The Application of Wavelet Transform Based Data compression in Different Type of Images

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Abstract: Wavelet transform base data compression technique plays a vital role in digital image processing. One of the most powerful and useful technique of digital image processing is image compression, which makes the image files smaller. In this study, we have discussed the Discrete Wavelet Transform (DWT) compression technique on different type of images. There are number of wavelets available in DWT family. All the wavelets of DWT family are not appropriate for the compression of different type of images. In present study, we have reviewed the type of wavelets of DWT family used for the compression of different type of images.

Keyword: Discrete wavelet transformation • Compression ratio • Image compression • Peak to noise ratio • Wavelet decomposition

Introduction

Digital images are widely used in different computer applications. Uncompressed digital images require large storage capacity and transmission bandwidth. Therefore efficient image compression techniques are required for the recent growth of data intensive, multimedia based web application. Wavelet transform based data compression technique is most popular and used for the compression of different type of digital images. Wavelet transform works on the concept of multi resolution analysis. In multi resolution analysis, a signal can be analyzed for any frequency component by selecting an appropriate scaling and translation vector. A number of wavelets are available in the family of DWT and any of them can be applied as per requirement of image under consideration.

The wavelet word was first introduced by Morlet (Hariharan 2019) in early 1980s. The wavelet transform based data compression technique is applied for the study of compression of various data signals such as medical images, seismic and biomedical signals (Goyal et al 2022). Currently, wavelet transform is not only applied in digital imaging but it is also utilized by FBI to encrypt database of one million fingerprints. Wavelet transform is better than Fourier transform because DWT has a better ability to localize time and frequency. This makes image compression easier.

Image compression techniques are broadly classified into two categories – lossless and

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lossy compression techniques. In lossless compression the image reproduced after compression is exactly original whereas in lossy compression algorithm loss some information but lossy part is not noticed by human eye.

Haar wavelet of DWT family is applied for image compression and quality of image has been evaluated using some factors like compression ratio (CR) and peak noise to signal ratio (PNSR). The experiment result shows proposed technique gives higher compression ratio (CR) compared to other compression thresholding techniques (Nashat and Hussain Hassan 2016). Higher compression ratio is obtained after three level of decomposition with haar wavelet based DWT compression and decomposed image is reconstructed without any appreciate loss in original image (Kanagaraj and Muneeshwaran 2020). DWT image compression is applied on standard image Lena of size 256 × 256 of 8 bit depth and two set of results are obtained by applying two different thresholding techniques (Global and Level dependent thresholding). Global thresholding can be applied successfully to compress images but at the same time it leads to unnecessary loss in PNSR.

The thresholding strategy was improved by using local rather than global technique (Yadav et al 2012).

In this paper, we have explained the effect of wavelets and number of decomposition level on the compression ratio (CR) of different type of images.

Discrete Wavelet Transform (DWT) based image compression methodology: Discrete wavelet transform is a wavelet transform in which wavelets are sampled discretely. The sampling of the signal is done by Nyquist theorem. The wavelet based image compression typically consists of three major components (i) discrete wavelet which decomposes an image into wavelet coefficients. (ii) quantizer which removes the redundancy in image. (iii) entropy encoder which encoded the quantized coefficients into bit stream. Wavelet based image compression is shown in Fig 1.

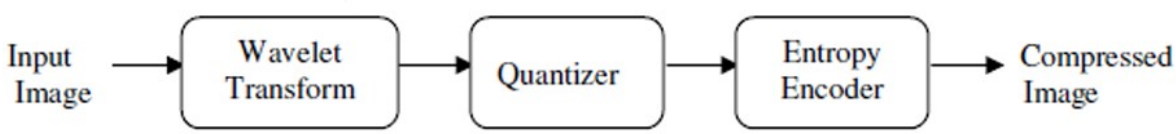

Figure 1. Wavelet based image compression

Wavelet Decomposition: Wavelet transform is a pair of filters. Each pair of filters consists of a low pass filter and high pass filter. Output of each filter is down sampled by two. Each of these two output signals can be further applied to a pair of low pass and high pass filter. This process can be repeated recursively several times, which results a tree structure, called decomposition tree. Wavelet transform can decompose images and signals (Deshmuk et al 2004). The two dimensional image is passed through a pair of low pass filter and a high pass filter along the rows. This operation creates two sub images namely horizontal approximation in low frequency region and horizontal detail in high frequency in high frequency region.

