lossless compression techniques. The principle objective of this paper is to discuss some basic compression techniques such as Huffman encoding, LZW coding, VQ compression and some recently used new hybrid techniques for compression.**

Index Terms— **curvelet, DCT, DWT, DFT,N Square, VQ, wavelets**

I. INTRODUCTION

A digital image requires a huge amount of data to store its contents in a system since it contains complex information .So, to make the processing of digital images much faster; we use the concept of image compression. By reducing the amount of data associated with these images, the amount of storage space required can also be minimized, allowing long image sequences to be stored on a single disk [2].Image compression is carried out by removing some redundancies in the image.

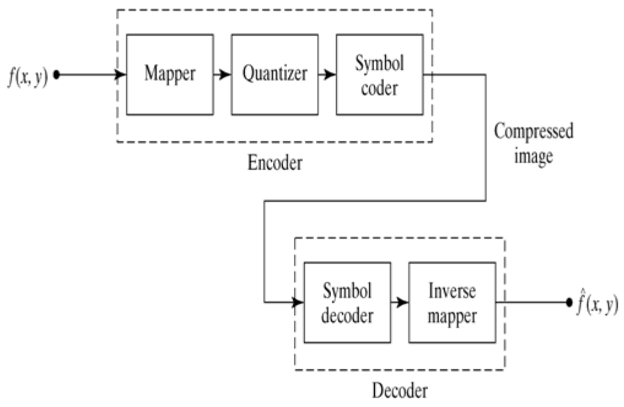

Fig. 1: Image Compression Model

There are three types of redundancies in digital image compression:

1) *Coding redundancy: It* occurs in the cases where less than optimal code words are used.
2) *Interpixel redundancy*: It is due to correlations between the image pixels.
3) *Psychovisual redundancy*: It occurs when the information is visually not essential.

An inverse process of compression is called decompression which is applied on compressed image to get the original image.

II. TYPES OF COMPRESSION

There are basically two types of compression techniques: LOSSLESS and LOSSY.

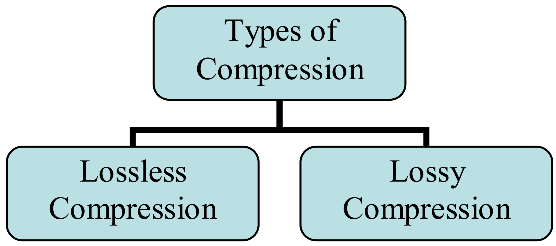

Fig. 2: Types of Image Compression

A. Lossless Compression

This is an image compression technique in which the image produced after applying compression method is numerically identical to the original image i.e. there is no loss of image information. It is used in the field of medical imaging, for clip arts etc. Various techniques under this category are:

1) Run Length Encoding:

It is one of the simplest methods of image compression. It is used for sequential data only. This technique Replaces sequences of identical symbols (pixels), called runs by shorter symbols [3].It is represented as {v, r} where v denotes intensity of Pixel and r denotes the intensity of this pixels.

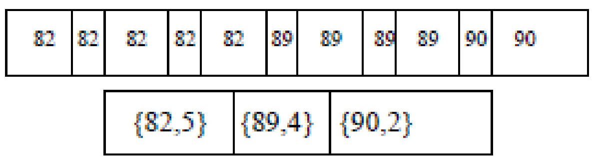

Fig. 3: Run length Encoding.

It is used in pallet based images such as computer icons and also in fax machines. [1]

2) Huffman Encoding:

This method was developed by D.A .HUFFMAN. This methodology is used to remove coding redundancy in the image. In this approach, we code the symbols based on the statistical occurrence of frequencies and accordingly we make a tree. According to this method, Symbols with the most frequency will result in shorter code words and Symbols with lower frequency will have longer codeword's. It is also called variable length coding.

Fig. 4: Original Image

Fig. 5: Uncompressed Image

Algorithm:

- Firstly read the image into the workspace of MATLAB.
- Convert it into grey level image
- Use a function which will find the symbols.
- Calculate the probability of each symbol using a function.
- Arrange the probabilities in decreasing order and merge them.
- Symbols are given corresponding codes.
- Generate a tree on this basis.
- Perform these steps until the last element is encountered.

