

# Image Compression Techniques Review: DCT, DWT, VQ and Fractal Compression

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**Abstract:** Image compression is one of the most widespread techniques for applications that require transmission and storage of images in databases. In this paper we discuss about the image compression techniques, their need for compression, their characteristics, principles, and classes of compression and various algorithm of image compression. This paper discuss about available image compression algorithms based on Wavelet, JPEG/DCT, Vector Quantizer and Fractal compression. We also sum up the advantages and disadvantages of these algorithms for compression of grayscale images.

**Keyword:** Image compression, JPEG, Discreet Cosine Transform, Vector Quantizer, Wavelet Transform, Fractal Compression. representation of the image. Two fundamental components of compression are redundancy and irrelevancy reduction.

## 1. Introduction

Image compression is the technique of data compression which is implemented on digital images acquired from almost any source. In effect, the objective of compression algorithm is to reduce redundancy of the image data in order to be able to store or transmit data in an efficient form using minimum storage space and bandwidth. Uncompressed multimedia (graphics, audio and video) data requires considerable storage capacity and transmission bandwidth. Despite of high progress in mass-storage density, processor speeds, and digital communication system performance, demand for data storage capacity and data-transmission bandwidth continues to outstrip the capabilities of available network technologies. The high use of data intensive multimedia-based websites and web based applications have not only demanded the need for more efficient ways to encode signals and images but have made compression of such data essential for storage and communication.

## 2. PRINCIPLES OF COMPRESSION

A common feature of digital images is that the neighboring pixels are correlated and therefore contain redundant information. The primary task is to find less correlated

Redundancy reduction is known as removing duplicate files from the source of images/videos. Irrelevancy reduction removes parts of the signal that will not be noticed by the signal receiver, namely the Human Visual System (HVS). In general, three types of redundancies can be identified:

### 2.1 Coding Redundancy

A code is a system of symbols (letters, numbers, bits, and the like) used to represent a body of information or set of events. Each piece of information or events is assigned a sequence of code symbols, called a code word. The number of symbols in each code word is its length. The 8-bit codes that are used to represent the intensities in the most 2 Dimensional intensity arrays contain more bits than are needed to represent the intensities.

### 2.2 Spatial Redundancy and Temporal Redundancy

Because the pixels of most 2-D intensity arrays are correlated spatially, information is unnecessarily replicated in the representations of the correlated pixels. Also in video sequence, temporally correlated pixels duplicate the information.

## 2.3 Irrelevant Information

Most Two Dimensional intensity arrays contain information that is rejected by the system and human visual extraneous to the intended use of the image. It is redundant in the sense that it is not used. Image compression techniques aims at reducing the number of bits needed to represent an image by removing the spatial and spectral redundancies to a greater extent.

## 3. NEED OF COMPRESSION

The following table shows the qualitative transition from simple text to full-motion video data and the disk space transmission bandwidth, and transmission time required to store and transmit such uncompressed data.

Multimedia Data	Size/Duration	Bits/Pixel or Bits/Sample	Uncompressed Size (B for bytes)	Transmission Bandwidth (b for bits)	Transmission Time
A page of text	11"x8.5"	Varying resolution	4-8KB	32-64 Kb/page	1.1 - 2.2 sec
Telephone quality speech	10 sec	8 bps	80 KB	64 Kb/sec	22.2 sec
Grayscale Image	512x512	8 bpp	262KB	2.1 Mb/image	1 min 13 sec
Color Image	512x512	24 bpp	786KB	6.29 Mb/image	3 min 39 sec
Medical Image	2048x1680	12 bpp	5.16 MB	41.3 Mb/image	23 min 54 sec
SHD Image	2048 x 2048	24 bpp	12.58 MB	100 Mb/image	58 min 15 sec

Table 1: Multimedia types and uncompressed storage space, bandwidth, and transmission time required.

The various values given in the table clearly illustrate the need for sufficient storage space, large transmission bandwidth, and long transmission time for image, audio, and video data. With latest technology, the only solution is to compress multimedia data before its storage and transmission, and decompress it at the receiver for playback. For example, with a compression ratio of 32:1, the space, bandwidth, and transmission time requirements can be reduced by a factor of 32, with acceptable quality.

## 4. CLASSES OF COMPRESSION TECHNIQUES

Two ways of classifying compression techniques are mentioned here.

### 4.1. Lossless vs. Lossy compression

In lossless compression schemes, the reconstructed image, after compression, is visibly similar to the original image. However lossless compression can only achieve a certain amount of compression. An image reconstructed following lossy compression contains degradation as compared to the original. Often this is because the compression scheme completely discards redundant information. However, lossy schemes are capable of achieving much higher compression. Under normal viewing conditions, no visible loss is perceived (visual lossless).

