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# A Survey on Image Compression Methods

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**Abstract:** Introduction of computer technology in various fields has simplified the job of human being but has also resulted in large amount of digital data. The challenge is managing the large amount of data, i.e. storing and retrieving it. People are sharing, transmitting and storing millions of images every moment. Although data compression is mostly done to avoid occupancy of more memory, and increase capacity of memory devices, The process of reducing data size without losing the crucial information is known as data compression. There is various data compression technique which can use. These techniques can be classified into two types i.e. Lossy and Lossless compression. In this paper some of the lossy image compression is discussed in detail.

*Keywords:* Compression Ratio; Lossless; Lossy; Principal Component Analysis; Peak-Signal-to Noise Ratio; Wavelet Difference Reduction

## I. Introduction

Digital images have become admired for transferring, sharing, storing and visual information and hence high speed compression techniques are needed. The most important one is to reduce the time taken in transmission of images. Data compression [1], particularly image compression [2] play a very crucial role in the field of multimedia computer services and other telecommunication applications. The field of image compression has a wide spectrum of methods ranging from classical lossless techniques and admired transform approaches to the more recent segmentation based (or second generation) coding methods. Until recently, the discrete cosine transforms (DCT) [3] has been the most popular technique for compression due to its optimal performance and ability to be implemented at a reasonable cost. The fundamental principles used in image compression are to avoid redundancy and irrelevant information. Compression is achieved by removal of one or more of the three basic data redundancies.

1. Coding redundancy.
2. Inter pixel redundancy.
3. Psycho-visual redundancy.

**Coding Redundancy:** The uncompressed image usually is coded with each pixel by a fixed length. For example, an image with 256 gray scales is represented by an array of 8- bit integers. Using some variable length code schemes such as Huffman coding and arithmetic coding may produce compression.

**Inter-Pixel Redundancy:** It is a redundancy corresponding to statistical dependency among pixels, especially between neighboring pixels.

**Psycho-visual Redundancy:** It is a redundancy corresponding to different sensitivities to all image signals by human eyes. Therefore, eliminating some less relative important in formation in our visual processing may be acceptable. There are different methods to deal with different kinds of aforesaid redundancies. As a result, an image compressor often uses a multi - step algorithm to reduce these redundancies.

This paper divided into 8$^{th}$ section in which each section is as fallow II- image compression methods, III- Measurements for compression methods, IV-Advantages of image compression, V- Types of images, VI- PCA (Principal component analysis), VII- the WDR algorithm and VII-Conclusion.

## II. Image Compression Methods

The Image compression methods are generally divided into two categories [4] depending whether or not exact imitation of the original image could be reconstructed using the compressed image.

1. Lossless compression method.
2. Lossy compression method.

### 2.1 Lossless compression methods

In lossless compression method, the original image can be perfectly recovered from the compressed image. These are also called noiseless i.e. they do not add noise to the signal (image). It is also called as entropy coding, to eliminate or to minimize redundancy it uses statistic or decomposition methods. Lossless compression is used only for few applications with rigorous requirements such as medical imaging.

Following methods are included in lossless compression:

1. Run length encoding
2. Huffman encoding
3. LZW coding
4. Area coding

### 2.1.1 Run length encoding:

This is very simple procedure used for sequential data. It is very useful in case of redundant data. This method replaces sequences of identical symbols (pixels), called runs by shorter symbols. [5] The run length code for a gray scale image is represented by a sequence {V, R} where **V** is the intensity of pixel and **R** is the number of consecutive pixel with the intensity **V** example is shown bellow

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1** | **1** | **1** | **1** | **0** | **0** | **2** | **2** | **2** | **2** |

**{1, 4}** **{0, 2}** **{2, 4}**

The steps of algorithm for RLE are as follows.

**Step 1:** Input the string.

**Step 2:** From first symbol or character give a unique value.

**Step 3:** Read the next character or symbol, if character is last in the string then exit otherwise.

**A: If:** next symbol is same as previous symbol then give same unique value as previous.

**B: Else if:** next symbol is not same, than give its new value that is not matched from previous value.

**Step 4:** Read and count additional symbols.

**Step 5:** Go to step 3 until a non matching value to the not same symbol for previous.

**Step 6:** Display the result that is count of occurrence of single symbol with that particular symbol, [7].

### 2.1.2 Huffman encoding:

This is a common method for coding symbols based on their statistical occurrence of frequencies (probability). [8] The pixels in the image are treated as symbols. The symbols that occur more frequently are assigned a smaller number of bits, while the symbols that occur less frequently are assigned a relatively larger number of bits. Huffman code is a prefix code. This means that the (binary) code of any symbol is not the prefix of the code of any other symbol. Most image coding standards use lossy methods in the earlier stages of compression and use Huffman coding as the last step.

The example of Huffman coding with algorithm is as follows.

