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Review Article

IMAGE COMPRESSION USING WAVELET BASED CODING TECHNIQUES: A REVIEW

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A R T I C L E I N F O

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A B S T R A C T

Multimedia information and digital nature data has increased drastically within few span of years tend to make a necessity of image compression as it reduces the irrelevant and redundant data for the transmission. Over the last two decades, image compression based on wavelet has been developed and this method has the advances of bit-level and continuous compression, supercilious low-bit rate performance, lossless and lossy image compression, transmission by pixel in progressive manner high resolution, increase in compression ratio. The highest perceptual quality and lowest error per compression rate are achieved by Embedded Zerotree Wavelet algorithm; Set Partitioning in Hierarchical Tree, Set Partitioned Embedded Block algorithm, Wavelet Difference Reduction and the Adaptive Scanned Wavelet Difference Reduction algorithms are scrutinized in this paper.

INTRODUCTION

Digitized era has played a big role to make availability of large data (images, videos and audio) requires high storage capacity and transmission bandwidth. Despite the speed of processor, rapid progress in storage media, cost of system; bandwidth of transmit data continues to outperforms the capability of existing technologies. The abundance of data available due to multimedia-base web applications required efficiently encoders and compression techniques for images and audio files [2] [5]. Compression is classified as lossy and lossless compression; the reorganised data is perceptual good quality that is lossy compression whereas reorganised data is replica of original data called lossless compression [23]. The main motive of image compression is to achieve a high visual quality of decompressed images and to gain a very low bit rate. The basic techniques of video compression are based on the schemes of still grey level image compression and colored image compression. Image compression has used all fields of media communication such as digital image processing, medical image recognition, multimedia.

In recent years, many different algorithms suggested and normalized for compression. Joint Photographic Experts Group (JPEG) is standard for still images [20] and Motion Pictures Expert Group (MPEG) is standard for videos images [21]. JPEG and MPEG are Discrete Cosine Standard (DCT) based standards [22]. At low bit rates, DCT works systematically.

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The drawback of DCT is it cannot décor-relate the blocks at the boundaries. Thus Discrete Wavelet Transform (DWT) has been developed. DWT performs better than DCT. At low bit rates, high compression quality provides by DWT [19]. DWT localized on both time and frequency. An image is represented on the different resolution by DWT. In this paper, several wavelet-based image compression algorithms are discussed. These algorithms include Embedded Zero-tree Wavelet [8], Set Partitioning of Hierarchical Tree [11], Set Partitioning Embedded Block [14], Wavelet Difference Reduction [15] and Adaptive Scanned Wavelet Difference Reduction [16]. These algorithms support to take decision for selecting a compression techniques so that we get are desired results.

Image Compression

Image compression basically decrements in image size by minimizing the number of bits required for image representation. Originally image compression was started in 1970; initially, it is obtained by mathematical transformations and quantization with encoding techniques. Original image contains information which we do not want to loss and also want to represent an image in lesser number of bits.

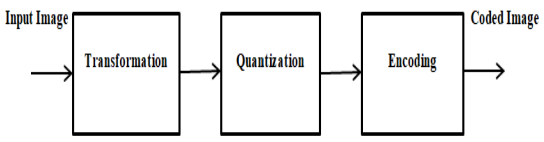

Fig 1 Block diagram of image compression system

This objective is obtained by the process of image compression [1]. Figure 1 represents the block diagram of

image compression system; consists of three basic steps i.e. transformation, quantization and encoding which are required for the accomplishment of basic process of image compression [2]

Transformation: Transformation is the most important part of image compression system. The main motive of transformation is the de-correlation of input pixels. It should reduce the size of resultant data set as compared to original data set. In the technical field, these transformation methods are named as mapping [2]. There are various transformation techniques Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), Karhunen Loeve Transform (KLT), Modified Hermite Transform (MHT), and Wavelet transform. In the field of research, transform selecting process is still active [2].

Quantization: The process in which continuous set of values are imprecised into small set of values in the image data is known as quantization. In thresholding process, if the sample value is less than the threshold value then the sample is eliminated whereas, in quantization process, the quantization factor is used to scale each sample. There is more loss of information if the value of the threshold is high. Quantization is a process of approximation [2]. Psycho-visual redundancy is reduced by quantization process. Data is compressed by eliminating some of the information thus, it is an irreversible operation. Quantize block uses in lossy compression and eliminated in the case of lossless compression. Two basic types of quantization: Scalar quantization (SQ) and Vector quantization (VQ). SQ performs on each individual value whereas VQ performs on a group of values together. Shannon [3] results showed that VQ is better than SQ as it gives result in low bit rate.

