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Image Compression Using Wavelet Transform: A Literature

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Abstract:- With the development of good quality of image capturing device, it produces high resolution of images but they requires huge amount of storage space which creates problem during transmission and storage. Hence, the reduction of image size is necessary which will lessen the storage and improve the transmission capacity. Image processing plays an important role in image processing which reduces the image size efficiently without degrading the quality of image. Image compression is classified into categories namely: lossy and lossless image compression. There are various image compression techniques such as Run Length Encoding, DWT, DCT etc. In this paper, a comprehensive review on literature study of image compression by various authors is presented and also discusses the different compression techniques with their merits and demerits.

Keywords: - Image Compression, Lossy Compression, Lossless Compression, DCT, DWT

INTRODUCTION

Image compression is diminishing the size of a graphical file without degrading the quality of the image to an unsatisfactory level. The reduction in file size allows more images to be stored in a given amount of disk or memory space. It also reduces the time required for images to be sent over the Internet or downloaded from Web pages. The objective of image compression is to reduce the irrelevance and redundancy of image data. Image compression may be lossy or lossless. In case of lossless compression we can obtain the exact replica of original image by decompression. Lossless technique is used for the compression of binary data such as executables, documents etc. The binary data need to be exactly reproduced when decompressed. Run length coding, entropy encoding, LZW coding are the generally used loss less compression methods. But in most cases images need not be reproduced exactly, an approximation of the original image is enough .The error between the original and the compressed image is tolerable. This type of image compression is considered as lossy compression. Chromo sub sampling, transform coding are the generally used lossy techniques [1]. Two fundamental components of compression are redundancy and irrelevancy reduction. Redundancy reduction aims at removing duplication from the signal source (image/video). Irrelevancy reduction omits parts of the signal that will not be noticed by the signal receiver, namely the Human Visual System (HVS). In general, three types of redundancy can be identified:

Irrelevant Information

Most 2-D intensity arrays contain information that is ignored by the human visual system and extraneous to the intended use of the image. It is redundant in the sense that it is not used. Image compression research aims at reducing the number of bits needed to represent an image by removing the spatial and spectral redundancies as much as possible.

Coding

A code is a system of symbols (letters, numbers, bits, and the like) used to represent a body of information or set of events. Each piece of information or events is assigned a sequence of code symbols, called a code word. The number of symbols in each code word is its length. The 8-bit codes that are used to represent the intensities in the most 2-D intensity arrays contain more bits than are needed to represent the intensities.

Spatial and Temporal Redundancy

Because the pixels of most 2-D intensity arrays are correlated spatially, information is unnecessarily replicated in the representations of the correlated pixels. In video sequence, temporally correlated pixels also duplicate information.

In this paper, we present the comprehensive review of image compression technique and earlier work done by various researchers in this area using wavelet transform. The organization of the remaining section of paper is done as follows: Section II presents different image file format. In section III describes the related work done in the field of image compression. In section IV, various image compression techniques is discussing and last section gives overall conclusion of the research and future work.

IMAGE FILE FORMAT

There are various types of image file format which is described below:

JPEG

JPEG is short for Joint Photographic Experts Group, and is the most popular among the image formats used on the web. JPEG files are very 'lossy', meaning so much information is lost from the original image when you save it in JPEG file. This is because JPEG discards most of the information to keep the image file size small; which means some degree of quality is also lost.

As shown above, image compression is not that evident at first glance. But if you take a closer look, the JPEG image is not as sharp as the original image. The colors are paler and the lines are less defined and the picture is noisier. If you zoom in there are JPEG artifacts like any other JPEG files.

Fig.1.1 : JPEG Medium Compressed File

Pros of JPEG:

- 24-bit color, with up to 16 million colors
- Rich colors, great for photographs that needs fine attention to color detail
- Most used and most widely accepted image format
- Compatible in most OS (Mac, PC, Linux)

Cons of JPEG:

- They tend to discard a lot of data
- After compression, JPEG tends to create artifacts
- Cannot be animated
- Does not support transparency

GIF

GIF, short for Graphics Interchange Format, is limited to the 8 bit palette with only 256 colors. GIF is still a popular image format on the internet because image size is relatively small compared to other image compression types.

