ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 8, August 2014

A Survey on Image Compression Techniques

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Abstract: Social and network computing demands effective, sharing and saving of image data, which has always been a great challenge. People are sharing, transmitting and storing millions of images every moment. Although, data compression is mostly done to avoid the occupancy of more memory, and enhance capacity of storage devices, production of digital images has been increased proportion. Consequently, the demand of perfect, image compression algorithm is very high which can be used to reduce the resources usage, such as data storage space or transmission capacity. Bhammar M.B. et al, [1]. This document presents the review of various lossless and lossy compression techniques.

Keywords: Chroma subsampling, Transform coding, Fractal Compression, Vector Quantization (V.Q), Block truncation Run length encoding(RLE) , Huffman encoding , LZW coding, Area coding , Arithmetic coding.

I. INTRODUCTION

Digital images have become popular for transferring, sharing storing and visual information and hence high speed compression techniques are need Among many advantages of image compression, the most important one is to reduce the time for the transmission of images. Basically these compression techniques can be categorized into the Lossy compression techniques and lossless compression techniques, Kaimal.A .B el al, [4]. The lossy compression technique produces imperceptible differences that may be called visually lossless. Lossless compression is preferred for archival purposes and often for medical imaging, technical drawings, clip art, and comics. [Wiki]. The fundamental principles used in image compression are to avoid redundancy and irrelevancy. Compression is achieved by removal of one or more of the three basic data redundancies; Bhammar M.B et al, [1] .as follows:

1. Coding redundancy
2. Inter pixel redundancy
3. Psycho visual redundancy

1.1 Compression

Compression is a method that reduces the size of files, The aim of compression is to reduce the number of bits that are not required to represent data and to decrease the transmission time, Long P.M. et al, [5] . Achieve compression by encoding data and the data is decompressed to its original form by decoding. A common compressed file extensions is *.sit*, *.tar*, *.zip*; which indicates different types of software used to compress files, Nachappa M.N. et al, [3].

1.2 Decompression

The compressed file is firstly decompressed and then used. There are many softwares used to decompress and it depends upon which type of file is compressed. For example WinZip software is use to decompress .zip file, Nachappa M.N et al, [3]. The basic block diagram of Compression, Decompression and reconstructed data/images is as follows:

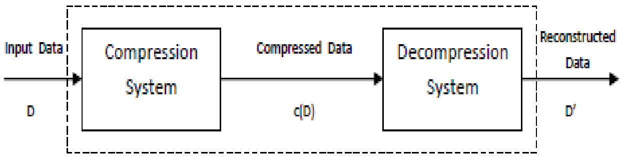

Fig 1. Block diagram of Compression and Decompression of image.

2. TYPES OF IMAGE COMPRESSION TECHNIQUES

There are two categories of image compression i.e. lossless and lossy compression. Lossless compression is used in artificial images. Basically, it uses low bit rate. In the Lossy compression techniques, there is the possibility of losing some information during this process. While lossless compression is basically preferred in medical images and military images, owing to the lesser possibility of loss of information. The explanation of these methods is as follow:

2.1 Lossy Image Compression:

In compression technique, accuracy is very important in compression and decompression. There will be a possibility of data/information loss but it should be under the limit of tolerance. It should be good enough for application of image processing. This kind of compression is used for sharing, transmitting or storing multimedia data, where some loss of data or image is allowed. JPEG is examples of lossy processing methods. When the receiver is human eye, lossy data is allowed, because human eye can tolerate some imperfection in data/information. Some lossy compression techniques are explained as follow, Bhammar M.B et al, [1].

ISSN (Online) : 2278-1021
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International Journal of Advanced Research in Computer and Communication Engineering
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1 Chroma Subsampling
2. Transform Coding
3. Fractal Compression
4.Vector Quantization
5.Block Truncation

2.1.1 Chroma Subsampling

This method contains the advantage of the human visual system's lower acuity for color differences. This technique basically used in video encoding for example jpeg encoding and etc. Chroma Subsampling is a method that holds color information of lower resolution and intensity information. Further the overwhelming majority of graphics programs perform 2x2 chroma subsampling, which breaks the image into 2x2 pixel blocks and only stores the average color information for each 2x2 pixel group, Kaimal A. B. el al , [4].

