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A Study of 2-D Image Compression Technique

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Abstract: In this paper, different types of images and image compression, need of compression, its principles, and classes of compression and various algorithm of image compression have been reviewed and discussed. Image compression is a technique of reducing the image size without degrading the quality of the image. Image compression is the solution associated with transmission and storage of large amount of information for digital image. Transmission of images includes different applications like broadcasting of television, remote sensing via satellite and other long distance communication while image storage is required for medical images, satellite images and pictures. This paper attempts to give a recipe for selecting one of the popular image compression algorithms based on Wavelet, JPEG/DCT, VQ, and Fractal approaches. The advantages and disadvantages of these algorithms for compressing greyscale images, give an experimental comparison on commonly used image of Lenna, has also been discussed.

Keywords: DCT; Fractal; Image compression; JPEG; VQ; Wavelet.

I. Introduction

Image is a 2-Dimensional signal represented by digital system. Usually image taken from camera is in the analog form. However, for processing, transmitting and storage, images are converted into digital form. A digital image is basically 2-Dimensional array of pixels [1].Uncompressed multimedia (graphics, audio and video) data requires large amount of storage capacity and transmission bandwidth. Uncompressed images occupy a large amount of memory in RAM and in storage media, and they take more time to transfer from one device to another device. Table 1 below shows the comparative size from normal text to high compressed image.

Image compression is an application of data compression on digital images. The objective is to reduce redundancy of the image data in order to be able to store or transmit datain an efficient form. Basically compressing of image is different than compressing digital data. General purpose data compression algorithm can be used for image compression but its result is less than required [2]. Compression is achieved by removing redundant or extra bits from the image. This paper reviews and lists the characteristics of four popular image compression techniques based on(a) Wavelet, (b) JPEG/DCT, (c) VQ, and (d) Fractal methods, gives experimental comparisons of these algorithms on real image. The purpose is to give an algorithm for selecting an appropriate image compression technique for the problems in hand.

Table1: Multimedia data types & uncompressed storage space, transmission bandwidth, and transmission time required

Multimedia Data	Size/ Duration	Bits/Pixel or Bits/ Sample	Uncompressed Size (B for bytes)	Transmission Bandwidth (b for bits)	Transmission Time
A page of text	11"x8.5"	Varying resolution	4-8KB	32-64 Kb/ page	1.1 - 2.2 sec
Telephone quality speech	10 sec	8 bps	80 KB	64 Kb/sec	22.2 sec
Grayscale Image	512x512	8 bpp	262KB	2.1 Mb/ image	1 min 13 sec
Color Image	512x512	24 bpp	786KB	6.29 Mb/ image	3 min 39 sec
Medical Image	2048x 1680	12 bpp	5.16 MB	41.3 Mb/ image	23 min 54 sec
SHD Image	2048 x 2048	24 bpp	12.58 MB	100 Mb/ image	58 min 15 sec

II. PRINCIPLE OF COMPRESSION

Digital image is basically array of various pixel values [1]. A common characteristic of most of the images is that the neighbouring pixels are correlated and therefore contain redundant information. The foremost task is to find less correlated representation of the image. Two fundamental components of compression are redundancy and irrelevancy reduction [3]. Redundancy reduction aims at removing duplication from the source of the signal (image/video). Irrelevancy reduction omits parts of the signal that will not be noticed by the signal receiver, i.e. Human Visual System (HVS). In general, three types of redundancy can be identified:

1. Coding Redundancy
2. Interpixel Redundancy
3. Psycho visual Redundancy

Coding redundancy is present when less than optimal code words are used. Interpixel redundancy results from correlations between the pixels of an image. Psycho visual 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 same as that of the original image by taking advantage of these redundancies.

III. TYPES OF IMAGES

A. TIFF

The TIFF (Tagged Image File Format) is a flexible format which can be used for lossless or lossy compression [4].In practice, TIFF is used as a lossless image storage format in which image compression is not used. TIFF files are not used for web transmission because TIFF files require large size.

B. GIF

Graphics Interchange Format (GIF) is useful for images that have less than 256 colors, grayscale.GIF is limited to an 8 bit or 256 colors so that it can be used to store simple graphics, logos and cartoon style images. It also uses loss less compression.

C. RAW

RAW file format includes images directly taken from Digital cameras. These formats normally use loss less or lossy compression method and produce smaller size images. The disadvantage of RAW image is that they are not standardized image and it will be different for different manufacture thus, requiring manufacture's software to view the images.

D. PNG

The PNG (Portable Network Graphics) file format supports 8 bit, 24 bit and 48 bit true color with and without alpha channel. Lossless PNG format is best compare to lossy JPEG. Typically, an image in a PNG file can be 10% to 30% more compressed than in a GIF format [5].PNG format have smaller size and more colors compare to others.