It has some limitations. So, a better version called Double Huffman coding was developed which provides better results.

3) LZW Encoding:

Limpel-Ziv-Welch is a technique used for compression of data .It was developed by Abraham Lempel, Jacob Ziv, and Terry Welch. LZW encoding is working based on the occurrence multiplicity of bit sequences in the pixel to be encoded [4]. This is an error free compression approach which focuses on removing spatial redundancy [5]. It assigns fixed length code words to variable length sequences of source symbols. It works on file formats such as GIF, TIFF, and PDF.

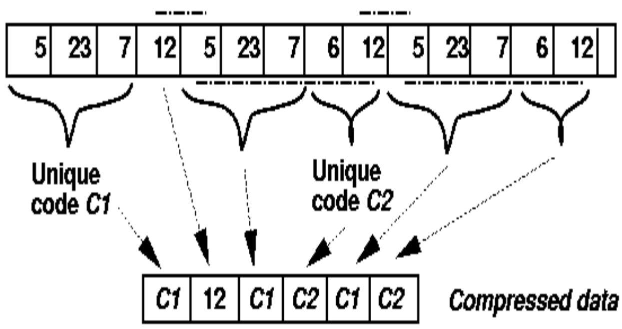

Fig. 6: LZW Encoding

4) Area Encoding

It is an improved form of run length coding. It mainly focuses on two dimensional characteristics of an image. This is one of the best techniques out of all lossless techniques discussed before. This technique checks the rectangular regions bearing same characteristics and then analyzing it. The major drawback of this method is that it is a non linear method and it can't be implemented in hardware.

5) N-Square Approach:

This approach reduces the erraticism of Huffman coding. It finds the code words faster than any other technique. It provides efficient results of compression and decompression than the methods discussed above. The entire number of messages to be transmitted is called message ensemble. In this, the coding symbols are represented by numbers. So, if there M symbols, they will be represented as 1, 2 …M-1.

Algorithm:

- Find the RANGE in which N-Square lies from the values of N.
- Assign M to the upper boundary of N of the range. e.g.: N=20, so the range is [4, 5].

Table 1: Shows N values

N^2	N
1^2	1
2^2	4
3^2	9
4^2	16
5^2	25
6^2	36
.	.
N^2	N

- Then we calculate the number of messages we want to send and put it in an ensemble .Lets denote it with X.It is given by following formula:

J=2 + [(N-2) mod (M-1)] K=J+M-1 (1)

B.Lossy Compression

Unlike lossless technique, the image produced after compression is not identical to the original image. So, it is called lossy technique. It provides high compression ratio than lossless technique [3].It is further categorized into following types:

1) Discrete Cosine Transformation

It is a method to convert an image into its frequency components. It expresses a sequence of data points in terms of sum of cosine functions. It is used in compression of audio (MP3) and images (JPEG).We use cosine function instead of sine functions since it produces better results. It is almost similar to discrete Fourier transform. The Transformer transforms the input data into a format to reduce Interpixel redundancies in the input image [6].

Fig. 7: Original Image

Fig. 8: Reconstructed image after applying DCT

2) Discrete Fourier Transformation:

This is an image compression method in which we decompose an image into its constituent sine and cosine parts. The final output is presented in the frequency domain (or Fourier) while input is in spatial domain. The Fourier Transform is used in a wide range of applications, such as image analysis, image filtering, image reconstruction and image compression. For NXN image, DFT is defined as.

$$F(k,l) = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} f(i,j) e^{-ij\pi(\frac{Ki}{N}+\frac{ij}{N})} \quad (2)$$

It does not contain all frequencies in an image but a portion of it which is sufficient to describe spatial domain.

Fig. 9: Original Image

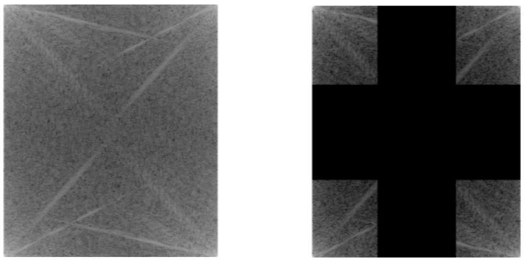

Fig. 10: After Appling DFT

3) Discrete Wavelet Transform

This is an effective image compression technique which makes use of wavelets. Wavelets are signals which are local in time and scale and generally have an irregular shape. The term 'wavelet' comes from the fact that they integrate to zero; they wave up and down across the axis.DWT firstly decomposes an image into sub bands and then the resulting components are compared with a threshold. The values of coefficients which lie below threshold are set to zero and which lie above threshold are encoded using lossless techniques.

