RESEARCH ARTICLE OPEN ACCESS

Jpeg Image Compression

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Abstract
One of the most common methods of representing graphical information in a digital form is by spatially sampling the color components of an image—red, green, and blue for example. These digitized samples can be placed in a long sequence for the purpose of storage and transmission. For any reasonably detailed image, this string of samples can become very long. As of this writing, a typical digital camera will produce images in excess of three million samples. Consequently, various methods are employed to translate this representation into a compact form. A particular approach to image data compression—known as the JPEG compression. The objective of JPEG image compression is simple: to store the data necessary to reconstruct a digital image using as little space as possible while maintaining enough visual detail so that storing the image is actually worthwhile.
The basis for the JPEG algorithm is the Discrete Cosine Transform (DCT) which extracts spatial frequency information from the spatial amplitude samples and huffman coding in MATLAB.
Keywords—compression, jpeg, discrete cosine transform, huffman coding.

I. INTRODUCTION

A. Overview

An image consists of rectangular array of dots called pixels which are mainly of three types:



BLACK&WHITE GREY COLOUR

A digital image is an array of real or complex numbers represented by finite number of bits.

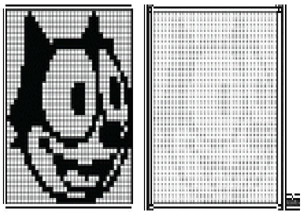


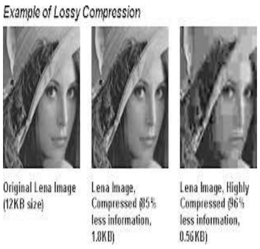
Image processing is the process of manupulating and analysing data in order to improve its quality.[6]There are three techniques of processing:[8]

a) *Image Enhancement:*
It refers to sharpening of image features.

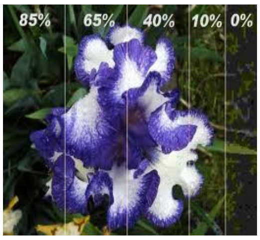
b) *Image restoration:*
It refers to filtering of observed image.

c) *Image compression:*
It refers to minimizing the number of bits required to represent image.

Image compression is the art and science of reducing the amount of data required to represent an image.It is most useful and commercially successful technologies in the field of Digital Image Processing. It is mainly of two types:



Lossy compression



Lossless compression

It should be noted early that, unlike compression techniques used with other types of data—like financial records, or word processing documents—JPEG is a lossy algorithm, meaning that visual information is selectively discarded in order to improve the compression ratio. Once discarded, this information can not be recovered, but it is selected to minimize the effect on the perception of someone viewing the reconstructed image. In order to determine which information can be removed, and to perform the removal in a straight forward fashion, the image data is converted from a space-intensity form to a space- frequency form.[5]

B. History

In the late 1980's and early 1990's, a joint com- mittee, known as the Joint Photographic Experts Group (JPEG), of the International Standards Organization (ISO) and the Comit´e Consultatif International T´ el´ephonique et T´ el´egraphique (CCITT) developed and established the first in- ternational compression standard for continuous-tone images. A good summary of their work can be found in.[5]

C. TECHNICAL DETAILS

A digitized sample is known as a picture element or pixel for short. Each pixel is most commonly represented by three 8-bit unsigned integers. The three values correspond to theintensity of three color components1 (e.g. red, green, and blue) on a scale of 0 to 255. JPEG compression operates on each color component separately, so the discussion that follows will deal only with 8-bit pixels. It may be useful for the reader to visualize grayscale images (like a black and white photograph), wherein each pixel can be stored as an 8-bit value indicating the amount of whiteness, instead of amounts of redness, greenness, and blueness. There are several variants—modes of operation—of the JPEG algorithm included in the standard. We are principally concerned with the Baseline DCT Sequential mode. This compression method takes place in four stages, which will be described in detail shortly. 1) The uncompressed source data is separated into 8×8 blocks of pixels. 128 is subtracted from the value of each pixel so that the new effective range is from -128 to 127. 2) Each block is transformed into an 8 × 8 block of frequency coefficients. 3) These coefficients are quantized. 4) An entropy encoder is applied to the quantized coeffi-cients.[5]

