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The Application Of Discrete Wavelet Transform In Medical Image Compression

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Abstract: Data compression techniques plays a vital role in the research area of digital image processing. It involves the processing of digital images with the combined assistance of computer and mathematics. In digital image processing, one can manipulate the images by pre-processing, image enhancement and display. Here we proposed a technique 'Discrete Wavelet Transform' (DWT) for the compression of medical images. The images that adopted for compression are medical images. Medical images needs a lot of space to maintain the medical records of a patient in a hospital. In the presented work here the DWT compression technique is applied to the magnetic resonance imaging (MRI) image of brain. The number of wavelets of DWT family is employed for this purpose. First the image under consideration is decomposed by the sub-band coding technique of DWT, and then applied the Embedded Zerotree Wavelet (EZW) encoding scheme. A comparative study is also done on all the resultant images in terms of Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Compression Ratio (CR) and Bits Per Pixel (BPP). In the presented study, Haar wavelet gives the better compression of MRI image. All the processing is done by well-known mathematical tool MATLAB.

Key words: Image compression • Discrete Wavelet Transform • Compression Ratio • Mean Square Error • Peak signal to Noise Ratio

Introduction

Due to increasing requirement of digital imaging in the field of medical treatment and hospitality to store different medical reports like X-ray, ultrasound, MRI etc, the scope of research in digital image processing also increases. A digital image is a representation of an image in terms of pixel values or intensities values. Image compression is nothing but the enhancement of the image by applying some algorithms or operations to these pixel values. Basically, there are two fundamental approaches to compress any image – lossy compression techniques and lossless compression techniques. In lossy compression techniques, there is a compromise in the information when the image is reconstructed but there is no loss found in reconstructed image obtained by the lossless compression technique also known as entropy encoding. (Deepanshu Arora and Sneha 2016).

Wavelet transform have found a number of applications in engineering and science. One of the major applications of wavelet transform is in digital image compression. Wavelet transform is initiated and developed on the basis of Fourier transform (Ravichandran et al 2016). Wavelet transform is a transform which works on the concept of multi resolution analysis (MRA).

Under 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 we can apply any one of them as per the requirement of the image in consideration.

Related Work

Ravichandran et al (2016) represented the medical image compression by the application of Daubechies wavelet filter and tried to find out the correlation between the level of decomposition of wavelet filter and quality of the reconstructed images after applying the different level of decomposition. The quantization is done by the global threshold and followed by the encoding through the Huffman encoding scheme. They found that the feature of the encoder is not significantly changed from third level to fifth level.

Agrawal et al (2019) have discussed advantages of double and triple level decomposition using multiple wavelet families and applied a number of standardized methods and algorithm in image compression. Namely the methods used are EZW, Set Partitioning In Hierarchical Trees (SPIHT), Spatial Orientation tree Wavelet (STW), Set Partitioning In Hierarchical Trees (SPIHT_3D), Wavelet Difference Reduction (WDR) and Adaptively Scanned Wavelet Difference Reduction (ASWDR). A comparative study of all these methods in terms of image analyzing parameters like PSNR, MSE, CR& BPP also discussed.

Alka 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 the second level decomposition. The outcomes are analyzed with respect to the input image with the parameters like Root-mean-square error (RMSE) & PSNR after first and second level of decomposition. After analyzing the performance and comparison with the input image, the PSNR value of output images is found high. This type of result makes the work quite reliable and one of the superior image compression methods for DICOM images.

Ramesh and Shanmugam (2010) proposed a lossless compression method for medical images. Two MRI and two CT grey scale images of size [128x128] are taken and the method of compression is based on the wavelet decomposition followed by the correlation among the wavelet coefficients (Ramesh and Shanmugam 2010). A new method ‘correlation graphical method’ is introduced which predicts the predictor variables to form a prediction equations for sub -bands which is the basis of correlation between the coefficients. The comparision of SPIHT and JPEG 2000 compression methods in terms of compression rates in bits per pixel is studied. This comparative study proposed the highest compression rate.

Shifali Patil (2016) and many more researchers (Manjunath and Mitra 1995, Naidu and Raol 2008, Shu-long Zhu 2002) have presented the application of DWT in image fusion. Fusion is the process to obtain a meaningful image by merging two or more images. Image fusion is one of the necessary part of the image processing tool and DWT is widely used for the purpose of image fusion of various kind of images.

Image Compression Methodology

A typical wavelet based image compression methodology has three main steps – decomposition of the image by DWT, quantization, Entropy encoding. A block diagram followed in image compression technique is shown in Fig.1.