E. JPEG

Joint Photographic Expert Group (JPEG) is a lossy compression technique to store 24 bit photographic images. It is widely accepted in multimedia and imaging industries. JPEG is 24 bit color format so it has millions of colors and more superior compare to others [6]. It is used for VGA (video graphics Array) display. JPEG have lossy compression and it support 8 bit gray scale image and 24 bit color images.

F. JPEG2000

JPEG 2000 is a compression standard for lossless and lossy storage. JPEG2000 improves the JPEG format. It is nearly same as JPEG.

G. Exif

The Exif (Exchangeable Image File Format) is similar to JFIF format with TIFF extension. It is used to record and exchange images with image metadata between the digital camera and editing and viewing software.

H. BMP

The Bitmap (BMP) file format deal with graphic file related to Microsoft windows OS. Normally these files are uncompressed so they are large. These files are used in basic windows programming. [7] BMP images are binary files. BMP file does not support true colors.

I. NETPBM

NetPbm format contain three family formats: the PPM (portable Pixel Map), the PGM (portable Gray Map) and the portable bit map [8]. These files are pure ASCII files or raw binary files.

IV. CLASSES OF IMAGE COMPRESSION

Two different ways of classifying compression techniques are:

A. Lossless Vs. Lossy compression

In lossless compression schemes, the reconstructed image, after compression, is numerically identical to the original image. However, lossless compression can only achieve a modest amount of compression. An image reconstructed following lossy compression contains degradation relative to the original is because the compression scheme completely omits redundant information. However, lossy schemes are capable of achieving much higher compression. Under normal viewing conditions, no visible loss is perceived (visually lossless).

B. Predictive vs. Transform coding

In predictive coding, information already sent or available is used to predict future values, and the difference is coded. Since this is done in the image or spatial domain, it is relatively simple to implement and is readily adapted to local image characteristics. Differential Pulse Code Modulation (DPCM) is one particular example of predictive coding. Transform coding, on the other hand, first transforms the image from its spatial domain representation to a different type of representation using some well-known transform and then codes the transformed values (coefficients). This method provides with higher data compression compared to the predictive methods, although at the expense of greater computation.

V. IMAGE CODER

A typical lossy image compression system which consists of three closely connected components namely (a) Source Encoder (b) Quantizer, and (c) Entropy Encoder. Compression is accomplished by applying a linear transform to decorrelate the image data, quantizing the resulting transform coefficients, and entropy coding the quantized values.

A. Source Encoder (or Linear Transformer)

Over the years, a variety of linear transforms have been developed which include Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) [9], Discrete Wavelet Transform (DWT)[10] and many more, each with its own advantages and disadvantages.

B. Quantizer

A quantizer simply decreases the number of bits needed to store the transformed coefficients by decreasing the precision of those values. Since this is a many-to-one mapping, it is a lossy process and is the main source of compression in an encoder. Quantization can be performed on each individual coefficient, which is known as Scalar Quantization (SQ). Quantization can also be performed on a group of coefficients together, known as Vector Quantization (VQ). Both uniform and non-uniform quantizers can be used depending on the problem in hand.

C. Entropy Encoder

An entropy encoder further compresses the quantized values of lossless to give better overall compression. It uses a model to accurately determine the probabilities for each quantized value and produces an appropriate code, based on these probabilities so that the resultant output code stream will be less than the input stream. The most commonly used entropy encoders are the Huffman encoder and the arithmetic encoder.

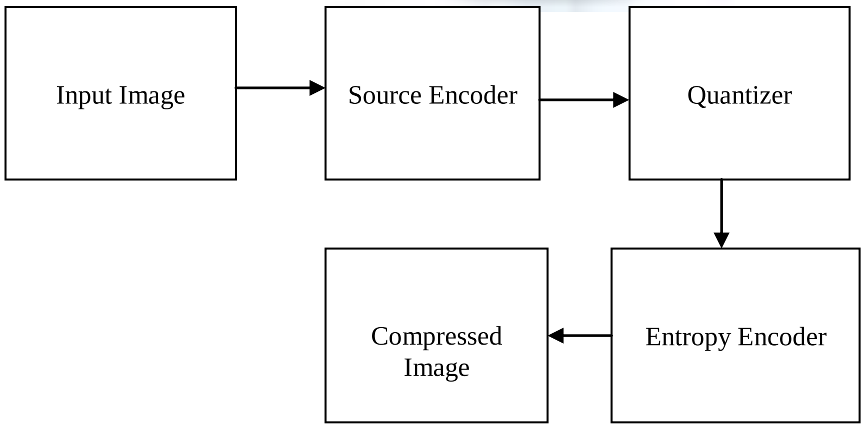

Fig 1: Block Diagram of Image Coder using Lossy Technique

VI. COMPRESSION ALGORITHMS

A. JPEG: DCT-Based Image Coding Standard

The JPEG/DCT still image compression has become a standard recently [11, 12]. JPEG is designed for compressing full-color or greyscale images.