Fig.1.2: GIF image type

GIF compresses images in two ways: first, by reducing the number of colors in rich color images, thus reducing the number of bits per pixel. Second, GIF replaces multiple occurring patterns (large patterns) into one. So instead of storing five kinds of blue, it stores only one blue.

Fig.1.3: GIF image type

GIF is most suitable for graphics, diagrams, cartoons and logos with relatively few colors. GIF is still the chosen format for animation effects.

Compared to JPEG, it is lossless and thus more effective with compressing images with a single color, but pales in detailed or dithered pictures. In other words, GIF is lossless for images with 256 colors and below. So for a full color image, it may lose up to 99.998% of its colors.

One edge of the GIF image format is the interlacing feature, giving the illusion of fast loading graphics. When it loads in a browser, the GIF first appears to be blurry and fuzzy, but as soon as more data is downloaded, the image becomes more defined until all the date has been downloaded.

Pros of GIF:

- Can support transparency
- Can do small animation effects
- 'Lossless' quality–they contain the same amount of quality as the original, except of course it now only has 256 colors
- Great for images with limited colors, or with flat regions of color

Cons of GIF:

- Only supports 256 colors
- It's the oldest format in the web, having existed since 1989. It hasn't been updated since, and sometimes, the file size is larger than PNG.

BMP

The Windows Bitmap or BMP files are image files within the Microsoft Windows operating system. In fact, it was at one point one of the few image formats. These files are large and uncompressed, but the images are rich in color, high in quality, simple and compatible in all Windows OS and programs. BMP files are also called raster or paint images.
BMP files are made of millions and millions of dots called 'pixels', with different colors and arrangements to come up with an image or pattern. It might an 8-bit, 16-bit or 24-bit image. Thus when you make a BMP image larger or smaller, you are making the individual pixels larger, and thus making the shapes look fuzzy and jagged.
BMP files are not great and not very popular. Being oversized, bitmap files are not what you call 'web friendly', nor are they compatible in all platforms and they do not scale well.

Fig.1.4: BMP image type

Pros of BMP:

- Works well with most Windows programs and OS, you can use it as a Windows wallpaper

Cons of BMP:

- Does not scale or compress well
- Again, very huge image files making it not web friendly
- No real advantage over other image formats

TIFF

TIFF was created by Aldus for 'desktop publishing', and by 2009 it was transferred to the control of Adobe Systems. TIFF is popular among common users, but has gained recognition in the graphic design, publishing and photography industry. It is also popular among Apple users.

Fig.1.5: TIFF image type

The TIFF image format is easy to use with software that deals with page layout, publishing and photo manipulation via fax, scanning, word processing, etc. TIFF is very flexible, it can be lossy or lossless. TIFF is a rich format and supported by many imaging programs. It is capable of recording halftone image data with different pixel intensities, thus is the perfect format for graphic storage, processing and printing. This makes TIFF the superior raster image format.

Pros of TIFF:

- Very flexible format, it supports several types of compression like JPEG, LZW, ZIP or no compression at all.
- High quality image format, all color and data information are stored
- TIFF format can now be saved with layers

Cons of TIFF:

- Very large file size–long transfer time, huge disk space consumption, and slow loading time.

PNG

PNG or (Portable Network Graphics) is a recently introduced format, so not everyone familiar with it. But PNG has been approved as a standard since 1996. It is an image format specifically designed for the web. PNG is, in all aspects, the superior version of the GIF. Just like the GIF format, the PNG is saved with 256 colors maximum but it saves the color information more efficiently. It also supports an 8 bit transparency.

Fig.1.6: PNG image type

PNG was actually created for the intent to replace the GIF as an image format that doesn't require a patent license. PNG can support 24 bit RGB color images, grayscale images, both with and without alpha channels. RGB cannot support CMYK color spaces, and is not designed for print graphics.

Pros of PNG:

- Lossless, so it does not lose quality and detail after image compression
- In a lot ways better then GIF. To start, PNG often creates smaller file sizes than GIF
- Supports transparency better than GIF

Cons of PNG:

- Not good for large images because they tend to generate a very large file, sometimes creating larger files than JPEG.
- Unlike GIF however, it cannot be animated.
- Not all web browsers can support PNG.

