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Performance Analysis of Wavelet Families for Image Compression

Amrut N. Patel, Ravindra M. Patel, D. J. Shah
Asst. Professors, U.V.Patel College of Engineering, EC department, Kherva
M.Tech student, U.V.Patel College of Engineering, EC Department, Kherva

Abstract*— Image compression defines as reducing the amount of data required to represent digital image. In recent time, wavelet transforms has emerged as a popular technique for image compression. The wavelet transform can be composed of any function that satisfies requirements of multiresolution analysis. It means that there exists a large choice of wavelets depending on the choice of wavelet function. The wavelet transform has high decorrelation and energy compaction efficiency. This paper presents a comparative study of various wavelet families for image compression and tests the results in terms of compressed image quality and mean square error (MSE). We have examined and compared various wavelet families such as Haar, Daubechies, Symlets, Coiflets, Biorthogonal and Reverse Biorthogonal using variety of test images. The results are measured in terms of MSE, CR and PSNR considering as subjective quality measures.

***Index Terms*— Image compression, Wavelet transform, Wavelet families, PSNR.**

I. INTRODUCTION

Image compression defines as reducing the amount of data required to represent digital image. However, image information contains a large of information, which brings a lot of difficulties for storage, processing and transmission. Thus image compression is very importance and necessity. There are two way to image compression (1) lossless compression and (2) lossy compression. Lossy image compression algorithms are applicable whenever the exact reconstruction of an image is not expected. These algorithms are usually based on transform methods. In recent years, a considerable effort have been made to design image compression method in which the main goal is to obtain good quality of decompressed images even at very low bit rates. Due to the great use of digital information, image compression becomes imperative in different areas such as image storage, transmission and processing. At these areas the representation of the information needs to be efficient. The goal of image coding is to reduce the bit rate for signal transmission or storage while maintaining an acceptable image quality for different purposes. A digital image is mainly composed by: edges, edge associated details and textures, and this three parts are very important in reconstructing an image. So in image compression, it is very necessary to preserve this information to get a good quality of reconstructed image. How to save these parts of an natural scene image by using a small description is a question that considered by many researchers. The Discrete Cosine Transform has attracted widespread interest as a method of information coding. The ISO/CCITT Joint Photographic Experts Group (JPEG) has selected the DCT for its baseline coding technique [2]. The fidelity loss in JPEG coding occurs entirely in quantization and much of the compression is gained by run length coding of coefficients which quantize to zero. Methods for determining the quantization table [3] are usually based on rate-distortion theory. These methods do achieve better performance than the JPEG default quantization table. However, the quantization tables are image-dependent and the complexity of the encoder is rather high. WT has attracted wide spread interest as a method of information coding [4]. JPEG-2000 has selected the WT for its baseline coding technique [5]. Wavelets provide good compression ratios, especially for high resolution images. Wavelets perform much better than competing technologies like JPEG [4], both in terms of signal-to-noise ratio and visual quality. Recently, Discrete Wavelet Transform (DWT) has emerged as a popular Technique for image compression applications with excellent compression performance. Therefore, much of the research activities in image compression have been focused on the discrete wavelet transform. Discrete wavelet transform can be efficiently used in image compression applications Wavelet transform (WT) of an image represents image as a sum of wavelets on multi-resolution levels. Multiresolution analysis is implemented via high-pass filters (wavelets) and low-pass filters (scaling functions). In wavelet transform any one-dimensional function is transformed into a two-dimensional space, where it is approximated by coefficients that depend on time (determined by the translation parameter) and on scale, (determined by the dilation parameter). The zoom phenomena of the WT offer high temporal localization for high frequencies while offering good frequency resolution for low frequencies. Hence, the wavelet transform is well suited to image compression. The choice of wavelet will affect wavelet transform coding system design and performance. The type of wavelet transform will directly impact on of the complexity of the calculation and, indirectly, affect the image compression and reconstruct the image with an acceptable error. When the wavelet transform with a scale function, the transformation can be achieved through a series of digital filters. In addition, wavelet make information focus on the less wavelet transform coefficients decides on using the wavelet compression and reconstruction capacities.

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II. METHOD OF IMAGE COMPRESSION

A. The possibility of image compression

Image information can be compressed depend on the follow characteristics: (1) Image information has a strong correlation in spatial domain;(2)The image is composed of significant low-frequency information and few high frequency information in frequency domain; (3)people's eyes show visual inert when people are watching something. So we can remove some of the information that can't damage image quality

B. Concept of irrelevance

The concept of irrelevance is applied to that information which is unnecessary for the exact reconstruction of an image. There are two different kinds of irrelevance: (1) Visual irrelevance, if the image contains details that cannot be perceived by human eye.(2)Irrelevance due to the fact that, for specific applications (for instance medical and military ones), only some specific regions of the image may be of interest rather than the image in its wholeness. Therefore, those parts that do not belong to the region of interest are classified as irrelevant [6].