Encoding: Using entropy encoding, redundancy is removed from the output of quantizer by removing repeated bit pattern. Commonly used entropy coders are Huffman Coding, Arithmetic Coding, Run Length (RL) Coding and Lempel-Ziv-Welch (LZW) Coding [4]. The reverse operation of encoding step is known as decoding process in which de-quantization step is exception as it cannot reverse exactly [2].

Principles behind Compression

The very common part in major of the images is co-relation among neighbouring pixels tend to have redundant information. The main motive is to get less correlated data of the images in order to reduce redundancy and irrelevant information. Signal source (video/image) which has some duplication should be reduced which is also the main aim of the redundancy reduction whereas; a signal receiver should not notice some of the parts of the signal which should be eliminated with the help of irrelevancy reduction [5]. Generally [5], redundancy can be classified into three types:

- Correlation between neighboring pixels intensities – Spatial Redundancy
- Due to correlation between different color planes – Spectral Redundancy

Error Metrics

MSE i.e. Mean Square Error and PSNR i.e. Peak Signal to Noise Ratio is the two error metrics which are used to compare various image compressions. Error between original image and compressed image should also be measured with the help of two factors which are MSE and PSNR. To minimize the MSE and maximize the PSNR for good quality of decoded images most image compression systems are designed [5]. The mathematical formulae of MSE and PSNR are:

error E = original image – compressed image (1)
MSE = E/ size of image (2)
PSNR = 20* log (255/ √MSE) (3)

Wavelet

The wavelet-based image compression has obtained much popularity because it localized on both time and frequency and is more secured among a variety of other new algorithms that developed for image compression [2, 19, 25]. Wavelet-based coding gives high compression ratio with the useful improvements in image quality [6]. In the single algorithm, integration of various compression techniques is allowed by wavelet compression. A wavelet analysis is known as competent approach in which coefficient are approximated to represent image or signal. The direction of pixel value is shown by approximating wavelet coefficient in analysis of one level image and diagonal, horizontal and vertical details are shown in three detailed coefficient. With rise in number of wavelet coefficient compression ratio also rises. Practically, wavelet coefficient is needed in fewer numbers to represent images, Haar and Daubechies are two family of DWT. After decomposition, the original image is recovered in lossless compression [5]. In wavelet, horizontal data is filtered at every level of decomposition and from this approximation and details are produced on columns. In below figure, approximate details, vertical details, horizontal details and diagonal details are the four sub-images obtained at each level [7].

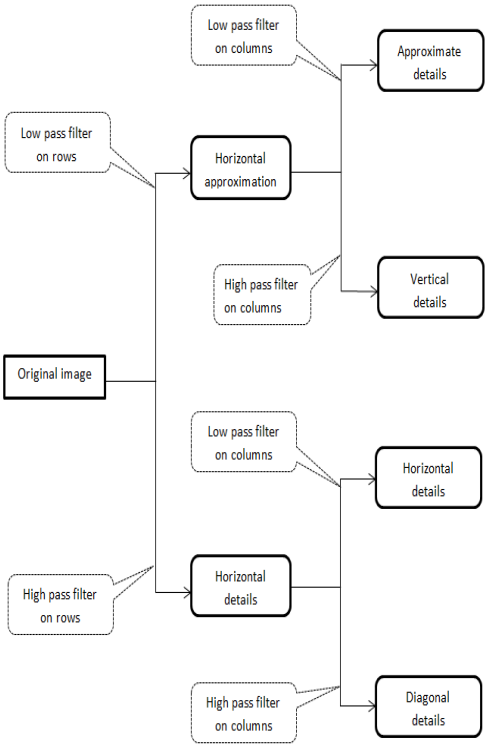

Fig 2 Decomposition of images using wavelet

Various Coding Methods of Wavelet Coefficients

Over the past few years, image compression has been purposed number of wavelet-based schemes. Some of the schemes are Embedded Zero Tree Wavelet, Set-Partitioning in Hierarchical Trees, Set Partitioned Embedded Block Coder, and Embedded

Block Coding with Optimized Truncation, Wavelet Difference Reduction, and Adaptively Scanned Wavelet Difference Reduction [2].

Embedded Zero Wavelet (EZW)

Wavelet-based image compression's full power was firstly shown by EZW. Shapiro [8] ground-breaking paper introduced this. To show the usage of a wavelet transform, EZW encoder was introduced. Originally, this technique operated on 2D signals but other dimensional could also be used. Progressive encoding is that in which EZW encoder in based for the compression of an image with increasing accuracy into bit streams. This meant that more details will be contained in the decoded image if more bits will be added to the stream. E in EZW was explained by embedded encoding which was also another name of progressive encoding [8].

