Image Compression Algorithm and JPEG Standard

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Summary. The interest in digital image processing is growing at an enormous place in last decades.
As a result, different data compression techniques has been proposed which are concerned in minimization of the information used for representation of image.

In this paper we provide an overview, needs of data compression techniques in image processing, focusing on JPEG image compression technique.

Keywords: Data compression ,Karhunen-Loeve Transformation**,** Discrete Cosine Transform (DCT), Huffman coding, Quantization, JPEG Standard

I. INTRODUCTION

Large amounts of data are used to represent an image.The amount of storage media needed for storage is enormous.One approach to decreasing the amount of storage is to work with compressed image data. In data compression, we remove correlated data to by using appropriate compression transformation, without losing the ability to reconstruct the image. The more correlated data, the more data items can be removed.

There are many compression standards, JPEG, JPEG-LS and JPEG-2000. Nowadays, JPEG is widely used in many application areas. JPEG-LS is also called lossless compression so exactly what you see is what you compress in that case there is no irrelevant information added.

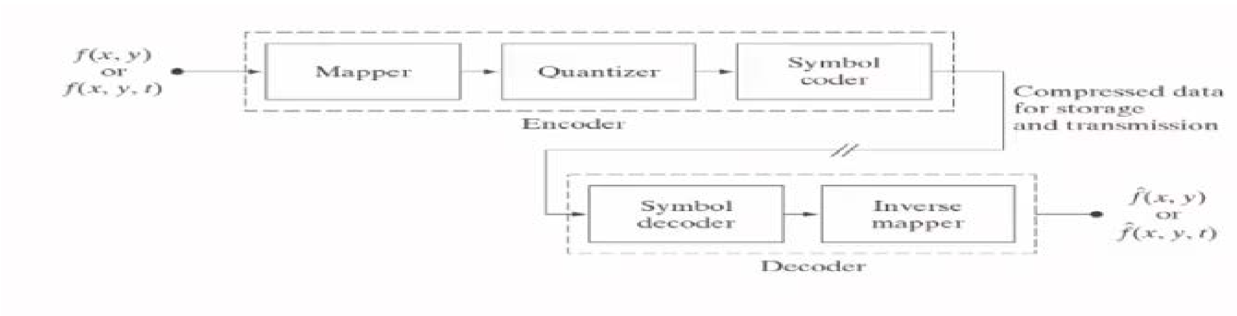

Fig. 1 JPEG Image Compression Technique

This chapter begins with discussion of image compression techniques and its types. Then introduced the concept of data compression, followed by quantization and entropy coding which is used to compress the data. Later we talk about JPEG Standard along with example. Finally, a conclusion section ends the chapter.

II. DATA COMPRESSION

In data compression less number of data is used to represent the original data taking account of the information contained on it. If we do look at the **Fig. 1**, encoder receives the target image and then it converts the image into bitstream. On the other part , the decoder is used to convert the bitstream back to the image I. If the quantity of bitstream is lesser than original image then this process *Image Compression Coding.*

(a) Original image 4718592 bytes (b) Compressed image 695755 bytes

Fig. 2 Examples of image compression technique using JPEG standard

The compression ratio is 695755/4718592, about 0.14744, which is about x7 still being extremely conservative. We can see the images are slightly, parts of information are lost during compression. The decoder cannot rebuild image perfectly as before and this kind of compression technique is called *non-reversible* or *lossy coding*. But, in *reversible coding,* we can perfectly rebuild the original image without any distortion and the ratio of compression is much lower.

Since, there is distortion between the images i.e original image and decoded image. We need to evaluate the coding efficiency. The common evaluation tools, which are used to calculate the coding efficiency are *Mean Square Error (MSE)* and *Peak Signal to Noise Ratio (PSNR)* which are defined as follows:

$$\mathrm{MSE} = \sqrt{\frac{\sum_{x=0}^{W-1}\sum_{y=0}^{H-1}\left(f(x,y) - f'(x,y)\right)^2}{WH}} \quad \textbf{(1)}$$

$$\mathrm{PSNR} = 20\log_{10}\frac{255}{\mathrm{MSE}} \quad \textbf{(2)}$$

Eq. (1), f (x, y) and f ′(x, y) represents the original image and decoded image, respectively. The image size is **W** × **H** . In **Eq. (2)**,

The image coding algorithm consists of reducing correlation exists between pixels, quantization and entropy coding.

