Review of Image Compression Techniques

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Abstract — Image compression is an important technique to reduce the number of bits per pixel in an image. This reduces the storage space needed by an image that makes transportation of the images easier. The main purpose of image compression is to reduce the redundancy from the image. From a long time, a lot of attention and regression work is being done on medical images analysis and hence compression of medical images. This paper elaborates various possible techniques for an efficient image compression with encoding techniques and evaluation of image quality.

Keywords — Discrete Cosine Transformation, Image Compression, Neural Network, Vector Quantization, Wavelet

I. INTRODUCTION

Image compression is highly important technique that reduces the storage requirement of images with easier and fast transportation of images. The demand of communication through multimedia is gradually increasing with time. In order to optimize usage of bandwidth, compression acts as a good technique and therefore it is the demand to develop efficient image compression technique which could give best results in compression.

Removal of redundancy of bit patterns in images is major factor that is considered for image compression. If the original image contains some kind of redundancy, better and effective compression can be achieved by reducing degree of redundancy in that image. The redundancy related to image compression is mainly of three types:

- Psycho-visual redundancy,
- Inter pixel redundancy
  - Spatial- correlation between adjacent pixels of an image
  - temporal redundancy- correlation between pixels in two adjacent frames of a video
- coding redundancy

Inter pixel and coding redundancy are also called as statistical redundancy. Mainly temporal redundancy is focused under video compressions. So our motive is to remove or reduce any of these redundancies from the image for an efficient, optimize or effective image compression. Information retained after compression and decompression by an image is known as the Retained *Energy (RE)*.

II. IMAGE COMPRESSION TECHNIQUES

Compression is known as lossless if there is 100% RE and reconstruction of the image is exactly same as the original otherwise lossy compression [1]. In case of image, features define the behavior of an image with storage consumed and classification efficiency with time consumption [4]. Image compression techniques can be categorized as under:

A. Lossless Compression (A reversible compression)

This compression technique simply means “no loss of data from the original image” that has been chosen for compression. When this compressed image is decompressed, it will give the same data as in original image. In case of text and program files, introduction of single error can seriously change the meaning of a text file, or can cause a program not to function according to expected behavior or not run at all. So, the data needed to be reproduced after decompression must be same as original. Lossless image compression techniques reduce the space needed for storing the file to a good extent. It is used only for some specific applications along with the rigid needs like a medical-imaging. TIFF and PNG file formats are based on Lossless compression technique [2].

B. Lossy Compression - An irreversible compression.

Lossy compression is identifying and eliminating non-essential information from image. So, removing such type of undesired information will actually reduces the size of image. It basically decreases the bits/pixel in an image and hence the storage size required than original image. In lossy image compression, reproduced data must not be same as of original image data. Still, as far as the errors are concerned between the actual and compressed image, the reproduced image after decompression is indistinguishable by human eye [3].

III. ENCODING TECHNIQUES

Various encoding techniques are available which can be illustrated as under [5]:

A. Run length encoding:

Run-length encoding (RLE) basically compresses the string by means of counting the characters or symbols present in the string and then placing a character in destination attached with it count. RLE performs significant well with Black and white images and cartoon images. Consider an example:
String to compress: "aaaabbcccddddd"
Compressed form: a4b2c3d5.
Advantages of RLE are: Easy to implement, Good alternative for a complex compression algorithm, Fast to execute;
Applications are in TIFF, PDF, BMP;
Drawback is that it can't achieve the high compression ratio.

B. Lempel-Ziv-Welch(LZW)

It is another lossless compression algorithm developed by Terry Welch that replaces the data with table look up. During compression, table is formed with encoding of data and also when data is decoded. The important steps for this technique are given below:

- Firstly, it will read the file and given a code to all character.
- If the same characters are found in a file then it will not assign the new code and then use existing code from a dictionary.
- The process is continuous until the characters in a file are null.

It is simple and fast compression technique where dynamic code word table is built for each file. Decompression creates the code word table. It is widely used in TIFF, GIF and PDF. Drawback is that management of string table is difficult. It works only for English text and needs a dictionary

C. Entropy Encoding

Entropy encoding works independent of the specific characteristics of the image and is used as lossless compression technique. It can be used to measure the similarity in data streams by creating a unique prefix code which is assigned to unique symbol in the input. Unlike RLE, Entropy encoders work by compressing data through replacing the fixed length output with a prefix code word. The code produced will be of varying size after creating the prefix code There are many entropy coding methods. The most common techniques are Huffman coding and arithmetic coding. Huffman coding was developed by David A. Huffman. It will use a variable-length code table for encoding a source symbol (such as a character in a file). Arithmetic coding is optimal for symbol by symbol encoding and is similar to block encoding technique where prefix code is known as prefix-free codes [7].

D. Huffman coding

The Huffman code is prepared by combining together two least possible characters that are repeating in this process till only the one character remains. A code-tree is hence prepared and then a Huffman code is generated from the labeling of code tree. It is the best prefix code that is generated from the set of the probabilities and which has been used in the different applications of the compression.
These generated codes are of different length of code which is using integral number of the bits. This concept results in a decrease in average length of the code and hence the whole size of the compressed data is become smaller as compare to the original one. The Huffman's algorithm is the first that provides the solution to the issue of constructing the codes with less redundancy. It is easy to implement and fast to execute which produces lossless compression. It is used in ZIP, MPEG, JPEG, ARJ, It depends on statistical model of data. Also, its decoding is difficult because of different code length.

