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A Detailed Analysis of Lossless Image Compression Techniques

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Abstract:

An image in its original form contains large amount of redundant data which consumes huge amount of memory and can also create storage and transmission problem. The rapid growth in the field of multimedia and digital images also needs more storage and more bandwidth while data transmission. By reducing redundant bits within the image data the size of image can also be reduced without affecting essential data. In this paper we are representing existing lossless image compression techniques. The image quality will also be discussed on the basis of certain performance parameters such as compression ratio, peak signal to noise ratio, root mean square.

Keywords — **Image Compression, lossless Compression, Huffman Coding, Run Length Encoding, LZW, Redundancy.**

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I. INTRODUCTION

A digital image is basically a 2-Dimensional array of pixels. Images from the significant part of data, particularly in remote sensing, biomedical and video conferencing applications are types of digital images. An image is essentially a 2-D signal processed by the human visual system. The signals representing images are usually in analog form. However, for processing, storage and transmission by computer applications, they are converted from analog to digital form. A digital image is basically a 2-Dimensional array of pixels. With growth of technology dependence on information technology and computers rapidly growing, so need for efficient ways of storing and transmitting large amounts of data also growing [1]. The Prime need of Image Compression is to reduce the size the image for storage purpose Lossy methods are particularly suitable for expected images such as photographs in applications where negligible thrashing of commitment is tolerable to accomplish a generous lessening in bit rate. The lossy compression that produces unnoticeable differences may be called visually lossless. Image compression is a procedure that deals with tumbling the quantity of data mandatory to symbolize a digital image by removing the superfluous data. It is been used to curtail the size in bytes of a graphics file exclusive of corrupting the excellence of the image to an undesirable intensity. The lessening in file dimension allows supplementary images to be stored in a specified quantity of diskette or recollection space. Image Compression also reduce the redundancy, extra information, & to transform data in efficient manner. There is the need of short data because it reduces the transmission and storage cost.

II. IMAGE COMPRESSION AND TYPES

Image compression addresses the problem of reducing the amount of data required to represent a digital image [2]. It is a process intended to yield a compact representation of an image, thereby reducing the image storage/transmission requirements. Compression is achieved by the removal of one or more of the three basic data redundancies:

- Coding Redundancy
- Interpixel Redundancy
- Psychovisual redundancy

Coding redundancy is present when less than optimal code words are used. Interpixel redundancy results from correlations between the pixels of an image. Psychovisual redundancy is due to data that is ignored by the human visual system (i.e. visually non essential information). The objective of image compression is to reduce the number of bits. It needs to represent an image by removing the Spatial and Spectral redundancies as much as possible, while keeping the resolution and visual quality of the reconstructed image as close to the original image by taking advantage of these redundancies [3]. An inverse process called decompression is applied to the compressed data to get the reconstructed image.

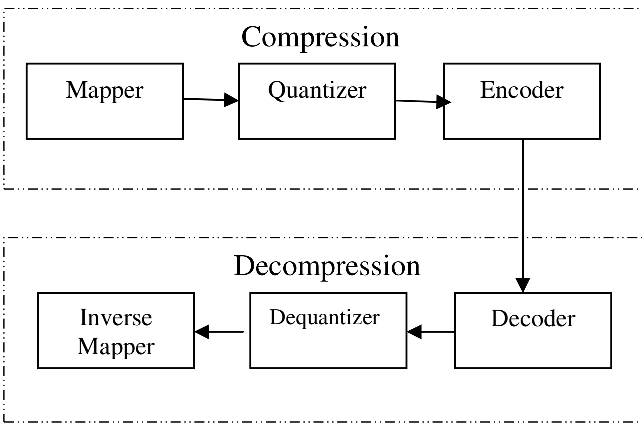


Fig.1 Image Compression and Decompression

Image Compression is possible because most of the real world data is very redundant. Image Compression is basically defined as a technique that reduces the size of data by applying different methods that can either be Lossy or Lossless. A compression program is used to convert image from an easy-to-use format to one optimized for compactness. Two basic classes of image compression are applied in different areas [4]. One of these is lossy image compression, which is widely used to compress image data files for communication or archives purposes. The other is lossless image compression that is commonly used to transmit or archive text or binary files required to keep their information intact at any time.