### 4.2 Predictive vs. Transform coding

In predictive coding, information already sent or available is used to predict future values, and the difference is coded. Since this is done in the image or spatial domain, it is relatively simple to implement and is readily adapted to local image characteristics. Differential Pulse Code Modulation (DPCM) is one particular example of predictive coding technique. Transform coding, on the other hand, 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). This method provides greater data compression as compared to predictive methods, although at the expense of greater computation.

## 5. IMAGE CODERS

A typical lossy image compression system which consists of three closely connected components namely (a) Source Encoder (b) Quantizer, and (c) Entropy Encoder. Compression is accomplished by applying a linear transform to de-correlate the image data, quantizing the resulting transform coefficients, and entropy coding the quantized values.

### 5.1 Source Encoder (or Linear Transformer)

Over the years, a variety of linear transforms have been developed which include Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) [1], Discrete Wavelet Transform (DWT)[13] and many more, each with its own advantages and disadvantages.

### 5.2 Quantizer

A quantizer simply reduces the number of bits needed to store the transformed coefficients by reducing the precision of those values. Since it's a many-to-one mapping, it is a lossy process and is the main source of compression in an encoder.

Quantization can be performed on each individual coefficient, which is known as Scalar Quantization (SQ). Quantization can also be performed on a group of coefficients together, and this is known as Vector Quantization (VQ). Both uniform and non-uniform quantizers can be used according the requirement.

### 5.3 Entropy Encoder

An entropy encoder further compresses the quantized values lossless to deliver better overall compression. It uses a model to accurately determine the probabilities for each quantized value and produces an appropriate code based on these probabilities so that the resultant output code stream will be smaller than the input stream. The most commonly used entropy encoders are the Huffman encoder and the arithmetic encoder, although for applications requiring fast execution, simple run-length encoding (RLE) has proven very effective.

## 6. VARIOUS COMPRESSION TECHNIQUES

### 6.1 JPEG: DCT-Based Image Coding Standard

The JPEG/DCT still image compression has become a standard recently. JPEG is designed for compressing full-colour or gray-scale images of natural, real-world images. To further study this method, an image is first partitioned into non overlapped  $8 \times 8$  blocks. A discrete Cosine transform (DCT) [10, 14] is applied to each block to convert the gray levels of pixels in the spatial domain into coefficients in the frequency domain.

The coefficients are normalized by different scales according to the quantization table provided by the JPEG standard conducted by some psycho visual evidence. The quantized coefficients are rearranged in a zigzag scan order to be further compressed by an efficient lossless coding strategy such as run length coding, arithmetic coding, or Huffman coding. The decoding is simply the inverse process of encoding. So, the JPEG compression takes about the same time for both encoding and decoding. The encoding/decoding algorithms provided by an independent JPEG group [14] are available for testing real-world images. The information loss occurs only in the process of coefficient quantization. The JPEG standard defines a standard  $8 \times 8$  quantization table [14] for all images which may not be appropriate. To achieve a better decoding quality of various images with the same compression by using the DCT approach, an adaptive quantization table may be used instead of using the standard quantization table.

## 6.2 Image Compression by Discrete Wavelet Transform

Wavelets are functions defined over a finite interval and having an average value of zero. The basic idea of the wavelet transform is to represent any arbitrary function ( $t$ ) as a superposition of a set of such wavelets or basic functions. These basic functions or baby wavelets are obtained from a single prototype wavelet called the mother wavelet, by dilations or contractions (scaling) and translations (shifts). The Discrete Wavelet Transform of a finite length signal  $x(n)$  having  $N$  components, for example, is expressed by an  $N \times N$  matrix. For a simple and excellent introduction to wavelets, see [3].

Despite all the advantages of JPEG compression schemes based on DCT namely simplicity, satisfactory performance, and availability of special purpose hardware for implementation; these are not without their shortcomings. Since the input image needs to be “blocked”, correlation across the block boundaries is not eliminated. This results in noticeable and annoying “blocking artifacts” particularly at low bit rates as shown in Fig.1. Lapped Orthogonal Transforms (LOT) [5] attempt to solve this problem by using smooth overlapping blocks.

Although blocking effects are reduced in LOT compressed images, increased computational complexity of such algorithms do not justify wide replacement of DCT by LOT.