RELATED WORK

Remya George, Manimekalai. M.A.P (2014). Proposed a novel image compression technique based on EZW (Embedded Zero Tree Wavelet Coding) algorithm is presented. EZW algorithm encodes the image to compress it into a bit stream of high accuracy. The proposed technique uses 6 symbols instead of 4 symbols used in Shapiro's EZW algorithm. This approach can produce higher PSNR and compression ratio than EZW algorithm, without affecting the computing time. In this approach the total no of bits required is also less than EZW algorithm.[1]

G. Bhoopathi, S. Arockiasamy (2011). Proposed a technique for image compression using modified Self-Organizing Map (SOM) based vector quantization. Self-Organizing Feature Map (SOFM) algorithm is a type of neural network model which consists of one input and one output layer. Each input node is connected with output node by adaptive weights. By modifying the weights between input nodes and output nodes, SOFM generate codebook for vector quantization. If the compression is performed using Vector Quantization (VQ), then it results in enhanced performance in compression than any other existing algorithms. Vector Quantization is based on the encoding of scalar quantities. The experimental result shows that the proposed technique obtained better PSNR value end also reduces Mean Square Error.[3]

Aldjia Boucetta and Kamal Eddine Melkemi (2012). Described a color image compression technique based on Discrete Wavelet Transform (DWT) and Genetic Algorithm (GA). High degree of correlation between the RGB planes of a color image is reduced by transforming them to more suitable space by using the GA. This GA would enable us to find T1T2T3 representation, in which T1 energy is more maximized than that of T2 and T3. The result of the proposed method is compared with previous similar published methods and the former is found superior in terms of quality of the reconstructed image. Further, proposed method is efficient in compression ability and fast in implementation.[4]

Ashwaq T. Hashim, Suhad A. Ali (2016). It is concerned with the design and implementation of a compression method for color image. This method based on Differential Pulse Code Modulation (DPCM), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) and Quadtree Coding Scheme. As a first step the DPCM technique is used to isolate blocks of an image into correlated and uncorrelated blocks. The isolated correlated blocks have been compressed using DCT based compression method then each block has been embedded with zeros on the original image. Each uncorrelated block has been compressed using DWT based method and put the compressed block in its location on the original image. Then, the result (i.e., the zeros blocks and compressed blocks with DWT) coded using Quadtree spatial coding. The output from DWT based and DCT based passed through shift coding stage to gain a possible further compression. The performance results of proposed hybrid algorithms produces better quality of image in terms of Peak-Signal-to-Noise Ratio (PSNR) with a higher Compression Ratio (CR) compared to standalone DCT or DWT. The PSNR values of the reconstructed images after applying proposed system are ranged from 30.62 to 40.95dB and CR on average, have been reduced to be around 1:19.6 of the size of the original image.[5]

G. Panda, Saroj K. Meher (2015) proposed a novel hybrid approach which would offer higher compression ratio than the WT alone keeping the quality of reproduced image identical in both cases. This is achieved with the incorporation of a second image compressor in sequence with WT so that the overall compression becomes better than the individual method. The second compressor used in the paper is based on Artificial Neural Network (ANN). The WT is employed to achieve the first stage of compression, which is followed, by a second stage of compression using the ANN technique. In the ANN technique both multi layered ANN (MLANN) and the radial basis function (RBF) networks have been proposed. The compression performance has been assessed in terms of peak-signal-to-noise-ratio (PSNR) and energy retained in the reconstructed image. Through computer simulation it has been demonstrated

that the combined approach offers high rate of compression maintaining identical reconstructed image quality compared to its WT counterpart.[6]

C.Vimalraj, S.Stebilin Blessia , S.Esakkirajan (2012) this scheme consists of three operations, which are the transform, quantization and entropy encoding operations. Wavelet Transform and Wavelet Packet Transform are efficient tools to represent the image. Wavelet Packet Transform is a generalization of Wavelet Transform which is more adaptive than the Wavelet Transform because it offers a rich library of bases from which the best one can be chosen for a certain class of images with a specified cost function. Wavelet Packet decomposition yields a redundant representation of the image. In this work, Singular Value Decomposition is used as a tool to select the best basis. After selecting the best tree, the coefficients of the best tree are quantized using dead zone quantization. To reduce the number of bits required to transmit the indexes of the codeword, a lossless Huffman algorithm was implemented as the final stage of the encoding process. To reconstruct the compressed image, the operations are reserved. The simulation result reveals that, the quantity of the image is good even though the compression ratio is increased due to reduction in Wavelet Packet sub-bands.[7]