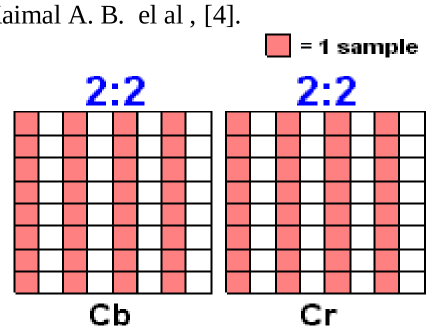

Fig 2. Block diagram of 2x2 pixel Chroma Subsampling Technique.

2.1.2 Transform Coding

This compression technique compresses basically natural data like photographic images. But it will produce a low quality output of original image. This is a linear process and no information is lost, the number of coefficients produced is equal to the number of pixels transformed. There are many types of transforms tried for picture coding, for example Fourier, Karhonen-Loeve, Walsh-Hadamard, lapped orthogonal, discrete cosine (DCT), and recently wavelets, Kaimal A. B. el al, [4]. Transform coding is used to change the pixels of original image into frequency domain coefficients that is called as Transform Coefficients. Transform coding technique uses linear mathematical transform to map the pixel values into a set of coefficients, which are quantized and encoded. The key idea of transform based coding scheme depends on resulting coefficients for most natural images which have small magnitudes and can be quantized (or discarded altogether) without causing significant distortion in the decoded image. Different mathematical transforms, such as Fourier (DFT), Walsh-Hadamard (WHT), and Karhunen-Loeve (KLT), are considered for this task. For compression purposes, the higher capability of compressing information in fewer coefficients, the better is the transform obtained and for that reason, the Discrete Cosine Transform (DCT) has become the most widely used transform coding technique, Singh. A et al, [19].

Basic algorithm steps of Transform encoding (DCT).

1. **Step 1:** Input the Image.
2. **Step 2:** The image firstly broken into 8x8 blocks of pixels.
3. **Step 3:** The Discrete Cosine Transform (DCT) is applied to each and every block, it reads pixels from left to right, and top to bottom.
4. **Step 4:** Each block is compressed using quantization table.
5. **Step 5:** The array of compressed blocks of image is occupy less memory space.
6. **Step 6:** When desired, the image is reconstructed through decompression, a process that uses the Inverse Discrete Cosine Transform (IDCT). Grewal R. K et al, [24].

2.1.3Fractal Compression

Fractal encoding is a mathematical process that is used to encode bitmap real-world image into set of mathematical data and describes the fractal properties of the image. The fractal compression objects contain redundant information in the form of similar, repeating patterns that is called as fractals. Fractal encoding is heavily used for converting bitmap images to fractal codes. Fractal decoding is just the reverse of fractal encoding, where a set of fractal codes are converted into a bitmap. The encoding process is extremely computationally intensive. Millions of iterations are required to find the fractal patterns in an image. Decoding a fractal image is a much simpler process than finding all the fractals of the image during the encoding process. Fractal compression is an asymmetrical process that takes large amount of time to compress and to decompress an image. This characteristic limits the usefulness of fractally compressed data to applications where image data is constantly decompressed but never recompressed. Fractal compression is highly suited for use in image databases and CD-ROM applications Dr. Singh. A et al, [19].

Fractal has the following properties:

1. It has a fine structure that shows details on arbitrarily small scales.
2. It converts real world images into set of mathematical data to represent the fractal properties of images.
3. Its fractal dimension (Hausdorff dimension) is usually higher than its Euclidean dimension.
4. Mostly a fractal is defined in a very simple way, perhaps, recursively. Most of the fractal compression algorithms requires the segmentation of the image into blocks, Sharma S. et al, [25].

