A Brief Introduction on Image Compression Techniques and Standards

Vartika Singh , O P Singh, G R Mishra
Deptt. of Electronics & Electrical Engineering (ASET), Amity University, Lucknow, Uttar Pradesh.
Email: vartika5988@gmail.com, opsingh@amity.edu, gr_mishra@rediffmail.com

***Abstract*-This paper presents an extensive survey on image compression techniques and standards; it is applicable to various fields of image processing. Image compression is very important for efficient transmission and storage of image. On the basis of evaluating and analyzing the current image compression techniques this paper presents the Principal Component Analysis approach applied to image compression. There are some techniques that perform this compression in different ways; some are Lossless and keep the same information as the original image using entropy codings some others lossy compression which losses information when compressing the image. A part from these techniques, JPEG, JPEG2000, MPEG, H.26x are the different existing standards in still and moving Image Compression. My aim with this paper is to make a comparison of some of the most used image compression technique on a set of images.**

***Key Words*-Image compression, lossless compression, lossy compression, JPEG and JPEG 2000.**

1. INTRODUCTION

Image compression is very important for several applications, like storage of images in a data base, transferring image data through internet, picture archiving, TV, facsimile transmission and video conferencing [1]. Demand for communication of multimedia data through the telecommunications network and accessing the multimedia data through Internet is growing explosively. With the use of digital cameras, requirements for storage, manipulation, and transfer of digital images has grown explosively [2]. These image files can be very large and can occupy a lot of memory. Downloading these files from internet can be very time consuming task. It consuming so much time, space and bandwidth, therefore development of efficient techniques for image compression has been very necessary. The basic objective of image compression is to find an image representation in which pixels are less correlated with neighboring pixels. The important fundamental principle used in compression is redundancy; it removes redundancy from the signal source [2]. Compression is achieved by the removal of one or more of the three basic data redundancies:

1. Spatial Redundancy
2. Spectral Redundancy
3. Temporal Redundancy

One other important feature is irrelevancy, its increases pixel value which is not notified by human eye.JPEG and JPEG 2000 are two important standards used for image compression. Since the mid-80s, members from both the International Telecommunication Union (ITU) and the International Organization for Standardization (ISO) have been working together to establish an international standard for the compression of grayscale and color still images. This effort has been known as JPEG, the Joint Photographic Experts Group[6].JPEG 2000 is a fairly new standard which was meant as an update of the wide-spread JPEG image standard. It has higher compression ratios than JPEG.

In this paper we attempt to evaluate and comparing image quality in mainly two mentioned still image coding system: lossy and lossless. Image coding standard JPEG and JPEG2000 use different compression techniques, which introduce different types of impairment in the reconstructed images.

2. IMAGE COMPRESSION

Image compression is the application of data compression on digital images. Image compression is used to minimize the amount of memory needed to represent an image[1]. Images often require a large number of bits to represent them, and if the image needs to be transmitted or stored, it is impractical to do so without somehow reducing the number of bits.

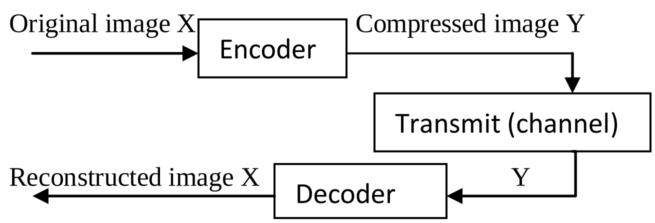


Fig.2.1- Block diagram of image compression system.

Main aim of image compression is-

- Digital images require a large amounts of space for storage and large bandwidths for transmission.
  - A 640 x 480 color image requires close to 1MB of space.
- The goal of image compression is to reduce the amount of data required to represent a digital image.
  - Reduce storage requirements and increase transmission rates.
- Reduction of the number of bits needed to represent a given image or its information.
- Image compression exploits the fact that all images are not equally likely.

Why Can We Compress-

Data redundancy is of central issue in digital image compression. If n1 and n2 denote the number of information carrying units in original and compressed image respectively, then the compression ratio CR can be defined as

$$CR=n1/n2;$$

And relative data redundancy RD of the original image can be defined as

$$RD=1-1/CR;$$

Three possibilities are here;

(1) If n1=n2, then CR=1 and hence RD=0 which implies that original image do not contain any redundancy between the pixels.

(2) If n1>>n1, then CR→∞ and hence RD>1 which implies considerable amount of redundancy in the original image.

