Image Compression Techniques

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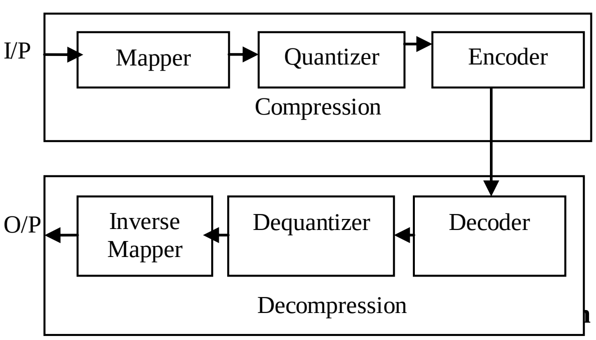
ABSTRACT
Digital images required large number of bits to represent them and in their canonical representation, generally contain significant amount of redundancy. Image compression techniques reduce the number of bits required to represent an image by taking advantage of these redundancies.To overcome this redundancy several image compression techniques are discussed in this paper along with their benefits.

1. INTRODUCTION

1.1Digital Image
Digital images are composed of pixels and each pixel represents the color at single point in the image. By measuring the color of an image at large number of points, we can create a digital approximation of the image. Pixels are arranged in regular pattern of rows and columns in arrays. A digital image is a numeric representation of a two-dimensional image.

1.2 Image Compression & Its Need
The objective of compression is to reduce redundancy of the image data in order to enable storing or transmitting data with minimal space or bandwidth as much as possible, while keeping the resolution and the visual quality of the reconstructed image as close to the original image. The principal approach in data compression is the reduction of the amount of image data (bits) while preserving information. Image data compression is an important component of digital camera design and digital photography.



As shown in figure 1, in first stage, the mapper transforms the input image into a format designed to reduce inter pixel redundancies. The second stage, quantizer block reduces the accuracy of mapper's output in accordance with a predefined criterion. In third and final stage, a symbol decoder creates a code for quantizer output and maps the output in accordance

With the code. These blocks perform, in reverse order, the inverse operations of the encoder's symbol coder and mapper block .The need of image compression becomes apparent when one computes the number of bits per image resulting from typical sampling rates. For example, consider the amount of storage space and transmission bandwidth required for images as shown in figure 2.A low resolution 512 ×512×8 bits/pixel × 3 color video image require 6×106 bits and over telephone lines of 9600 baud (bits/s) modem, the transmission would take approximately 11 minutes for just a single image.

1.3 Why can we compress

1.3.1 Spatial Redundancy
Neighboring pixels are not independent but correlated. So unnecessary data repeated within one frame can be removed.

1.3.2 Temporal Redundancy
Reduction of the number of bits needed to represent a given image or its information.

1.3.3 Spectral Redundancy
This is due to the correlation between different color planes.

Figure 2: Digital Image

2. BENEFITS OF COMPRESSION
1. The smaller file size that compression provides can take up much less room on your hard drive, web site or digital camera. It will also allow for more images to be recorded on other media, such as a photo CD. Compressed images also take less time to load than their more cumbersome originals, making it possible to view more images in a shorter period of time.
2. On the internet, compressed images not only reduce a web page's uploading and downloading time. They also take up less space on the server in terms of space and bandwidth. so overall execution time can be improved.
3. It also reduces the probability of transmission errors since fewer bits are transferred.
4. It also provides a level of security against illicit monitoring.

3. IMAGE COMPRESSION TECHINQUES
There are many approaches to image compression, but they can be categorized into two fundamental groups.

1. Lossless Techniques

2. Lossy Techniques

3.1 Lossless (Reversible) Techniques

Lossless image compression techniques allow the exact original data to be reconstructed from the compressed data. Lossless compression is used in cases where it is important that the original and the decompressed data be identical. Compression ratio is low. Examples are executable programs, text documents, and source code. Some image file formats, like PNG or GIF, use only lossless compression. Following techniques (Figure B) are included in lossless compression.

