Image compression

The objective of image compression is to reduce the redundancy of the image and to store or transmit data in an efficient form. Image compression is an application of data compression that encodes the original image with few bits, decodes and decoded image can be similar to the original image. Figure 1 depicts the Image compression scheme.

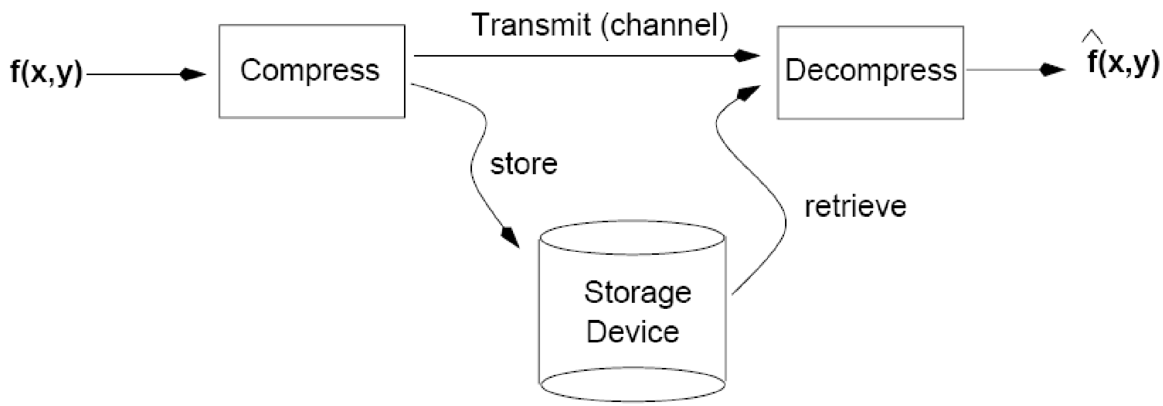

Figure 1: The Image compression scheme

Image Compression Coding:

Image compression coding is to store the image into bit-stream as compact as possible and to display the decoded image. When the encoder receives the original image file, the image file will be converted into a series of binary data i.e., bit stream. The decoder then receives the encoded bit-stream and decodes it to form the decoded image. The full compression flow is as shown in Figure.2.

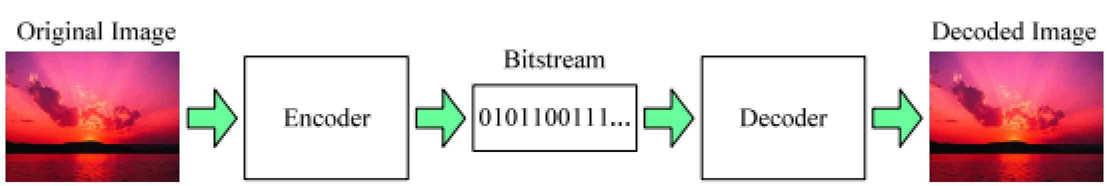

Figure 2: The basic flow of image compression coding

Compression ratio $C_R = \frac{n_1}{n_2}$, where n1 is the data rate of original image and n2 is that of the encoded bit-stream. In order to evaluate the performance of the image compression coding, it is necessary to define a measurement that can estimate the difference between the original image and the decoded image. Two common used measurements are the **Mean Square Error (MSE)** and the **Peak Signal to Noise Ratio (PSNR).**

$$MSE = \sqrt{\frac{\sum_{x=0}^{W-1}\sum_{y=0}^{H-1}[f(x,y) - f'(x,y)]^2}{WH}}$$

$$PSNR = 20\log_{10}\frac{255}{MSE}$$

$f(x,y)$ is the pixel value of the original image, and $f'(x,y)$is the pixel value of the decoded image. Most image compression systems are designed to minimize the MSE and maximize the PSNR.