Both the sub images are further passed again through a pair of low pass filter and high pass filter along the column and each sub image produces two sub images. Therefore an image can be decomposed into four bands using these filters in one stage. There are four type of details of an image (i) approximate image (LL) obtained two low pass filters (ii) vertical detail (LH) obtained by one low pass filter and other high pass filter (iii) horizontal detail (HL) obtained by one high pass filter and other low pass filter (iv) diagonal detail (HH) obtained by two low pass filters. The wavelet transform decomposition technique and the formation of four sub images of the original image is shown in Fig 2

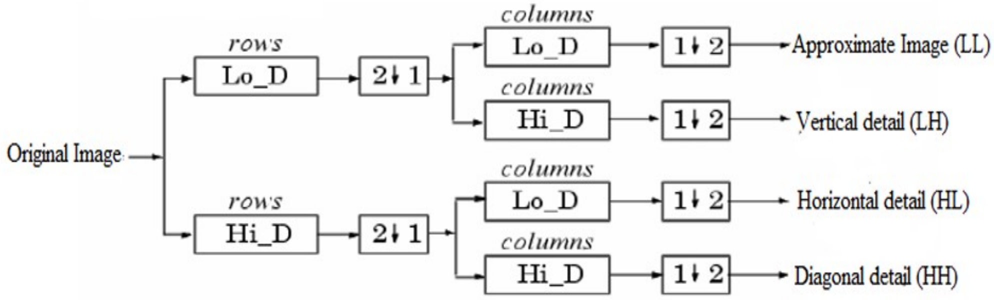

Figure 2. Wavelet Decomposition

The wavelet decomposition can be repeated on the approximate band (LL) using second identical filter bank (Grigic et al 2001). The decomposition process can be iterated and successive iterations are applied on the approximate band (LL). The quality of compressed image depends on the number of decompositions. Higher order decomposition does not give better quality of compressed image. There is a limiting factor for decomposition. To achieve a high compression, it is necessary to choose appropriate wavelet and decomposition level. The selection of wavelet plays a crucial role in compressing the images, because there is no wavelet that performs best for all type of images (Saha and Rao 2000). Three level of wavelet decomposition is shown in Fig 3

Quantization: After wavelet decomposition, the second step is quantization or thresholding, which is neglecting certain wavelet coefficients. The quantization can be done by two ways – (i) pixel values less than the threshold value are made zero. (ii) the values less than the threshold value are made zero and the values greater than the threshold value are subtracted from threshold (Ravichandran et al. 2016). Quantization step can be skipped, if lossy compression is not required. There are two methods of thresholding (i) local or level dependent thresholding (ii) global thresholding. In level dependent thresholding, different threshold values for different level of decomposition are used whereas in global thresholding, a single threshold value for all the level of decomposition is used.

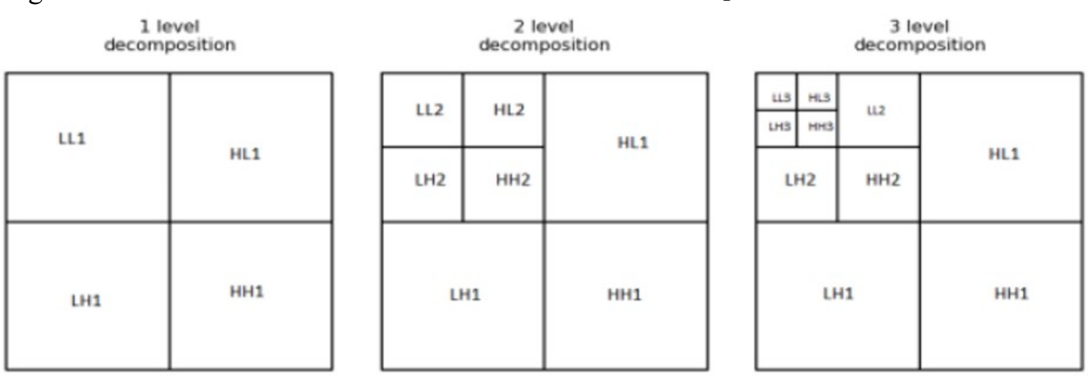

Figure 3. Three level wavelet decomposition

Entropy Encoding: Entropy encoding is a process in which the quantized values are further compressed losslessly to provide better compression. Entropy encoder uses a model in which probability of all the quantized value is determined and assigns a suitable code according to their probability. There are many entropy encoders proposed to encode images. Few of the encoders are Huffman coding, Set Partitioning in Hierarchical Trees (SPIHT) (Said and Pealman 1996), Embedded Zerotree Wavelet (EZW) (Shapiro 1993), Context-based, Adaptive, Lossless image Codec (CALIC) (Wu and Memon 1997).

Application of DWT based compression on different type of images: DWT based compression can be applied on the different type of images like medical image, fingerprint image etc. Wavelets available in the DWT family are Haar, Daubechies, Biorthogonal, Coiflets, Symlets, Morlet, Meyer. Wavelet used for image compression depends upon the image under consideration. Some researchers have applied various wavelets and number of decomposition level on different type of images.