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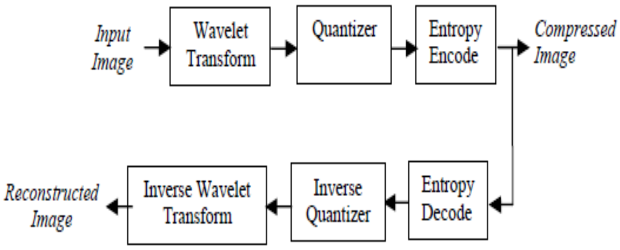

Fig. 11: DWT Model

Fig. 12: Original Image

Fig. 13: Compressed Image

4) Embedded Zero tree Wavelet (EZW) Coding:

It is a wavelet based compression technique. It mainly operates on 2-D images. It is based on the principle of progressive encoding. According to this principle, image is compressed into a bit stream with high accuracy. It is also called embedded coding. EZW encoding uses a predefined scan order to encode the position of the wavelet coefficients [7].

5) Fractional Compression:

In some images, one part of an image resembles another part of the image. This technique converts these parts into mathematical form called fractal codes. These are also called Iterated Function System (IFS) codes which are applied to the blocks of images which produce an image which is almost identical to original image. It is basically used for applying compression on textures.IFS exhibits self-similarity [8].

6) Block Truncation Coding:

This is technique used in case of grey scale images. In this scheme, the image is divided into non overlapping blocks of pixels. Then, its threshold and reconstruction values are found. Threshold is the mean value of all pixels in the image. An important version of BTC is Absolute Moment Block Truncation Coding (AMBTC) in which the first absolute moment is preserved over mean instead of standard deviation.

C. Hybrid Image Compression using DWT and Neural Network:

All the techniques discussed above don't provide much compression ratio. In this, a hybrid approach was used which combines both DWT and Neural networks to provide substantial improvements[9].Wavelet based image compression provides higher compression ratios .Neural networks also produce most efficient results as compared to traditional approaches. With wavelet transform based compression, the quality of compressed images is usually high. Unlike DCT, wavelet transform is not Fourier based and thus, wavelets do a better job of handling discontinuities in data. Neural networks have proved to be useful because of their parallel architecture and flexibility.

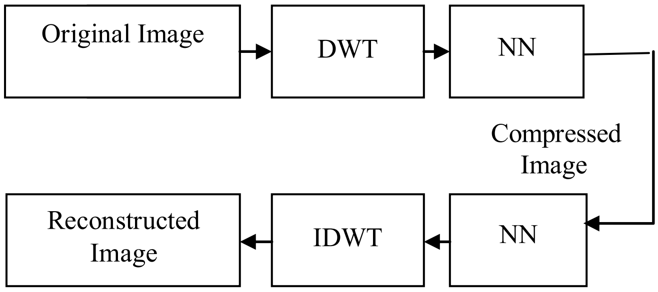

Fig. 14: Basic idea Behind Using the Hybrid Approach

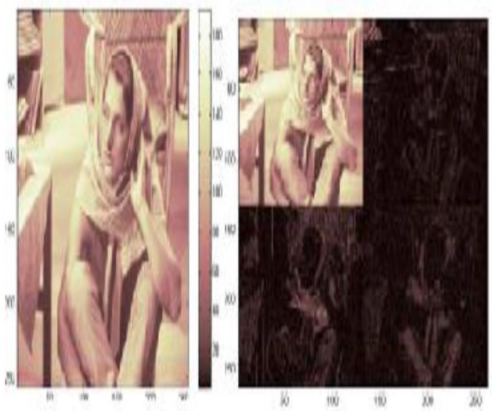

Fig. 15: One Level Decomposition

Fig. 16: Two Level Decomposition

D. Image Compression using Fusion Technique:

This technique is the combination of wavelet transform and curvelet transform which gives equal to importance all the regions of image [10]. Unlike in wavelet transform which has lack of directional selectively, curvelet transform is multi-scale transform with a very high degree of directional characteristics. Combination of wavelet and curvelet transform works fairly well for gray scale image as well as colored images also.

