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Image Compression Using Run Length Encoding (RLE)

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Abstract: The goal of image compression is to remove the redundancies by minimizing the number of bits required to represent an image. It is used for reducing the redundancy that is nothing but avoiding the duplicate data. It also reduces the storage memory to load an image. Image Compression algorithm can be Lossy or Lossless. In this paper, DCT and DWT based image compression algorithms have been implemented using MATLAB platform. Then, the improvement of image compression through Run Length Encoding (RLE) has been achieved. The three images namely Baboon, Lena and Pepper have been taken as test images for implementing the techniques. Various image objective metrics namely compression ratio, PSNR and MSE have been calculated. It has been observed from the results that RLE based image compression achieves higher compression ratio as compared with DCT and DWT based image compression algorithms.

Keywords: *Image Compression, JPEG, RLE, Fourier transform, Spatial Domain, Frequency Domain, Quantization.*

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1. INTRODUCTION

Image compression aims to represent an image in the fewest number of bits without losing vital information content within an original image. Image compression is an important step of digital image processing for reducing the amount of data to represent a digital image. It find applications in the field of video-conferencing, remote sensing, facsimile transmission (FAX), documents and medical imaging *etc*. Image compression can be achieved by removing one or more of the three basic data redundancies and briefly outlined below:

Coding redundancy: Coding redundancy is present when less than optimal code words are used. Examples of image coding schemes that explore coding redundancy are the Huffman coding and Arithmetic coding techniques.

Inter pixel redundancy: This redundancy exists as image neighboring pixels are not statistically independent. It results from correlations between the neighboring pixels of an image.

Psycho visual redundancy: It is due to data that is ignored by the human visual system (*i.e.* visually non essential information).

Image Compression techniques reduce the number of bits required to represent an image by taking advantage of these redundancies. An inverse process called decompression (decoding) is applied to the compressed data/image to get the reconstructed image. The objective of compression is to reduce the number of bits as much as possible, while keeping the resolution and the visual quality of the reconstructed image as close to the Original Image as possible. Image Compression systems are composed of two distinct structural blocks: an Encoder and a Decoder. Compression is typically a three step process (Figure 1):

1. **Mapper:** uncorrelate the data
2. **Quantizer:** round off data
3. **Coder:** assign codes to data

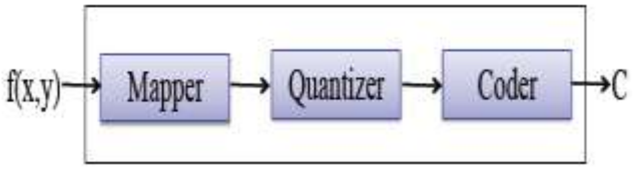

Figure 1: Process of Compression

Let n_1 and n_2 denote the number of information carrying units (usually bits) in the Original and Encoded Image respectively, the Compression that is achieved can be quantified numerically via the compression ratio:

$$CR = n_1 / n_2$$

As shown in figure-1, the coder is responsible for reducing the coding, inter pixel and Psycho visual redundancies of Input Image. In first stage, the Mapper transforms the input image into a format designed to reduce Inter pixel redundancies. The second stage, Quantizer block quantizes Mapper’s output in accordance with a predefined criterion. In third and final stage, coder creates a code for Quantizer output and maps the output in accordance with the coding algorithm. These blocks perform, in reverse order, the inverse operations of the encoder's symbol coder and Mapper block. As Quantization is irreversible, an Inverse Quantization is not included.

Decompression is typically a two step process:
1. Decoder: look up data values for codes
2. Inverse Mapper: undo the mapping step

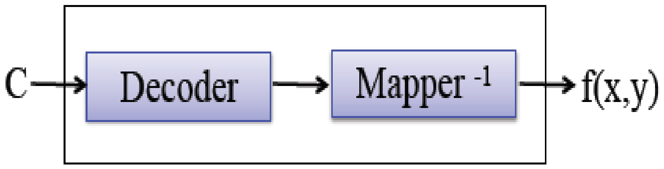

Figure 2: Process of Decompression

There is no way to reverse the data loss caused by Quantization

1.1. Benefits of Image Compression

- It provides a potential cost savings associated with sending less data over switched telephone network where cost of call is usually based upon its duration.
- It not only reduces storage requirements but also overall execution time.
- It also reduces the probability of transmission errors since fewer bits are transferred.
- It also provides a level of security against illicit monitoring.

2. IMAGE COMPRESSION TECHNIQUES

The Image Compression techniques are broadly cl into two categories depending upon whether or not an exact replica of the Original Image could be reconstructed using the compressed image. These are lossless and lossy techniques and have been briefly discussed below:

2.1. Lossless Compression Technique

In Lossless compression techniques, the Original Image can be perfecty recovered from the compressed (encoded) image. These are also called noiseless since they do not add noise to the signal (image).It is also known as Entropy Coding since it uses statistics/decomposition techniques to eliminate/minimize redundancy. Lossless Compression is used only for a few applications with stringent requirements such as medical imaging.