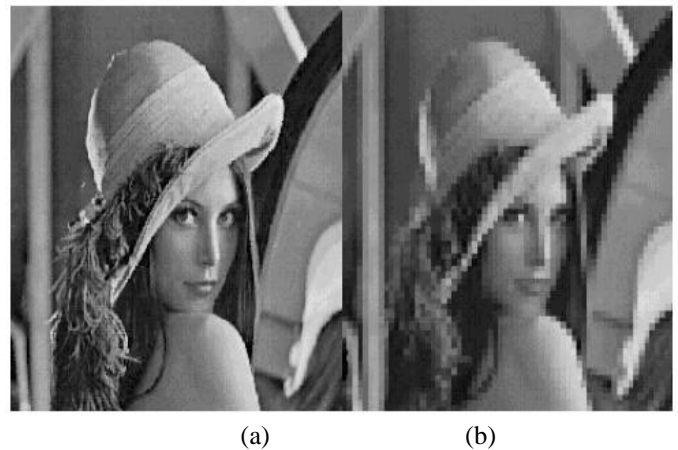


Fig.1. (a) Original Lena Image, and (b) Reconstructed Lena with DC component only, to show blocking artifacts.

Over the past years, the wavelet transform has gained widespread acceptance in signal processing in general and in image compression research in particular. In many applications wavelet-based schemes (also referred as sub band coding) outperform other coding schemes like the one based on DCT. Since there is no need to block the input image and its basic functions have variable length, wavelet coding schemes at higher compression avoid blocking artifacts. Wavelet-based coding [2] is more robust under transmission and decoding errors, and also facilitates progressive transmission of images. In addition, they are better matched to the HVS characteristics. Because of their inherent multi-resolution nature [6], wavelet coding schemes are especially suitable for applications where scalability and tolerable degradation are important.

## 6.3 Vector Quantizer Compression

A vector quantizer is composed of 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 that offers the lowest distortion. In this case the lowest distortion is found 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. When the encoder receives the index of the codeword, it replaces the index with the associated codeword.

The fundamental idea of VQ[4] for image compression is to establish a codebook consisting of code vectors such that each code vector can represent a group of image blocks of size  $m \times m$ , ( $m=4$  is always used). An image or a set of images is first partitioned into  $m \times m$  non overlapping blocks which are represented as  $m^2$ -tuple vectors, called training vectors. The size of training vectors can be very large. For example, a  $512 \times 512$  image contributes 16,384 training vectors.

The goal of codebook design is to establish a few representative vectors, called code vectors of size 256 or 512, from a set of training vectors. The encoding procedure is to look for a closest code vector in the codebook for each non overlapped  $4 \times 4$  block of an image to be encoded. The most important work is to design a versatile codebook. Nasrabadi and King [11] give a good review of VQ. Chen’s comparison [16] indicates that a codebook developed based on LBG [12]

algorithm generally has higher PSNR values over some other schemes despite its slow off-line training.

## 6.4 Fractal Compression

Fractal image coding was introduced in the late 1980s and early 1990s [20]. It is used for encoding/decoding images in Encyclopedia [15]. Fractal coding is based on the Collage theorem and the fixed point theorem [15, 19] for a local iterated function system consisting of a set of contraction affine transformations [15]. A fractal compression algorithm first partitions an image into non overlapping 8×8 blocks, called range blocks and forms a domain pool containing all of possibly overlapped 16×16 blocks, associated with 8 isometries from reflections and rotations, called domain blocks. For each range block, it exhaustively searches, in a domain pool, for a best matched domain block with the minimum square error after a contractive affine transform is applied to the domain block.

A fractal compressed code for a range block consists of quantized contractive coefficients in the affine transform, an offset which is the mean of pixel gray levels in the range block, the position of the best matched domain block and its type of isometry. The decoding is to find the fixed point, the decoded image, by starting with any initial image. The procedure applies a compressed local affine transform on the domain block corresponding to the position of a range block until all of the decoded range blocks are obtained. The procedure is repeated iteratively until it converges (usually in no more than 8 iterations).

Two serious problems that occur in fractal encoding are the computational demands and the existence problem of best range-domain matches [19]. The most attractive property is the resolution-independent decoding property. One can enlarge an image by decoding an encoded image of smaller size so that the compression ratio may increase exponentially [15, 18].

An algorithm based on [20] using range and domain block matches of fixed sizes is written and is used for a comparison in this paper [17].

## 7. CONCLUSION

We have reviewed the characteristics of various image compression techniques and different image compression algorithms based on Wavelet, JPEG/DCT, VQ, and Fractal approaches. For practical applications, we conclude that Wavelet based compression algorithms are strongly recommended, DCT based approach might use an adaptive quantization table, VQ approach is not appropriate for a low bit rate compression although it is simple and Fractal approach should utilize its resolution-free decoding property for a low bit rate compression.

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