(3) If n1<<n2, then CR>0 and hence RD→-∞ which indicates that the compressed image contains more data than original image.

3. IMAGE COMPRESSION CODING

Image compression coding is to store the image into bit-stream as compact as possible and to display the decoded image in the monitor as exact as possible[3]. Now consider an encoder and a decoder as shown in Fig.3.1. When the encoder receives the original image file, the image file will be converted into a series of binary data, which is called the bit-stream. The decoder then receives the encoded bit-stream and decodes it to form the decoded image. If the total data quantity of the bit-stream is less than the total data quantity of the original image, then this is called image compression. The full compression flow is as shown in Fig.3.1.

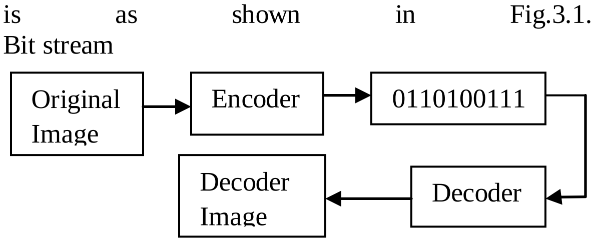


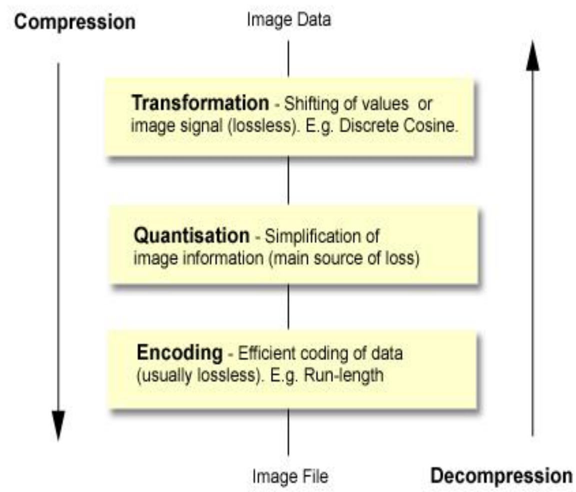
Fig.3.1-The basic flow of image compression coding.

The compression ratio is defined as follows:

$$Cr=n1/n2,$$

Where *n1* is the data rate of original image and *n2* is that of the encoded bit-stream.

4. IMAGE COMPRESSION MODEL



4.1) Transformer-

It transforms the input data into a format to reduce interpixel redundancies in the input image[5]. Transform coding techniques use a reversible, linear mathematical transform to map the pixel values onto a set of coefficients, which are then quantized and encoded.

4.2) Quantizer-

It reduces the accuracy of the transformer's output in accordance with some pre-established fidelity criterion. Reduces the psycho visual redundancies of the input image[8]. This operation is not reversible and must be omitted if lossless compression is desired.

4.3) Symbol (entropy) encoder-

It creates a fixed or variable-length code to represent the quantizer's output and maps the output in accordance with the code. In many cases, a variable-length code is used. An entropy encoder compresses the compressed values obtained by the quantizer to provide more efficient compression.

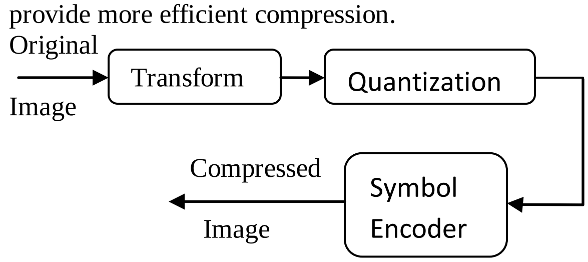


Fig.4.1-Image Compression model

5. 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 technique

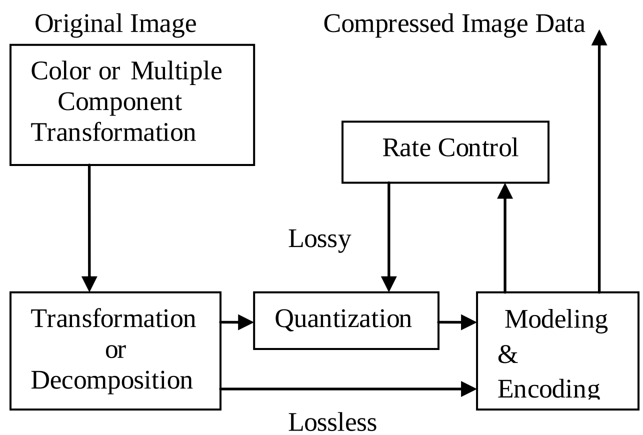


Fig.5.1-Compression Framework

Lossless compression allows the reconstruction of the original image data from the compressed image data. With lossy compression a higher compression rate is possible by allowing small differences between original and reconstructed images.

