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Image Processing Using Different wavelet families and their Performance analysis

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Abstract - This paper presents high speed discrete wavelet transform based image compression using different wavelet families called Daubechies, Symlets, Coiflets Wavelets and result comparison has been done in terms of PSNR and image processing time using different wavelets. The wavelet transform has emerged as a benchmark, in the field of image compression. Wavelet based coding provides substantial improvements in picture quality at higher compression ratios. Images have been processed and simulated using MATLAB. The simulated results show that the Daubechies Wavelet has shown better PSNR by taking less processing time as compared to Symlet and Coiflet Wavelets for different scaling factors and Coiflet Wavelet works only for smaller values of scaling factors.

Keywords – Coiflets, Daubechies, Image compression, PSNR, Symlets, Wavelet.

I. INTRODUCTION

Digital image processing is the subcategory of the digital signal processing. A Digital image is obtained from real image through the process of sampling and quantization. [1]. It is the implementation of the computer algorithms on images to perform their processing and enhancement. With the increasing use of multimedia applications, need of communication of the multimedia information through telecommunication network and data accessing through internet is growing tremendously [2]. To address these needs, many efficient image compression techniques, with considerably different features, have been developed. Traditionally, image compression adopts Discrete Cosine Transform, that is simple and practical to use, but the method has several shortcomings. One of these is blocking artifact and bad subjective quality when the image restoration is done using this method [3]. Image processing is used to alter the picture characteristics by enhancing and restoring them, to extract information (analysis, recognition), and change their structure (composition, image editing). Images can be processed using optical, photographic, or electronic means, but the processing done by digital computers is the most common and efficient technique because they are fast, flexible, and precise [4]. The number of image compression methods available today fall into two major categories: lossy and lossless image compression. In lossless compression, every single bit of data that was originally in the file remains after the file is uncompressed. All of the information is completely restored. Medical imaging, technical drawings, and astronomical observations typically use lossless compression techniques. The Graphics Interchange File (GIF) is an image format used on the Web that provides lossless compression. The lossy compression reduces a file by permanently eliminating certain information, especially redundant information. The original image cannot be reconstructed again. When the file is uncompressed, only a part of the original information is still there. Pictures and videos taken from digital cameras are examples files that are compressed using lossy methods. Simple concept of lossy image compression is reduction of the color space to a smaller set of colors. The JPEG image file, commonly used for photographs and other complex still images on the Web, is an image that has lossy compression [5]. In this paper, a digital image compression comparison based on discrete wavelet transforms and it various family wavelet techniques is discussed and the results are compared.

II. WAVELETS

Wavelets were first found in the works of Grossmann and Morlet. The term wavelet was found from the fact that the signal integrate to zero, wave up and down across the axis. The wavelet transform is a technique for processing of signal that can be utilized to represent real-time non-stationary signals with high efficiency [6]. They are characterised by how scaling functions are defined [7]. Wavelets are mathematical functions that divide the data into approximation of different frequency components. This approximation shows the variation of the pixel values and the details of the horizontal, vertical and the diagonal details or changes in the image. They satisfy certain mathematical functions and are used to represent the data. The signal under test is split into an approximation and a detail component up to and n-level decomposition. The scale or the scaling factor plays a vital role in the analysis. The amount of information retrieved after compression and decompression of an image is known as the energy retained. Wavelets are gaining popularity in almost every field of technology like astronomy, acoustics, nuclear engineering, image processing, neurophysiology, music, optics turbulence, earthquake-prediction, radar and many more [8].

Types of Wavelets:

Wavelet transforms are classified into three classes: continuous, discrete and multi-resolution-based wavelet transforms. In the first type, a finite energy signal is projected onto a continuous frequency band. The discrete type of wavelet transform is symmetric in nature, so the discrete subset of any half sub plane will be sufficient to reconstruct the signal from the wavelet coefficients. The later type of the wavelet reduces the numerical complexity by utilizing the scaled and shifted wavelets with only a finite number of wavelet coefficients for each bounded rectangular region in the upper half plane.

There are a number of different wavelet families whose properties vary with several criteria. These are:

1. The ψ function: The speed at which they converge to 0 when time t or the frequency approaches infinity is an important property.
2. They provide symmetry that is used in removing the phasing distortion in processing of images.
3. The vanishing moments count is useful in compression techniques.
4. The regularity is used in achieving sharp features, like smoothness of reconstructed image.
5. Wavelet offer regularity and smoother wavelets provide sharper frequency resolution [9].

