ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 4, Issue 7, July 2016**

# Image Compression Algorithms for Real Time Applications

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**ABSTRACT**: Image compression is an application of data compression that encodes the original image with few bits. The objective of image compression is to reduce the redundancy of the image and to store or transmit data in an efficient form. Real time processing and transmission using these devices requires image compression algorithms that can compress efficiently with reduced complexity. Due to limited resources, it is not always possible to implement the best algorithms inside these devices. In uncompressed form, both raw and image data occupy an unreasonably large space. However, both raw and image data have a significant amount of statistical and visual redundancy. Consequently, the used storage space can be efficiently reduced by compression. some novel low complexity and embedded image compression algorithms are developed especially suitable for low bit rate image compression using these devices. Portable multimedia devices such as digital camera, mobile devices, personal digital assistants (PDAs), etc. have limited memory, battery life and processing power. The browsing of images over Internet from the image data sets using these devices requires fast encoding and decoding speed with better rate-distortion performance. With progressive picture build-up of the wavelet based coded images, the recent multimedia applications demand good quality images at the earlier stages of transmission. These wavelet based codecs code zero to each insignificant subband as it moves from coarsest to finest subbands. It is also demonstrated that there could be six to seven bit plane passes where wavelet coders encode many zeros as many subbands are likely to be insignificant with respect to early thresholds. Bits indicating insignificance of a coefficient or subband are required, but they don’t code information that reduces distortion of the reconstructed image. This leads to reduction of zero distortion for an increase in non zero bit-rate.

**KEYWORDS**: Digital Image, PDAs, Transform, Image Denoising, Algorithms, JPEG, DCT, FDCT.

## I. INTRODUCTION

Pictures have been with us since the dawn of the time. However, the way the pictures have been presented and displayed has changed significantly. In old age, pictures are represented and displayed in a physical way such as painting in cave walls or etching in stones. In recent times, pictures are dealt electronically. Interestingly, the representation used for storage and transmission is quite different from its display. For example, in traditional broadcast television, where this representation which is transmitted is not directly related to the intensities of red, green and blue electron guns in a television set. The possibilities of image representation increases dramatically by storing images in digital form. There can be numerous ways an image can be stored in any representation, provided that there should be algorithms to convert back to a form usable for display. This process of changing the representation of an image is called image coding. If the image representation consumes less storage space than the original, it is called image compression [1]. Most of the encoders discussed in this thesis are based on progressive encoding to compress an image into a bit stream with increasing accuracy. This means that when more bits are added to the bit stream, the decoded image will contain more details, a property similar to progressive Joint Picture Expert Group (JPEG) encoded images. It will be similar to the representation of a number like π where addition of every digit increases the accuracy of the number, but it can stop at any desired accuracy as needed. Progressive encoding is also known as Embedded encoding.

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### 1.1 Need of Image Compression

The raw data required by a single color image may not be a great deal of storage space. Total storage requirements become overwhelming as the number of images need to be stored or transmitted increases. the storage size, transmission bandwidth and transmission time needed for various types of uncompressed images [2]. It is obvious that images requires large transmission bandwidths, more transmission time and large storage space, which are proportional to the size of the image. With the present state of technology, the only solution is to compress the image before its storage and transmission. Then, the compressed image can be decompressed at the receiver end.

## II. IMAGE COMPRESSION FUNDAMENTALS

The 2D intensity arrays the preferred format for human viewing and interpretation. When it comes to compact image representation, these formats are far from optimal. The reason is that it suffers from three principal kind of data redundancy. These are be explained below:

**Coding Redundancy:** Coding redundancy is present when the codes assigned to gray levels do not take full advantage of gray levels probability. For example, considering a gray level image having n pixels, the number of gray levels in the image is L and the number of pixels with gray level k is nk. Then, the probability of occurring gray level k is p(k) $=n_k/n$. If the number of bits used to represent gray level k is l(k), then the average number of bits required to represent each pixel is

$$L_{avg} = \sum_{k=0}^{L-1} l(r_k) p_k(r_k).$$

Hence, the number of bits required to represent the whole image is n × Lavg. Maximum compression ratio is achieved when Lavg is minimized. The gray levels are coded in such a way that it results in an image containing coding redundancy if Lavg is not minimized.