Basic working of Fractal encoding of images is as follows:

1. Take a image and divide the input image into square blocks that are typically called as "**Parent Blocks**".
2. Parent block is again divided into 4 blocks that are known as "Child Blocks".
3. Compare each child block against a subset of all possible overlapping blocks of parent block size. There is a need to reduce the size of the parent to allow the comparison to work.

ISSN (Online) : 2278-1021
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4. Determine which larger parent block has the lowest difference, according to some pre defined measure, between parent and the child block.
5. Calculate a grayscale transform to match intensity levels between parent block and child block precisely. Typically a fine transform is used (w*x = a*x + b) to match grayscale levels, [26].

2.1.4Vector Quantization

Vector Quantization is an efficient technique of image compression. VQ compression system contains two components that is VQ encoder and decoder. The VQ encoder finds a closest match codeword for each image block in the codebook or directory and the index of the codeword is transmitted to VQ decoder. The next phase is decoding phase in which VQ decoder replaces the index values with the respective codeword from the codebook and produces the quantized image that is called as reconstructed image, Somasundaram. K. et al, [11]. A vector quantization is usually defined as a block of pixel values. The basic idea behind VQ technique is to develop a dictionary of fixed-size vectors that is called a code vector. Vector Quantization is also known as "**Block Quantization**" or "**Pattern Matching Quantization**". This technique is commonly used in lossy compression methods. It works by encoding values from a multidimensional vector space into a finite set of values. A lower-space vector requires less storage space, so the data is compressed. Due to the density matching property of vector quantization, the compressed data contains errors that are inversely proportional to density. The transformation is usually carried out by projection or codebook, Singh. A et al, [19].

Basic working of Vector Quantization is as following:

1. Input image.
2. Find the closest match code/vector for each image block from the directory or codebook.
3. Replaces code /vector by transmitted index of code for further processing.
4. Above property is used to reduce the storage space of image.

2.1.5 Block truncation

Block truncation coding (BTC) is a simple and fast lossy image compression technique, which work with digitized gray scale images and introduced by Delp and Mitchell. The key idea of BTC is to perform moment preserving (MP) quantization for blocks of pixels. So that the quality of the image will be acceptable and at the same time the demand for the storage space will decrease. BTC technique can be improved by dividing the encoding into three separate tasks: performing the quantization of a block, coding the quantization data, and coding the bit plane, Fränti .P. et al, [12]. In this technique, the image is divided into non overlapping blocks of pixels. Then, determine the threshold and reconstruction value for each block. The threshold is usually the mean of the pixel values in the block. The bitmap of the block is derived by replacing all pixels whose values are greater than or equal (less than) to the threshold by 1 (0). Then for each segment (group of 1s and 0s) in the bitmap, the reconstruction value is determined. This is the average of the values of the corresponding pixels in the original block, [20].

2.2 Lossless image compression:

In the decompression phase of lossy image compression , the output images are almost the same as input images. In addition, this method is useful where a little information from each pixel is important. The lossless method is also called as wavelet technique. The example of lossless compression methods are RLE, LZW, Entropy coding, Bhammar M.B et al, [1].

Some of the lossless compression techniques are

1. Run Length Encoding
2. Huffman Encoding
3. LZW Coding
4. Area Coding
5. Arithmetic Coding

2.2.1. Run Length Encoding

Run Length Encoding (RLE) is a simplest compression technique which is most commonly used. This algorithm searches for runs of bits, bytes, or pixels of the same value, and encodes the length and value of the run. RLE achieves best results with images containing large areas of contiguous colour, and especially monochrome images, For example The string is aaaaaaaabbbbbcc would have representation as (a; 8)(b; 5)(c; 3) Then compress each (char; length) as a unit using, say, Huffman coding. Clearly, this technique works best when the characters repeat often, Husseen A.H et al, [6].

