A Survey of different Image Compression Techniques

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Abstract:
Nowadays transmission of images in computer, mobile and internet are essential. To store an image, large quantities of digital data are required. Due to the problem of limited bandwidth, it becomes mandatory to compress the image before transmission. To get clear concept of this problem several image Compression techniques have been developed in image processing. This study presents a survey of different Image Compression Techniques.

Keywords: *Image Compression, Lossy and Lossless Compression, Huffman encoding, Fractal Coding*

1. Introduction

Image compression is used to minimize the size without affecting or less affecting the quality of the image. The reduction in the size of image allows more image to be stored in the disk or in given memory space. The compression techniques reduce the size of data that requires less bandwidth and less transmission time and related cost. The best image quality at a given bit rate or compression rate is the main goal of image compression. The quality of a compression method often is measured by the peak signal to noise ratio. It measures the amount of noise introduced through a lossy compression of the image. The two common compressed graphic image formats are the JPEG format and the GIF format for internet use. JPEG method is used for photographs and the GIF method is used for line art and other images in which geometric shapes are relatively simple. Image compression software are constantly used to store or transmit information with methods that try to reduce redundant information in file content and thus minimizing their physical space. Since various amounts of data can be used to represent the same amount of information, the principal approach in compression is the reduction of the amount of image data (bits) while preserving information (image details). Image can be classified as vector or raster image. Raster images are made up of array of pixel while vector image is made up of lines and curves that are results of mathematical calculations from several points, thus forming an object image. All compression algorithms are applied to raster or bitmap image as their size is comparatively very large as compare to victor image. Thus, when we talk about image here it should be considered as raster. Images generally consist of redundant information which can be classified as statistically redundant or visually irrelevant. Targeting these areas defines the type of technique to be used for compression. In this paper we first describe various compression techniques based on Lossy and Lossless techniques.

A general compression model consists of an encoder and decoders consist of two relatively independent functions or sub blocks. The encoder is made up of source encoder, which removes input redundancies, and a channel encoder, which increases the noise immunity of the source encoders output. Similarly, the decoder includes a channel decoder followed by a source decoder. If the channel between the encoder and decoder is noise free, the channel encoder and decoder are omitted, and the general encoder and decoder is noise free, the channel encoder and decoder are omitted, and the general encoder and decoder become the source encoder and decoder, respectively.

2. Compression Techniques

There are two types of compression techniques: Lossless and Lossy. In the Loss less compression the compressed image is totally replica of the original input image, there is not any amount of loss present in the image. While in Lossy compression the compressed image is not same as the input image, there is some amount of loss is present in the image

2.1 Lossless Compression Techniques

The feature of the Lossless compression technique is that the original image can be perfectly recovered from the compressed image. It is also known as entropy coding since it use decomposition techniques to eliminate or minimize redundancy. Lossless compression is mainly used for applications like medical imaging, where the quality of image is important. The following are the methods that fall under Lossless compression: Run length encoding, Huffman encoding, LZW coding and Area coding.

2.1.1 Run length encoding

Run length encoding is an image compression method that works by counting the number of adjacent pixels with the same gray-level value. This count, called the run length, is then coded and stored. The number of bits used for the coding depends on the number of pixels in a row: If the row has 2^n pixels, then the required number of bits is n. A 256 x 256 image requires 8 bits, since $2^8 = 256$.

2.1.2 Incremental Encoding

Incremental encoding is enhanced form of run length coding of lossless compression. This coding uses an array of sequence building up a two dimension object. The algorithms for this coding try to find rectangular region with the same characteristics and these regions are coding in a descriptive form as an element with two points and a certain structure. The problem with this coding is that, it cannot be implemented in hardware because of non-linear method.

2.1.3 Huffman encoding

Huffman coding can generate a code that is as close as possible to the minimum bound, the entropy. This method results in variable length coding. For complex images, Huffman code alone will reduce the file size by 10 to 50%. By removing irrelevant information first, file size reduction is possible. In order to encode images the following steps are used:
1. First of all image is divided into 8X8 blocks
2. Then each block is coded with particular symbols
3. Huffman code is applied to the each block
4. Encoding all the blocks

2.1.4 LZW coding

LZW (Lempel- Ziv – Welch) coding can be static or dynamic, which is a dictionary based coding. In static dictionary coding, dictionary is fixed during the encoding and decoding processes. On the other hand in dynamic dictionary coding, the dictionary is updated on fly. The computer industry is widely using LZW. It is also implemented as compress command on UNIX.

2.1.5 Area coding

Area coding is an enhanced form of run length coding, which reflects the two dimensional character of images. It is a significant advancement over the other lossless methods. It does not make much of a meaning to interpret the coding of an image as a sequential stream, as it is in fact an array of sequences building up a two dimensional object. The idea behind this is to find the rectangular regions with the same characteristics. These rectangular regions are coded in a descriptive form as an element with two points and a certain structure. Area coding is highly effective and it can give high compression ratio but the limitation being non-linear in nature, which prevents the implementation in hardware.