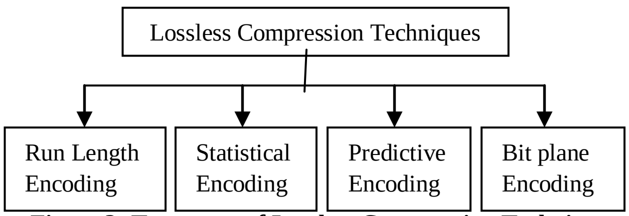


Figure 3: Taxonomy of Lossless Compression Techniques

3.1.1Run Length Encoding

Run-length encoding is probably the simplest method of compression .It is very useful in case of repetitive data. This technique replaces sequences of identical symbols (pixels), called runs by shorter symbols. The general idea behind this method is to replace consecutive repeating occurrences of a symbol by one occurrence of the symbol followed by the number of occurrences

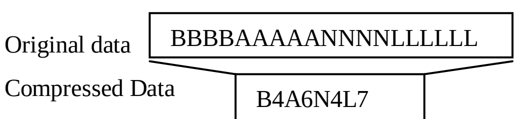


Figure 4: Run Length encoding overview

3.1.1.1Statistical Encoding

3.1.1.2Huffman Encoding

Huffman code is a prefix code. This mean that the code of any symbol is not prefix of the code of any other symbol. The principle is to use lower number of bits to encode the data that occurs more frequently. Huffman coding assigns shorter codes to the symbols that occurs more frequently and longer codes to that those occurs less frequently. Codes are stored in code book which may be constructed for each image. Following steps are used to encode image:

1. Divide image into 8*8 blocks

2. Each block is a symbol to be coded.

3. Compute Huffman codes for set of block.

4. Encode block accordingly.

3.1.2.2 Arithmetic Coding

Unlike Huffman coding, arithmetic coding doesn´t use a discrete number of bits for each symbol to compress. the whole data sequence is coded with a single code. Thus, the correlation between neighboring pixels is exploited. The biggest drawback of the arithmetic coding is it´s low speed since of several needed multiplications and divisions for each symbol. The main idea behind arithmetic coding is to assign to each symbol an interval. Starting with the interval [0...1), each interval is divided in several subintervals, which sizes are proportional to the current probability of the corresponding symbols of the alphabet.

3.1.1.2 LZW Encoding

Lempel Ziv Welch encoding is an example of a category of algorithms called dictionary-based encoding. The idea is to create a dictionary (a table) of strings used during the communication session. If both the sender and the receiver have a copy of the dictionary, then previously-encountered strings can be substituted by their index in the dictionary to reduce the amount of information transmitted.

3.1.1.3 Predictive Encoding

Statistical estimation procedure where future random variables are estimated/predicted from past and present observable random variables. The lossless differential pulse code modulation (DPCM) technique is the most common type of lossless predictive coding. In the lossless DPCM scheme, each pixel value (except at the boundaries) of the original image is first predicted based on its neighbors to get a predicted image. Then the difference between the actual and the predicted pixel values is computed to get the differential or residual image. The residual image will have a much less dynamic range of pixel values. This image is then efficiently encoded using Huffman coding.

3.1.1.4Bit Plane Encoding

In most images the neighboring pixels are correlated. That means the values of the neighboring pixels differ by small amounts. They can be captured by the representation of pixel values in gray code so that the values of neighboring bits in the bit planes are similar. This makes the individual bit planes. Each of the bit planes can then be efficiently coded using a lossless technique. So it is based on decomposing a multilevel image into a series of binary images and compressing each binary image.

3.2 Lossy Techniques

Lossy compression works very differently. These programs

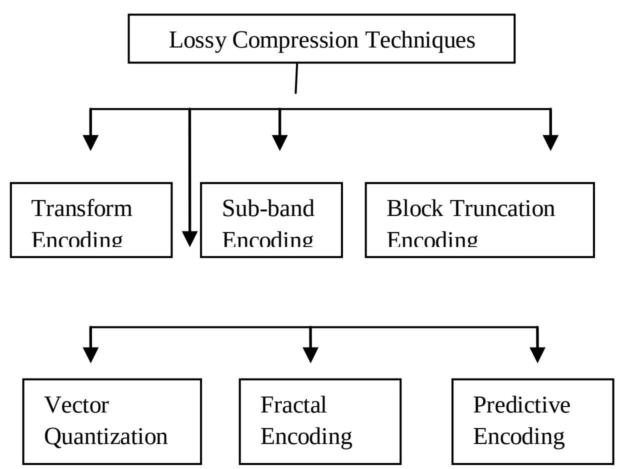


Figure 5: Taxonomy of Lossy Compression Techniques

simply eliminate "unnecessary" bits of information, tailoring the file so that it is smaller. This type of compression is used a lot for reducing the file size of bitmap pictures, which tend to be fairly bulky. This may examine the color data for a range of pixels, and identify subtle variations in pixel color values that are so minute that the human eye/brain is unable to distinguish the difference between them. The algorithm may choose a smaller range of pixels whose color value differences fall within the boundaries of our perception, and substitute those for the others. Lossy compression framework shown in figure 6.

