Image Compression Approaches: A Comprehensive Study

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[1]***Abstract*— In the present scenario where the amount of data is increasing exponentially by the second, there is a high requirement for efficient storage and transmission of such data. This also extends to different formats like images, video, audio etc which furthermore demand such improvement. With regard to this, the paper throws light on certain key image compression techniques used like Joint Photographic Experts Group (JPEG), Graphics Interchange Format (GIF) and Discrete Wavelet Transformation (DWT). It also provides a clear comparison of the above mentioned techniques by taking into account various parameters. Image compression plays a key role in numerous situations where applications deal with enormous image type data storage, processing and transmission. Applications in the domain of videoconferencing and image sharing are the main entities requiring image compression. In simple terms, the end result of image compression is to produce an image of smaller size in terms of storage. This can be achieved by eliminating the repeating or redundant content in the image. Hence, image compression mainly focusses on reducing the amount of time required to transmit an image and the memory required for storage of the same.**

***Index Terms* -Compression Ratio, DWT, GIF, Image compression, JPEG, MSE, PSNR.**

I. INTRODUCTION

Image compression algorithms are basically of two types. Namely, lossy image processing and lossless image processing. Lossless as the name suggests, is a compression algorithm wherein there is no loss of any information during the process of compression. This can be used to generate the exact copy of the original image from the compressed image. This is also known as entropy coding, mainly because of the increased randomness in the compressed image than the original. This technique even though prevents loss of information, does not provide a sufficiently high compression ratio. Hence, the applications of this is limited to storage domain where images are compressed and stored for future purposes like medical imaging, image archives, etc; Techniques that employ lossless compression include Entropy coding, Bit-plane coding, Run-length coding, Huffman coding and Lempel Ziv Welch (LZW) coding[8].

Contrasting to the lossless image compression, the lossy image compression technique is one in which a great amount of reduction in image size is achieved. But, this occurs at the cost of losing minute details of the image. Lossy technique reduces the size greatly without affecting the overall appearance of the original image. Hence, it is preferred in situations where transmission of images is the primary need and thereby reduces the overall bandwidth necessary for transmission of images. Some of the methods that employ this technique are Fractal compression, Fourier-related transform, Wavelet Transform, Transform coding and Discrete Cosine Transform[7].

This paper mainly focusses on the experimental comparisons of image compression techniques like JPEG, GIF and DWT. Quality measurement variables like peak signal to noise ratio (PSNR) and mean square error (MSE) have been estimated to determine how well an image is reproduced with respect to the reference image.

The article is structured as follows: Section 2 describes the basic principles of image compression technique, Section 3 provides a brief description of the compression techniques and the methodology, Section 4 focusses on the discussion and experimental results. Section 5 is the final section drawing necessary conclusions about the topic.

II. IMAGE COMPRESSION AND RECONSTRUCTION

Further shown Fig. 1 clearly shows the basic steps of process of image compression. The system is composed of 2 main blocks: an encoder and a decoder. Image *f(x, y)* is fed into the encoder. The encoder is one which generates a set of symbols from received data and uses them to represent the image. Image $\hat{f}(x, y)$ denotes and approximation of the input image that results from compressing and subsequently decompressing the input image[1][5].

The compression ratio can be denoted as:

$$C_R = n_1/n_2 \quad (1)$$

where n_1 and n_2 indicate the number of information carrying bits in the reference image and compressed image respectively. A ratio of 14:3 indicates that the reference image has 14 information carrying bits for every 3 bits of the compressed image.

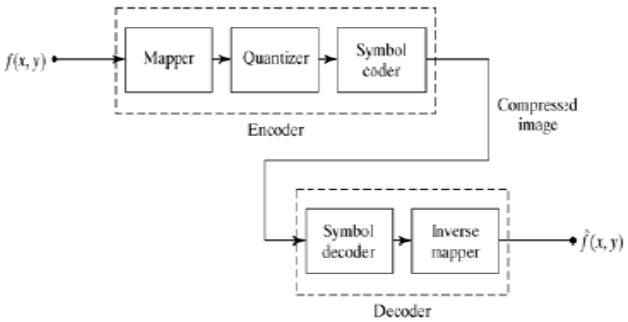

Fig. 1 Block diagram of image compression

Parameters like PSNR (peak signal-to-noise ratio) and MSE (mean square error) are a clear indication of how well the image is reproduced with respect to the original image/ These

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variables signal fidelity metrics an do not measure how viewers perceive impairments.