2.2. Lossy Compression Technique

Lossy schemes give much better compression ratios as compared with Lossless schemes. These types of schemes are commonly used as the quality of the reconstructed image is satisfactory for most applications. This scheme results decompressed image that is not like to the Original Image, but reasonably close to it.

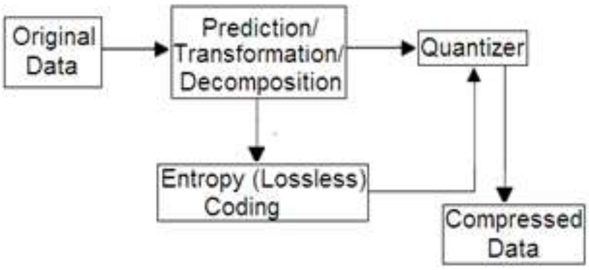

Figure 3: Outline of Lossy Image Compression

The outline of Lossy Compression technique is shown above in figure-3. In this prediction – transformation – decomposition process is completely reversible. The Quantization process results in loss of information. The Entropy Coding after the Quantization step, however, is Lossless. The Decoding is a reverse process. Firstly, Entropy Decoding is applied to compressed data to get the quantized data. Secondly, de Quantization is applied to it and finally the inverse transformation to get the reconstructed image.
Major performance considerations of a Lossy Compression scheme include:

1. Compression ratio
2. Signal-to- noise ratio
3. Speed of encoding and decoding.

Lossy Compression techniques include following schemes:

1. Transformation Coding
2. Vector Quantization
3. Fractal Coding
4. Block Truncation Coding
5. Sub band Coding.

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. Fig 4 shows the block diagram of the general image storage system. The main goal of such system is to reduce the storage quantity as much as possible, and the Decoded Image displayed in the monitor should be similar to the Original Image as much as can be. The essence of each block will be introduced in the following paragraph.

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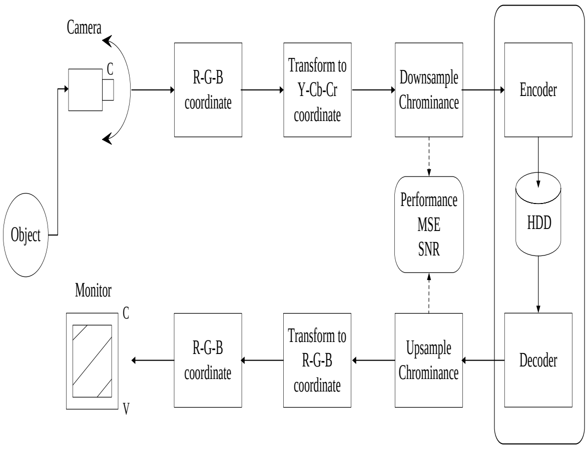

Figure 4: General Image Storage System

The presence of cameras in cell phones is becoming extremely commonplace as the price of inclusion plummets. As more and more people are equipped with these cameras it becomes feasible to develop a range of applications that utilize the camera for purposes other than simply taking a snapshot. One such application is to use the camera to sample the data contained in a visual code marker and to use this as a code to reference information. A typical use might be to include a visual code marker next to the advertisement for a movie. By taking an image of the marker the phone can decode the data and then query a backend database for the local screening times of the movie. To achieve this type of application the camera must be able to reliably identify and decode visual markers.

3. IMAGE COMPRESSION AND DECOMPRESSION

The purpose of the Image Compression algorithm is to reduce the amount of data required to represent the image with less degradation in the visual quality and without any information loss. In Image Compression three redundancies (Inter pixel redundancy, coding redundancy and Psycho visual redundancy) can be identified and exploited. There are various issues related to Image Compression methods such as:

- ❖ We can use different image compression techniques, but which one is better?
- ❖ Which parameters are of significance while compressing an image using Image Compression techniques?

Comparing the performance of compression technique is difficult unless identical data sets and performance measures are used.

3.1. Image Compression & Color Specifications

The Y, Cb, and Cr components of one color image are defined in YUV color coordinate, where Y is commonly called the Luminance and Cb, Cr are commonly called the Chrominance. The meaning of Luminance and Chrominance is described as follows

- ❖ **Luminance:** It is the brightness of the light, which is proportional to the total energy in the visible band.
- ❖ **Chrominance:** It describes the perceived color tone of light, which depends on the wavelength composition of light. Chrominance is in turn characterized by two attributes – hue and saturation.