This paper is divided into four sections :
I . Compression
II . Discrete cosine transform
III. Huffman coding
IV. Results
V . Applications
VI. References

II. COMPRESSION

A. Compression Framework:

The objective of image compression is to reduce irrelevance and redundancy of the image data in order to be able to store or transmit data in an efficient form.[1] Image compression is minimizing the size in bytes of a graphics file without degrading the quality of the image to an unacceptable level. The reduction in file size allows more images to be stored in a given amount of disk or memory space. It also reduces the time required for images to be sent over the Internet or downloaded from Web pages. Ideally, an image compression technique removes redundant and/or irrelevant information, and efficiently encodes what remains. Practically, it is often necessary to throw away both non- redundant information and relevant information to achieve the required compression.[7]

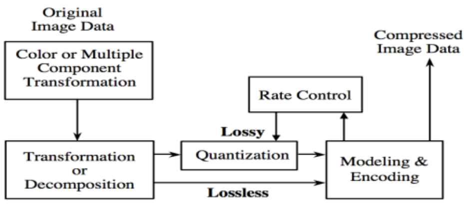


Fig1:compression framework

B. Block Diagram:

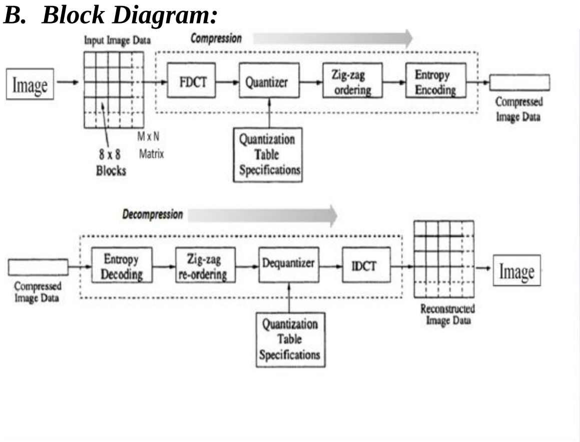
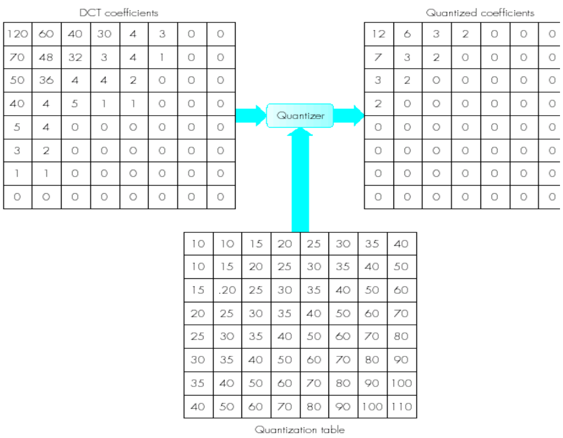


Fig 2: Block diagram

1. Quantization:

In addition to classifying the spatial frequency components the quantization process aims to reduce the size of the DC and AC coefficients so that less bandwidth is required for their transmission (by using a divisor)[2].The sensitivity of the eye varies with spatial frequency and hence the amplitude threshold below which the eye will detect a particular frequency also varies. The threshold values vary for each of the 64 DCT coefficien`1ts and these are held in a 2-D matrix known as the quantization table with the threshold value to be used with a particular DCT coefficient in the corresponding position in the matrix.[7]



DCT coefficients

120	60	40	30	4	3	0	0
70	48	32	3	4	1	0	0
50	36	4	4	2	0	0	0
40	4	5	1	1	0	0	0
5	4	0	0	0	0	0	0
3	2	0	0	0	0	0	0
1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Quantizer

Quantized coefficients

12	6	3	2	0	0	0
7	3	2	0	0	0	0
3	2	0	0	0	0	0
2	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

10	10	15	20	25	30	35	40
10	15	20	25	30	35	40	50
15	.20	25	30	35	40	50	60
20	25	30	35	40	50	60	70
25	30	35	40	50	60	70	80
30	35	40	50	60	70	80	90
35	40	50	60	70	80	90	100
40	50	60	70	80	90	100	110

Quantization table

The quantized DCT coefficients are computed with

$$B_{j,k} = \text{round}\left(\frac{G_{j,k}}{Q_{j,k}}\right) \quad \text{for } j = 0,1,2,\cdots,7; k = 0,1,2,\cdots,7$$

Where *G* is the un quantized DCT coefficients; *Q* is the quantization matrix above; and *B* is the quantized DCT coefficients.