U. S. Ragupathy, D. Baskar, A. Tamilarasi (2008). The wavelet based Set Partitioning In Hierarchical Trees (SPIHT) algorithm gives better compression. For best performance in image compression, wavelet transforms require filters that combine a number of desirable properties, such as orthogonality and symmetry, but they cannot simultaneously possess all of these properties. The relatively new field of multiwavelets offer more design options and can combine all desirable transform features. But there are some limitations in using the SPIHT algorithm for multiwavelet coefficients. This paper presented a new method for encoding the multiwavelet decomposed images by defining coefficients suitable for SPIHT algorithm which gives better compression performance over the existing methods in many cases.[8]

K. Kalaivani B. E, C. Thirumaraiselvi M.E, R. Sudhakar(2013). An algorithm based on Kohonen's self organizing maps is proposed in this paper for quantising the image data. This algorithm uses its roots in neural networks based on neighbourhood relationships. Wavelet transform is also a cutting edge technology in the field of image compression. This provides substantial improvement in picture quality at high compression ratios. Experimental results obtained demonstrate the effectiveness of the proposed algorithm.[9]

Murat CANAYAZ, Ali KARCI (2015). A new approach can be using at image compression process will be introduced. Firstly, image subjected to discrete wavelet transform for extracting feature. Then multi-level threshold values will be finding with Shannon entropy in the obtained image. The maximum value of objective function will be obtained with the help of cricket algorithm at the threshold values finding step. This algorithm is a meta-heuristic algorithm that based on population. The threshold values that obtained through algorithm using to compressing the images will be provided. At the end of the study, the image compression ratio, the proposed approach running on a standard test image will be given.[10]

IMAGE COMPRESSION TECHNIQUES

Digital Data Compression can also be made potential as most of the real world data is very superfluous. It is basically defined as a system that dwindle the size of data by applying unusual methods that can be either be Lossless or Lossy [11]. It is an imperative application in the areas of data transmission and data storage although the large ability storage devices are existing these days. Therefore, we need a proficient way to accumulate and broadcast dissimilar types of data such as text, image, audio and video to reduce execution time and memory size. There are two types of data compression techniques:

- Lossless Data Compression
- Lossy Data Compression

Lossless Data Compression

Lossless compression means when the data is decompressed, the result is a bit-for-bit perfect match with the original one.

The name of lossless means no data is lost, the data is only saved more efficiently in its compressed state, but nothing of it is removed [12]. Lossless data compression methods may be categorized according to the type of data they are designed to compress. Compression algorithm algorithms are basically used for compression of text, images and sound. The example of lossless compression is RLE, Predictive Coding and Multi-resolution Coding etc.

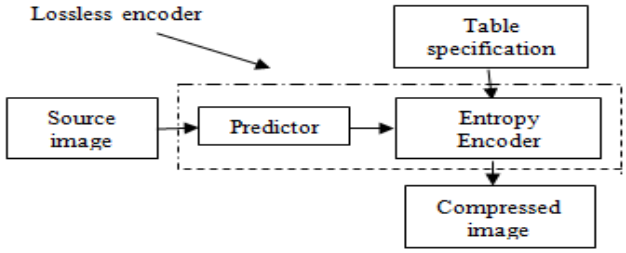

Fig.1.7: Lossless Compression[17]

Run Length Encoding

Run length coding replaces data by a (length, value) duo, where "value" is the recurring value and "length" is the quantity of repetitions. This method is especially winning in compressing bi-level images since the happening of a long run of a value is unusual in usual gray-scale images. A resolution to this is to decay the gray-scale image into bit planes and compress individual bit-plane separately. Efficient run-length coding technique is one of the variations of run length coding [13].