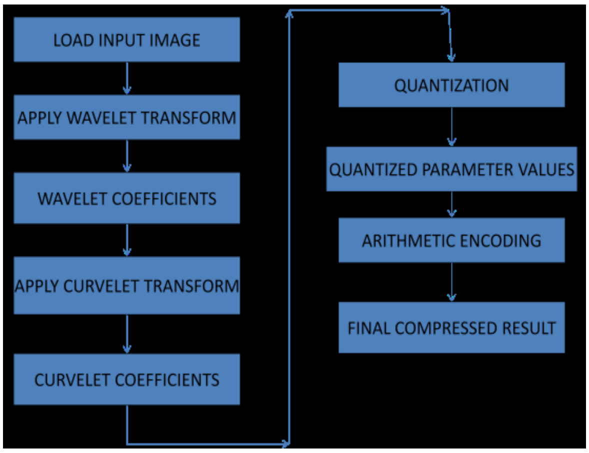

Fig. 17: Compression Process

E. Vector Quantization technique:

In this, we establish a codebook consisting of code vectors such that each code-vector represents a group of image blocks of size maximum.

Fig. 18: Original Image

Fig. 19: Compressed Image

An image or a set of images is first partitioned into m × m non-overlapping blocks which are represented as m2-tuple vectors, called training vectors.

F. JPEG Compression

An image is partitioned into non-overlapped 8X8 blocks. Then we apply DCT to convert the gray level of pixels in spatial domain into coefficients in frequency domain.

Fig. 20: Original Image

Fig. 21: Compressed Image

We normalize these coefficients in the quantization table. After this, we rearrange the coefficients in zigzag scan order. Then, it is further compressed using run length coding, arithmetic coding etc. But the information is lost while using this compression. Instead, we can use an adaptive quantization table as compared to a standard table for more efficient *results.*

III. LITERATURE REVIEW

Srinivas, Prasad Reddy and K.Gayatri Devi [2] presented a lossless technique called "N-square approach "for image compression and decompression.This technique eliminates the the erraticism of non binary Huffman coding regarding the value of D.It has been presented in this paper a pattern for finding the D value as per the value of N thorugh N square approach.

Sonal and Dinesh Kumar [3] introduced a new approach Principal Component Analysis for image compression. PCA approach is implemented in two ways – PCA Statistical Approach & PCA Neural Network Approach. PCA is a technique for simplifying a dataset by reducing multidimensional datasets to lower dimensions for analysis. PCA is also called the KARHUNEN-LOEVE Transform (KLT, named after Kari Karhunen & Michel Loeve) or the HOTELLING Transform.Its general objective is data reduction and interpretation.

Manjinder kaur and Gaganpreet Kaur [4] analyzed the difference between lossless and lossy image compression techniques.In lossless compression,the exact original data can be reconstructed and the image quality is maintained.Whereas in lossy technique,an approximation of image of the original data is obtained.It was found that lossy compression techniques provide high compression ratio as compared to lossless technique.Two new techniques were introduced called DCT and DWT.

Gonzalez and R. C explained the technique LZW[5] encoding that it is an error free compression approach which focuses on removing spatial redundancy.

Gaganpreet Kaur and Sandeep Kaur[6] introduced the techniques such as DFT,DCT,DWT and wavelets for better image compression.In this paper,it

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was found that wavelets (e.g DWT) produce the most efficient results out of DFT,DCT And DWT.

R.Sudhakar, Ms R Karthiga, S.Jayaraman[7] presented embedded zero tree wavelet (EZW) coding SPIHT (set partitioning in hierarchical trees) algorithm, SPECK(Set Partitioned Embedded Block Coder), WDR (waveletdifference reduction) algorithm, and ASWDR (adaptivelyscanned wavelet difference reduction) algorithm. Theseare relatively recent algorithms which achieve some of the lowest errors per compression rate and highest perceptual quality.