**Step 1:** Input the string

| | | | |
|---|---|---|---|
| 8<br>l | 3<br>k | 20<br>j | 15<br>h |

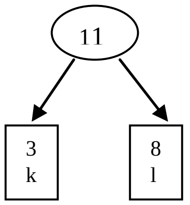
**Step 2:** Sorting the data by frequencies

| | | | |
|---|---|---|---|
| 3<br>k | 8<br>l | 15<br>h | 20<br>j |

**Step 3:** Choose two smallest frequencies count.

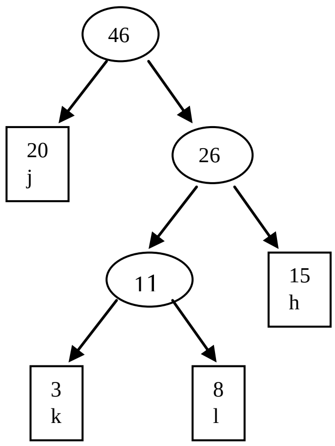
| | |
|---|---|
| 3<br>k | 8<br>l |

**Step 4:** Merge them together with sum of them and update the data.




**Step 5:** Repeat step 2, 3, 4.

The final Huffman tree is as follows:




### 2.1.3 LZW Coding

LZW (Lempel-Ziv-Welch) is a fully dictionary based coding. It is divided into two sub categories. In static, dictionary is fixed during the encoding and decoding processes. In dynamic, dictionary is updated if change is needed, [6]. LZW compression replaces strings of characters with single codes. It does not perform any analysis of the incoming text. Instead, it just adds every new string of characters from the table of strings. The code that the LZW algorithm outputs can be of any arbitrary length, but it must have more bits in it than a single character. LZW compression works best for files containing lots of repetitive data. LZW compression maintains a dictionary. In this dictionary all the stream entry and code are stored.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 8 | 3 | 22 | 5 | 7 | 8 | 3 | 9 | 22 | 5 | 10 |

Unique code          unique code

C1          C2

| | | | | | |
|---|---|---|---|---|---|
| C1 | C2 | C1 | 9 | C2 | 10 |

The steps in LZW algorithm

**Step 1:** Input the stream.

**Step 2:** Initialize the dictionary to contain entry of each character of stream.

**Step 3:** Read the stream, if current byte is end of stream, then exit.

**Step 4:** Otherwise read next character and produce a new code. If group of character is frequently occurring then give them to a unique code.

**Step 5:** Read next input character of stream from dictionary, if there are no such a character in dictionary, then.

**A:** Add new string to the dictionary.

**B:** Write the new code for new entered string.

**C:** Go to step 4.

**Step 6:** Write out code for encoded string and exit

### 2.1.4 Area coding

Area coding is an enhanced version of run length coding, reflecting the two dimensional character of images. This is an important and advance over the other lossless methods. For coding an image it does not make too much sense to interpret it as a sequential stream, as it is in fact an array of sequences, building up a two dimensional object. The algorithms for area coding try to find rectangular regions with the same characteristics. These regions are coded in a descriptive form as an element with two points and a certain structure. This type of coding can be highly effective but it bears the problem of a nonlinear method, which cannot be implemented in hardware. Therefore, the performance in terms of compression time is not competitive, although the compression ratio is.

### 2.2 Lossy compression methods

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Lossy compression as the name implies leads to loss of some information. The compressed image is similar to the original uncompressed image but not just like the previous as in the process of compression [9] some information concerning the image has been lost. They are typically suited to images. The most common example of lossy compression is JPEG. An algorithm that restores the presentation to be the same as the original image is known as lossy techniques. Reconstruction of the image is an approximation of the original image, therefore the need of measuring of the quality of the image for lossy compression technique. Lossy compression technique provides a higher compression ratio than lossless compression.

Types of lossy compression techniques are given bellows.

1. Transformation coding.
2. Vector quantization.
3. Fractal coding.
4. Block truncation coding.
5. Sub band coding.
6. Chroma subsampling.

**2.2.1 Transformation Coding:** DFT and DCT is a type of transforms which are used in changing the pixels of the original image into frequency domain coefficients. There are several properties in this type of coefficients. One is the compaction property. This is the basis for achieving the compression.

**2.2.2 Vector Quantization:** This is the method to develop a dictionary of Fixed- size vectors called code vectors. An image is divided into non-overlapping blocks and then for each value dictionary is determined as well as index is generated for the dictionary which is used as the encoding for an input original image.

**2.2.3 Fractal Coding:** Fractal coding introduces the idea of decomposition of an image into segments by using standard methods of image processing like color separation, edge detection and texture analysis. Each segment is stored in a library of fractals.