Predictive Coding

Lossless predictive coding (PC) predicts the value of every pixel by utilizing the values of its adjoining pixels. Consequently, each pixel is encoded with a prediction error somewhat than its actual value. Usually, the errors are a lot minor compared with the actual value so that fewer bits are obligatory to store them. DPCM (differential pulse code modulation) is a predictive coding based lossless image compression scheme. It is too the base for lossless JPEG compression. A variation of the lossless predictive coding is the adaptive prediction that divides the image into blocks and calculates the prediction coefficients separately for every block to attain high prediction performance. It can to be combined with other scheme to get a hybrid coding algorithm with superior performance.[14]

Multi-Resolution Coding

HINT (hierarchical interpolation) is a multi-resolution coding method based on sub-samplings. It begins with a low-resolution edition of the actual image, and interpolates the pixel values to consecutively generate superior resolutions. The errors among the interpolation values and the real values are stored, along with the first low-resolution image. Compression is attained since both the low-resolution image and the error values can be stored with lesser bits than the actual image. Laplacian Pyramid (LP) is an additional multiresolution image compression scheme developed by Burt and Adelson. It consecutively constructs inferior resolution editions of the actual image by down sampling so that the number of pixels reduces by a factor of two at every scale. The differences amongst consecutive resolution versions jointly with the lowest resolution image are stored and utilized to wholly reconstruct the actual image. But it cannot attain elevated compression ratio because the number of data values is improved by 4/3 of the actual image size. In general, the image is reversibly altered into a set of dissimilar resolution sub-images in multiresolution coding. Generally, it decreases the entropy of the image. Some kinds of tree representation could be worn to get more compression by exploiting the tree formation of the multiresolution methods.[14]

Lossy Data Compression

Lossy compression technique is especially suitable for natural images such as photos in application where minor loss of fidelity is acceptable. Lossy scheme is widely used must application. Fig shows the outline of lossy compression technique. Transformation is applied to the original image. The discrete wavelet transform cut the images into block of 64 pixels (8*8) and process each block independently, shifting and simplifying the colors so that there is less information to encode. Then the quantization process result in loss of information. In the quantization the value in each block are divided by a quantization coefficient.

This is the compression step where information loss occurs. Pixels are changed only in relation to the other pixel with their entropy coding is applied after quantization. The reduced coefficients are then encoded usually with entropy coding. The decoding is a reverse process. In the decoding process firstly entropy encoding is applied to compress data to get the quantized data after that dequantized is applied to it and finally the inverse transformation is applied to get the reconstructed image by this scheme the decompress image is not identical to the original image but reasonable close to it. This scheme provides much higher compression ratio than lossless scheme. There are the following major performance consideration of lossy scheme include: Compression ratio, Signal to noise ratio and Speed of encoding and decoding Lossy compression technique include following scheme such as Transformation coding, Vector Quantization, Fractal coding, Block truncation coding, Sub band coding etc.[15]

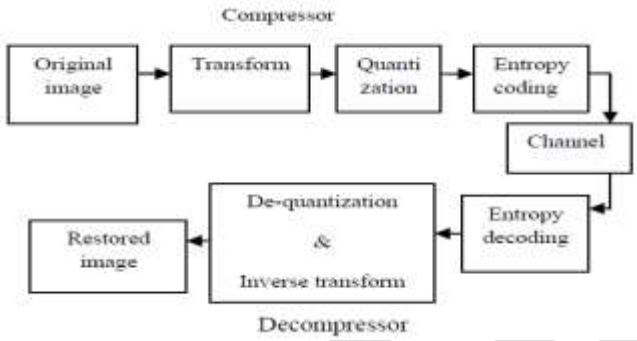

Fig. 1.8: Lossy Image compresseion

Transform Coding

Transformation coding (TC) is a lossy compression technique resulting in a lower quality copy of original signal. This scheme is used for „natural" data like audio signal or biomedical image. In transformation coding less bandwidth is required. In this coding scheme transform such as DFT (discrete Fourier transform0 and DCT (discrete coding transform) are used to change the pixel in the original image into frequency domain coefficients. These coefficients have several desirable properties; one is the energy compression property that results in most of the energy of the original data being concentrated in only a few of the significant coefficients are selected and remaining is discarded. The selected coefficients are further quantization and entropy encoding. DCT coding has been the most common approach to transform coding and also adopted in the JPEG image compression standard.