E. Transform coding

Transform coding is a well known image compression method providing greater data compression on behalf of large computation. Transform coding, first transforms the image from its spatial domain representation to a different type of representation using some well-known transform and then codes the transformed values (coefficients).

F. Vector coding

Vector quantization [VQ] is divided into two operations. The first is the encoder, and the second is the decoder. The encoder takes an input vector and outputs the index of the codeword with lowest distortion which is calculated by evaluating the Euclidean distance between the input vector and each codeword in the codebook. Once the closest codeword is found, the index of that codeword is sent through a channel (the channel could be computer storage, communications channel, and so on). On receiving the codeword index, index is replaced with the associated codeword by the encoder [8].

In VQ compression, a codebook is prepared that consists of code vectors where each code vector represents a group of image blocks of size n × n where n=4 is used. Image to be compressed is partitioned into m × m non-overlapping blocks that represent m2-tuple vectors, called training vectors. Training vectors size can be very large e.g. a 512 × 512 image produces 16,384 training vectors. Codebook gives code vectors called representative vectors of size 256 or 512, from a set of training vectors. For each non overlapped 4 × 4 block of an image, the encoding procedure checks for a closest code vector in the codebook. The most important work is to design a versatile codebook.

G. Fractal compression

Fractal image coding was introduced in the late 1980s and early 1990s based on the Collage theorem and widely used for encoding or decoding images in Encyclopedia. It represents a fixed point theorem consists of a set of affine transformations. A fractal algorithm divide an image into range blocks of 8×8 blocks (non-overlapping) and forms a domain pool with all possible overlapped domain blocks of 16×16 blocks associated with 8 isometrics from reflections and rotations [10].

H. Wavelet based compression

Wavelets are the signals with irregular shape that has an average value of zero. With wavelet analysis, Information of an image is partitioned into approximation and detail sub-signals. Wavelet transformation is done by calculating discrete data. A continuous wavelet transform can be equated as:.

$$C(s,\tau) = \int_{-\infty}^{\infty} f(S,T,t)dt$$

Where, T is the translation which is proportional to time information, t; and S is the scale that is proportional to the inverse of the frequency information [1].

IV. Evaluation of Image Quality

There are 2 methods for evaluation of image quality that are [13, 15]:

A. Objective methods

These methods are based on computable distortion measures. For image quality, reconstruction error can be used as the standard objective measure. Let us consider that for a system in which an input image element block {x(i)}, i=0,1,..., j-1 is reproduced as {y(i)}, n=0,1,..., j-1. The difference between x(i) and y(i) i.e. r(i)=x(i)-y(i) is known as reconstruction error, r(i).

The variances of x(i), y(i), and r(i) are σ_x^2, σ_y^2 and σ_r^2. For zero-means signals, over appropriate sequence length L, variances are equal to respective mean-square values.

$$\sigma_z^2 = \frac{1}{L}\sum_{i=1}^{L} z^2(i), \qquad z = x, y \text{ or } r$$

Signal-to-Noise Ratio (SNR) is used as a standard objective measure for coded image quality and can be defined as the ratio between signal variance and reconstruction error variance [mean-square error (MSE)] usually expressed in decibels (dB)

$$SNR(dB) = 10log_{10}\left(\frac{\sigma_x^2}{\sigma_r^2}\right) = 10log_{10}\left(\frac{\sigma_x^2}{MSE}\right)$$

In case of input signal is an R-bit discrete variable, variance or energy can be replaced by the maximum input symbol energy $(2^R - 1)^2$. For the input image of 8 bits per picture element, the peak SNR (PSNR) can be stated as:

$$SNR(dB) = 10log_{10}\left(\frac{255^2}{MSE}\right)$$

SNR is not enough for the measurement of picture quality because the reconstruction errors do not have the character of signal-independent additive noise.

B. Subjective Evaluation

It is experimentally difficult and lengthy to do Subjective assessments of image quality, Depending on the test conditions, the results may vary. Perception based subjective evaluation is quantified by mean opinion score (MOS). As a reference, the original source image is used. This method uses the five-scale impairment categories with proper description for each scale: 1–very bad; 2–bad; 3–average; 4–traceable; 5–unnoticeable; For each test condition and test image, MOS is evaluated as:

$$MOS = \sum_{n=1}^{5} n.p(n)$$

Where n is scale and p(n) is scale probability [15].

V. CONCLUSION

This paper gave a brief review of existing image compression techniques and summarizes the characteristics, need of compression, principles behind compression, and different classes of compression techniques. It is found that Lossless compression doesn't reduce the file as much as lossy compression. Sound data cannot be compressed well with conventional text compression algorithms. In lossy compression, text and data cannot be compressed. Different lossless algorithms can be improved to enhance the performance of the compression ratio/factor for text thereby preserving retained energy to a certain extent with evaluating image quality.

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