An Introduction to Image Compression

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Abstract: **This paper addresses the area of image compression as it is applicable to various fields of image processing. On the basis of evaluating and analyzing the current image compression techniques this paper presents the Principal Component Analysis approach applied to image compression. PCA approach is implemented in two ways – PCA Statistical Approach & PCA Neural Network Approach. It also includes various benefits of using image compression techniques.**

Keywords: **LZW, DFT DWT, UTQ.**

1. INTRODUCTION

1.1 DIGITAL IMAGE

A digital image, or "bitmap", consists of a grid of dots, or "pixels", with each pixel defined by a numeric value that gives its color. The term data compression refers to the process of reducing the amount of data required to represent a given quantity of information. Now, a particular piece of information may contain some portion which is not important and can be comfortably removed. All such data is referred as Redundant Data. Data redundancy is a central issue in digital image compression. Image compression research aims at reducing the number of bits needed to represent an image by removing the spatial and spectral redundancies as much as possible.

A common characteristic of most images is that the neighboring pixels are correlated and therefore contain redundant information. The foremost task then is to find less correlated representation of the image. Images have considerably higher storage requirement than text; Audio and Video Data require more demanding properties for data storage. An image stored in an uncompressed file format, such as the popular BMP format, can be huge. An image with a pixel resolution of 640 by 480 pixels and 24-bit colors resolution will take up 640 * 480 * 24/8 = 921,600 bytes in an uncompressed format. The huge amount of storage space is not only the consideration but also the data transmission rates for communication of continuous media are also significantly large. An image, 1024 pixel x 1024 pixel x 24 bit, without compression, would require 3 MB of storage and 7 minutes for transmission, utilizing a high speed, 64 Kbits /s, ISDN line. Image data compression becomes still more important because of the fact that the transfer of uncompressed graphical data requires far more bandwidth and data transfer rate. For example, throughput in a multimedia system can be as high as 140 Mbits/s, which must be transferred between systems. This kind of data transfer rate is not realizable with today's technology, or in near the future with reasonably priced hardware.

1.2 TECHNIQUE BEHIND IMAGE COMPRESSION

A common characteristic of most images is that the neigh boring pixels are correlated and therefore contain redundant information. The foremost task then is to find less correlated representation of the image. Two fundamental components of compression are redundancy and irrelevancy reduction. Redundancy reduction aims at removing duplication from the signal source (image/video). Irrelevancy reduction omits parts of the signal that will not be noticed by the signal receiver, namely the Human Visual System (HVS). In general, three types of redundancy can be identified:

- Spatial Redundancy or correlation between neigh boring pixel values.
- Spectral Redundancy or correlation between different color planes or spectral bands.
- Temporal Redundancy or correlation between adjacent frames in a sequence of images (in video applications).

Image compression research aims at reducing the number of bits needed to represent an image by removing the spatial and spectral redundancies as much as possible. Since we will focus only on still image compression, we will not worry about temporal redundancy.

Often signals we wish to process are in the time-domain, but in order to process them more easily, other information such as frequency is required. Mathematical transforms translates the information of signals into different representations. For example, the Fourier transform converts a signal between the time and frequency domains, such that the frequencies of a signal can be seen. However the Fourier transform cannot provide information on which frequencies occur at specific times in the signal as time and frequency are viewed independently. To solve this problem the Short Time Fourier Transform (STFT) introduced the idea of windows through which different parts of a signal are viewed. For a given window in time the frequencies can be viewed. However Heisenberg's Uncertainty Principle states that the resolution of the signal improves in the time domain, by zooming on different sections, the frequency resolution gets worse. Ideally a method of multi-resolution is needed, which allows certain parts of the signal to be resolved well in time and other parts to be resolved well in frequency. The power and magic of wavelet analysis is exactly the multi-resolution.

Wavelet analysis can be used to divide the information of an image into approximation and detail sub-signals. The approximation sub-signals shows the general trend of pixel values and three detail sub-signals show the vertical, horizontal and diagonal details or changes in the image. If these details are very small then they can be set to zero without significantly changing the image. The value below which details are considered small enough to be set to zero is known as the threshold. The greater the no. of zeros the greater the compression that can be achieved.

The amount of information retained by an image after compression and decompression is known as the 'energy retained' and this is proportional to the sum of the squares of the pixel values. If the energy retained is 100% then the compression is known as 'lossless', as the image can be reconstructed exactly. This occurs when the threshold value is set to zero, meaning that the detail has not been changed. If any values are changed then energy will be lost and this is known as 'Lossy' compression. Ideally, during compression the no. of zeros and the energy retention will be as high as possible. However, as more zeros are obtained more energy is lost, so a balanced between the two needs to be found.

2. IMAGE COMPRESSION TECHNIQUES

The image compression techniques are broadly classified into two categories depending whether or not an exact replica of the original image could be reconstructed using the compressed image.