Discrete Wavelet Transform

Discrete Wavelet Transform using the wavelets is a method of decomposing signals. The idea behind wavelets is to analyze signal at different scales [10]. It has gained a great deal of popularity in recent years. There are two classifications of wavelets (a) orthogonal (the low pass and high pass filters have same length) and (b) biorthogonal (the low pass and high pass filters do not have same length). Based on the application, either of them can be used. [11]. The DWT analyzes the signal at different frequency range with different resolutions by decomposing the signal into an approximation and detail information [3].These are special functions in terms of sine and cosines terms used to represent the signals. In this the most relevant information appears in high amplitudes and the less important information appears in low amplitudes. Data compression can be achieved by discarding these low amplitudes. For an image in 2-D, DWT processes the image by utilizing the 2-D filters for each dimension. These filters divide the image into four sub-bands that are non-overlapping and have multi-resolution LL1, LH1, HL1 and HH1. Multi-resolution means simultaneous representation of image on different resolution levels. Here the sub-band LL1 represents the coarse-scale DWT coefficient and the sub-bands LH1, HL1 and HH1 represent the fine-scale of DWT coefficients. To obtain the next coarse level of coefficients, the LL1 is further processed till some scale N is reached. At N, there will be 3N+1 sub-bands consisting of the multi-resolution sub-bands LLN and LHx, HLx and HHx where x ranges from 1 to N. Figure 1 shows this process diagrammatically [12].

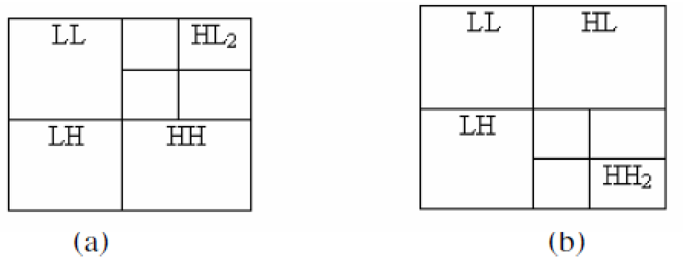

Figure 1: Sub bands obtained after applying Multi-resolution DWT.

There are a number of different wavelet families that are widely used. The credit goes to Ingrid Daubechies, one of the pioneers in the world of wavelet research, who invented the compactly supported orthonormal wavelets that made the discrete wavelet analysis practicable. The notation used for the Daubechies family wavelets is dbN, where N stands for order, and db is the "surname" of the wavelet. These wavelets are characterized by a maximum number of vanishing moments for a given system. With each wavelet, there is a scaling function which generates an orthogonal multi-resolution analysis**.** These wavelets are compact in nature. The associated scaling filters with them are the minimum phase filters. Figure 2 below shows the representation of Daubechies Wavelets for different scaling factors. The db1 wavelet is also known as the Haar wavelet. The Haar wavelet is the only orthogonal wavelet with linear phase. [13].

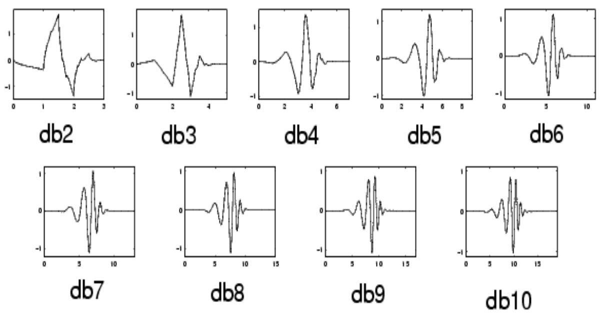

Figure 2: Daubechies wavelet for different scaling functions

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Another member of wavelet family is the Symlets wavelets. They are a modified version of Daubechies wavelets with increased symmetry. These wavelets are nearly symmetrical wavelets proposed by Ingrid Daubechies as modifications to his earlier proposed db family. The properties of the two wavelet families are similar. These are compactly supported and have the least asymmetry. The scaling factors associated with them are near linear phase filters. These wavelets are a function of psi. Figure 3 shows the different symlet wavelets for different psi factors [13].