1. **hue:** Specify the color tone, which depends on the peak wavelength of the light
2. **saturation:** Describe how pure the color is, which depends on the spread or bandwidth of the light spectrum

The RGB coordinates/components commonly used for color display mixes the Luminance and Chrominance attributes of light. In many applications, it is desirable to describe a color in terms of its Luminance and Chrominance content separately, to enable more efficient processing and transmission of color signals. Towards this goal, various three-component color coordinates have been developed, in which one component reflects the Luminance and the other two collectively characterize hue and saturation. One such coordinate is the YUV color space. The $[Y\ Cb\ Cr]^T$ values in the YUV coordinate are related to the $[R\ G\ B]^T$ values in the RGB coordinate by

$$\begin{pmatrix} Y \\ Cb \\ Cr \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.334 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} + \begin{pmatrix} 0 \\ 128 \\ 128 \end{pmatrix} \quad \textbf{(1.1)}$$

Similarly, if we would like to transform the YUV coordinate back to RGB coordinate, the inverse matrix can be calculated from (1.1), and the inverse transform is taken to obtain the corresponding RGB components.

3.2 Image Compression Coding

What is the so-called Image Compression coding? Image Compression coding is to store the image into bit-stream as compact as possible and to display the decoded Image in the monitor as exact as possible. Now consider an Encoder and a Decoder as shown in figure-5. When the encoder receives the Original Image file, the Image file will be converted into a series of binary data, which is called the bit-stream. The Decoder then receives the encoded Bit-stream and decodes it to form the decoded Image. If the total data quantity of the bit-stream is less than the total data quantity of the Original Image, then this is called Image Compression. The full Compression flow is as shown in Fig. 5.

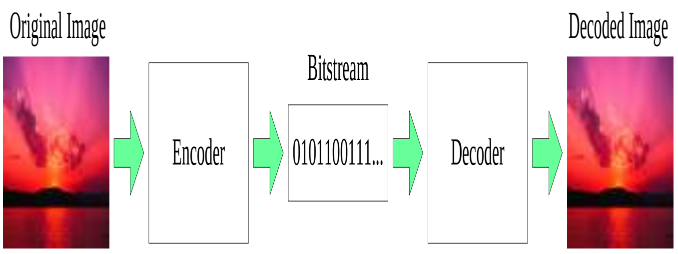

Figure 5: Basic Flow of Image Compression Coding

The Compression Ratio (CR) is defined as follows:

$$CR = \frac{n_1}{n_2} \quad \textbf{(1.2)}$$

where n_1 is the data rate of Original Image and n_2 is that of the Encoded bit-stream.

In order to evaluate the performance of the Image Compression technique, it is necessary to define a measurement that can estimate the difference between the Original Image and the Decoded Image. Two commonly used measurements are the **Mean Square Error (MSE)** and the **Peak Signal to Noise Ratio (PSNR)**, which are defined in (1.3) and (1.4), respectively. 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.

$$MSE = \sqrt{\frac{\sum_{x=0}^{W-1}\sum_{y=0}^{H-1}[f(x,y) - f'(x,y)]^2}{WH}} \quad \textbf{(1.3)}$$

$$PSNR = 20\log_{10}\frac{255}{MSE} \quad \textbf{(1.4)}$$

The General Encoding architecture of Image Compression system is shown is Fig. 6. The fundamental theory and concept of each functional block will be introduced in the following sections.

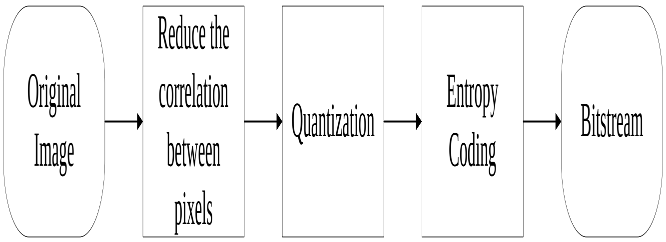

Figure 6: General Encoding Flow of Image Compression

3.3. Correlation between Pixels

The correlation between one pixel and its neighbour pixels is very high, or we can say that the values of one pixel and its adjacent pixels are very similar. Once the correlation between the pixels is reduced, we can take advantage of the statistical characteristics and the Variable Length Coding theory to reduce the storage requirement. This is the most important part of the Image Compression algorithm; there are a lot of relevant processing methods proposed in literature. The best-known methods are as follows:

Predictive Coding: Predictive Coding such as DPCM (Differential Pulse Code Modulation) is a Lossless coding method, which means that the Decoded Image and the Original Image have the same value for every corresponding element.

Orthogonal Transform: Karhunen-Loeve Transform (KLT) and Discrete Cosine Transform (DCT) are the two most well-known Orthogonal Transforms. The DCT-based Image Compression standard such as JPEG is a Lossy Coding method that will result in some loss of details and unrecoverable distortion.