An 8 × 8 block from the Y image of 'Lena'

200	202	189	188	189	175	175	175
200	203	198	188	189	182	178	175
203	200	200	195	200	187	185	175
200	200	200	200	197	187	187	187
200	205	200	200	195	188	187	175
200	200	200	200	200	190	187	175
205	200	199	200	191	187	187	175
210	200	200	200	188	185	187	186

$f(i,j)$

515	65	-12	4	1	2	-8	5
-16	3	2	0	0	-11	-2	3
-12	6	11	-1	3	0	1	-2
-8	3	-4	2	-2	-3	-5	-2
0	-2	7	-5	4	0	-1	-4
0	-3	-1	0	4	1	-1	0
3	-2	-3	3	3	-1	-1	3
-2	5	-2	4	-2	2	-3	0

$F(u,v)$

Fig. 9.2: JPEG compression for a smooth image block.

Fig 3: computation of a set of quantized DCT coefficients

2. Zigzag Ordering:

Irregular ordering of the AC coefficients is called zigzag Encoding. This is done so that the coefficients are in order of increasing frequency. The higher frequency coefficients are more likely to be 0 after quantization. This improves the compression of run-length encoding.[6]

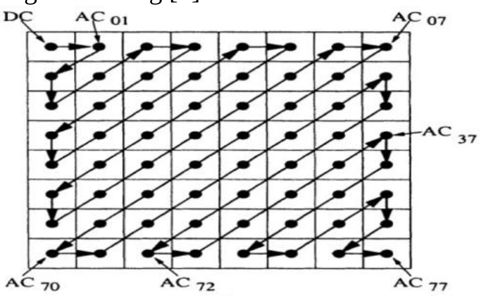


Fig 4: Zigzag scanning order

3. Entropy Encoding:

Entropy coding is a special form of lossless data compression. It involves arranging the image components in a "zigzag" order employing run-length encoding (RLE) algorithm that groups similar frequencies together, inserting length coding zeros. The term data compression refers to the process of reducing the amount of data required to represent a given quantity of information .Entropy encoding includes Run length coding and Huffman coding. Run length coding is done on DC as well as AC coefficients. The differentially coded DC coefficients are ordered in a separate file and AC coefficients in another. Run length coding is done individually for them. And then Huffman coding is done on what is left.[2]

III. DISCREATE COSINE TRANSFORM(DCT)

This transformation can be developed starting with the Fourier series, extending to the Fourier transform, switching from continuous to discrete, and finally using a cosine instead of a complex exponential for the basis. The details of that progression will not be reproduced here because they are thoroughly covered elsewhere [3]. Instead, it will be most useful to investigate the DCT in the context of vector spaces, projections, and matrices.The DCT transforms the data from the spatial domain to the frequency domain. The spatial domain shows the amplitude of the color as you move through space. The frequency domain shows how quickly the amplitude of the color is changing from one pixel to the next in an image file.[3]

The $(u,v)^{th}$ DCT coefficient is given by the formula

$$dct(u,v) = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} image(x,y) * h(x,y,u,v)$$

where

$$h(x,y,u,v) = \alpha(u)\alpha(v)cos\left[\frac{(2x+1)u\pi}{2N}\right] cos\left[\frac{(2y+1)v\pi}{2N}\right]$$

$$\alpha(v),\alpha(u) = \begin{cases} \sqrt{\frac{1}{N}} & \text{for } u = 0 \\ \sqrt{\frac{2}{N}} & \text{for } u = 1, 2, \ldots, n-1 \end{cases}$$

A . Proposed DCT Algorithm:

- The following is a general overview of the JPEG process.
- The image is broken into 8x8 blocks of pixels.
- Working from left to right, top to bottom, the DCT is applied to each block.
- Each block is compressed through quantization.
- The array of compressed blocks that constitute the image is stored in a drastically reduced amount of space.
- When desired, the image is reconstructed through decompression, a process that uses the inverse Discrete Cosine Transform (IDCT).[3]