Data Redundancy is $R_D = 1 - C_R$

Types of redundancy

- **Coding redundancy:** Most 2-D intensity arrays contain more bits than are needed to represent the intensities
- **Spatial and temporal redundancy/ Interpixel Redundancy:** Pixels of most 2-D intensity arrays are correlated spatially and video sequences are temporally correlated
- **Irrelevant information/ Psychovisual Redundancy:** Most 2-D intensity arrays contain information that is ignored by the human visual system

Coding Redundancy:

Basic idea: Different gray levels occur with different probability (non uniform histogram). Use shorter code words fore the more common gray levels and longer code words for the less common gray levels. This is called Variable Length Coding . Coding methods is Huffman coding

Spatial and Temporal Redundancy

There is often correlation between adjacent pixels, i.e., the value of the neighbors of an observed pixel can often be predicted from the value of the observed pixel. Coding methods: Run-Length coding. Difference coding.

Psycho-Visual Redundancy:

If the image will only be used for visual observation (i.e., illustrations on the web, etc.), much of the information is usually psycho-visually redundant. It can be removed without changing the visual quality of the image. This kind of compression is usually irreversible.

Compression can be of two types.

1. **Lossless Compression:** Information is preserved and hence achieves low compression ratios.
2. **Lossy Compression:** Not information preserving, but achieves high compression ratios

Data compression aims to reduce the amount of data while preserving as much information as possible. Trade-off is between information loss **vs** compression ratio.
The general encoding architecture of image compression system is shown is Figure.3.

Figure 3: A general encoding flow of image compression

Image Compression Standards

The most commonly used compression standards for images are: JPEG, JPEG2000

JPEG – Joint Picture Expert Group

The block diagram for encoder and decoder model of JPEG is shown in Figure 4 and Figure 5 respectively.

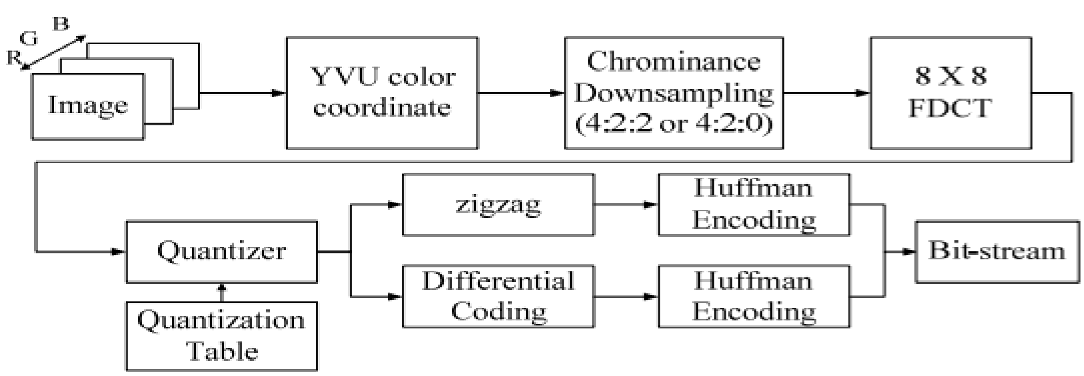

Figure.4: Encoder model of JPEG compression standard

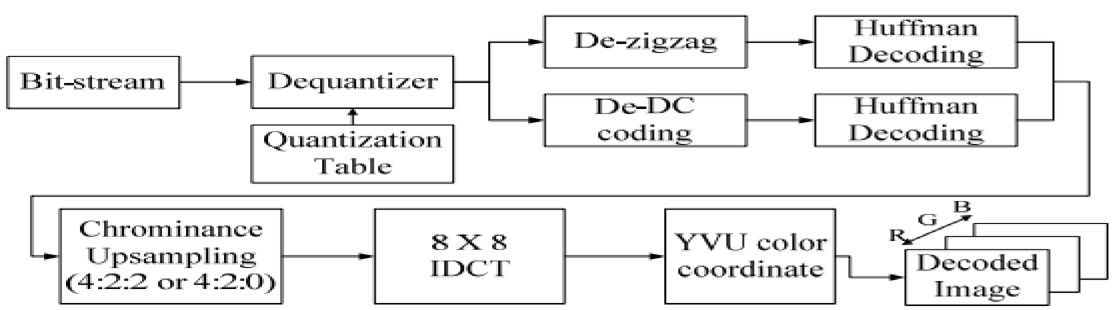

Figure.5: Decoder model of JPEG compression standar

Reference: Digital Image Processing by Rafael C Gonzalez Chapter 8 for detailed description of each functional block and JPEG 2000.