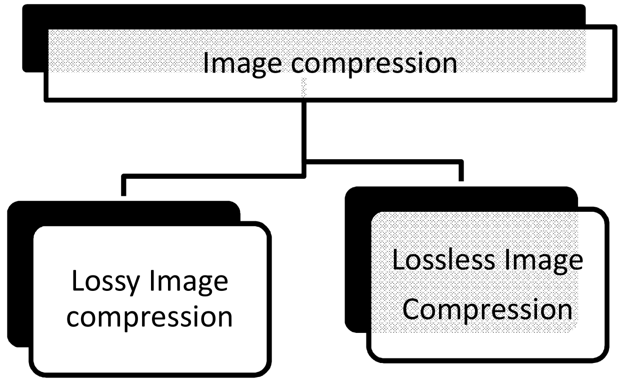


Fig. 2 Classification of Data Compression

III. BENEFITS OF LOSSLESS COMPRESSION

A. *Storage Space*

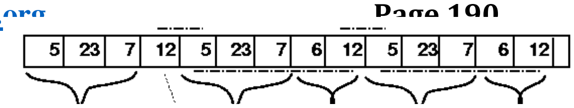
Compressing data files allows one to store more files in the storage space that is available. Lossless compression, used in zip file technology, will typically reduce a file to 50 percent of its original size. However, difference in the file size is not seen if the zip files are already in a compressed format, such as MP3 audio files or PDF (Portable Document Format) text-only files [5].

B. *Transfer Speed*

The download process uses network bandwidth whenever we download a file, such as an MP3 audio file, from a server on the Internet. Bandwidth is defined as the speed at which the network transfers data and is measured in Mbps (megabits per second). Compressed files contain fewer "bits" of data than uncompressed files, and, as a consequence, use less bandwidth when we download them. This means that the transfer speed, that is the time it takes to download a file, is quicker. It will take 10 seconds to download a file if bandwidth of 1Mbps is available, and for downloading a file that is 10Mb (megabits) in size, it will only take 5 seconds to download the file if the file is compressed to 5Mb [6].

C. *Cost*

The costs of storing the data are reduced by compressing the files for storage because more files



can be stored in available storage space when they are compressed. We will need to buy a second 250MB drive if we have 500MB (megabytes) of uncompressed data and a 250MB hard drive on which to store it. You will not need to buy the extra hard drive if you compress the data files to 50 percent of their uncompressed size [6].

D. Accuracy

It also reduces chance of transmission errors because as we reduce data redundancy which increases consistency and decreases chance of error. Moreover by compressing very fewer bits are transferred.

IV. LOSSLESS COMPRESSION TECHNIQUES

Lossless data compression is a technique that which allows the use of data compression algorithms to compress the data file and also allows the exact original data to be reconstructed from the compressed data. This is in contrast to the lossy data compression in which the original data cannot be restored from the compressed data. The popular ZIP file format that is being used for the compression of data files is also an application of lossless data compression approach. Lossless text data compression algorithms usually exploit statistical redundancy in such a way so as to represent the sender's data more concisely without any error or any sort of loss of important information contained within the text input data [7].

A. LZW Coding

LZW (Lempel-Ziv–Welch) is a totally dictionary based coding. Lzw encoding is further divided into static & dynamic. In static, dictionary is fixed during the encoding and decoding processes. In dynamic dictionary coding, the dictionary is updated if needed. 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 [8]. 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.

Fig.3 Example of LZW Coding

Basic steps of LZW coding are given below.

- Input the data stream
- Initialize the dictionary to contain entry of each character of stream.
- Read the stream if current byte is the end of stream, then exits.
- Otherwise read next character and produce a new code. If the bunch of character is frequently occurring then give them a unique code (according to the diagram)
- Read next input character of stream from dictionary
  If there is no such pattern of stream in dictionary,then
  a) Add new string to the dictionary
  b) Write the new code for new entered string.
  c) Go to step 4.
- Write out code for encoded string and exit.

B. Huffman coding

Huffman coding deals with data compression that follows top down approach means the binary tree is built from the top down to generate an optimal result. In Huffman Coding the characters in a data file are converted to binary code and the most common characters in the file have the shortest binary codes, and the characters which are least common have the longest binary code [9]. Every node contains the relative probability of occurrence of the characters belonging to the sub tree beneath the node. The edges are labelled with the bits 0 and 1. The algorithm to generate Huffman code is:

- Parse the input and count the occurrence of each symbol.

- Determine the probability of occurrence of each symbol using the symbol count.
- Sort the symbols according to their probability of occurrence, with the most probable first.
- Then generate leaf nodes for each symbol and add them to a queue.
- Take two least frequent characters and then logically group them together to obtain their combined frequency that leads to the construction of a binary tree structure.
- Repeat step 5 until all elements are reached and there remains only one parent for all nodes which is known as root.
- Then label the edges from each parent to its left child with the digit 0 and the edge to right child with 1. Tracing down the tree yields to "Huffman codes" in which shortest codes are assigned to the character with greater frequency.

C. Lossless JPEG

Lossless JPEG was developed as a late addition to JPEG in 1993, using a completely different technique from the lossy JPEG standard. It can perform lossless compression as long as the image size is a multiple of MCU (Minimum Coded Limit). It uses a predictive scheme based on the three nearest neighbors upper, left and upper-left and entropy coding is used on the prediction error. It uses a simple predictive algorithm and Huffman algorithm to encode the prediction difference. This technique is rarely used since its compression ratio is very low when compared to Lossy modes. This technique is very useful in the case of medical image compression where the loss of information is not tolerable [10]. The main steps of lossless operation mode are depicted in Fig.4.