**Spatial and temporal redundancy:** Since the neighbouring pixels in an image are highly correlated, information is unnecessary replicated in the representations of correlated pixels. In a video sequence, temporally correlated pixels also duplicate the information.

**Psycho visual redundancy:** Image contain information which is not sensitive to the human visual system (HVS) and/or extraneous to the intended use of image.

**Measuring Image Information:**
An important question to answer is 'How many bits are necessary to represent the information of an image ?' or alternatively, Is there any minimum amount of data that are sufficient to describe an image without loss of information ?'. The information theory states that, generation of information can be modeled as a probabilistic process. A random event E with probability P(E) contains

$$I(E) = \log \frac{1}{P(E)} = -\log P(E)$$

units of information. For true events (i.e., P(E)=1), I(E)=0 and such events do not contain information. Therefore, information is a measure of uncertainty. The base of the logarithm determines the number of units used to measure information. If the base 2 is used, the unit of information is the bit. When P(E) = 1/2 , I(E) = $-\log_2 1/2$ = 1 bit. Therefore, 1 bit is conveyed when one of the two possible equally likely events occurs. For a source of statistically

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independent random events a1, a2, ....aJ with associated probabilities P(a1), P(a2), ....P(aJ ), the average information (entropy of the source) per source output is:

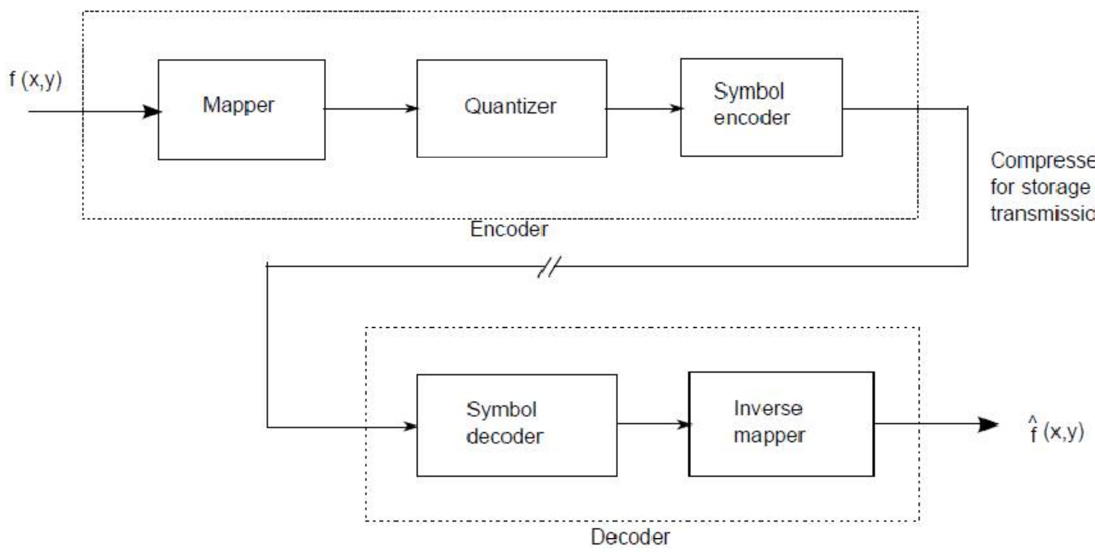
$$H = -\sum_{j=1}^{J} P(a_j) \log P(a_j).$$

where aj , j = 1, 2, ...J are symbols. Since they are statistically independent, the source is called a zero-memory source. Considering an image as an output of an imaginary zero-memory 'intensity source', the histogram of the image can be used to estimate the symbol probabilities of source. The intensity of entropy of source is:

$$\hat{H} = -\sum_{k=1}^{L-1} P_r(r_k) \log_2 P_r(r_k)$$

It is not possible to code the intensity values of the imaginary source (and thus the sample image) with fewer ˆH bits/pixel.