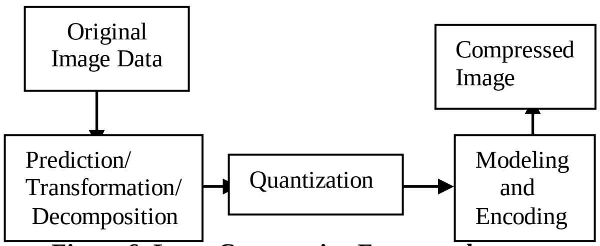


Figure 6: Lossy Compression Framework

To achieve this goal one of the following operations is performed. 1. Predicted image is formed by predicting pixels based on values of neighboring pixels of the original image. Then residual image is formed which is difference between predicted image and original image. 2. Transformation a reversible process that reduces redundancy and/or provides an image representation that is more amenable to the efficient extraction and coding of relevant information. 3. Quantization process compresses a range of values to a single quantum value. When the number of discrete symbols in a given stream is reduced, the stream becomes more compressible. Entropy coding is then applied to achieve further compression. Major performance considerations of a lossy compression scheme are: a) the compression ratio (CR), b) the signal-to noise ratio (SNR) of the reconstructed image with respect to the original, and c) the speed of encoding and decoding.

3.2.1. Transform Coding

Transform coding algorithm usually start by partitioning the original image into sub images (blocks) of small size (usually 8 x 8). For each block the transform coefficients are calculated, effectively converting the original 8 x 8 array of pixel values into an array of coefficients closer to the top-left corner usually contain most of the information needed to quantize and encode the image with little perceptual distortion. The resulting coefficients are then quantized and the output of the quantized isused by a symbol encoding technique to produce the output bit stream representing the encoded image.

3.2.2 Sub-band Coding

The fundamental concept behind Sub-band Coding (SBC) is that 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.

3.2.3 Block Truncation Coding

Block Truncation Coding is a lossy image compression techniques .It is a simple technique which involves less computational complexity. BTC is a recent technique used for compression of monochrome image data. 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 in the bitmap, the reconstruction value is determined. This is the average of the values of the corresponding pixels in the original block.

3.2.4 Vector Quantization

It provides a high compression ratio and a simple decoding process. This technique is to develop a dictionary of fixed-size vectors, called code vectors. A given image is then partitioned into non-overlapping blocks called image vectors. Then for each image vector, the closest matching vector in the dictionary is determined and its index in the dictionary is used as the encoding of the original image vector. Because of its fast lookup capabilities at the decoder side, VQ-based coding schemes are particularly attractive to multimedia applications.

3.2.5 Fractal Coding

The method is best suited for textures and natural images, relying on the fact that parts of an image often resemble there parts of the same image by converting these parts into mathematical data called "fractal codes" which are used to recreate the encoded image. Once an image has been converted into fractal code its relationship to a specific resolution has been lost; it becomes resolution independent. The image can be recreated to fill any screen size without the introduction of image artifacts or loss of sharpness that occurs in pixel-based compression schemes.

3.2.6 Predictive Encoding

The lossy DPCM (Differential Pulse Code Modulation is very similar to the lossless version The major difference is that in lossy DPCM; the pixels are predicted based on the “reconstructed values” of certain neighboring pixels. The difference between the predicted value and the actual value of the pixels is the differential (residual) image. It is much less correlated than the original image.

4. CONCLUSIONS

The large use of digital images is expected to continue at an ever faster pace in the coming years. The huge size requirements of images coupled with the explosive increases are straining the storage capacities and transmission bandwidths. Compression is a viable way to overcome these bottlenecks. There are basically two types of compression techniques. One is Lossless Compression and other is Lossy Compression Technique.

The best algorithm is measured depends on the following 3 factors:

1. The quality of the image

2. The amount of compression

3. The speed of compression.

4. FUTURE SCOPE OF WORK

There are good scopes for future improvements in the proposed compression techniques. In lossless scheme the prediction can be further improved by using Neuro-Fuzzy technique which will reduce the prediction error further. Image quality and compression ratio can be improved further by using some adaptive reversible technique. Computational complexity is more in most of the algorithms which can be improved further.

5. REFERENCES

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