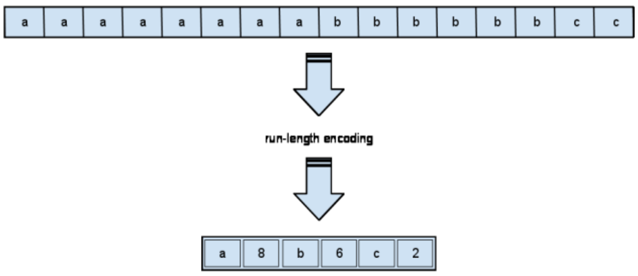

Fig 3.Example of Run length encoding.

Steps of algorithm for RLE are as follows.

Step 1: Input the string.
Step 2: From first symbol or character give a unique value .
Step 3: Read the next character or symbol, if character is last in string then exit otherwise.
a: If: next symbol is same as the previous symbol then give same unique value as pervious.
b: Else if: next symbol is not same, than give its new value that is unmatched from previous value.
Step 4: Read and count additional symbols
Step 5: Go to step 3 until a non matching value to the not same symbol from previous.

ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
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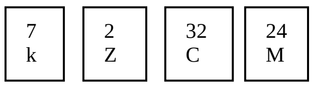
Step 6: Display the result, that is count of occurrence of single symbol with that particular symbol,[22].

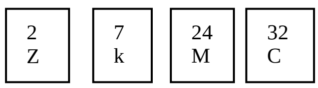
2.2.2. Huffman encoding

Huffman coding is an entropy encoding algorithm used for lossless data compression. The term refers to the use of a variable-length code table for encoding a source symbol , where the variable-length code table has been derived in a particular way based on the estimated probability of occurrence. Huffman coding is based on frequency of occurrence of a data item, Bahrami A. Set al, [7]. The pixels in the image are treated as symbols. The symbols that occur more frequently are assigned a smaller number of bits, while the symbols that occur less frequently are assigned a relatively larger number of bits. Huffman code is a prefix code. The binary code of any symbol is not the prefix of the code of any other symbol. Most of the image coding standards uses lossy techniques in earlier stages of compression and use Huffman coding as the final step, Chang. C. J. , [8]. Huffman algorithms have two ranges static as well as adaptive. Static Huffman algorithm is a technique that encodes the data in two passes. In first pass, it is required to calculate the frequency of each symbol and in the second pass it constructs the Huffman tree. Adaptive Huffman algorithm is expanded on Huffman algorithm that constructs the Huffman tree in one pass, but takes more space than Static Huffman algorithm, Dr. Singh. A et al, [19]. On average, using Huffman coding on standard files can shrink them anywhere from 10% to 30% depending on the character distribution. Huffman encoding creates the tree like structure when it encodes the given string. The example of Huffman Encoding with algorithm is as follows

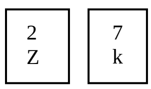
Step 1: Input the string



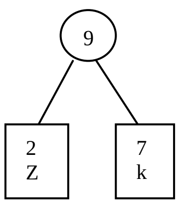
Step 2: Sorting the data by frequencies



Step 3: Choose two smallest frequencies count.

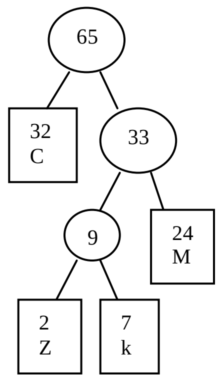


Step 4: Merge them together with sum of them and update the data



Step 5: Repeat step 2, 3, 4.

The final Huffman tree is as follows:



2.2.3. LZW Coding

LZW (Lempel-Ziv–Welch) is a totally dictionary based coding. Lzw encoding is further divided into static & dynamic. In static, dictionary is fixed during the encoding and decoding processes. In dynamic dictionary coding, the dictionary is updated if needed, Chang. C. J, [8]. LZW compression replaces strings of characters with single codes. It does not perform any analysis of the incoming text. Instead, it just adds every new string of characters from the table of strings. The code that the LZW algorithm outputs can be of any arbitrary length, but it must have more bits in it than a single character. LZW compression works best for files containing lots of repetitive data. LZW compression maintains a dictionary. In this dictionary all the stream entry and code are stored.