## III. IMAGE COMPRESSION MODEL




A general image compression model is shown . The encoder performs compression and decoder performs decompression. The encoder consists of mapper, quantizer and symbol encoder. Usually the mapper transforms an image into an invisible format designed to reduce spatial and temporal (in video sequences) redundancy. Generally, this operation is reversible and may or may not reduce the amount of data needed to represent the image. In video applications, the mapper uses previous and future frames to facilitate removal of temporal redundancy. The quantizer reduces the accuracy of the output of mapper according to the fidelity criterion. This operation is irreversible and targets to remove irrelevant in-formation from the image. When lossless compression is needed, quantizer must be removed. The final stage of the encoding process is the symbol encoder, which generates a fixed or variable-length code to represent the quantizer output. Usually the shortest code words are assigned to the most frequently occurring quantizer output values to minimize coding redundancy.

This operation is reversible. These three operations lead to removal or decrease of all three redundancies from the input image. The decoder contains two components: symbol decoder and inverse mapper performing the inverse operations of the symbol encoder and mapper. The inverse quantizer block is not included since quantization is irreversible. Suppose b and b′ represent number of bits in the original data f(x, y) and compressed data f′(x, y) respectively. The relative data redundancy R of the representation
with b bits is:

$$R=1-1/C$$

where C is called the compression ratio, is expressed as:

$$C=b/b'$$

If C = 10, the larger representation b has 10 bits of data for every 1 bit of data in the smaller representation b′. This indicates that 90% data(R = 0.9) are redundant. In the context of digital image compression, b usually is the number of bits needed to represent the original image as 2D array of intensity values (pixels). Considering the case of gray scale image, 8 bits are needed to represent each pixel. Another term called bit rate (BR) which is expressed as:

$$BR=8/C \text{ bits/pixels(bpp)}$$

BR = 0.8 bpp for C = 10. That means, the number of bits that is required to represent the compressed image is 0.8 bits/pixel.

### 3.1 JPEG Baseline Image Compression

JPEG is the first international image compression standard for continuous-tone still gray scale and color images [4]. The goal of this standard is to support a variety of applications for compression of continuous-tone still images of different image sizes in any color space. It has user-adjustable compression ratio with very good to excellent reconstruction quality. It has lower computational complexity for widespread practical applications. Discrete cosine transform (DCT) [5] is used as the transform in the JPEG standard. JPEG defines four modes of operations:

**Sequential lossless mode:** It compresses the image in a single scan and the decoded image is an exact replica of the original image.

**Sequential DCT-based mode:** It compresses the image in a single scan using DCT-based lossy compression technique. Therefore, the decoded image is an approximation of the original image. This Mode is also called as JPEG baseline mode and it is widely used.

**Progressive DCT-based mode:** It compresses/decompresses the image in multiple scans. Each successive scan produces better quality image.

**Hierarchical mode:** It compresses the image at multiple resolutions for display on different devices. Sequential lossless mode: It compresses the image in a single scan and the decoded image is an exact replica of the original image.

**Sequential DCT-based mode:** It compresses the image in a single scan using DCT-based lossy compression technique. Therefore, the decoded image is an approximation of the original image. This Mode is also called as JPEG baseline mode and it is widely used.