**2.2.4 Block Truncation Coding:** In this method, firstly the image is divided and then arrange a block of pixels and find a threshold and reconstruction values for each block then a bitmap of the block is derived and all those pixels got replaced which have the value greater than or equal to the threshold value by 1or 0.

**2.2.5 Sub band Coding:** The image got analyzed as to produce the components which contain frequencies of well-defined blocks and sub bands. Quantization and coding is applied to each of the bands and then each sub bands will be designed separately.

**2.2.6 Chroma subsampling:** This method contains the advantage of the human visual system's lower acuity for color differences. This technique basically used in video encoding for example jpeg encoding and etc. Chroma Subsampling is a method that holds color information of lower resolution and intensity information. Further the over whelming majority of graphics programs perform 2x2 chroma subsampling, which breaks the image into 2x2 pixel blocks and only stores the average color information for each 2x2 pixel group, Kaimal A.B. et al ,[11].

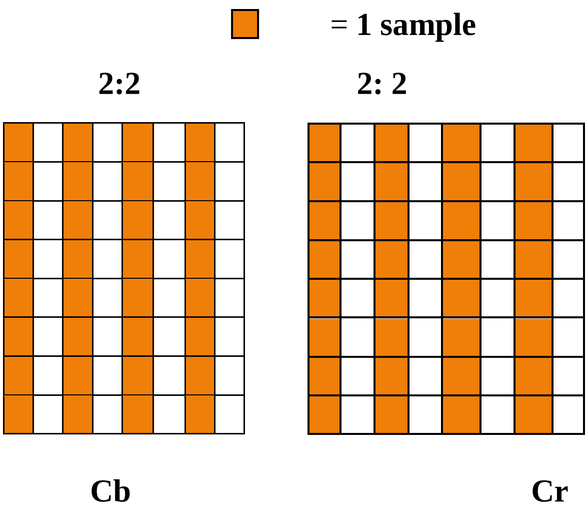


**Fig.** Block diagram of $2 \times 2$ pixel Chroma Subsampling technique.

## III. Measurements for Compression Methods

There are a variety of ways in which different compression algorithms can be evaluated and compared. For quantifying the error between images, two measures are being commonly used. They are Compression Ratio (CR), Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR).

### 1. Compression Ratio (CR)

CR is the ratio between numbers of bits required to represent original image to the number of bits in the compressed image and is given below

$$CR = \frac{n_1}{n_2}$$

Where $n_1$ = number of bits in original image

And $n_2$= number of bits in compressed image.

### 2. Mean Square Error (MSE)

MSE is one of the error metrics used to compare quality of various image compression technique.

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} (P(i,j) - Q(i,j))^2$$

Where, $P(i,j)$ is the original image, $Q(i,j)$ is the approximated image or decompressed image and $m \times n$ is the dimension of the image.

### 3. Peak Signal-to-Noise Ratio (PSNR)

Another error metric used to compare the subjective fidelity criteria of the uncompressed image is PSNR. PSNR is the quality measure of the compressed image. Since it is a logarithmic measure and our brain seems to respond logarithmically to intensity values [10]. It can define using MSE as.

$$PSNR = 10log_{10}(\frac{m \times n}{MSE})$$

## IV. Advantages of Image Compression

There are following advantages of image compression:

### 4.1 Size reduction

The size reduction is most significant benefit of the image compression. It takes up less space on the hard drive and retains the same physical size, unless edit the image's physical size in an image editor. The file size reduction with the help of internet to create image rich sites without using much bandwidth or storage space.

### 4.2 Data loss

Some common files like JPEG, which an image shrinks in the size of compression, will discard some of the photo's data permanently. So compress the images to ensure that decompressed back up before starting. Otherwise lose the high quality of the original decompressed image permanently

### 4.3 Slow devices

Various electronics devices may load large compressed image slowly. For example CD devices can only read data at a specific rate and cannot display large images in real time. Also do some webhost that transfer data slowly compressed images remain necessary for a fully functional websites? Image compression allow for the faster loading of data on slower devices

## V. Types of Images

**Table: Image formats and its features**

| Format | Features |
|---|---|
| TIFF (Tagged Image File Format) (lossy and lossless) | Flexible format, save 8 or 16 bits per color (RGB) totally 24 or 48 bit. |
| GIF (Graphics Interchange Format) | Grayscale and black white Image, it works with 8 bits per pixel or less which indicates 256 or less colors. It states simple graphics, logos and cartoon style image. |
| PNG (Portable Network Graphics) (Lossless) | Same 8 bits, 24 bits and 48 bits per pixel. 10 to 30 % compressed than GIF format PNG format have smaller size and more colors compare to others. |
| JPEG (Joint Photographic Expert Group) | It support 8 bits gray scale and 24 bits color images. provide motion video compression, compress the meal would subjects, photographs and video stills |

| | |
|---|---|
| (Lossy) | |
| BMP (Bitmap) (don't compress) | Graphics file related to Microsoft window operating system, simplicity. BMP images are binary files. |
| RAW (lossless/lossy) | File size smaller than TIFF format. Available on digital cameras. |

## VI. PCA (Principal Component Analysis)

In statistics, PCA is a method for simplifying a dataset by reducing multidimensional datasets to lower dimensions for analysis. PCA is a standard method commonly used for data reduction in statistical pattern recognition and signal processing. PCA is noted to be one of the most valuable results from applied linear algebra. It is used abundantly in all forms of analysis from neuroscience to computer graphics, because it is a simple non - parametric method of extracting relevant information from confusing datasets.