C. The method of image compression

According to the error which between original image and reconstructed image after decompression, the classification of image compression in coding which can be composed Lossy coding and nondestructive coding. The lossy coding removes independent information as possible and reserve significant information only. So the image of reconstruction can't accurately approximate the original image. The coding method is widely used in signal compression of ordinary images. Nondestructive image compression only remove redundant image information .It can precisely reconstruct the image as original image. This method is applied in special images which are in high quality. (2) According to the principle of coding, which can be divided into entropy coding, forecast coding, transform coding, hybrid encoding. Entropy coding employs the coding technology of statistical characteristics of the signal. It is attributed to nondestructive image compression. On the basis of image redundancy characteristics of space and time, forecast coding use the known pixels values of adjacent to predict the current pixels, and then quantize and code. Transform coding changes the image information of airspace into another domain. The correlation between the image coefficients is reduced greatly after transform coding. Hybrid encoding mixes several kinds of coding methods which are introduced above.

III. WAVELET TRANSFORM OF IMAGES

Morlet who was a French scientist proposed the theory of wavelet analysis in 1980.The theory of wavelet analysis make remarkably achievement after decades of development. Wavelet transform belongs to transform coding. Wavelet transform is provided with excellent characteristics in special and frequency domain, multi-resolution, low complexity in time and so on. Base on the excellent characteristics, wavelet transform is suitable for processing non-stationary signal particularly. Because digital image signal is a typical non stationary signal, so wavelet transform is widely used in the field of image information processing. JPEG2000 which is the standards of international image coding is adopted the method of wavelet transform coding. A Wavelet is a foundation for representing images in various degrees of resolution. Wavelet transforms is just the representation of functions by a wavelet, which is a mathematical function, dividing the function into various frequency component matching the resolution. Wavelet transformation methodology has been used because of the disadvantages in Fourier Transformation [12]. A wavelet transformation has been classified as discrete wavelet transforms (DWTs) and continuous wavelet transforms (CWTs). A wavelet is represented as multi resolution level where each analysis is implemented through high pass and low pass filters, where each high pass filter is passed on wavelets and low pass filters is based on scaling functions. The wavelet transform function is based on the conversion of one dimensional function into two dimensional space involving translation and dilation parameters related to time and scale factors. Both the high and low frequency supports well for wavelet transform hence are well suited for image compression.

A. Wavelet and relevant concepts

Wavelet is one kind of function that can attenuate to zero fast in the limited range, so 'wavelet' named. Wavelet analysis does the work that it decomposes the original signal into the wavelet which has different phase and length between original wavelet. The wavelet analysis can be used both in one-dimensional signals too in two-dimensional.

B. Wavelet transform

Image wavelet transform adopts the fast algorithm of two dimensional wavelet transform. The original image is decomposed into four sub-bands after passing a high- pass filter and low- pass filter [7]. The four sub-bands are LL, HL, LH and HH respectively. LL is a low frequency sub-band of the approximate image. HL is a high frequency sub-band of the horizontal details of the image. LH is a high frequency sub-band of the vertical details of the image. HH is a high frequency sub-band of the diagonal details of the image. The process is called the first level of wavelet decomposition. The low frequency sub-band can be continually decomposed into four sub-bands. The decomposition can be infinitely repeated in theory. But people must take the quality of the reconstructed image into consideration. Thus, people don't decompose image beyond the fifth level. Researchers usually use the third level. The model of wavelet decomposition of the third level is shown in Fig.1. Image information does not reduce and can't realize image data compression after the wavelet transform. But the energy of whole image is redistributed after this transform. The image of low frequency sub-band contains major information. The values of high frequency sub-band approximate zero, the more high frequency the more obvious this situation. For image, the part

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of the low frequency is primary part which can represent the image information. So researchers take full advantage of the characteristic after wavelet transform and employ proper method to process the image coefficients for achieving effective compression.

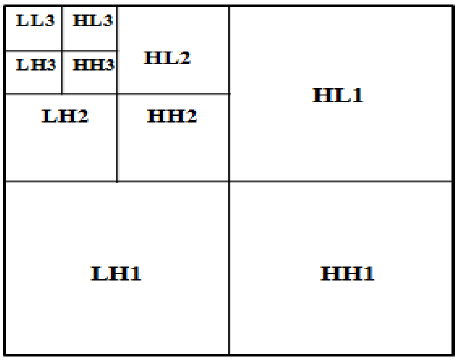

Fig 1. 3 Level of Wavelet Decomposition

IV. WAVELET FAMILIES

Haar wavelet is the simplest of the wavelet transforms [3]. This transform cross-multiplies a function against the Haar wavelet with various shifts and stretches, like the Fourier transform cross-multiplies a function against a sine wave with two phases and many stretches. Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support [8]. Meyer's wavelet construction is fundamentally a solvent method for solving the two-scale equation. Symlet wavelet is only nearly symmetric, and is not exactly symmetrical. Coiflets are discrete wavelets designed by Ingrid Daubechies, to have scaling functions with vanishing moments. Biorthogonal wavelet is a wavelet where the associated wavelet transform is invertible but not necessarily orthogonal. Reverse biorthogonal is a spline wavelet filters.