The peak signal-to-noise ratio (PSNR) is given by:

$$PSNR = 10\log_{10}(255^2 / MSE)\ \text{dB} \qquad (2)$$

And the mean square error (MSE) is given by,

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}\left[f(x,y) - \hat{f}(x,y)\right]^2 \qquad (3)$$

III. IMAGE COMPRESSION ALGORITHMS

A. *Discrete Wavelet Transform (DWT)*

Wavelets are signals that are local in time and scale and usually have an irregular shape[2]. It is nothing but a waveform of effectively limited duration that has an average value of zero. In DWT, the signal is decomposed into several wavelets and then the coefficients of the wavelets are decimated to remove the details[10].

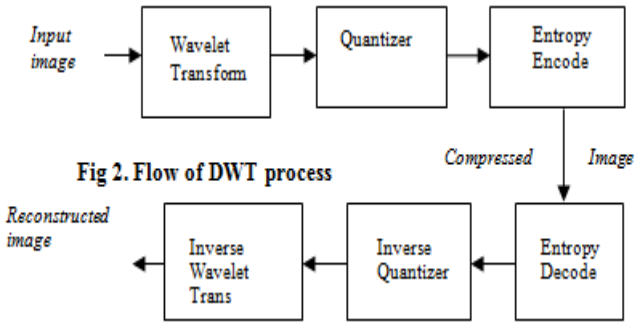

Fig 2. Flow of DWT process

The sequence of operation that happen in DWT are as follows:

1) Decompose

Decompose is a process where the wavelet is chosen along with a level, N. Once, these 2 entities are selected, the wavelet is computed and eventually, the signals are decomposed at level N[9].

2) Threshold detail coefficients

This is the step wherein, a threshold is selected at each level 1 to N and hard threshold is applied to the detail coefficients.

3) Reconstruct

Compute wavelet reconstruction using the original approximation coefficients of level N and the modified detail coefficients of levels from 1 to N.

B. *JPEG compression*

JPEG is a lossy compression technique[3] mainly employed in transmission requirements of images. It works on the basis of discrete cosine transform converting each frame/ field of the source from spatial (2D) domain to the frequency domain[4]. The block diagram and the steps are as shown below.

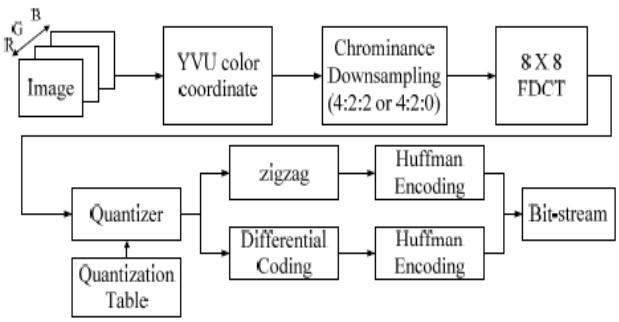

Fig 3. Flow of JPEG Process

The sequence of operation that happen in JPEG compression are as follows:

I. Conversion of RGB color space to a YCC color Space.

II. Spatial subsampling of the chrominance channels in YCC space.

III. Transformation of a blocked representation of the YCC spatial image data to a frequency domain representation using the discrete cosine transform.

IV. Quantization of the blocked frequency domain data according to a user-defined quality factor.

V.Coding of the frequency domain data, for storage, using Huffman coding.

C. *GIF compression*

GIF is a lossless image compression technique and preserves the information post compression too. This method uses LZW compression approach and makes use of the repetition in data streams and performs the compression[6]. The steps are shown below.

The sequence of operations is as shown below:

I. Initialize the dictionary to contain all strings of length one.

II. Find the longest string W in the dictionary that matches the current input.

III. Emit the dictionary index for W to output and remove W from the input.

IV. Add W followed by the next symbol in the input to the dictionary.

V. Go to Step 2.

IV. RESULTS AND DISCUSSIONS

This section show the results obtained on execution of the compression techniques discussed so far. The table shown below indicates the compression ratio, PSNR and the compressed file size after applying the compression techniques on the reference image file.

Compression Technique	File Size (KB)	Compression Ratio	PSNR (dB)
Reference Image (bmp)	47.00	-	-
GIF	6.40	7.34:1	27.37
JPEG	3.38	13.90:1	24.42
DWT	1.94	24.22:1	19:86

Table 1. Comparison between the compression techniques

The above table clearly demonstrates the performance results of the techniques and from the results obtained, it can be concluded that DWT is the most optimal compression technique.

V. Conclusion

As discussed in this paper, there are various techniques of image compression. Each technique has its own pros and cons due to which they are preferred in different situations. From the results obtained by experiments, it can be concluded that lossless image compression can be used for archival purposes and lossy technique for transmission purposes. It can also be seen clearly that DWT technique is the most optimal technique at the moment. Further research is continuously being carried out in the field neural networks to improve the efficiency of compression techniques.

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