Hitashi,Gaganpreet Kaur and Sugandha Sharma [8]analyzed the Fractal Image Compression.In this paper they discussed the the basic principles of the construction of fractal objects with iterated function systems (IFS). An important property offractals is that they exhibit self-similarity. By partitioning an image into blocks, typically 8x8 or 16x16 pixels, it becomes possible to map small portions of an image to larger portions.

M. Venkata Subbarao, N.Sayedu Khasim, Jagadeesh Thati and M. H. H.Sastry[9] analyzed a hybrid technique combining the use of wavelets and neural networks to obtain better quality images. All the disadvantages of Joint Photographic Expert Group (JPEG) have overcome in Neural Network based Hybrid image compression. The Hybrid image compression is to combine Discrete Wavelet Transform (DWT) and Neural Network (NN) with Biorthogonal high compression ratio with good quality compressed image and optimize-area and power is observed.

T.Rammohan, K.Sankaranarayan and Shalakha Rajan [10] explained a fusion technique combining wavelet transform and curvelet transform for image compression. Both the transforms when used individually shows some disadvantages. Wavelets though optimal for point singularities have limitations with directional properties. Similarly curvelets are challenged with small features. By combining both the transforms , the number of bits used to represent the image is reduced. This technique works fairly well for grayscale as well as colour images

Chaur-Chin Chen [11] introduced four techniques for image compression i.e wavelets,fractal, JPEG compression and Vector Quantization. VQ approach is not appropriate for a low bit rate compression although it is simple.Jpeg is a current standard used nowdays.wavelet has high compression ratio as compared to all the techniques.Fractal is a good mathematical encoding frame.

IV. Critical Analysis Results

After, in depth study of various Image Compression Techniques we got the Following results:

Table 2: Critical Analysis

COMPRESSION TECHNIQUES	DESCRIPTION	ADVANTAGES	DISADVANTAGES	APPLICATIONS
Run Length Encoding	In which *runs* of data (that is, sequences in which the same data value occurs in many consecutive data elements) are stored as a single data value and count, rather than as the original run.	It can be used to compress data made of any combination of symbols. It does not need to know the frequency of occurrence of symbols.	It does not work well at all on continuous-tone images such as photographs,	Is well suited to palette - based bitmapped images such as computer icons Run- length encoding is used in fax machines. (combined with other techniques into Modified Huffman coding)
Huffman Coding	The use of a variable-length code table for encoding a source symbol (such as a character in a file)	High transmission speed Easy to implement	Compression of image files that contain long runs of identical pixels by Huffman is not as efficient when compared to RLE. Efficiency depends on the accuracy of the Statistical model used and type of image.	It used as a "back-end" to some other compression method. DEFLATE (PKZIP's algorithm) and multimedia codec's such as JPEG and MP3 have a front-end model and quantization followed by Huffman coding.
Transform coding (DCT, DFT etc.)	Knowledge of the application is used to choose information to discard, thereby lowering its bandwidth.	Provides most efficient results	Compression is lossy	Natural data like audio signals or photographic images
LZW coding	encodes sequences of 8-bit data as fixed-length 12-bit codes	No need to Analyse the incoming text	Only good at text files but not on other files	Is used in the GIF and TIFF image format.
Wavelet Transform	Improvement of picture quality at higher compression	Good frequency and Time scaling.	Always stop at some ratio and cannot compress further -Generally works	Transform based image compression

	ratios.		better for gray image than colour images, due to 3-color accumulated layer error Inability to detect directional properties.	
Curvelet Transform	Challenged with small features.	High degree of directional characteristics.	Computational cost is higher than wavelet.	Performs well in image de-noising
VQ compression	we establish a codebook consisting of code vectors	Easy and simple to implement Compression ratio is < 32	Not appropriate for a low bit rate compression	Used for lossy data compression, lossy data correction, pattern recognition and density estimation.
JPEG Compression	Based on DCT	Compression ratio <50	Doesn't give efficient results if we use standard quantization table	

V. CONCLUSION

From the above discussion, we have concluded that compression using wavelets prove to be providing the best results. Wavelets combine the lossless and very high quality lossy compression algorithm as in case of hybrid compression technique and fusion technique.The administrational and storage costs of Wavelets are less than all other techniques explained above. Also, it has short and nearly symmetric compression and decompression times. Thus, wavelets combined with neural networks or curvelet produce the most efficient results.

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