Vector quantization

In vector quantization (VQ) a dictionary of fixed-size vectors, is to be develop, called code vectors. A vector is usually a block of pixel values. So image is then partitioned into non-overlapping blocks (vector) called image vectors. Subsequently, for each in the dictionary is determined and its index in the dictionary is used as the encoding of the original image vector. Thus each image is represented by a sequence of indices that can be further entropy coded.

Fractal Coding

In fractal coding (FC) decompose the image into segments by using standard image processing techniques such as edge detection, color separation, and spectrum and texture analysis. Then each segment is looked up in a library of fractals. The library actually contains codes called iterated function system (IFS) codes, which are compact sets of numbers. Using a systematic procedure, a set of codes for a given image are determined, such that when the IFS codes are applied to a suitable set of image blocks yield an image that is a very close approximation of the original. This scheme is highly effective for compressing images that have good regularity and self-similarity.

Block truncation coding

The principle applied here is that the image is divided into non overlapping blocks of pixels. The mean of the pixel values in the block (threshold) and reconstruction values are determined for each block. Then a bitmap of the block is created by replacing all pixels whose values are greater than or equal (less than) to the threshold by zero or one. Then for each segment (group of 1s and 0s) in the bitmap the renovation value is strong-minded. This is the average of the values of the corresponding pixels in the original block.

Sub Band Coding

In the sub band coding the image is analyzed and find the components containing frequencies in different bands, the sub bands. Then the quantization and coding are performed for each sub-band. The main advantage of this coding is that quantization and coding for each sub-band can be designed separately.

Discrete Cosine Transform

A discrete expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies. Discrete Cosine Transform is a lossy compression technique which is widely used in area of image and audio compression. DCTs are used to convert data in the summation of series of cosine waves oscillating at different frequencies. There are very similar to Fourier Transforms, but DCT involves use of Cosine functions and real coefficients, Fourier Transforms use both sine and cosine functions are much more efficient as fewer functions are needed to approximate a signal. Both Fourier a spatial domain into a frequency domain and their respective functions converting thing back.[16]

Table 1: Advantages and Disadvantages of Compression Techniques

Methods	Advantages	Disadvantages
RLE	This technique is simple to implement and does not necessitate much CPU horsepower and also reduces the amount of hardware required.	RLE compression is only proficient with files that contain lots of repetitive data. It only support for white or black regions of image data compression.
PC	It provide effective and accurate output parameter which is efficient to operate	It makes the low bit rate speech coder a practical reality. But this model is also inaccurate in many circumstances, creating annoying artifacts.
LP	It requires less computation cost to implement it. It is efficient to compute: indeed pyramid filtering is faster than the equivalent filtering done with a fast Fourier transform. It is very fast algorithm	It provides the inherent oversampling and complex in designing
TC	This compression technique is more robust under transmission and decoding errors and also very efficient at very low bit rates. This scheme also provides higher compression avoiding blocking artifacts.	It is shift sensitivity, poor directionality and requires more storage and bandwidth.
VQ	Simple decoder No-coefficient quantization	Slow codebook generation Small bpp
FC	Good ,mathematical Encoding-frame	Slow Encoding
SBC	It is advantageous to choose the representative. It provides the shorter codeword length, even though its associated distortion might be slightly larger. Since there are more bits	it is unstructured due to this behaviour it require more time in execution and computation cost is more

	remaining, the resulting overall distortion will be smaller.	
DCT	It is real valued, battery energy compaction, and coefficient are nearly correlated.	Truncation of higher spectral coefficients results in blurring of the images, especially wherever the details are high and Coarse quantization of some of the low spectral coefficient introduces graininess in the smooth portions of the images

CONCLUSION

Image compression is the serious issue now days due to the development in multimedia technology whose image, audio/ video size of is very large. So reduction of size is very essential which reduce the storage cost and improves transmission of such data. Various techniques have been developed for the size reduction of this multimedia file format. In this, we presented the various image file format and different image compression techniques with advantage and disadvantages. Some are helpful in reducing the compression ratio but all are not much suitable in reducing the size of multimedia file and also degraded the quality of images. In future need to design hybrid compression technique which uses the effective feature of lossy and lossless compression both and comparatively reduces the huge size of multimedia file.

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