5.1-Lossless Compression Technique-

In lossless compression techniques, the original image can be properly recovered from the compressed image[11]. These are also called noiseless since they do not add noise to the image. It is also known as entropy coding since it use statistics/decomposition techniques to minimize redundancy. Lossless compression is used only for a few applications with stringent requirements such as medical imaging.

- The image after compression and decompression is identical to the original.
- Only the statistical redundancy is exploited to achieve compression.
- Data compression techniques such as LZW or LZ77 are used in GIF, PNG, and TIFF file formats and the Unix "Compress" command [12].
- Image compression techniques such as lossless JPEG or JPEG-LS perform slightly better.
- Compression ratios are typically 2:1 for natural imagery but can be much larger for document images.

Lossless methods yield lower compression ratios but preserve every pixel in the original image[7]. The main method lossless compressions techniques are to that allow an image to be encoded into a smaller size and then decoded into the original format. The common lossless compression methods are-
1. Run length encoding
2. Huffman encoding
3. LZW coding
4. Area coding

5.1(1) Run Length Encoding-

Run length encoding is a very simple method for compression of sequential data. This technique replaces sequences of identical symbols, called runs by shorter symbols[8]. The run length code for a gray scale image is represented by a sequence (Ir ,Nr)} where Ir is the intensity of pixel and Nr refers to the number of consecutive pixels.

5.1(2) Huffman Encoding-

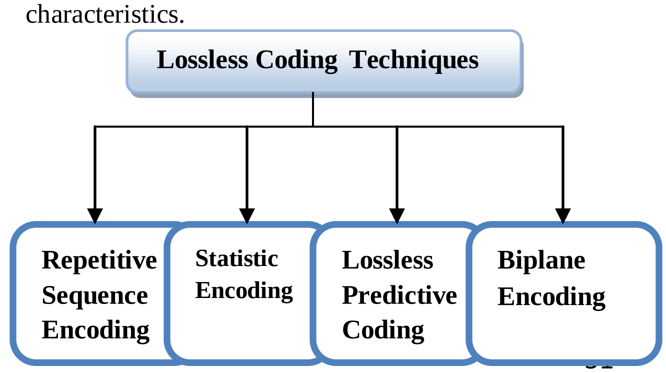
This algorithm, developed by D.A. Huffman, is based on the fact that in an input stream certain tokens occur more often than others. The pixels in the image are treated as symbols[14]. The symbols that occur more frequently are assigned a smaller number of bits, while the symbols that occur less frequently 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.

5.1(3) LZW Coding-

LZW (Lempel-Ziv-Welch) is a dictionary based coding. Dictionary based coding can be static or dynamic[9]. 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.

5.1(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. The algorithms for area coding try to find rectangular regions with the same characteristics.



5.2- Lossy Compression Technique-

Lossy technique deliver higher compression ratios, but compromise the ability reproduce the original, uncompressed pixel for pixel. JPEG is the best lossy compression standard and widely used to compress still images stored on compact disc. It is considerably more complicated than RLE, but it produces correspondingly higher compression ratios – even for images containing little or no redundancy[4]. The decompressed image is not same to the original image, but reasonably close to it. As shown in fig 5.2 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.

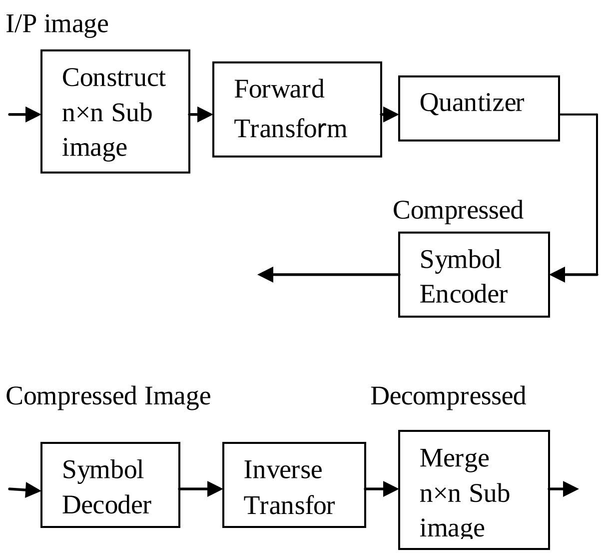


Fig.5.2- Lossy Compression Schemes

Main performance considerations of a lossy compression scheme include: 1. Compression ratio, 2. Signal - to – noise ratio, 3. Speed of encoding & decoding.