V. PERFORMANCE CRITERION

The performance is evaluated by the following two Essential criteria: the obtained compression ratio CR and the quality of the reconstructed image PSNR.

A. Compression ratio

The Compression ratio (CR) is the ratio between the size of the original image and the size of the compressed image.

$$CR = \frac{n1}{n2}$$

B. Distortion measure

Mean Square Error (MSE) is used to measure the rate of distortion in the reconstructed image.

$$MSE = \frac{1}{M * N} \sum_{x=1}^{M} \sum_{y=1}^{N} [f(x,y) - f'(x,y)]^2$$

PSNR is used as an approximation to human perception of reconstruction quality. PSNR has been accepted as a widely used quality measurement in the field of image compression.

$$PSNR = 20 \log_{10} \frac{MAX}{MSE}$$

A high PSNR would normally indicate high reconstruction quality.

VI. PERFORMANCE ANALYSIS

We have performed the experiments and analyzed different wavelets. Six wavelets are chooses from the different wavelet families namely: HAAR, DB_7, SYM_4, COIF_2, BIOR_4.4 RBIO_1.3 and DMEY for the evaluation of the test images. The test image is Lena (256x256) in table -1 and Cameraman (256x256) in table-2 with threshold value is 20.The compression performance is the basis for the choice of these wavelets among the different wavelet families in terms of PSNR and visual quality. The experimental results for all the seven wavelet family have been analyzed for the test images. The results are shown in the Table-I, measured in terms of PSNR (Peak Signal to Noise Ratio) and Compression Ratio (CR). The characteristics of the wavelet family for the test image show in Table-1. Initially for low compression ratio 'dmey' is effectively work but when the compression ratio increases then the value of the 'dmey' is fast decrease. Also the 'db7' is giving the good performance over the low and high compression ratio for image compression. Here we show the 'haar' gives the lowest performance for image compression.

Table 1

D level	parameter	Haar	Db7	Sym4	Bior4.4	Rbio1.3	Dmey
1	MSE	14.8433	12.1902	11.7764	11.3684	11.6898	11.6933
1	PSNR	36.4155	37.2707	37.4207	37.5738	37.4527	37.4515
1	CR	58.1999	55.6749	57.4467	57.1085	58.0746	22.5048
2	MSE	25.3072	24.7402	22.598	21.3608	21.9711	23.6104
2	PSNR	34.0984	34.1968	34.5901	34.8346	34.7123	34.3998
2	CR	75.8566	72.7118	74.7086	74.5726	75.7492	23.7507
3	MSE	37.4885	40.0633	34.9385	33.1562	35.6313	39.1665
3	PSNR	32.3918	32.1033	32.6978	32.9252	32.6125	32.2017
3	CR	80.9013	77.1463	79.6049	79.5403	80.653	7.0627

Table 2

D level	parameter	Haar	Db7	Sym4	Bior4.4	Rbio1.3	Dmey
1	MSE	18.6707	19.3292	19.052	18.2629	18.4764	19.7124
1	PSNR	35.4192	35.2687	35.3314	35.5151	35.4646	35.1834
1	CR	60.3294	57.0753	59.0891	58.5428	59.618	24.7541
2	MSE	23.6626	28.2815	25.9101	24.9942	25.4962	28.2546
2	PSNR	34.3902	33.6158	33.9961	34.1524	34.066	33.6199
2	CR	75.8713	71.8733	74.0196	73.6252	75.1585	23.4518
3	MSE	30.4054	38.0432	34.2085	33.2795	34.3835	37.5324
3	PSNR	33.3013	32.328	32.7895	32.909	32.7673	32.3867
3	CR	80.6662	76.2289	78.6634	78.4395	79.867	13.4741

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VII. CONCLUSION

In this paper we study about the wavelet transform and a comparative study of different wavelet family on to test images set has been done using PSNR and compression ratio. This study gives the choice of optimal wavelet for image compression. The Compression Ratios and Visual Image Quality are also presented. We used, Peak signal to noise ratio (PSNR) as the objective quality measure. Therefore, conclusively we can say that the "best wavelet" choice of wavelet in the image compression of images dependent on to the image content and desired image quality.

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AUTHOR'S PROFILE

Prof. A. N. Patel is working as an assistant professor at U.V.Patel College of Engineering, Ganpat Vidyanagar, Kherva since march 2004. He has done his B.E (EC) from Government Engineering College, Modasa and M.E. from Dharmsinh Desai University, Nadiad. His areas of interest are image processing, microwave antenna and wave propagations.

Ravindra M. Patel is currently pursuing M.Tech from U.V.Patel College of Engineering, Ganpat Vidyanagar, Kherva. He has done his B.E. (E.C) from Dharmsinh Desai University, Nadiad.