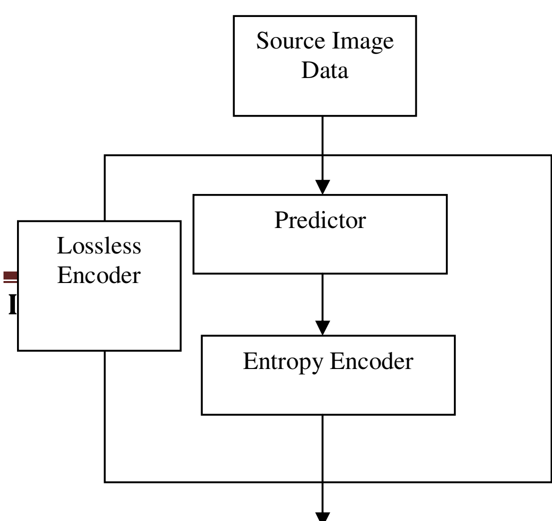


Fig.4 Lossless JPEG Compression

D. FELICs

FELICS is the compression that runs very fast with only minimal loss of compression efficiency. We call this technique FELICS, for Fast, Efficient, Lossless Image Compression System. It use raster-scan order, and we use a pixel's two nearest neighbors to directly obtain an approximate probability distribution for its intensity, in effective combining the prediction and error modeling steps. It use a novel technique to select the closest of a set of error models, each corresponding to a simple prefix code. Finally It encode the intensity using the selected prefix code. The resulting compressor runs about five times as fast as an implementation of the lossless mode of the JPEG proposed standard while obtaining slightly better compression on many images [11]. By using an appropriate pixel sequence we can obtain a progressive encoding, and by using sophisticated prediction and error modeling techniques in conjunction with arithmetic coding It can obtain state-of-the-art compression efficiency.

E. Wavelet Transform Based Compression

The DCT based JPEG image compression will not have a significant effect on geometry by using Blocking artifacts" and the edge effects are produced under the large compression ratio. A good solution to this problem is the use of "wavelet". So from the last two decades for "image Analysis and coding", DWT has become an important tool [12].

- ***Integer Wavelet Transform***

The main drawback of the DWT is that the wavelet coefficients are real numbers. In this case efficient lossless coding is not possible using linear transforms. The lifting scheme (LS) presented by Sweldens allows an efficient implementation of the DWT. Another of its properties is that perfect reconstruction is ensured by the structure of the LS itself. This allows new transformations to be used. One such transformation is the integer wavelet transform (IWT) [12] it is a basic modification of linear transforms, where each filter output is rounded to the nearest integer. IWT can be used to have a unified lossy and lossless codec. It is also of interest for hardware implementations, where the use of floating point is still a costly operation.
The wavelet Lifting Scheme is a method for decomposing wavelet transforms into a set of stages. The convolution-based 1-D DWT requires both a large number of arithmetic computations and a large memory for storage. Such features are not desirable for either high speed or low power image processing applications. The main feature of the lifting-based wavelet transform is to break-up the high pass and the low pass wavelet filters into a sequence of smaller filters. The lifting scheme requires fewer computations compared to the convolution-based DWT. Therefore the computational complexity is reduced to almost a half of those needed with a convolution approach. The main advantages of lifting scheme are as follows:

- It allows a faster implementation of the wavelet transforms.
- The lifting scheme allows a fully in-place calculation of the wavelet transform. In other words, no auxiliary memory is needed and the original signal (image) can be replaced with its wavelet transform.
- With the lifting scheme, the inverse wavelet transform can immediately be found by undoing the operations of the forward transform. In practice, this comes down to simply reversing the order of the operations and changing each + into a - and vice versa.

Because of the superior energy compaction properties and correspondence with human visual system, wavelet compression methods have produced superior objective and subjective results. Since wavelet basis consists of functions with both short support (for high frequencies) and long support (for low frequencies), large smooth areas of an image may be represented with very few bits, and details are added where it is needed.

V. CONCLUSIONS

Here different lossless Image Compression Techniques are discussed. Image Compression plays a significant role in reducing the transmission and storage cost. All the image compression techniques are useful in their related areas and every day new compression technique is developing which gives better compression ratio. In Lossless compression, the image is compressed and decompressed without any lose of information. Now a day a wavelet Lossless image Compression Technique is used and Integer Wavelet Transform is giving better compression ratio as like lossy compression without compromising the quality of image. Based on Different Technology conclude that the quality of the image can be measured by the important factor as like peak signal to noise ratio and mean square error and Compression ratio.

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