- The reconstructed image contains degradations with respect to the original image[15].
- Both the statistical redundancy and the perceptual irrelevancy of image data are exploited.
- Much higher compression ratios compared to lossless[2].
- Image quality can be traded for compression ratio.
- The term visually lossless is often used to characterize lossy compression schemes that result in no visible degradation under a set of designated viewing conditions.

Lossy compression techniques includes following schemes:

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

5.2(1) - *Transformation coding*-

A general transform coding scheme involves subdividing an NxN image into smaller nxn blocks and performing a unitary transform on each sub-image as shown in fig 5.2. In this coding, transforms such as DFT and DCT are used to change the pixels in the original image into frequency domain coefficients (called transform coefficients)[10]. The aim of the transform is to decorrelate the original signal, and this decorrelation generally results in the signal energy being redistributed with only a small set of transform coefficients.

5.2(2) - *Vector Quantization*-

The basic idea of this technique is to develop a dictionary of fixed-size vectors, called code vectors. A vector is generally a block of pixel values. A given image is divided into non-overlapping blocks (vectors) called image vectors. Each image is represented by a sequence of indices that can be further entropy coded.

5.2(3) - *Fractal Coding*-

Fractal parameters, including fractal dimension, color separation, edge detection, and spectrum and texture analysis have the potential to provide efficient methods of describing imagery in a highly compact fashion for both intra- and interframe applications [12]. Fractal methods have been developed for both noisy and noise free coding methods.

5.2(4) - *Block Truncation Coding*-

In this coding, 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 to the threshold by a 1. Then for each segment (group of 1s) in the bitmap, the reconstruction value is determined.

5.2(5) - *Sub Band Coding*-

In this scheme, the image is analyzed to produce the components containing frequencies in well-defined bands, the sub bands[5]. 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.

6. IMAGE COMPRESSION STANDARDS

A lot of research work has been done on image compression since the establishment of the JPEG standard in 1992. To bring these research efforts into a focus, a new standard called JPEG-2000 for coding of images is currently under development [9]. These standards are making to advance standardized image coding systems. It will provide a set of features vital to many high-end and emerging image applications by taking advantage of new modern technologies. Mainly, this new standard will address areas where current standards fail to produce the best performance. It will also provide capabilities to markets that currently do not use compression. We will discuss spatially two standards, these are -

1. The JPEG Standard
2. The JPEG2000 Standard

6.1-The JPEG Standard-

JPEG (Joint Photographic Experts Group) is an algorithm designed to compress images with 24 bits depth or grayscale images[5]. It is a lossy compression algorithm. One of the characteristics that make the algorithm very flexible is that the compression rate can be adjusted. If we compress a lot, more information will be lost, but the result image size will be smaller. With a smaller compression rate we obtain a better quality, but the size of the resulting image will be bigger. This compression consists in making the coefficients in the quantization matrix bigger when we want more compression, and smaller when we want less compression[9]. The algorithm is based in two visual effects of the human visual system. First, humans are more sensitive to the luminance than to the chrominance. Second, humans are more sensitive to changes in homogeneous areas, than in areas where there is more variation (higher frequencies). JPEG is the most used format for storing and transmitting images in Internet.

Main Steps in JPEG Image Compression:

- Transform RGB to YIQ or YUV and subsample color.
- Zig-zag ordering and run-length encoding.
- DCT on image blocks.
- Quantization.
- Entropy coding.

Four commonly used JPEG modes are:

1. *Sequential Mode*- The default JPEG mode, implicitly assumed in the discussions so far. Each gray level image or color image component is encoded in a single left-to-right, top-to-bottom scan.
2. *Progressive Mode*- Progressive JPEG delivers low quality versions of the image quickly, followed by higher quality passes.
3. *Hierarchical Mode*- Similar to Progressive JPEG, the Hierarchical JPEG images can be transmitted in multiple passes progressively improving quality.
4. *Lossless Mode*- JPEG-LS is in the current ISO/ITU standard for lossless or "near lossless" compression of continuous tone images. Motivated by the observation that complexity reduction is often more important than small increases in compression offered by more complex algorithms. Main Advantage of lossless mode is Low complexity.