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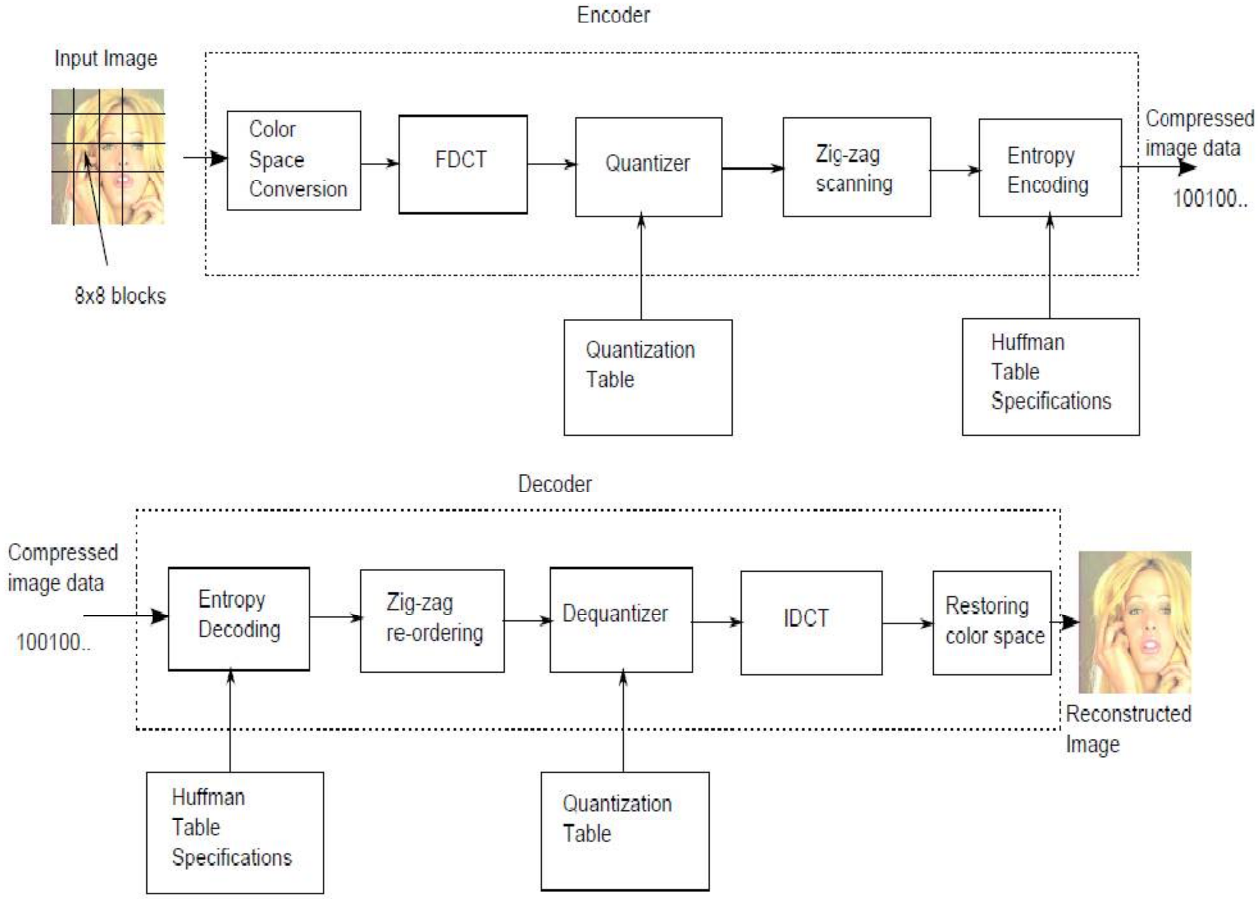
**Hierarchical mode:** It compresses the image at multiple resolution for display on different devices.




In JPEG baseline codec , a RGB color image is first mapped into Luminance-chrominance (L-C) color space such as YCbCr, YUV, CIELAB, etc in order to have a better decorrelation between color components. The chrominance channels contain more redundant information and can be subsampled without sacrificing any visual quality of the reconstructed image. Baseline supports 4:2:0, 4:2:2 and 4:4:4 color formats. 4:2:0 format is formed by subsampling the chrominance components by half horizontally and vertically. Each chrominance component in 4:2:2 color format has same vertical resolution as that of luminance component, but the horizontal resolution is halved. In 4:4:4 format both the chrominance components have identical vertical and horizontal resolution as that of luminance components. No color transformation is required for grayscale image.