IV. HUFFMAN CODING

Proposed by DR. David A.Huffman in 1952. —A method for the construction of minimum redundancy code .Huffman code is a technique for compressing data. It is a form of statistical coding which attempts to reduce the amount of bits required to represent the data.[5] It yields smallest possible code symbol per source symbol. Given a set of data symbols (an alphabet) and their frequencies of occurrence (or, equivalently, their probabilities), the method constructs a set of variable-length codeword with the shortest average length and assigns them to the symbols. The Huffman encoding algorithm starts by constructing a list of all the alphabet symbols in descending order of their probabilities. It then constructs, from the bottom up, a binary tree with a symbol at every leaf. This is done in steps, where at each step two symbols with the smallest probabilities are selected, added to the top of the partial tree, deleted from the list, and replaced with an auxiliary symbol representing the two original symbols.[4]When the list is reduced to just one auxiliary symbol (representing the entire Alphabet), the tree is complete. The tree is then traversed to determine the code words of the symbols.[1]

For example:

Symbols	Probabilities	Code Words
A1	0.4	00
A2	0.2	10
A3	0.2	11
A4	0.1	010
A5	0.1	011

Jpeg Huffman coding is done using the table provided below. There are separate tables for AC and DC coefficients. According to the value the category is decided and then further coding is done. The concept of a value’s magnitude, designated its category, is used extensively by the compression procedures. Mathematically it’s expressed as:-

Cat = ceil (log2 (abs (value) + 1))

Where Cat defines category

A sample of values and the equivalent categories is shown here:-

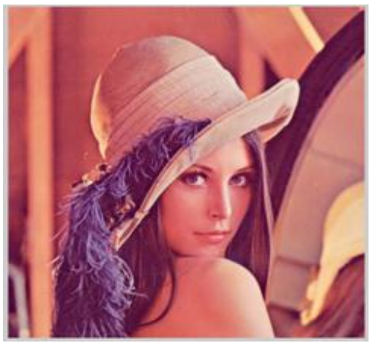
Value	Category
0	N/A
1	1
-3	2
-127	7
256	9

Table1:JPEG Huffman coding(value,category)

V. RESULTS

1. For scaling factor 2:

*F*ig1:Original image

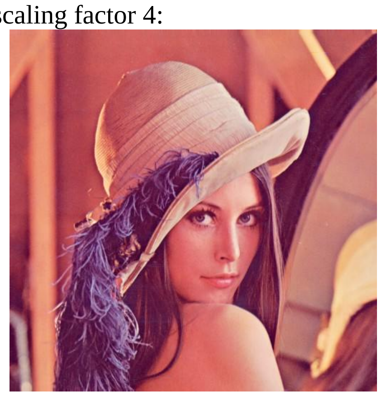


*F*ig2:Decoded image

SCALING FACTOR	COMPRESSION RATIO	ERROR	MEAN SQUARE ERROR
2	19.8482	2.0216	16.0713

TABLE 2: *Error Analyses for Scaling Factor 2*

2. For scaling factor 4:



*F*ig3: Original image

*F*ig4:Decoded image

SCALING FACTOR	COMPRESSION RATIO	ERROR	MEAN SQUARE ERROR	PEAK SIGNAL TO NOISE RATIO
4	30.1640	2.8752	24.8827	38.2292

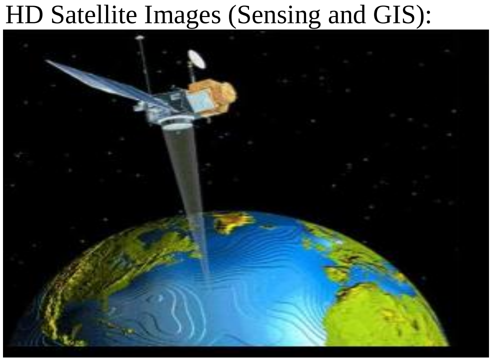
TABLE 3: *Error Analyses for Scaling Factor 4*

VI. APPLICATION

Along with these applications, image compression plays an important role in many other areas including[9]:

1. Office Automation:

2. HD Satellite Images (Sensing and GIS):



3. Medical:

4. Industrial & Scientific:

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