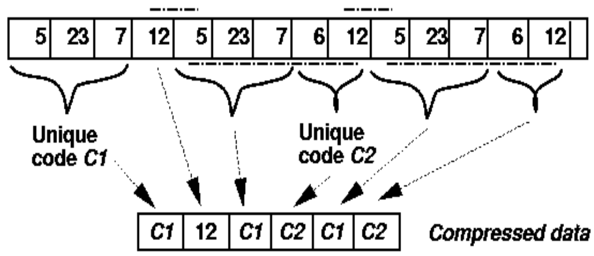


Fig 4. Example of LZW coding.

The basic steps of LZW algorithm are as follows:

Step 1: Input the stream.

Step 2: Initialize the dictionary to contain entry of each character of stream.

Step 3: Read the stream

If current byte is end of the stream, then exit.

Step 4: Otherwise read next character and produce a new code.

If the bunch of character is frequently occurring then give them a unique code (according to the diagram)

Step 5: Read next input character of stream from dictionary

If there is no such character in dictionary, then

A: Add new string to the dictionary.

B: Write the new code for new entered string.

C: Go to step 4.

Step 6: Write out code for encoded string and exit

2.2.4. Area Coding

Area Coding is an enhanced form of run length encoding (RLE), It shows the two dimensional character of images as a run length encoding . The algorithms for area coding tries to find out rectangular regions with the same characteristics. These regions are coded in a descriptive form as an element with two points and a certain structure. This type of coding can be highly effective but it bears the problem of a nonlinear method, which cannot be implemented in hardware. Thus, the performance in terms of compression time is not competitive, although the compression ratio is, Chang. C. J , [8]. In this technique, special codeword are used to identify large areas of contiguous 1's or 0's. In this method the whole image is divided into blocks size that is m*n pixels, which are classified into some blocks having only white pixels and some blocks having only black pixels or blocks with mixed intensity. The most frequent occurring category is then assigned a 1-bit codeword 0 and the remaining other two categories are assigned with 2-bit codes 10 and 11. The code assigned to the mixed intensity category is used as a prefix, which is followed by the mn-bit pattern of the block. Compression is achieved because the mn bits that are normally used to represent each constant area are replaced by a 1-bit or 2-bit codeword. White text documents compression is slightly simpler approach that is called as white block skipping. That is used to code the solid white areas as 0 and all other blocks including the solid black blocks are coded as 1 followed by the bit pattern of the block. This approach takes advantage of the anticipated structural patterns of the image to be compressed. As few solid black areas are expected, they are grouped with the mixed regions, allowing a 1-bit codeword to be used for the highly probable white blocks, [21].

3.2.5. Arithmetic Coding

The fundamental problem of lossless compression technique is to decompose data set into a particular event, then encode events using few bit as possible. This idea is useful to assign short code word to more probable event and longer code word to less probable events, Howard P. G. et al. [9]. AC is the most powerful technique for statically lossless encoding that has attracted much attention in the recent work on lossless techniques. It provides more flexibility and better efficiency than the celebrated Huffman coding does. The aim of AC is to define a method that provides code words with an ideal length. The average code length is very close to the possible minimum given by information theory. In other words, AC assigns an interval to each symbol whose size reflects the probability for the appearance of this symbol. The codeword of a symbol is an arbitrary rational number belonging to the corresponding interval, Kaur M. et al, [10].

Properties of Arithmetic Coding:

1. It uses binary fractional number.
2. Suitable for small alphabet with highly skewed probabilities.
3. Incremental transmission of bits are possible, avoiding working with higher and higher precision numbers.
4. This encoding takes a stream of input symbol and it replaces it with floating point number (0,1).
5. It produces result in stream of bits, [27].