To apply Forward DCT (FDCT), first the image is divided into non-overlapping 8×8 blocks in raster scan order from left to right and top-to-bottom . Then, each pixel is level shifted to convert into signed integer by subtracting 128 from each pixel. The FDCT of an 8×8 block of pixels f(x, y) for (x, y = 0, 1, ....7) is expressed as follows:

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$$F(u,v) = \frac{1}{4}C(u)C(v) \sum_{x=0}^{7}\sum_{y=0}^{7} f(x,y) \cos\left[\frac{\pi(2x+1)u}{16}\right] \cos\left[\frac{\pi(2y+1)v}{16}\right]$$

for $u = 0, 1, \ldots\ldots, 7$ and $v = 0, 1, \ldots\ldots, 7$, where

$$C(k) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for } k = 0 \\ 1 & \text{otherwise.} \end{cases}$$

After transformation, the transformed coefficients are need to be quantized. This step is primarily responsible for the loss of information and hence introduces distortion in the reconstructed image. Each 64 DCT coefficients are uniformly quantized according to the formula

$$F_q(u,v) = Round\left(\frac{F(u,v)}{Q(u,v)}\right)$$

where F(u, v) is a DCT coefficient and Q(u, v) is the quantizer step-size parameter. The standard does not define any quantization table. It is prerogative of the user’s choice to select the quantization matrix. JPEG standard defines two quantization matrices for luminance and chrominance planes. These two quantization matrices have been designed based on the psycho visual experiments by Lohsceller [8] to determine the visibility threshold for 2-D basis functions. These matrices are best suited for natural images with 8-bit precision. If the elements in these tables are divided by 2, perceptually lossless compression is obtained. Quality of the reconstructed image can be controlled by scaling the matrices. After the transformation and quantization over an 8 × 8 image sub-blocks, the new 8 × 8 sub-block shall be reordered in zigzag scan into a linear array. The first coefficient is the DC coefficient and the other 63 coefficients are AC coefficients. The DC coefficient contains lot of energy, hence it is usually of much larger value than AC coefficients. Since there is a very close relation between the DC coefficients of adjacent blocks, the DC coefficients are differentially encoded.

This process further reduces entropy. The entropy coding process consists of Huffman coding tables as recommended in JPEG standard. These tables are stored as header information during the compression process so that it is possible to uniquely decode the coefficients during decompression process.

### 3.2. JPEG2000 Image Coding Standard

Although baseline JPEG has been very successful in the market place for more than a decade, it lacks many features desired by interactive multimedia applications, its usage in wired or wireless environments and Internet applications. A fundamental shift in the image compression approach came after the Discrete Wavelet Transform (DWT) became popular [9]-[12]. Exploiting the interesting features in DWT, many scalable image compression algorithms were proposed in the literature . To overcome the inefficiencies in JPEG standard and serve emerging applications areas in the age of mobile and Internet communications, the new JPEG2000 standard has been developed by ISO/IEC standard committee. It provide a unified optimized tool to accomplish both lossless and lossy compression, as well as decompression using the same algorithm.

The systems architecture is not only optimized for compression efficiency for very low bit rates, but also optimized for scalability and interoperability in networks and noisy environments. The JPEG2000 standard will be effective in wide application areas such as Internet, digital photography, digital library, image archival, compound documents, image databases, color reprography (photocopying, printing, scanning, facsimile), graphics, medical imaging, multispectral imaging such as remotely sensed imagery, satellite imagery, mobile multimedia communications, 3G cellular telephony, client-server networking, e-commerce, etc. The main drawback of the JPEG2000 standard compared to

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ISSN (Print): 2320-9798

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JPEG is that the coding algorithm is much more complex and the computational needs are much higher. Moreover, the bit-plane wise processing may restricts computational performance in a general-purpose computing platform. Analysis shows that the JPEG2000 compression is more than 30 times complex as compared with JPEG. JPEG2000 standard has 12 parts (Part 7 abandoned) with each part adding new features to the core coding standard in Part 1. Out of 11 parts some parts are still under development (Part 8-Part 12).

## IV. CONCLUSIONS

It provides a brief introduction about the fundamentals of image compression and theory. The fidelity criteria for evaluating the quality of decoded images is discussed. A brief introduction to JPEG image compression and embedded image compression is presented. The background and scope of the work, the motivation and the objective of the thesis are systematically discussed. A brief chapter wise description has been also presented.

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