Arora and Sneha (2016) applied various wavelets of wavelet families on two different biomedical images, MRI images of liver and shoulder. SPIHT and EZW algorithm are applied for compression. SPIHT algorithm is initiated for optimal progressive transmission and compression. EZW encoding is lossy image compression technique. In this algorithm, if there is an insignificant DWT coefficient having zero value or nearly zero in the lowest frequency subband, then its all decedents would be zero. It makes tree of zeros in the lowest frequency subband and if this tree is explored upto the corresponding spatial coefficients in the next higher frequency subband, there is a greater probability that there would be one or more sub trees would be zero, known as zerotree.

Ravichandran et al. (2016) has discussed the wavelet based image compression on the biomedical images like X-ray, MRI images and CT imaging etc. in this case, Daubechies wavelets are used for multilevel decomposition of medical images. The quantization is done by global thresholding. The quantized image is further encoded by Huffman encoding scheme. The researcher used the MATLAB toolbox for this purpose and identifies upto which level the decomposition can be possible in case of medical images without significant loss of information.

Ramesh and Shanmugam (2010) proposed a lossless compression method for medical images. Two MRI and two CT grey scale images of size [218 × 218] are taken and the method of compression is based on the wavelet decomposition followed by correlation among the wavelet coefficients. A new method ‘correlation graphical method’ is introduced which predicts the predictor variables to form a prediction equation for sub bands which is the basis of correlation between coefficients. The comparison of SPHIT and JPEG 2000 compression methods in terms of compression rates in bits per pixel is studied. This comparative study proposed the highest compression rate.

Sharma et al (2013) presented their work on Digital Imaging and Communication in Medicine (DICOM) CT images. DWT performance with haar wavelet is used and the image is compressed upto second level decomposition. The outcomes are analyzed with respect to input image with parameters like RMSE and PNSR after first and second level of decomposition. After analyzing the performance and comparison with the input image, the PNSR value of output images is found high.

Shivanand S. Gornale et al. (2007) proposed a fingerprint image compression technique using wavelet transform. Three wavelet transforms (Haar, Daubechies and Symlet Transforms) are applied on noisy and noiseless fingerprint image of size 374 × 388 with varying threshold value. The compression ratio is obtained for every threshold value of these transform for both type of images. The compression ratio can be increased by selecting appropriate threshold

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value. The compression ratios of both type of images are determined by Number of Zeros (NZ) and Retain Energy (RE). Higher compression ratio is achieved in case of noiseless fingerprint image rather than noisy fingerprint image.

Kasaei et al (1996) introduced a modified wavelet transform which uses a fixed decomposition structure to decompose into 73 subbands. Both hard and soft thresholding schemes are used in this algorithm. Each subimage uses a different quantization schemes which depends on the entropy of each subimage. Only most efficient data is used and bit allocation for each subimage of modified coefficient is determined. This algorithm gives a high compression ratio and a high reconstructed image quality compared to other algorithm. A lossless compression technique, Huffman encoding is used to obtain further compression. The performance of the proposed algorithm was examined using 512 × 512 gray level fingerprint image. The selected symmetric filter with a biorthogonal wavelet basis produces the best performance among all type of subbands.

Stromvig and Dongxiao (2024) proposed fingerprint image compression using biorthogonal and haar wavelets at different levels of DWT. DWT is applied to the image for different levels with combination of Bio4.4 in initial levels and haar wavelet in the remaining levels. The experiment is divided into two parts. In first part of the experiment, the numbers of levels of wavelet transform is fixed and vary the Bio4.4 and haar wavelet levels to match the total number of levels which is fixed. It is observed that the combination of Bio4.4 wavelet for first three transformation levels and haar for remaining levels provides improved results. At this combination, MSE is minimum and PNSR is maximum. In second part of the experiment, a comparison is made between the proposed method and the transformation with only Bio4.4. SPIHT technique is used to compress fingerprint image after transformation.

Mozammel et al. (2012) proposed a new image compression technique using Discrete Wavelet Transform (DWT). The proposed technique decomposes the original image into coefficients which are called sub bands. Only the coefficients above the threshold are encoded while the coefficients below the threshold value are set to zero. The researcher used Visual C++ for the implementation of algorithm. The effectiveness of this algorithm has been justified over test image of bmp format and the performance of the proposed method has been compared with other compression techniques. The experimental results shows that the proposed image compression technique gives better performance compared to other standard compression techniques. Digital images are classified into number of categories like medical images, fingerprint images etc. Various wavelets are applied on these digital images.

For Medical images: Goyal et al (2023) proposed DWT technique for the compression of medical images. DWT compresson technique was applied to the MRI image of human brain of size 256 × 256 shown in figure 4. The number of wavelets of wavelet family namely Haar, Daubechies (db), Bior_4.4, Coiflets (coif), Symlets(sym), DMeyer (dmey) was employed on the MRI image of brain.