6.2- The JPEG2000 Standard-

JPEG 2000 (Joint Photographic Experts Group 2000) is a wavelet-based image compression standard. It was created by the Joint Photographic Experts Group committee with the intention of superseding their original discrete cosine transform based JPEG standard [14]. JPEG 2000 has higher compression ratios than JPEG. It does not suffer from the uniform blocks, so characteristics of JPEG images with very high compression rates. But it usually makes the image more blurred that JPEG.

• Design Goals:

- To provide a better rate-distortion trade off and improved subjective image quality.
- To provide additional functionalities lacking in the current JPEG standard.
- In addition, JPEG2000 is able to handle up to 256 channels of information whereas the current JPEG standard is only able to handle three color channels.

• The JPEG2000 standard addresses the following problems:

- Lossless and Lossy Compression: There is currently no standard that can provide superior lossless compression and lossy compression in a single bit stream.
- Low Bit-rate Compression: The current JPEG standard offers excellent rate-distortion performance in mid and high bit-rates.
- Large Images: The new standard will allow image resolutions greater than 64K by 64K without tiling. It can handle image size up to $2^{32} - 1$.
- Single Decompression Architecture: The current JPEG standard has 44 modes, many of which are application specific and not used by the majority of JPEG decoders.

- Transmission in Noisy Environments: The new standard will provide improved error resilience for transmission in noisy environments such as wireless networks and the Internet.

Main Steps of JPEG2000 Image Compression:

- Embedded Block coding and bit stream generation.
- Post compression rate distortion (PCRD) optimization.
- Layer formation and representation.

7. CONCLUSION

This paper presents a comprehensive study of mainly two types of image compression techniques. One is Lossless Compression and other is Lossy Compression Technique. The advantage of lossy methods over lossless methods is that in some cases a lossy method can produce a much smaller compressed file than any known lossless method, while still meeting the requirements of the application. Lossy methods are most often used for compressing sound, images or videos.

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.

REFERENCES

1. Subramanya A, "Image Compression Technique," Potentials IEEE, Vol. 20, Issue 1, pp 19-23, Feb-March 2001,
2. Digital Image Processing Using MATLAB by Rafael C.Gonzalez,Richard E.Woods & Steven L.Eddins.
3. C.K. Li and H.Yuen, "A High Performance Image Compression Technique For Multimedia Applications," IEEE Transactions on Consumer Electronics, Vol. 42, no. 2, pp 239-243, 2 May 1996.
4. Dr. Charles F. Hall, " A Hybrid Image Compression Technique," Acoustics Speech & Signal Processing, IEEE International Conference on ICASSP' 85, Vol.10, pp 149- 152, Apr, 1985
5. Wikipedia: http://es.wikipedia.org
6. The JPEG web page: http://www.jpeg.org/.
7. Diffuse (2002). Guide to image compression, Retrieved October 23, 2003, from http://www.diffuse.org/compress.html
8. Grgic, S. Mrak, M., & Grgic, M. (2001) Comparison of JPEG image coders. Retrieved October 23, 2003, from http://www.vcl.fer.hr/dtv/sgrgic_vip2001.pdf
9. JPEG2000 info. Retrieved October 23, 2003, from http://www.jpeg2000info.com/index.html
10. Lerner, G. (2003). Image compression techniques. Retrieved October 23, 2003, from http://www.ee.bgu.ac.il/~greg/graphics/compress.html
11. Rajaravivarma, V., Lord, E., & Barker, J. (2001). Data compression techniques in image compression for multimedia systems. Retrieved October 23, 2003, from http://mmlab.snu.ac.kr/course/AdvancedInternet/reading/datacompression.pdf
12. Tracey, L. (2000). More on the image compression techniques. Retrieved October 23, 003, from, http://www.wavestore.com/files/VideoCompression2.Pdf
13. Wilson, N. A. (1997). Image compression techniques. Retrieved October 23, 2003, from http://faculty.millikin.edu/~moconner/Graphics/Image_Compression.html
14. Tracey, L. (2000). More on the image compression techniques. Retrieved October 23, 003, from, http://www.wavestore.com/files/VideoCompression2.Pdf
15. Wilson, N. A. (1997). Image compression techniques. Retrieved October 23, 2003, from http://faculty.millikin.edu/~moconner/Graphics/Image_Compression.html
16. Tracey, L. (2000). More on the image compression techniques. Retrieved October 23, 003, from, http://www.wavestore.com/files/VideoCompression2.Pdf
17. Wilson, N. A. (1997). Image compression techniques. Retrieved October 23, 2003, from http://faculty.millikin.edu/~moconner/Graphics/Image_Compression.html