(a) Source Encoder: Source encoder aimed at decorrelating input signal by transforming its representation . where set of data values is sparse, thus compacting the information content of the signal into the smaller number of coefficients.

b) Quantizer: A quantizer aims at reducing the number of bits needed to store transformed coefficients by reducing the precision of those values. Quantization performs on each individual coefficient i.e. Scalar Quantization (SQ) or Vector Quantization (VQ).

c) Entropy Coding: Entropy encoding aims to remove redundancy by removing repeated bit patterns. The most common entropy coders are the Huffman Coding, Arithmetic Coding, Run Length Encoding (RLE) and Lempel-Ziv (LZ) algorithm.

The constitution of image coding algorithm model is in **Fig. 3**.which will be discussed in following chapters.

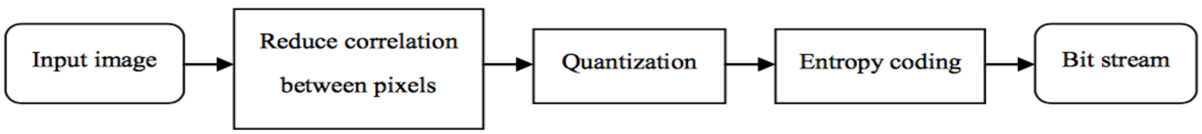

Fig. 3 Constitution of image coding algorithm

III. KARHUNEN-LOEVE TRANSFORMATION AND DISCRETE COSINE TRANSFORM

A. Karhunen-Loeve Transformation

Images have high correlation, for an image with size **K1 × K2** , we divide it into several small blocks with size **N1 × N2** and deal with each blocks with transformation. Which helps to reduce its pixel correlation.In JPEG standard, we do not use KLT because the transform is computationally expensive.

B. Discrete Cosine Transform

Problems like computation power, storage , cost goes more if we use KLT in orthogonal transform of KLT , to deal with the problems and also to preserve optimal property of KLT for image. we have Discrete Cosine Transform (DCT). which is defined as

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

$$\text{for } u=0,\ldots,7 \text{ and } v=0,\ldots,7$$

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

(3)