Figure 4. MRI image of human brain

The Mean Square Error (MSE), Peak Signal to Noise Ratio (PNSR), Compression Ratio (CR) and Bits Per Pixel (BPP) values after first level of decomposition for different wavelets of wavelet family with Embedded Zerotree Wavelet (EZW) encoding scheme are shown in Table 1.

Table 1. MSE, PSNR, CR and BPP values for different wavelets after first level of wavelet decomposition

S. N	Wavelet	MSE	PSNR	CR	BPP	L-2 NORM RATIO
1	Haar	0.0268	64.97	105.27	8.4213	100.00%
2	Daubechies(db)	0.2001	55.12	77.57	6.2059	100.00%
3	Bior_4.4	0.04029	62.06	96.26	7.7327	100.00%
4	Coiflets (coif)	0.03441	62.76	99.45	7.9563	100.00%
5	Symlets(sym)	0.02757	63.73	101.49	8.1194	100.00%
6	DMeyer(dmey)	0.04594	61.71	100.63	8.05	100.00%

On the basis of the result obtained after first level of decomposition, it is found that haar wavelet shows the best compression in terms of MSE, PSNR, CR and BPP.

For Fingerprint images: Goyal et al. (2024) has presented fingerprint image compression using DWT technique. DWT image compression was applied to two sample fingerprint images of size 480 × 400 shown in figure 5. Researchers have applied six wavelets of wavelet family namely Haar, Daubechies(db2), Coiflets, Symlets(sym2), DMeyer(dmey) and biorthogonal(bior4.4) on the two fingerprint sample images.

The MSE, PNSR and CR values for fingerprint images after first level of decomposition for different wavelets of wavelet family with EZW encoding are shown in table 2.

Haar, daubechies(db2) and Symlets(sym2) wavelets were selected for fingerprint image compression on the basis of minimum MSE values and higher PSNR values. The fingerprint images were further decomposed at higher level with Haar, daubechies(db2) and Symlets(sym2) wavelets. Three level of wavelet decomposition for fingerprint image was selected on the basis of MSE values shown in

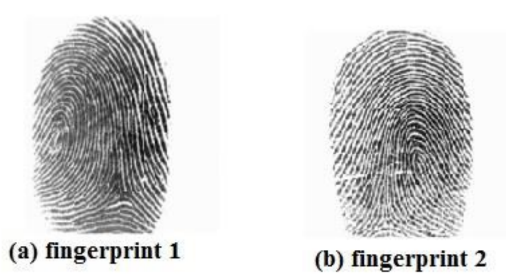

Figure 5. Sample fingerprint images of size (480 × 400)

Table 2. Comparison table of MSE, PSNR and CR for different wavelets after first level of wavelet decomposition

S.No.	Wavelet	Fingerprint 1			Fingerprint 2		
		MSE	PSNR	CR	MSE	PSNR	CR
1.	Haar	0.02281	64.55	121.35	0.01944	65.24	125.22
2.	Daubechies (db2)	0.02786	63.68	117.53	0.02459	64.22	121.13
3.	Coiflets(coif2)	0.03035	63.31	115.21	0.02734	63.76	117.28
4.	Symlets(sym2)	0.02786	63.63	117.54	0.02459	64.22	121.13
5.	DMeyer(dmey)	0.03773	62.36	114.52	0.03543	62.63	115.35
6.	Biorthogonal(bior 4.4)	0.03547	62.63	112.80	0.03131	63.17	115.14

Table 3. Comparison table of MSE at different level of wavelet decomposition

S.No.	MSE at different level of Decomposition	Fingerprint 1			Fingerprint 2		
		Haar	Db2	Sym2	Haar	Db2	Sym2
1.	Level 1	0.02281	0.02786	0.02786	0.01944	0.02459	0.02459
2.	Level 2	0.0274	0.1292	0.1292	0.02447	0.1032	0.1032
3.	Level 3	0.1174	0.7281	0.7281	0.09079	0.5817	0.5817
4.	Level 4	0.5957	4.255	4.255	0.4188	3.738	3.738
5.	Level 5	3.602	21.39	21.39	2.744	3.748	3.748

Thus, Haar, daubechies(db2) and Symlets(sym2) wavelets were selected for fingerprint image compression till three level of wavelet decomposition.

Conclusion

In this study, we have studied the different type of wavelets of wavelet family used for the compression of different type of images. All the wavelets of wavelet family are not suitable for the compression of different type of images. The compression ratio (CR) of images are affected by the wavelets and number of decomposition level. Medical images give better CR with haar wavelet whereas fingerprint images give better CR with haar, daubechies(db2) and Symlets(sym2) wavelets. Further research is required to get appropriate wavelet and number of decomposition level.

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