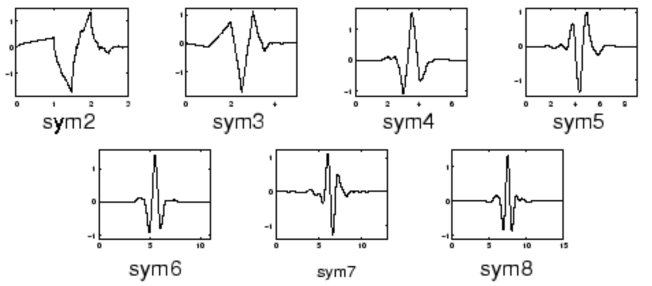

Figure 3: Symlet Wavelet for different psi functions

The next member is the Coiflet Wavelets that were built by Ingrid Daubechies on request of Ronald Coifman for the purpose of having scaling functions with vanishing moments.These wavelets are nearly symmetric with vanishing momenst of N/3 and scaling function is given by N/3 - 1. The notation used for Coiflet Wavelet family is coifN where N is the number of vanishing moments and its values can vary from 1,2,3,4,5. The scaling function and the wavelet function must be normalised by a factor of $1/\sqrt{2}$. Figure 4 shows the outcome of coif wavelet for different values of N [13].

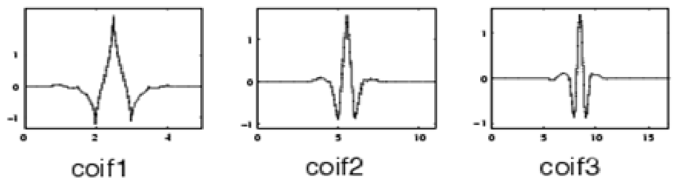

Figure 4: Coiflet wavelet for different scaling functions.

III. WAVELET BASED SIMULATION

In this paper, comparison of image processing using three types of wavelet transforms - Daubechies, Symlets and Coiflet wavelet transforms is performed for indexed images. The metrics for the comparison used here are the PSNR and the time taken for compression or the speed at which these wavelets processes the image for different vanishing moments of these wavelets. The image used here are wbarb and flujet. The calculation metrics used are defined below.

1. PSNR: It is defined as ratio of maximum possible power of a signal to the power of corrupting noise signal. The PSNR is most commonly used as a measure of quality of reconstruction in image compression. The MSE, PSNR vary inversely [14].

$$\text{PSNR} = 10\, log_{10}\, {255^2}/{MSE}\ (db) \qquad \text{----- (1)}$$

Where MSE is the mean squared error [14].

2. Time Taken: It is the CPU time in seconds that has been used by the MATLAB process to run the operation.

$$t = \text{cputime-t} \qquad \text{---- (2)}$$

The numerical results have been calculated using MALAB programming [15]. Below are the experimental results. The picture used is the wbarb. Figure 1 shows the original image taken for the processing, figure 2 is the reconstructed image using the wavelet techniques and the figure 3 depicts the difference image between the former two.

Figure 5: Original wbarb standard image taken for the processing using wavelets.

Figure 6: Reconstructed wbarb image obtained after application of the wavelets.

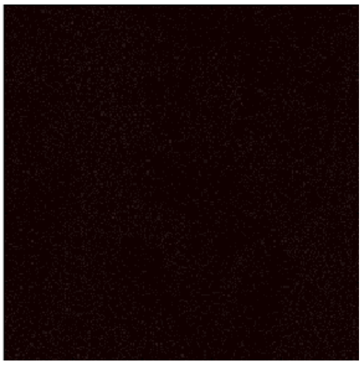

Figure 7: The difference image obtained by comparing the original and the reconstructed image.

IV. Result Analysis

The experimental tabulation for the proposed wavelet techniques are shown in the table 1 for Daubechies Wavelet, table 2 for Symlet Wavelet and table 3 for Coiflet wavelet for different scaling values or vanishing moments. The PSNR and the time taken for the compression are calculated for different wavelets. The best results from each family are tabulated in the table 4.

Table 1: Daubechies Wavelets Analysis for different vanishing moments.

Wavelets	PSNR	Time Taken
db1	44.4499	1.5132
db2	44.5530	1.5912
db3	44.4191	1.6380
db5	44.4910	1.8720
db10	44.4790	1.9188
db15	44.5069	2.0592
db20	44.6370	2.4336
db25	44.6439	2.6832
db30	44.7295	2.7456

Table 2: Symlet Wavelets Analysis for different psi values

Wavelet	PSNR	Time Taken
sym1	44.4499	1.5600
sym2	44.5530	1.5756
sym3	44.4191	1.5912
sym5	44.3650	1.6068
sym10	44.3728	1.6536
sym15	44.3854	2.7768
sym20	44.4081	6.7392
sym25	44.3525	18.8137
sym30	44.3749	151.5238

Table 3: Coiflet Wavelets Analysis for different vanishing moments.

Wavelet	PSNR	Time Taken
coif1	44.5158	1.5756
coif2	44.3839	1.5912
coif3	44.3726	1.6692
coif4	44.3574	1.6848
coif5	44.3453	1.7628

Table 4: Best results for the metrics for each wavelet family.