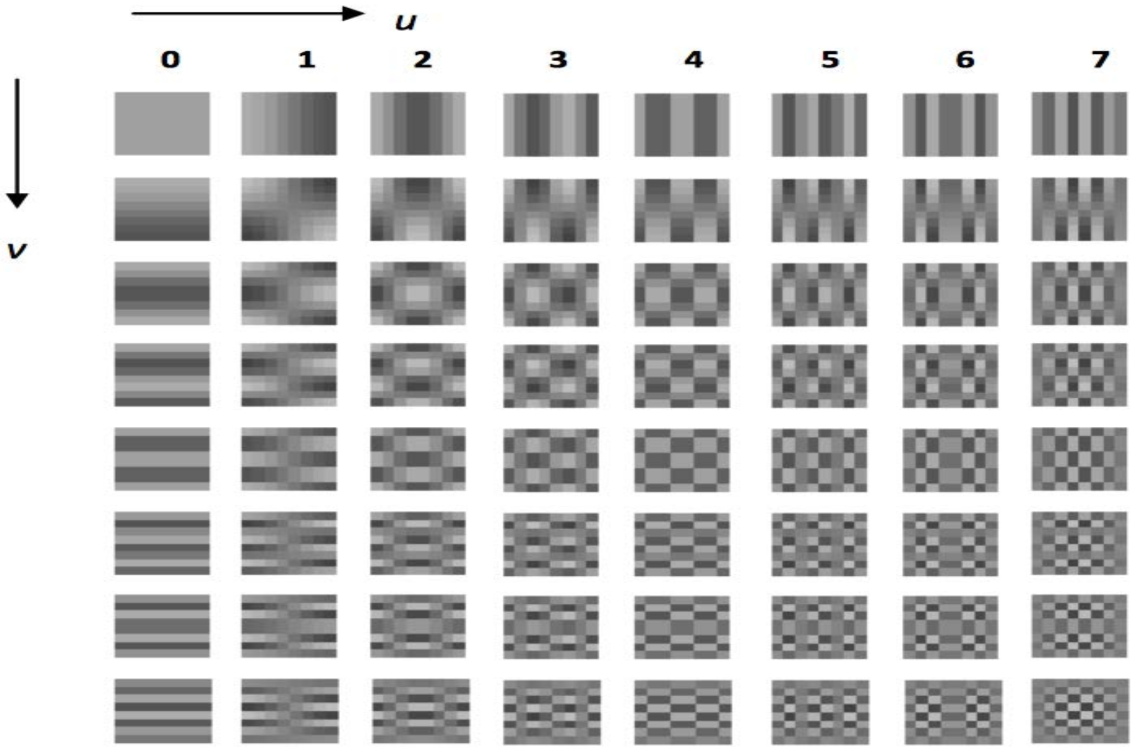

Fig. 4 The 8 × 8 DCT basis ωx,y (u,v)

And inverse DCT is defined as:

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

(4)

The **F(u,v)** is called DCT coefficient, and basis of DCT is:

$$\omega_{x,y}(u,v)=\frac{C(u)C(v)}{4}\cos\left[\frac{\pi(2x+1)u}{16}\right]\cos\left[\frac{\pi(2y+1)v}{16}\right]$$

(5)

Thus can rewrite by **Eq. (5)**:

$$f(x,y)=\sum_{u=0}^{7}\sum_{v=0}^{7}F(u,v)\omega_{x,y}(u,v)\quad \text{for } x=0,\ldots,7 \text{ and } y=0,\ldots,7$$

(6)

The 8 × 8 two dimensional DCT basis is represented in **Fig. 4.**

IV. QUANTIZATION

In **Fig. 4** we represent the transformed 8 × 8 block that consists of 64 DCT coefficients. The first coefficient which is denoted by **F(0,0)** is the DC component and the rest are AC component. The DC component denoted by **F(0,0)** is the sum of 64 pixels which is multiplied by the scaling factor (¼)C(0)C(0) =⅛ as shown in **Eq. (3)** for F(u,v).

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

17	18	24	47	99	99	99	99
18	21	26	66	99	99	99	99
24	26	56	99	99	99	99	99
47	66	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99
99	99	99	99	99	99	99	99

Fig. 5 Quantization matrix

The next step is to quantize transformed coefficients. Each DCT coefficients F(u,v) is uniformly quantized and can be obtained by dividing it by the corresponding quantize step-size parameter Q(u,v) and then rounded to the nearest integer as below :

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

(7)

JPEG standard does not define fixed quantization matrix. It is of the user to select a quantization matrix. **Fig. 5** shows quantization matrices of JPEG standard .

In JPEG compression quantization process removes high frequencies present in original image.We do so cause our eyes is much sensitive to lower spatial frequencies Bigger the values in quantization table, bigger error introduced by lossy process resulting smaller visual quality.

V. JPEG STANDARD

Joint Photographic Experts Group (**JPEG**) has built up a worldwide standard for universally useful, shading, still-picture compression. There are numerous compression standards such as JPEG, JPEG-LS and JPEG-2000. JPEG-LS is also called loss less compression so exactly what you see is what you compress in that case there is no irrelevant information added. The block diagram of Baseline JPEG Transformation is shown in **Fig. 1.**

A. Zig-Zag Reordering

We obtain new 88 blocks after DCT and quantization, which is our frequency domain value for the original blocks. In order to encode the value we need to reorder values into one dimensional form. The DCT coefficient is encoded by difference coding and AC terms are scanned in Zig-Zag manner and we do it to get a vector sorted on basis of the spatial frequency. **Fig. 6** shows Zig-zag reordering process.

0	1	5	6	14	15	27	28
2	4	7	13	16	26	29	42
3	8	12	17	25	30	41	43
9	11	18	24	31	40	44	53
10	19	23	32	39	45	52	54
20	22	33	38	46	51	55	60
21	34	37	47	50	56	59	61
35	36	48	49	57	58	62	63

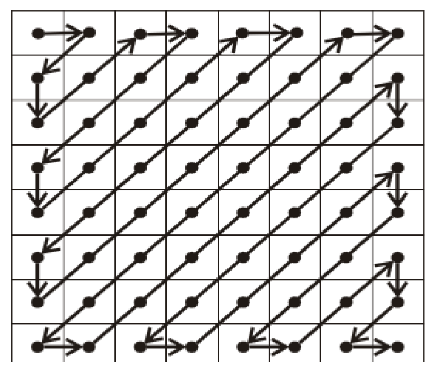

Fig. 6 Zig-Zag reordering matrix

B. Zero Run Length Coding

The quantized AC coefficients for the most part contains continuous zeros. Therefore, an advantage can be acquired by utilizing a run-length method, where upper four bits of code image demonstrate the quantity of back to back zeros previously the following coefficient, and lower four bits show the quantity of huge bits in the following coefficient.