These are:

1. Lossless technique
2. Lossy techniqne

2. 1 Lossless compression technique

In lossless compression techniques, the original image can be perfectly recovered form the compressed (encoded) image. These are also called noiseless since they do not add noise to the signal (image).It is also known as entropy coding since it use statistics/decomposition techniques to eliminate/minimize redundancy. Lossless compression is used only for a few applications with stringent requirements such as medical imaging. Following techniques are included in lossless compression:

1. Run length encoding
2. Huffman encoding
3. LZW coding
4. Area coding

2.2 Lossy compression technique

Lossy schemes provide much higher compression ratios than lossless schemes. Lossy schemes are widely used since the quality of the reconstructed images is adequate for most applications .By this scheme, the decompressed image is not identical to the original image, but reasonably close to it.
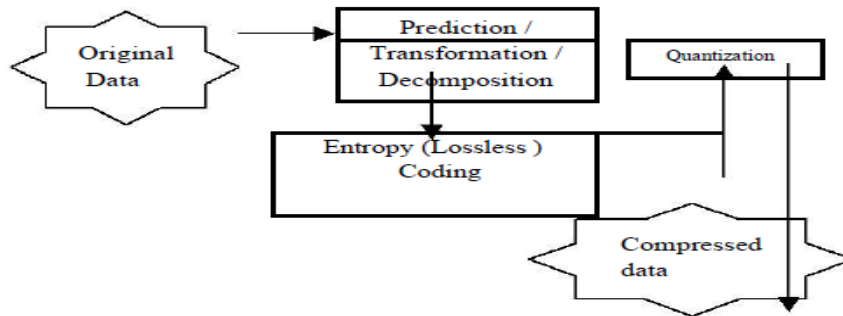
Figure 1: Outline of lossy image compression

As shown above the outline of lossy compression techniques .In this prediction – transformation – decomposition process is completely reversible .The quantization process results in loss of information. The entropy coding after the quantization step, however, is lossless. The decoding is a reverse process. Firstly, entropy decoding is applied to compressed data to get the quantized data. Secondly, dequantization is applied to it & finally the inverse transformation to get the reconstructed image. Major performance considerations of a lossy compression scheme include:

1. Compression ratio
2. Signal - to – noise ratio
3. Speed of encoding & decoding.

Lossy compression techniques includes following schemes:

1. Transformation coding
2. Vector quantization
3. Fractal coding
4. Block Truncation Coding
5. Subband coding

2.3 LOSSLESS COMPRESSION TECHNIQUES

2.3.1 Run Length Encoding

This is a very simple compression method used for sequential data. It is very useful in case of repetitive data. This technique replaces sequences of identical symbols (pixels) ,called runs by shorter symbols. The run length code for a gray scale image is represented by a sequence { V_i , R_i } where V_i is the intensity of pixel and R_i refers to the number of consecutive pixels with the intensity V_i as shown in the figure. If both V_i and R_i are represented by one byte, this span of 12 pixels is coded using eight bytes yielding a compression ration of 1: 5
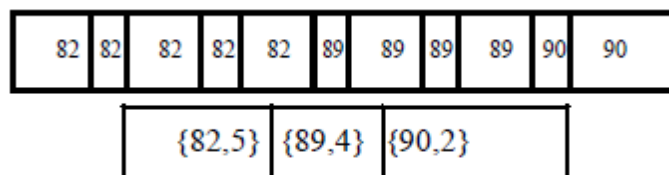

Figure 2: Run –Length Encoding

2.3.2 Huffman Encoding

This is a general technique for coding symbols based on their statistical occurrence frequencies (probabilities). 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. This means that the (binary) code of any symbol is not the prefix of the code of any other symbol. Most image coding standards use lossy techniques in the earlier stages of compression and use Huffman coding as the final step.

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2.3.3 LZW Coding

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

2.3.4 Area Coding

Area coding is an enhanced form of run length coding, reflecting the two dimensional character of images. This is a significant advance over the other lossless methods. For coding an image it does not make too much sense to interpret it as a sequential stream, as it is in fact an array of sequences, building up a two dimensional object. The algorithms for area coding try to find 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.

2.4 LOSSY COMPRESSION TECHNIQUES

2.4.1. Transformation Coding

In this coding scheme, transforms such as DFT (Discrete Fourier Transform) and DCT (Discrete Cosine Transform) are used to change the pixels in the original image into frequency domain coefficients (called transform coefficients).These coefficients have several desirable properties. One is the 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. This is the basis of achieving the compression. Only 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. It is also adopted in the JPEG image compression standard.

2.4.2 Vector Quantization

The basic idea in this technique is to develop a dictionary of fixed- size vectors, called code vectors. A vector is usually a block of pixel values. A given image is then partitioned into non-overlapping blocks (vectors) called image vectors. Then for each in the dictionary is determined and its index in the dictionary is used as the encoding of the original image vector. Thus, each image is represented by a sequence of indices that can be further entropy coded.

2.4.3 Fractal Coding

The essential idea here is to decompose the image into segments by using standard image processing techniques such as colour separation, edge detection, and spectrum and texture analysis. Then each segment is looked up in a library of fractals. The 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, such that 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.

2.4.4 Block truncation coding

In this scheme, the image is divided into non overlapping blocks of pixels. For each block, threshold and reconstruction values are determined. The threshold is usually the mean of the pixel values in the block. Then a bitmap of the block is derived by replacing all pixels whose values are greater than or equal (less than) to the threshold by a 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.

2.4.5 Sub band coding

In this scheme, the image is analyzed to produce the components containing frequencies in well- defined bands, the sub bands. Subsequently, quantization and coding is applied to each of the bands. The advantage of this scheme is that the quantization and coding well suited for each of the sub bands can be designed separately.

3. CONCLUSION

This paper presents various types of image compression techniques. There are basically two types of compression techniques. One is Lossless Compression and other is Lossy Compression Technique. Comparing the performance of compression technique is difficult unless identical data sets and performance measures are used. Some of these techniques are obtained good for certain applications like security technologies. Some techniques perform well for certain classes of data and poorly for others. PCA (Principal Component Analysis) also found its applications as image compression. PCA

can be implemented in two forms i.e. either statistical approach or neural network approach. The PCA Neural Network provides new way of generating codebook based on statistical feature of PCA transformational coefficients. It leads to less storage of memory and reduction of calculation.

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