Table 1 PSNR and Compression ratio for Lena and Barbara images using EZW

Bit rate	Compression ratio	PSNR	
		Lena images	Barbara images
1.0	8:1	39.55	35.14
0.5	16:1	36.28	30.53
0.25	32:1	33.17	26.77

A. Ouafi [9] approached modified EZW. In the MEZW algorithm, six symbols are used instead of four symbols used in original EZW algorithm. Without affecting the computing time, PSNR and compression ratio obtained by Shapiro was improved by this algorithm.

Table 2 PSNR and Compression ratio for Lena and Barbara images using MEZW

Bit rate	PSNR	
	Lena images	Barbara images
1.0	40.64	36.77
0.5	36.93	31.41
0.25	33.20	27.23

D Vijendra Babu and Dr. N.R Alamelu [10] had presented Enhanced Image Compression method uses a partial EZW (P-EZW) algorithm. The use of partial EZW algorithm was to overcome the problem in EZW that losses efficiency while transmitting lower bit planes. As compared to EZW algorithm, the P-EZW algorithm is better in both lossy as well as lossless coding. P-EZW shows good result in medical images.

Table 3 PSNR and Compression ratio for medical images using P-EZW

Image	PSNR	Compression ratio
MRI	37	12
CT	36.1	20

Set Partitioning In Hierarchical Tree (SPIHT)

SPIHT is the high improved version of EZW. Amir Said and Pearlman, W. A [11] realize this method consist matched coding and decoding algorithm. An embedded bit stream produces by this image compression algorithm. Thus, various bit rates mean square error extracted best-reconstructed images. Simple quantization algorithms, high PSNR, good image quality are some of the features of SPIHT. It could be seen that increase in decomposition level, root levels were the one on which higher magnitude coefficients concentrated. With this compression ratio also increases. But one disadvantage with this is decreased resolution of the reconstructed image.

Table 4 PSNR for Lena images using SPIHT

Bit rate	PSNR
0.5	37.2
0.25	34.1
0.15	31.9

Rania Boujelbene *et al*. [12] purposed an optimal spline wavelet transform depended efficient codec image compression and revamped SPIHT algorithm Peak signal-to-noise ratio, structural similarity index measure and encoding time are used for evaluation purpose. The obtained results prove the efficiency and the speed of the proposed codec.

Table 5 PSNR for Lena and Barbara images

Bit rate	PSNR	
	Lena image	Barbara image
1.0	40.2	36.62
0.75	38.99	34.59
0.5	37.2	31.69
0.25	34.08	27.5

Meng-Ju Shih *et al*. [13] used modified SPIHT algorithm in their paper because the traditional SPIHT algorithm was not suitable for the design of wearable devices. Two reasons for this unsuitability are low storage and time- consuming nature. This modified SPIHT was based on quantized wavelet coefficients' bit-plane. Tree data structure was used to represent the bit plane which consisted of two types of primitive trees. Logic-level decisions are the ones in which the simplification of assembly rules is done in terms of a flag scheme. Advantages of algorithm are that it is simple, modular and regular.

Set Partitioned Embedded Block Coder (SPECK)

SPECK is one of the successive algorithm need for reducing the number of bits. William A. Pearlman, Asad Islam *et al*. [14] introduced Set Partitioned Embedded block coder's. The main motive in hierarchical structures of transformed images is to take advantage of the clustering of energy in frequency and space. In this, a subband transformation is used to transform any image. Mostly the discrete wavelet transform is used. The hierarchical pyramidal structure is used to represent a transformed image. The structure is described on the basis of decomposition and the root of the structure is the topmost level. The topmost level has rough images while finest images are at bottom level. Less complexity, less memory requirement, high efficiency and fast processing are some the features of SPECK

Table 6 PSNR for Lena and Barbara images using SPECK

Bit rate	PSNR	
	Lena images	Barbara images
1.0	40.25	36.49
0.5	37.10	31.54
0.25	34.03	27.76

Xiaoli Tang *et al*. [18] a low complexity, embedded, block-based, image wavelet transform coding algorithm was discussed in this paper. Modified the Set Partitioned embedded Block (SPECK) embedded coding algorithm and expanded to three dimensions. They performed a comparison of loosy implementation with 3D-SPIHT and JPEG2000 algorithm. In

addition to being flexible, highly competitive and better compression efficiency 3D-SPECK was better than JPEG2000.