The following code symbol are significant bits of the coefficient, where length is determined by the lower four bits of the code. The inverse run-length coder takes the current code symbol and appends to the output array the number of zeros which is corresponding to the four bits used for the run-length code . Coefficients are placed in the output array has the number of bits determined by the lower four bits of the run-length code and a value determined by the number of trailing bits.

C. Difference Coding

DC coefficients are highly correlated with each other in the blocks. DC coefficients contains more energy so they have much larger value than AC coefficients. This is why we have to reduce the correlation before doing encoding. JPEG standard encodes the resulting difference between the DC coefficients. The difference value between adjacent DC values can be compute by the following equation:

$$Diff_i = DC_i - DC_{i-1} \quad \textbf{(8)}$$

The initial DC value is set to zero, then difference is Huffman encoded together with the encoding of AC coefficients. Difference coding process are shown in **Fig. 7**.

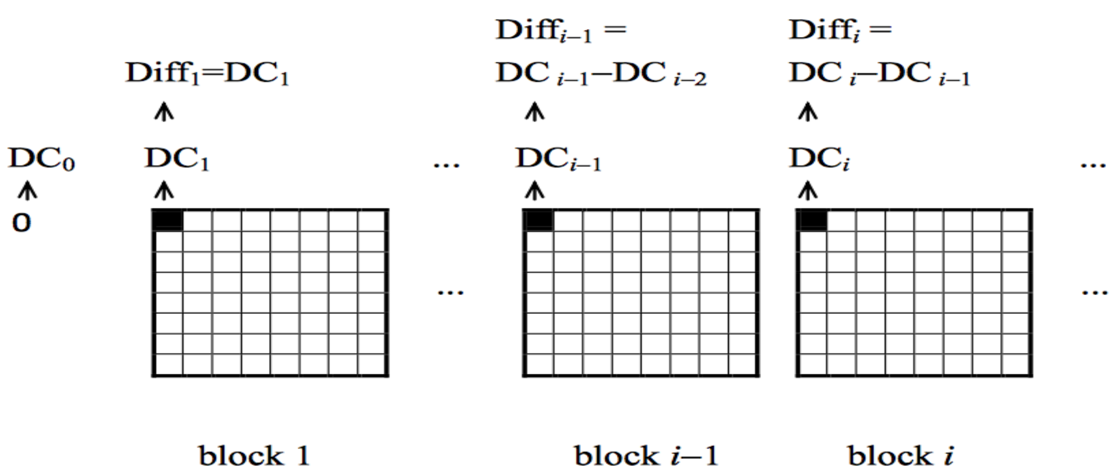

Fig. 7 Difference coding of DC coefficients

D. Huffman coding

During data transmission,data need to be encoded and is converted into binary format with values 0 and 1.If all the character data is converted to binary format of same length irrespective of their priority,length of the entire code will be large.

So,huffman encoding follows a rule of assigning short length code for most frequently used words and longer length code for less frequently used words.Thus the length of entire code gets reduced.

E. Decompression

In decompression, the compression phase is reversed in the opposite order to get the image . In first step, we restore the Huffman tables from the image and then decompressing the Huffman tokens in the image.Then, DCT values for each block will be the first things needed to decompress a block. The other 63 values of each blocks are decompress by JPEG, filling the appropriate number and last step is combined of decoding the zigzag order and then recreating the **8 × 8** blocks. The inverse DCT (IDCT) takes each value present in the spatial domain and examines the each contributions of the 64 frequency make to that pixel.

VI. CONCLUSIONS

We discussed about the basic concepts of image compression along with the overview of JPEG standard. Although, there is much more details we did not mentioned, the important parts are discussed in this paper. The JPEG standard has become on of the the most popular image format and widely used in many applications; it still has some properties which needs further improvement.

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