IMAGE COMPRESSION – A SURVEY

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Abstract: Image compression is one of the most important perspectives in image processing. It is concerned with reducing the number of fundamental elements needed to represent an image. An immense amount of memory and high data transfer capacity are required for the continuous transmission of pictures. Hereafter, to build the organizational capacities of winning organizations successfully and to increase the interest in capacity to an economical level, image compression gives a quick solution for this arrangement. The article discusses several methods for compressing images. This study gives a survey of previous research papers based on an analysis of the different picture compression approaches.

Index Terms – Image, Image compression.

I. INTRODUCTION

A digital image represents a two-dimensional image as a finite set of digital values, called picture elements or pixels. It provides a major role in many important and diverse applications, including tele-video conferencing, remote sensing, document and medical imaging, FAX, and the control of remotely piloted vehicles in military space and hazardous waste management applications. In essence, a picture is a 2-D input that our brain has processed. An image's information is often analogue[1]. However, they are digitally transformed from analogue forms for specific uses. A 2-D collection of pixels makes up a computer picture. If an image is represented by f(x, y), then each pixel's spatial coordinates are represented by x and y. This array of images is transformed into a matrix format for digital processor manipulation.

The formats for image files are common methods for organizing and keeping digital photographs. The different generic image formats are TIFF (Tagged Image File Format), GIF (Graphics Interchange Format), PNG (Portable Network Graphics), PNG (Portable Network Graphics), BMP (BitMaP) and PPM (Portable Pixel Map). The Utilisation of Digital Images is growing quickly and at the same time digital images facing serious issues with storing and transferring the enormous amount of data that represents the images. Because these uncompressed multimedia (audio, video, and graphics) data require a significant amount of bandwidth for transmission. Researchers are under a lot of pressure to figure out how to use images in web applications given the recent growth in data-intensive multimedia web applications. More Practically, Digital Movie Storage, High-Definition Television (HDTV), Satellite Communications, Internet Teleconferencing, and Medical Imaging Cannot Be Achieved Without Significant Compression. Because it helps lower the use of costly resources like hard disc space or transmission bandwidth, compression is helpful. Alongside the current uptick in digital image data generation, there has been a notable increase in research activities in the area of image compression [2].

The primary objective is to express an image in the fewest words possible without losing any of its important details. Repetitive data or duplication in an image not required to reconstruct the picture is referred to as redundancy in images. There are several methods to convey information. An encoder carries out the compression of images and outputs a compressed form of an image. In the processes of compression, the mathematical transforms play a vital role [3].

A general diagram of the compression process of the image can be represented as:

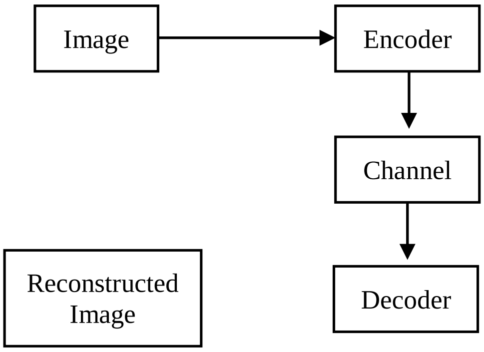

Figure 1: General diagram of Image compression System

The encoder and the decoder are the two blocks. The encoder removes the input redundancies while the decoder's function is to ensure that the system is to reconstruct the original data. The photo compression technique uses three primary redundancies to represent the image in a better-compressed form. Data redundancy is the main obstacle to digital image compression [4].

Two essential elements of compression are irrelevancy and redundancy. The goal of redundancy reduction is to eliminate information that is duplicated in the source signal. Irrelevancy reduction in digital picture compression ignores portions of an image that the recipient is unlikely to see. The three primary data redundancies in digital images that may be found and used to achieve compression are as follows: Three fundamental data redundancies can be found and capitalized [5]:

Coding redundancy: The source of coding redundancy is when pictures are coded for grey levels using more bits than are required to represent each grey level. By assigning shorter codewords to grey levels according to their probability of occurrence, this repetition may be prevented.

Interpixel redundancy: A pixel is considered to have this redundant character when its grey level may be reasonably predicted from that of its neighbors. The visual effect of the pixel on an image is superfluous. This redundancy may be reduced by presenting the picture in an improved nonvisual way, such as pixel difference representation.

Psychovisual redundancy: The human eye is not sensitive to every visual element in the same way. Psycho-visual redundancy is the result of one visual piece of information being somewhat less relevant than the other. This redundancy may be removed via quantization without significantly reducing the image's apparent quality. Typically, humans see decompressed pictures. As a result, the HVS's capabilities and limits apply to their fidelities.

Reduction or Elimination of Redundancies Leads to Image Compression. It is possible to reduce the file size of an image without sacrificing image quality; these methods are known as lossy compression and lossless compression, respectively.

II. NEED FOR IMAGE COMPRESSION

The image processing industry is gaining attention due to the rapid advancements in digital technology. This process involves altering and interpreting images in binary form, enabling the retrieval of relevant data and essential procedures. The image processing stage is crucial for improving graphical information for human observation and self-directed machine applications. Storage-related approaches are more versatile in terms of buffer size and compression speed compared to compression methods [6]. For example, a 10:1 compression ratio can reduce memory usage to 300 kB and reduce transmission time to 7 seconds. The demand for compression technology has increased due to redundancy in remote sensing sampling photographs, requiring a compression technique that can reduce size while maintaining image details.