Example of Arithmetic Coding:

The basic idea of arithmetic encoding is to have a probability line, 0-1, If once defined the ranges and the probability of line, then start to encode the given symbols, every symbol defines where the output floating point number lands. Let's say we have:

Table 1. Symbol, probability, and range of arithmetic example

Symbol	Probability	Range
A	2	[0.0 , 0.5)
B	1	[0.5 ,0.75)
C	1	[0.7.5 ,1.0)

The algorithm to compute the output number is:

- Low = 0.
- High = 1.
- Loop. For all the symbols.
  - Range = high - low
  - High = low + range (high_range of the symbol being coded)
  - Low = low + range (low_range of the symbol being coded)

- Range, keeps track of where the next range should be.
- High and low, specify the output number,[28].

Table 3. Summarizing the advantages and disadvantages of various data compression algorithm

Techniques	Advantages	Disadvantages
1.Runlength Encoding	This algorithm is easy to implement and does not require much CPU horsepower ,[13].	RLE compression is only efficient with files that contain lots of repetitive data .[13] White or black areas are more suitable then colored image. Jindal V. et al.[[14].
2.Fractal Encoding	This techniques include Good mathematical Encoding-frame , Kashyap .N et al, [18].	But this technique have slow Encoding, Kashyap .N et al. [18]

3.LZW Encoding	Simple, fast and good compression Jindal V.et al , [14] . Dynamic codeword table built for each file . Jindal V.et al , [14]. Decompression recreates the codeword table so it does not need to be passed. Jindal V.et al , [14]. Many popular programs, such as the UNIX-based, gzip and gunzip, and the Windows-based WinZip program, are based on the LZW algorithm, [16]	Actual compression hard to predict Jindal V.et al ,[14]. It occupies more storage space that is not the optimum compression ratio Jindal V.et al ,[14]. LZW algorithm works only when the input data is sufficiently large and there is sufficient redundancy in the data, [16].
4.Arithmetic encoding	Its ability to keep the coding and the modeler separate. Iombo C, [17]. No code tree needs to be transmitted to the receiver. Iombo C,[17]. Its use the fractional values, Iombo C, [17].	Arithmetic coding have complex operations because its consists of additions, subtractions, multiplications, and divisions, Iombo C, [17]. Arithmetic coding significantly slower than Huffman coding, there are no infinite precision Iombo C,[17]. Two issues structures to store the numbers and the constant division of interval may result in code overlap, Iombo C,[17].
5.Vector Quantization	This technique have simple decoder, there is no coefficient quantization , Kashyap .N et al ,[18].	This technique generates code book in very slow speed ,Small bpp , Kashyap .N et al, [18]
6.Huffman Encoding	This compression algorithm is very simple and efficient in compressing text or program files, Jindal V. et al, [14] . This technique shows shorter sequences for more frequently appearing characters , [15]. prefix-free: no bit-sequence encoding of a character is the prefix of any other bit-sequence encoding, [15].	Images that is compresses by this technique is better compressed by other compression algorithms Jindal V. et al, [14]. Code tree also needs to be transmitted as well as the message (unless some code table or prediction table is agreed upon between sender and receiver) ,[15]. Whole data corrupted by one corrupt bit, [15]. performance depends on good estimate if estimate is not good than performance is poor, [15].

4. CONCLUSION

This paper provides a short survey on recent lossy image compression algorithms. There are different types of image compression techniques. These techniques are basically classified into Lossy compression techniques and lossless compression technique. As the name indicate, in lossless technique the image can be decoded without any loss of information. But in case of lossy compression it causes some form of information loss. These techniques are good for various applications. But all methods of compression have some drawbacks also. Future efforts are intended to be put on the development of an efficient compression algorithm for reducing the drawbacks of existing algorithms and aggregating the advantages of most of the techniques

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