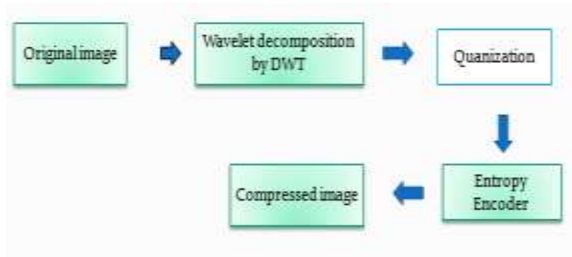

Fig. 1: Image Compression Technology

Discrete Wavelet Transform

It is not possible that CWT (Continuous Wavelet Transform) can be practically computed for all possible frequency values by the transformation equation. So, there is a necessity to discretize the transform. A DWT is a transform in which the wavelets are discretely sampled. The sampling is done according to the Nyquist's theorem which states that only half of the samples are required to reconstruct the image into its original form (Agarwal 2014). DWT works on the scheme of sub-band coding and multi resolution analysis.

In DWT, the image under processing is passed through a series of low pass filters and high pass filters. The high pass filter preserves high frequency components while low pass filter preserves low frequency components of image. Because the image is a two dimensional signal so first the image is passed through a low pass filter and a high pass filter along the rows. This operation provides two sub images namely horizontal approximation in low frequency region and horizontal detail in high frequency region. Both the sub images are further passed through a low pass filter and high pass filter again along the column and each sub image produces two sub images. Therefore, there are total four sub images – (i) approximate image, obtained by two low pass filters (LL) (ii) vertical detail, obtained by one low pass filter and then high pass filter (LH) (iii) horizontal detail, by one high pass filter and a low pass filter (HL) (iv) diagonal detail, by two high pass filters (HH).

A sub-band coding technique and the formation of four sub images of the original image is shown in Fig.2 and Fig.3.

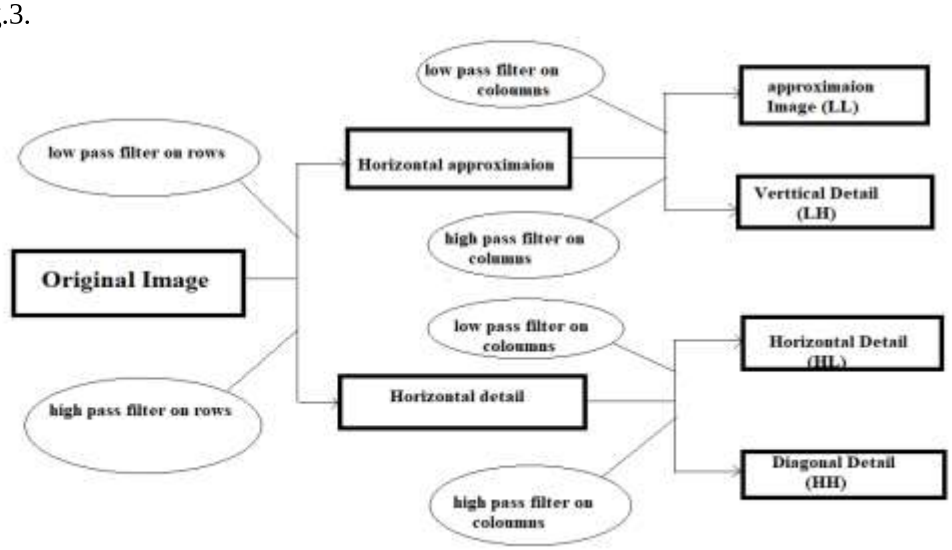

Fig. 2: Sub-band coding scheme

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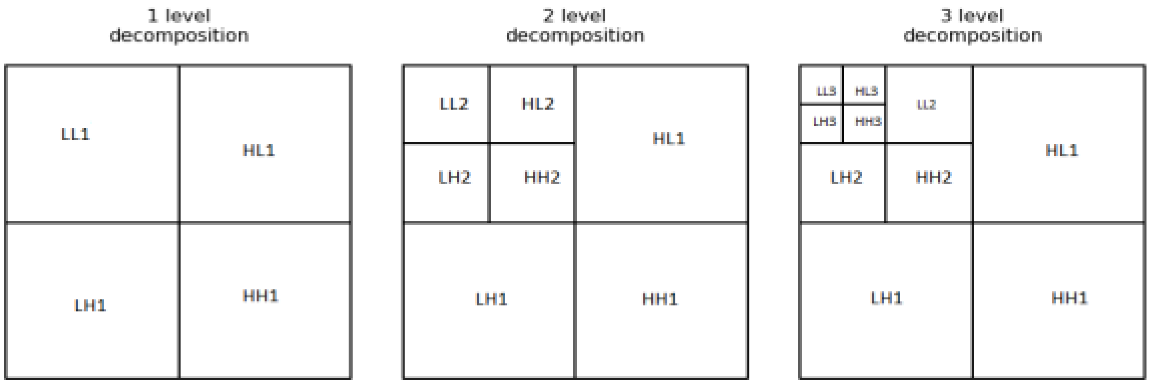


Fig. 3: Wavelet decomposition at level 1,2&3

In this way, at every level of decomposition among the four sub images one explained the approximation and three showed the horizontal, vertical and diagonal details are obtained.