Subband Coding: Subband Coding such as Discrete Wavelet Transform (DWT) is also a Lossy coding method. The objective of Subband coding is to divide the spectrum of one image into the Lowpass and the Highpass components. JPEG 2000 is a 2-dimension DWT based Image Compression standard.

Run-length encoding: Run Length Encoding is a very simple form of data compression in which runs of data (that is, sequences in which the same data value occurs in many consecutive data elements) are stored as a single data value and count, rather than as the Original run. This is most useful on data that contains many such runs: for example, relatively simple graphic images such as icons, line drawings, and animations.

4. RESULTS & DISCUSSION

In this paper, image compression using Run Length Encoding (RLE) has been applied on three test images namely Baboon, Lena and Pepper using MATLAB platform. These test images are shown in figure 7 to which image compression algorithm using RLE is applied for the generation of compressed and decoded image.

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Figure7: Original Test Images in first column and Decoded Images in the Second Column

Various image objective quality metric such as compression ratio, PSNR, MSE are calculated and represented in Table1 along with original and compressed size of the image. It has been observed that image compression using RLE provides storage capacity or compression ratio 45% for Baboon, 44% for Lena, 35% for Pepers. While in the case image compression by Reza Jafari *et al* [9]., using DCT; it is 34% for Baboon, 31% for Lena and 29% for Paper and using DWT; it is 35% for Baboon, 33% for Lena and 31% for Papper. This shows that image compression using RLE is better approach as compared with DCT and DWT for a given set of test images in terms of saving storage capacity.

Table 1: Image Metrics of Various Test Images for RLE

Metrics	Test Image		
	Baboon	**Lena**	**Pepper**
Compression ratio	45	44	35
PSNR (db)	27	32	37
MSE	133	38	14
Original Size (KB)	138	100	91
Compressed Size (KB)	76	56	58

Graphical analysis in terms of compression ratio for the three test images namely Baboon, Lena and Pepper using image compression algorithms namely RLE, DCT and DWT is depicted in figure 8.

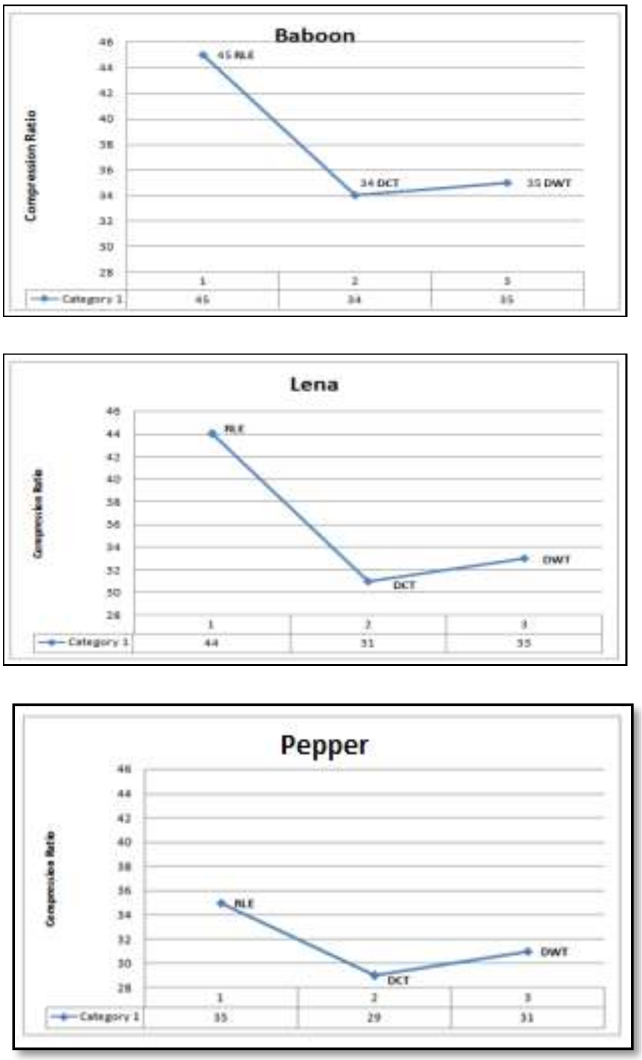

Figure 8: Compression Ratio Analysis

5. CONCLUSIONS AND FUTURE SCOPE

In this paper, the improvement of image compression through Run Length Encoding (RLE) is demonstrated. Experimental results show that the higher data redundancy helps to achieve more compression. By considering Baboon, Lena and Pepers as inputs, it is observed that RLE based image compression achieves higher compression ratio, as compared with Reza Jafari *et al.*

As future work, compression of images for storing and transmitting images can be done by developing other lossy and lossless methods of image compression.

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