In this method, an image is first partitioned into nonoverlapped 8×8 blocks. A Discrete Cosine Transform (DCT) [11, 13] is applied to each block to convert the gray levels of pixels in the spatial domain to coefficients in the frequency domain. The coefficients are normalized by different scales according to the quantization table provided by the JPEG standard conducted by some psycho visual evidence. The quantized coefficients are then rearranged in a zigzag scan in order to be further compressed by an efficient lossless coding strategy such as runlength coding, arithmetic coding, or Huffman coding [11]. The decoding is basically the inverse process of encoding. The JPEG compression takes about the same amount of time for both encoding and decoding. The encoding/decoding algorithms provided by an independent JPEG group [14] are available for testing the real-world images.

The information loss occurs only in the process of coefficient quantization. The JPEG standard defines a standard 8×8 quantization table [11] for all images which may not be appropriate. To achieve a better decoding quality of various images with the same compression by using the DCT approach, an adaptive quantization table may be used instead of using the standard quantization table.

B. Wavelet Transform

Wavelets are functions that are defined over a finite interval and have an average value of zero. The idea of the wavelet transform is to represent any function (t) as a superposition of such wavelets or basis functions. These basis functions are obtained from a single prototype wavelet called the mother wavelet, by dilations or contractions (scaling) and translations (shifts). The Discrete Wavelet Transform of a finite length signal x (n) having N components, for example, is expressed by an N x N matrix [15].

Despite of all the advantages of JPEG compression schemes based on DCT namely simplicity, satisfactory performance, and availability of special purpose hardware for implementation these are not without shortcomings. Since input image needs to be 'blocked', correlation across the block boundaries is not eliminated. This results in noticeable and annoying 'blocking artefacts' particularly at low bit rates. Lapped Orthogonal Transforms (LOT) [16] attempts to solve this problem by using smooth overlapping blocks. Although blocking effects are reduced in LOT compressed images, increased computational complexity of such algorithms do not justify wide replacement of DCT by LOT.

(a) (b)

Figure 2: (a) Original Lena Image, and (b) Reconstructed Lena with DC component only, to show blocking artefacts.

Image compression based on wavelet transforms has recently received an increasing interest [17, 18, 19, 20]. The current wavelet approach applies a wavelet transform on images in a pyramid fashion up to the desired scale using the theory of multiresolution signal decomposition with the wavelet representation [21, 22] and the concept of embedded zero tree wavelet (EZW) based on the decaying spectrum hypothesis [20]. In a pyramidal structure after a particular scale of wavelet transforms on an image, an algorithm[20] successively determines if a coefficient is significant in the spatial-frequency domain to form a significance map consisting of the sign (+ or −) of a significant coefficient, an insignificant symbol, and a zero tree symbol. It assumes that wavelet coefficients of an image in the finer resolutions corresponding to a zero tree mark have smaller magnitudes than the one marked as zero tree in a coarser resolution for this image according to a practical, but false decaying spectrum hypothesis. This algorithm has been widely tested and shown to be very effective [19].

In many applications wavelet-based schemes (also referred as sub band coding) outperform other coding schemes like the one based on DCT. Since there is no requirement to block the input image and its basis functions have variable length, wavelet coding schemes at higher compression avoid blocking artefacts. Wavelet-based coding [17] is more robust under transmission and decoding errors, and also facilitates progressive transmission of images. In addition, they are better matched to the HVS characteristics. Because of their inherent multi-resolution nature [21], wavelet coding schemes are especially suitable for applications where scalability and tolerable degradation are important.

C. VQ Compression

A vector quantizer comprises of two operations. The first is the encoder, and the second one is the decoder. The encoder takes an input vector and outputs the index of the codeword that offers lowest distortion. In this scenario the lowest distortion is found by evaluating the Euclidean distance between the input vector and each codeword in the codebook. Once the closest codeword is found, the index of that codeword is sent through a channel (the channel could be communications channel, computer storage, and so on). When the encoder receives the index of the codeword, it replaces the index with the associated codeword.