Wavelet	PSNR	Time Taken
Daubechies	db40(44.8189)	db1(1.5132)
Symlets	Sym2(44.5530)	sym1(1.5600)
Coiflets	coif1(44.5158)	coif1(1.5756)

Next the same process is repeated for another matlab standard colour image flujet. Below are the experimental results for the processing done using similar wavelet families. Figure 8 shows the original image taken for the processing, figure 9 is the reconstructed image using the wavelet techniques and the figure 10 depicts the difference image between the former two. The experimental tabulation for the proposed wavelet techniques are shown in the table 5 for Daubechies Wavelet, table 6 for Symlet Wavelet and table 7 for Coiflet wavelet for different scaling values or vanishing moments. The PSNR and the time taken for the compression are calculated for different wavelets. The best results from each wavelet family are tabulated in the table 8.

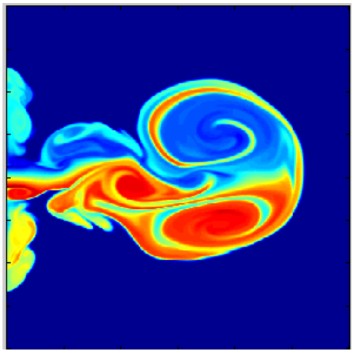

Figure 8: Original flujet standard image taken for the processing using wavelets

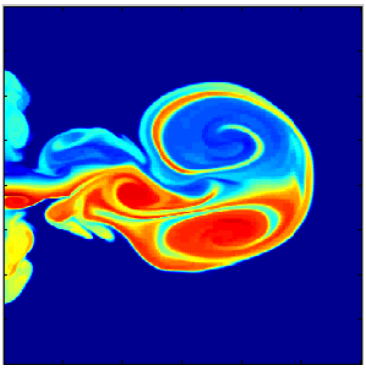

Figure 9: Reconstructed flujet image obtained after application of the wavelets.

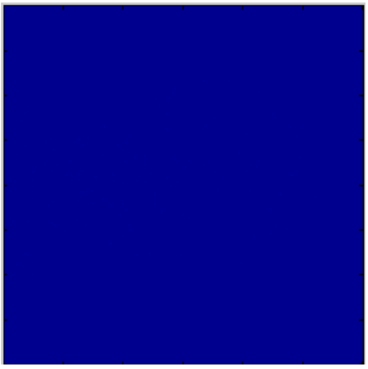

Figure 10: The difference image obtained by comparing the original and the reconstructed image.

Table 5: Daubechies Wavelets Analysis for different vanishing moments.

Wavelets	PSNR	Time Taken
db1	55.0210	1.5600
db2	55.9674	1.6068
db3	56.3318	1.6224
db5	56.5147	1.6536
db10	56.5079	1.6848
db15	56.2083	2.3088
db20	56.0557	2.8080
db25	55.9094	2.9640
db30	55.7250	2.9952

Table 6: Daubechies Wavelets Analysis for different vanishing moments.

Wavelet	PSNR	Time Taken
sym1	55.0210	1.5912
sym2	55.9674	1.6224
sym3	56.3318	1.6536
sym5	56.5509	1.5912
sym10	56.6667	1.9032
sym15	56.5713	2.8860
sym20	56.5280	6.6300
sym25	56.4427	18.4861
sym30	56.4997	149.4178

Table 7: Coiflet Wavelets Analysis for different vanishing moments.

Wavelet	PSNR	Time Taken
Coif1	55.9614	1.6068
Coif2	56.6192	1.6848
Coif3	56.6426	1.7004
Coif4	56.6394	1.7160
Coif5	56.6052	1.7472

Table 8: Best results for the metrics for each wavelet family.

Wavelet	PSNR	Time Taken
Daubechies	Db10(56.5079)	db1(1.5600)
Symlets	sym10(56.6667)	sym1(1.5912)
Coiflets	Coif1(55.9614)	coif1(1.6068)

V. CONCLUSION

The calculated results are analyzed for different wavelets for varying value of vanishing moments and PSNR and CPU time taken by each wavelet family for processing the image are compared. The best results for both images under consideration from the wavelets are observed and tabulated in table 4 and 8 respectively. It can be concluded that Daubechies wavelets provide best processing time for smaller values of N and PSNR is found in higher range of N. Image compression and processing using wavelets has revolutionized the compression field with unbelievable results. It has emerged as an extremely useful and powerful method for compressing data including images. This work can be further extended to processing the intensity images with use of Biorthogonal Wavelets.

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