III. Benefits of Compression

- Potential cost savings due to reduced data transmission.
- Reduces storage requirements and execution time.
- Reduces transmission error probability due to fewer bits transferred.
- Provides security against illicit monitoring.

IV. Types of Image compression

Based on our requirements, image compression techniques are broadly bifurcated into the following two major categories.

- Lossless image compression
- Lossy image compression

Lossless Compression Technique:
The original picture may be completely restored from the compressed (encoded) image using lossless compression methods. Since they don't introduce noise into the signal (picture), they are sometimes referred to as noiseless. Since it uses statistics and decomposition methods to reduce or remove duplication, it is also known as entropy coding. Only a few applications with strict requirements—like medical imaging—use lossless compression.

The following techniques are included in lossless compression:

1. Run length encoding: Run length Encoding (RLE) is a simple image compression technique that replaces a sequence of identical symbols with a pair containing the symbol and run length.

2. Huffman encoding: Huffman coding is an entropy encoding algorithm developed by Huffman for lossless data compression. It uses a variable-length code table to encode a source symbol, based on the estimated probability of occurrence for each possible value. The code table is derived based on the probability of occurrence for each possible symbol. The pixels in the image are treated as symbols, with symbols with higher frequency assigned a smaller number of bits and less frequently assigned a larger number. Huffman code is a prefix code, meaning the binary code of any symbol is not the prefix of any other symbol [7].

3. LZW coding: Lempel–Ziv–Welch (LZW) is a universal lossless data compression algorithm developed by Abraham Lempel, Jacob Ziv, and Terry Welch. It is a dictionary-based coding that can be static or dynamic. LZW is simple to implement and has potential for high throughput in hardware. It was the basis for the popular UNIX file compression utility compress and is used in the GIF image format. LZW became the first universal image compression method on computers, compressing large English text files to half their original size.

4. Arithmetic coding: Arithmetic coding is a lossless data compression method that converts a string into a single number, reducing the number of bits used in the process. This method differs from other entropy encoding methods like Huffman coding, as it encodes the entire message into a single number, rather than separating the input into component symbols and replacing each with a code. This results in fewer bits used in total [8].

Lossy Compression Technique:
Compared to lossless techniques, lossy systems provide much greater compression ratios. Since most applications can make good use of the reconstructed pictures, lossy techniques are often used. The decompressed picture, according to this approach, is quite similar to the original image but not the same.

Lossy compression techniques include the following schemes:

1. Transformation coding: The coding scheme uses transforms like DFT (Discrete Fourier Transform) and DCT (Discrete Cosine Transform) to convert pixels into frequency domain coefficients. These coefficients have desirable properties, such as energy compaction, concentrating most energy in a few significant transform coefficients. This is the basis for compression. Only these few significant coefficients are selected for further quantization and entropy encoding. DCT coding is the most common approach to transform coding and is also used in the JPEG image compression standard [9].

2. Vector quantization: Vector Quantization involves creating a dictionary of constant-size code vectors, composed of pixel values, which are then divided into non-recurring image vectors. This information is indexed and used to encode the original image, thereby entropy-coding every image using these indices. This process is crucial for efficient image processing.

3. Fractal coding: This coding method divides images into segments using standard points like color difference, edges, frequency, and texture. Fractal segments are used as a look-up table in a dictionary, and the library contains compact codes. The algorithm operates on fractals and encodes the image, making it more effective for compressing natural and textured images. This approach is particularly useful for compressed images.

4. Block Truncation Coding: The image is divided into blocks, like fractals, with a window of N by N pixels being considered a block. The mean value of all values in that window is determined using a threshold, which is typically the mean value of pixel values in the vector. A bitmap of that vector is generated by replacing pixels with a 1 and determining the average value for each segment in the bitmap [10].

Subband coding: This approach applies coding and quantization to all the sub-bands from the frequency component bands that are analyzed.
Because the sub-bands are more precisely subjected to quantization and coding, this coding is quite helpful.In this approach, the picture is analyzed to generate the subbands, or components, that include frequencies in well-defined bands. This approach has the benefit that each subband's optimal coding and quantization may be devised independently.

V. Comparative Analysis

Comparative analysis for lossless and lossy image compression techniques are done based on the CR (Compression ratio), PSNR (signal-to-noise ratio) and MSE (Mean square error).

MSE is the cumulative difference between the compressed image and the original image. The small amount of MSE reduces the error and improves image quality [11].

$$\text{MSE} = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N}$$

Compression is defined as the ratio between an uncompressed image and a compressed image.

$$C = \frac{\text{Compressed Image}}{\text{Original Image}}$$

PSNR is the measurement of the peak error between the compressed image and the original image. The higher the PSNR contains better the quality of the image [12].

$$\text{PSNR} = 10\log_{10}\left(\frac{R^2}{MSE}\right)$$

VI. Conclusion

This article discusses various lossless image compression techniques, which significantly reduce transmission and storage costs. These techniques are continuously developed to improve compression ratios. Lossless compression involves compressing and decompressing images without losing information. Wavelet Lossless Image Compression Technique and Integer Wavelet Transform are now used to achieve better compression ratios without compromising image quality. The quality of an image can be measured by factors like peak signal to noise ratio, mean square error, and compression ratio.

VII. References

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