The fundamental idea of VQ[23] for image compression is to establish a codebook comprising code vectors such that each code vector can represent a group of image blocks of size n × n, (n=4 is always used). An image or a set of images is first partitioned into m × m non overlapping blocks which are represented as m2-tuple vectors, called the training vectors. The size of training vectors can be very large. For example, a 512×512 image contributes 16,384 training vectors. The goal of codebook design is to establish a few representative vectors, called code vectors, from a set of training vectors. The encoding procedure is to look for a closest code vector in the codebook for each non overlapped 4×4 block of an image to be encoded. The most important work is to design a versatile codebook. Nasrabadi and King [24] give a good review of VQ. Chen's comparison [26] indicates that a codebook developed based on LBG [25] algorithm generally has higher PSNR values as compared to some other schemes despite its slow off-line training. In this paper, we adopt LBG algorithm for training a codebook of size 256×256 to meet a desired 0.5 bpp compression ratio.

D. Fractal Compression

Fractal image coding was introduced in the late 1980s and early 1990s. It is used for encoding/decoding images in Encarta/Encyclopaedia [27]. Fractal coding is based on the Collage theorem and the fixed point theorem [27] for a local iterated function system consisting of a set of contraction affine transformations [27]. A fractal compression algorithm first partitions an image into non-overlapping 8×8 blocks, called range blocks and forms a domain pool containing all of possibly overlapped 16×16 blocks, associated with 8 isometries from reflections and rotations, called domain blocks. For each range block, it exhaustively searches, in a domain pool, for a best matched domain block with the minimum square error after a contractive affine transform is applied to the domain block. A fractal compressed code for a range block consists of quantized contractivity coefficients in the affine transform, an offset which is the mean of pixel gray levels in the range block, the position of the best matched domain block and its type of isometry. The decoding is to find the fixed point, the decoded image, by starting with any initial image. The procedure applies a compressed local affine transform on the domain block corresponding to the position of a range block until all of the decoded range blocks are obtained. The procedure is repeated iteratively until it converges (usually in no more than 8 iterations). Two serious problems that occur in fractal encoding are the computational demands and the existence of best range-domain matches. The most attractive property is the resolution-independent decoding property. One can enlarge an image by decoding an encoded image of smaller size so that the compression ratio increases exponentially [27]. An algorithm based on using range and domain block matches of fixed sizes is written and is used for a comparison in this paper. Other algorithms using various block sizes of domain and range blocks associated with a quad tree structure can be found in.

VII. ADVANTAGES & DISADVANTAGES OF COMPRESSION ALGORITHM

There are some advantages and disadvantages of various algorithms which are shown in table below:

Method	Advantages	Disadvantages
Wavelet	• high compression ratio ratio • state-of-the-art	• coefficient quantization • bit allocation
JPEG (DCT)	• current standard	• coefficient quantization • bit allocation
VQ	• simple decoder • no coefficient quantization	• slow codebook generation • small bpp
Fractal	• good mathematical encoding frame • resolution-free decoding	• slow encoding

Method	Compression ratio	Appeared in
Wavelet	$\gg 32$	1992 [2] 1993 [17] 1996 [16]
JPEG (DCT)	≤ 50	1974 [1] 1993 [14]
VQ	< 32	1980 [12] 1989 [7]
Fractal	≥ 16	1992 [10] 1992 [8]

Table 2

VIII. EXPERIMENTAL COMPARISON

Image compression algorithms based on EZW [19], JPEG/DCT [14], VQ [26], and Fractal [27] methods were tested for four 256×256 real images: Lenna. The original images of Lenna are shown in Figure 3. The decoded images based on the four approaches are shown in Figures 4.

Fig 3: Original image of Lenna

(a) (b)

(c) (d)

Figure 4: Decoded Lennas by (a) Wavelet, (b) JPEG, (c) VQ, and (d) Fractal algorithms

IX. CONCLUSION

We have reviewed and summarized the characteristics of four up-to-date image coding algorithms based on Wavelet, JPEG/DCT, VQ, and Fractal approach. Experimental comparisons on four 256×256 commonly used images, Lennais shown. Any of the four approaches is satisfactory when only 0.5 bits per pixel (bpp) is requested. However, for a very low bit rate, for example 0.25 bpp or lower, the embedded zerotree wavelet (EZW) approach is superior to other approaches. For practical applications, we conclude that (1) Wavelet based compression algorithms [17, 18, 19, 20] are strongly recommended, (2) DCT based approach might use an adaptive quantization table, (3) VQ approach is not appropriate for a low bit rate compression although it is simple, (4) Fractal approach should utilize its resolution-free decoding property for a low bit rate compression, (5) Hybrid compression algorithms based on some of these four approaches may be pursued to achieve a higher compression ratio while preserving a better quality of up-to-date decoded images.

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