A. **<u>Multiple Choice Questions.</u>**

1. Digitizing image intensity amplitude is called
   A. Sampling
   B. Quantization
   C. Framing
   D. Both A and B
2. Replication of pixels is called
   A. coding redundancy
   B. spatial redundancy
   C. temporal redundancy
   D. both b and c

3. In Huffman coding the size of the codebook is L1, while the longest code word can have as many as L2 bits. What is the relationship between L1 and L2?
   A. L1<L2
   B. L1>L2
   C. L1=L2
   D. No relation
4. The transform used in JPEG image compression is
   B. Discrete cosine transform
   C. Walsh transform
   D. Discrete wavelet transform
   E. KL transform
5. In an image compression system 16, 38, 4 bits are used to represent a 128*128 image with 256 gray levels. What is the compression ratio for the system?
   A. 4
   B. 8
   C. 12
   D. 16
6. Which one of the following is lossy coding?
   A. Huffman coding
   B. Run length coding
   C. Uniform quantizer
   D. Predictive coding without quantizer

7. A 256*256 digital image has 8 distinct intensity levels. What is the minimum number of bits required to code this image in a lossless manner?
   A. 196606 bits
   B. 186608 bits
   C. 196608 bits
   D. 176600 bits

B. Assignment Questions:

1. Compute the entropy of the image given by

$$f(m,n) = \begin{bmatrix} 0\ 1\ 0\ 0 \\ 0\ 1\ 2\ 2 \\ 0\ 1\ 2\ 3 \\ 1\ 2\ 2\ 3 \end{bmatrix}$$

Hint: Entropy $H = -\sum_{i=1}^{N} p_i log_2^{p_i}$ bits per pixels.

2. Calculate the efficiency of Huffman code for the following symbols whose probability of occurrence is given below.

Symbol	Probability
A	0.9
B	0.06
C	0.02
D	0.02

3. Perform the compression and reconstruction of the 8*8 input image

$$f(m,n) = \begin{bmatrix} 183\ 160\ 94\ 153\ 194\ 163\ 132\ 165 \\ 183\ 153\ 116\ 176\ 187\ 166\ 130\ 169 \\ 179\ 168\ 171\ 182\ 179\ 170\ 131\ 167 \\ 177\ 177\ 179\ 177\ 179\ 165\ 131\ 167 \\ 178\ 178\ 179\ 176\ 182\ 164\ 130\ 171 \\ 179\ 180\ 180\ 179\ 183\ 164\ 130\ 171 \\ 179\ 179\ 180\ 182\ 183\ 170\ 129\ 173 \\ 180\ 179\ 181\ 179\ 181\ 170\ 130\ 169 \end{bmatrix}$$

With the JPEG baseline standard. The quantization matrix is given as

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

Hint:

Step 1: Level shift the image g(m,n)=f(m,n)-128

Step 2: Compute 2D DCT of level shifted image G(k,l)

Step 3: Perform quantization of DCT matrix Q'= G(k,l)/Q

Step 4: Zigzag scanning of quantized coefficients

Step 5: Multiplication of received value with quantization matrix

Step 6: Computation of IDCT

Step 7: Perform level shifting operation (Value of 128 is added to each element of the matrix obtained in step 6)

4. Generate an image strip of size 50*100, which consists of 5 vertical strips. The gray level of the strips from left to right are 128, 64, 32, 16 and 8. The corresponding widths of the strips are 35, 30, 20, 10 and 5 pixels respectively. If this strip image is coded by Huffman coding determine the efficiency.

5. Write a MATLAB program to compress an image using 2D-DCT and then try reconstructing the image by using only 50% of the DCT coefficients.