2.2 Lossy Compression Techniques

Lossy compression technique provides higher compression ratio than lossless compression. In this method, the compression ratio is high; the decompressed image is not exactly identical to the original image, but close to it. Different types of lossy compression techniques are widely used, characterized by the quality of the reconstructed images and its adequacy for applications. The quantization process applied in lossy compression technique results in loss of information. After quantization, entropy coding is done like lossless compression. The decoding is a reverse process. The entropy decoding is applied to compressed data to get the quantized data. Dequantization is applied to it and finally the inverse transformation is performed to get the reconstructed image. The methods that fall under lossy compression technique are listed below:

2.2.1 Vector Quantization

As part of vector quantization technique a dictionary of fixed- size vectors is developed and its index in the dictionary is used as the encoding of the original image vector. Normally entropy coding is used. It exploits linear and non- linear dependence that exists among the components of a vector. Vector quantization is superior even when the components of the random vector are statistically independent of each other.

2.2.2 Fractal Coding

Firstly, the image is decomposed into segments by using standard image processing techniques such as edge detection, colour separation and spectrum and texture analysis. Then each segment is looked up in a library of fractals. The Fractal coding library actually contains codes called iterated function system (IFS) codes, which are compact sets of numbers. Using a systematic procedure, A set of codes for a given image are determined using a systematic procedure; accordingly when the IFS codes are applied to a suitable set of image blocks yield an image that is a very close approximation of the original. This scheme is highly effective for compressing images that have good regularity and self- similarity.

2.2.3 Block truncation coding

The principle applied here is that the image is divided into non overlapping blocks of pixels. The mean of the pixel values in the block (threshold) and reconstruction values are determined for each block. Then a bitmap of the block is created by replacing all pixels whose values are greater than or equal (less than) to the threshold by zero or one. 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.

A. Standard BTC

Standard BTC works by dividing the image into small blocks of pixels and then reducing the number of gray levels within each block. This reduction is performed by a quantizer that adapts to the local image statistics. The basic form of BTC divides the whole image into N blocks and codes each block using a two-level quantizer. These two levels are selected using the mean and standard deviation of that block. Each pixel value within the block is then compared with the mean and then is assigned to one of the two levels, maintaining the same mean and standard deviation. If the pixel value of each block is greater than or equal to mean, it is represented by 1 and if it's less, it is represented by 0 in bit plane, allowing single bit to represent pixel. Thus, for 4x4 pixel block 16 bits are used.

B. Absolute Moment Block Truncation Coding (AMBTC)

It's the variant of BTC. In this method, two statistical moments a (lower mean) and b (higher mean) calculated, are preserved along with the bit plane. Processes of coding and decoding are fast for AMBTC because the square root multiplications are omitted.

C. Minimum Mean Square Error (MMSE)

MMSE is the iterative process of AMBTC. This technique is used to reduce MSE value. In this method, the threshold value is initialized by the average of minimum and maximum values of each block as shown in given equation. The threshold value thus calculated is optimized through iterations the optimization process is terminated when the threshold values of consecutive iterations converge.

$T_h = (X_l + X_h) / 2$

D. Adaptive Block Truncation Coding (ABTC)

ABTC uses multi level quantizer. The input blocks are categorized into three groups viz.

(1) Low activity blocks - where all the pixel values inside the block are approximately the same and visually represent a flat area of gray, (2) Medium activity blocks – small transitions between pixels but do not represent any contrasting edges, and (3) High activity blocks - contain big pixel value changes with contrasting edges. Three set of quantizer are used for these blocks. A 1-level quantizer for low activity blocks, a 2-level quantizer for the medium activity blocks, and a 4-level quantizer for the high activity blocks.

E. Improved Adaptive Block Truncation Coding (IABTC)

This method is based on ABTC and is used in further reducing the bit rate and to improve image quality. Blocks are categorized into three groups based on sum value.

2.2.4 Sub band coding

In the sub band coding, the image is analyzed and find the components containing frequencies in different bands, the sub bands. Then the quantization and coding are performed for each subband. The main advantage of this coding is that quantization and coding for each Subband can be designed separately.

2.2.5 Transformation Coding

Here a block of data is unitarily transformed so that a large fraction of its total energy is packed in relatively few transform coefficients, which are quantized independently. Transforms such as DFT (Discrete Fourier Transform) and DCT (Discrete Cosine Transform) are used to change the pixels in the original image into transform coefficients. These coefficients have several properties like energy compaction property that results in most of the energy of the original data being concentrated in only a few of the significant transform coefficients; those few significant coefficients are selected and the remaining are discarded. The selected coefficients are considered for further quantization and entropy encoding. DCT coding has been the most common approach to transform coding, which is also adopted in JPEG.

2.2.6 Wavelet compression

Wavelet mean a "small wave" the smallness implies to a window function of finite length. Wavelet are function that satisfy certain mathematically requirement and are used in representing data or other function. Wavelet compression involves a way of analyzing a decompressed image in a recursive fashion, resulting in series of higher resolution images. The primary steps of wavelet compression are performing a Discrete Wavelet Transformation (DWT), quantization of the wavelet space image Subband, and then encoding these sub-band that do the image compression. Image decompression, or reconstruction is achieved by carrying out the above steps in reverse and inverse order that is decode, dequantize and inverse Discrete Wavelet Transformation.

3. Conclusion

This paper represents the concept of image compression and various technologies used in the image compression. A survey is performed on the most essential and advance compression methods, including coding techniques based on DCT, DWT, VQ, Fractal approach and other methods. Many algorithms are developed by performing some variation on basic ideas of these techniques to provide better result and or performance. Though extensive research has been taking place in this area, keeping in view the ever-increasing need for low bit rate compression methods, scope exists for new methods as well as evolving more efficient algorithms in the existing methods. The review makes clear that, the field will continue to interest researchers in the days to come.

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