Table 7 Comparison between 3D-SPECK and JPEG-2000

SNR(db)	3D-SPECK	JPEG-2000
0.1	19.702	18.246
0.5	31.750	29.813
2.0	45.997	43.369
4.0	52.361	51.963

Wavelet Difference Reduction (WDR)

The position of significant coefficients is implicitly located is the major drawback of the SPIHT algorithm. Tian And Wells [15] [16], purposed Wavelet Difference Reduction algorithm. WDR suits low-resolution medical images at the low bit rate. At high compression ratio, WDR produces better image quality but not produce higher PSNR value as compared to SPIHT algorithm. Unlike SPIHT algorithm, there is no need of searching through quadtree.

Table 8 PSNR for Lena and Barbara images using WDR

Bit rate	PSNR	
	Lena images	Barbara images
0.5	36.45	30.68
0.25	33.39	26.87

Adaptive Scanned Wavelet Difference Reduction (ASWDR)

ADWDR is the improved version of WDR. James S. Walker [16] discussed Adaptive Scanned Wavelet Difference Reduction method. With ROI capability, an embedded bit stream produced by ASDWR method. As compared to WDR and SPIHT, ASWDR method shows the compressed image with better quality, especially in low bit rate. All WDR features include: Low complexity, ROI capability, embeddedness and progressive SNR are preserved by ASWDR.

Table 9 PSNR for Lena and Barbara images using ASWDR

Bit rate	PSNR	
	Lena images	Barbara images
0.5	36.64	30.87
0.25	33.64	27.03

S.P.Raja and Dr. A. Suruliandi [17] compared two image compression techniques based on wavelet. The comparison of WDR & ASWDR performed with DD 2+2,2 Wavelet Transform and Daub 9/7 Wavelet Transform. PSNR, MSE, and SNE are the parameters used to compare the result. As compared to WDR, the experimental result shows higher PSNR value and lower MSE value for the ASWDR compression. Thus, ASWDR is better compression technique than WDR

Table 10 PSNR values for WDR and ASWDR compression with DD 2+2,2 wavelet transform and daub 9/7 wavelet transform

Images	WDR DD 2+2,2	WDR Daub 9/7	ASWDR DD 2+2,2	ASWDR Daub 9/7
Lena	27.61	28.22	27.80	28.49
Camera man	26.04	27.18	26.50	27.42
Baboon	22.20	22.11	22.11	22.97
Boat	28.79	28.91	28.91	29.79

Table 11 MSE values for WDR and ASWDR compression with DD 2+2, 2 wavelet transform and daub 9/7 wavelet transform

Image	WDR DD 2+2,2	WDR Daub 9/7	ASWDR DD 2+2,2	ASWDR Daub 9/7
Lena	10.61	9.89	10.37	9.59
Camera man	12.70	11.14	12.05	10.84
Baboon	19.78	18.18	19.98	18.09
Boat	9.26	8.47	9.14	8.25

Each techniques discussed above has its own advantages. In below table, features and drawback of each wavelet coding technique discussed.

Types	Features	Drawback
EZW	• fast and effective method for symbols' entropy coding strings • Provides compact multiresolution	• Coefficient • Position's transmission is • missing • imaginary • Compression • accompanied by • arithmetic • encode
SPIHT	• Reconstructed images are of good quality, high PSNR • Optimized for progressive image transmission • Embedded coded file is produced • Simple algorithm • Decoding/coding is fast	• Excess memory • requirements • due to 3 lists • Single • bits is used to form transmitted • information • Suitable for variety of natural images • Perceptual • quality
SPECK	• Completely embedded • Employs progressive transmission • Low computational complexity • Fast encoding/decoding • Low dynamic memory requirements • High efficiency	
WDR	• ROI theory used. • Significant wavelet • transform values location encoded • Better perceptual image • quality than SPIHT • At low bpp rate low resolution medical images are supported • Less complex	SPIHT PSNR value higher than WDR
ASWDR	• Refined scanning order and encodes more remarkable values than WDR • Perceptual image quality and PSNR are better • Slightly higher edge • correlation values than WDR • Fine details are conserved	

CONCLUSION

Image compression based on wavelet is very powerful and most useful technique. In this paper, we discussed different wavelet-based image compression techniques. If only PSNR is examined then out of all analysed techniques, ASWDR has 33.64 PSNR at 0.25 bit level with lena images which is the highest. But if Barbara images are compressed then SPECK has the highest PSNR i.e. 27.76 at same bit level. Other

techniques have less PSNR than these but every technique has its own unique characteristics used for different applications. Further, we have to improve various schemes so that we obtained higher PSNR value and compression ratio.

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