The horizontal approximation sub signal of the image shows the general trend of pixel values as that of the original image and it is composed of the low frequency components of the original image. To find the higher level of resolution, one can allow the further decomposition of the approximation part to achieve more compression but as we move towards the successive decomposition, there is a compromise between quality of image and the space occupied on storage devices. The further steps of quantization and entropy encoding is applied on this approximation part of sub images.

Quantization

The second major step in image compression is quantization or thresholding employed after wavelet decomposition. Quantization is one of the lossy compression techniques and play a major role in compression. Quantization is the process of approximation to a range of values to a small and finite set of values which leads to the removal of redundancy in the image. This can be done by two ways- (i) selecting a threshold value and the pixel values less than the threshold value are allowed to make zero. (ii) the values less than the threshold value are made zero and the values exceeds the threshold value

are subtracted from threshold (Ravichandran et al 2016).

If lossy compression is not desired, quantization should be skipped.

Entropy Encoding

Entropy encoding is a lossless compression scheme that reduces the number of bits to store the image. In this coding the probability of all the quantized value is determined and assigned a suitable code according to that probability.

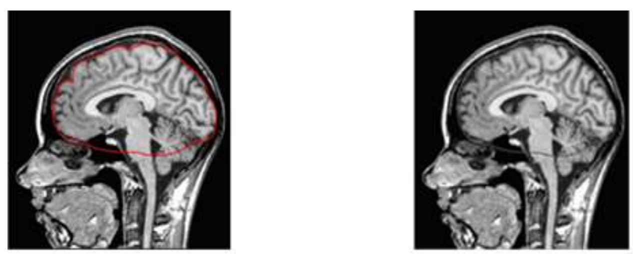
In the present work we applied embedded zero tree wavelet encoding scheme, proposed by Shaphiro (1993). To achieve the compression in images, redundancies must be exploited. In the case of EZW encoding scheme, the redundancies can be withdrawn by the coefficients that located at the same pixel location but in sequential subbands. According to shaphiro (op cit), there exists a parent child relationship among the DWT coefficients of successive sub-bands. It is well known that highly insignificant coefficients are found in the high frequency sub-band. If an insignificant coefficient is found in coarse resolution, then it's all descendants must be insignificant with respect to the threshold value. These all coefficients can be put as zero which makes a zero tree. This type of coding increase the accuracy of the image and compress the image into bit steam.

Implementation of Proposed Methodology

The methodology discussed above is applied on the MRI image of a human brain taken from internet web browser (https://www.medifee.com, 2015) and realize in MATLAB. The image under consideration is first converted into square image of size [256 x 256] and gray scale image and then the sub-band coding technique is applied. On applying the compression methodology through wavelets, Single compression using EZW encoding is implemented on true colour MRI image using different wavelets of wavelet families namely Haar (haar), Daubechies (db), Coiflets (coif), Symlets (sym), DMeyer (dmey) and discuss the comparative study of data obtained through compression measuring parameters like CR, PSNR, MSE and BPP is done using MATLAB code for each algorithm employed.

Results and Discussion

The compressed image shown in Fig.5 are obtained by the first level decomposition of different wavelets. Here in all these results, we have used the embedded zero tree wavelet as a image compression technique.