PCA is also called the KARHUNEN-LOEVE Transform (KLT, named after Kari Karhunen & Michel Loeve) or the HOTELLING Transform. Its general objectives are:

1. Data reduction
2. Interpretation

PCA is based on a creation of a new set of variables, referred to as principal components (PCs), which are completely uncorrelated and orthogonal to each other [12]. PCs allow us to identify the direction in which information varies. SVD is used to decompose the covariance matrix into three matrices $U$, $\Sigma$ and $V$ in such a way that $U$, $V$ are orthogonal matrices and $\Sigma$ is a diagonal matrix containing the sorted singular values of the input matrix in descending order [13]. The steps to perform PCA using SVD are given below:

1) Take an input image A of size $m \times n$.

2) Subtract mean from each column of A, which makes a mean centered data matrix X.

3) Create matrix Z using eq. 1 (given below) on X, and calculate covariance matrix $Z\,Z^T$ and perform SVD on it.

$$Z = \frac{1}{\sqrt{n-1}} X^T \tag{1}$$

For an input image of size $m \times n$, the orthogonal matrices $U$ and $V$ are of size $m \times m$, $n \times n$ respectively and diagonal matrix $\Sigma$ is of size $m \times n$, i.e,

$$S_{m\times n} = U_{m\times m}\Sigma_{m\times n}(V_{n\times n})^T \tag{2}$$

4) Select few dominant PCs and ignore the rest.

5) Project data onto PCs.

6) Back project data to original basis.

7) Display compressed image.

## VII. The WDR Algorithm

The WDR method is a given by Tian and Wells ([14] and [15]), so we shall begin by briefly summarizing the WDR method. The WDR method has two principal advantages. First, it produces an embedded bit stream—thereby facilitating progressive transmission over small bandwidth channels and/or enabling multi resolution searching and processing algorithms. Second, it encodes the precise indices for significant transform values—thereby allowing for Region of Interest (ROI) capability and for image processing operations on compressed image files.

The WDR algorithm is a remarkably simple procedure. A wavelet transform is applied to the image. Then, the bit-lane encoding procedure for the transform values, described in [16], is carried out. This bit-plane encoding procedure consists of a significance pass and a refinement pass. During the significance pass, the values of the wavelet transform of the image are scanned through in a linear order ($x[1], x[2], \dots\dots . x[M]$ where M is the number of pixels), and a value is deemed significant if it is greater than or equal to a threshold value. An index $n$ is removed from the scanning order if it is found to be significant. During the refinement pass, previous significant values are refined to a further precision.

The distinguishing feature of WDR is its method of encoding the positions of significant transform values. This method is called difference reduction. It is most easily described through an example. Suppose that the significant indices found in the significance pass are 2, 3, 7, 12, and 34. Rather than work with these values, we work with their successive differences: 2, 1, 4, 5, and 22. In this latter list, the first number is the starting index and each successive number is the number of steps needed to reach the next index. The binary expansions of these Successive differences are $(10)_2,\ (1)_2, (100)_2, (101)_2, and (10110)_2$. Since the most significant bit in these expansions is always 1, we can drop this bit and use the sign of the most significant transform values are $x[2]$ = +34.2, $x[3]$ = -33.5, $x[7]$ = +48.2, $x[12]$ = +40.34, and $x[34]$ = -54.36, then the resulting symbol stream would be +0 - +00 + 01 – 0110. Hens arithmetic coding is employed, then a probabilistic model is used for encoding the four symbols +, -, 0, and 1, into a compressed stream of bits.

## VIII. Conclusion

This paper presents various techniques of image compression. These are still a tough task for the researchers and academicians. There are mainly two types of image compression techniques exist. Comparing the performance of compression technique is difficult unless identical data sets and performance measures are used. Some of these techniques are obtained good for certain applications like security technologies. After study of all techniques it is found that lossless image compression techniques are most effective over the lossy compression techniques, but Lossy provides a higher compression ratio than lossless. The PCA principal component analysis and WDR is the lossy compression technique. WDR is a wavelet based coding technique so it exploits local characteristics of the image and leads to high Compression Ratio (CR). PCA gives high image quality but low CR on the other hand WDR works opposite of it.

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