(a) **(b)**

Fig. 4: (a) MRI Image of Human Brain (b) Grey scale MRI Image of Human Brain

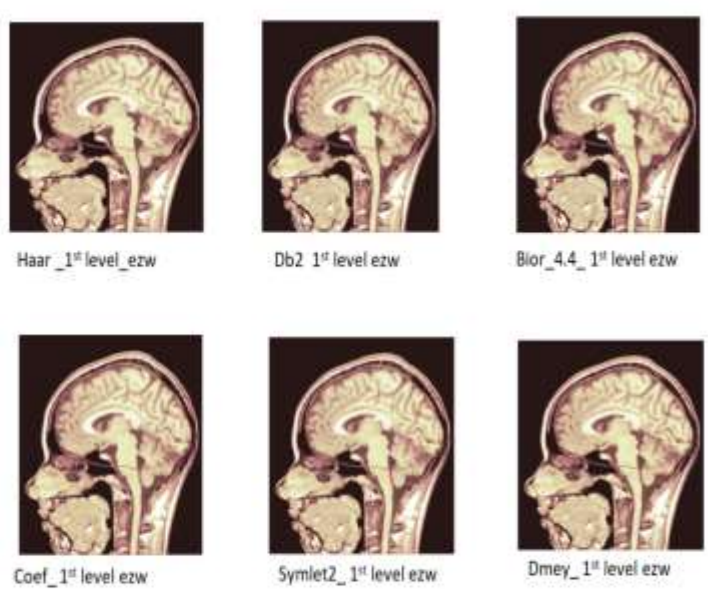


Fig. 5: MRI images after single compression with different wavelets using EZW

Table 1: Performance Result after compression Based on DWT decomposition level 1.

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 in the single compression using EZW encoding, it is found that the Haar wavelet shows the best compression results in terms of MSE, PSNR, CR, BPP. In series of this, we further processed the MRI image of brain with Haar wavelet single level decomposition followed by the EZW, SPIHT, STW and SPIHT_3D encoding schemes. Again, the comparison of different encoding schemes is studied in terms of MSE, PSNR, CR and BPP ratio.

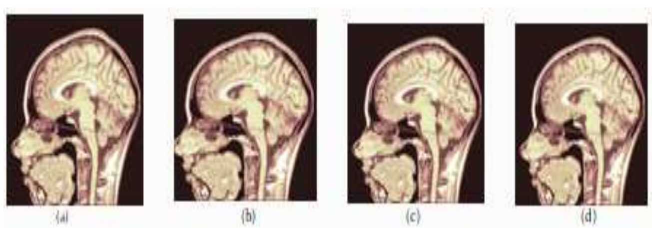


Fig. 6: Compressed MRI image of brain using Haar wavelet and encoding schemes (a) EZW (b) SPIHT (c) STW (d) SPIHT_3D

Table 2: Performance Results of Different Compression Methods on MRI Image of Brain at Decomposition level 1.

S. NO	ENCODING SCHEME	MSE	PSNR	CR	BPP	L-2 NORM RATIO
1	EZW	0.0268	64.97	105.27	8.4213	100.00%
2	SPIHT	5.145	41.02	118.15	9.4518	100.03%
3	STW	0.0843	58.87	91.59	7.3274	100.09%
4	SPIHT_3D	5.145	41.02	118.15	9.4518	100.03%

Among all the encoding schemes, The EZW showed the best MSE & PSNR values and SPIHT shows the best compression ratio values. Table 3, Table 4 and Table 5 shows the comparison of MSE, PSNR and Compression ratio for the MRI image of brain decomposed at different level of decomposition for different wavelets of wavelet family. The graph related to same is also plotted and shown in Fig. 6, Fig. 7 and Fig. 8.

Table 3: Comparison Table of MSE at Different level of Decomposition for different wavelets of wavelet family.

MSE at	Haar	Db2	Sym4	Coef 4	Bior 1.1
level 1	0.0268	0.2001	0.02757	0.03441	0.04029
level 2	0.9439	4.842	4.806	4.792	0.9439
level 4	20.05	19.07	17.31	16.39	20.05
level 5	72.02	62.51	55.24	47.54	72.02

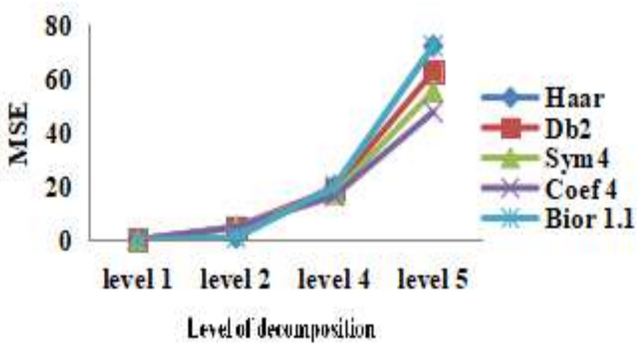


Fig. 7: Comparision of MSE at Different level of Decomposition

Table 4: Comparision Table of PSNR at Different level of Decomposition for different wavelets of wavelet family.

PSNR at	Haar	Db2	Sym4	Coef 4	Bior 1.1
level 1	64.97	55.12	63.73	62.76	62.06
level 2	63.98	54.68	54.68	53.97	53.23
level 3	55.94	47.56	47.56	47.12	53.17
level 4	48.33	47.55	47.55	47.11	46.8
level 5	41.38	41.2	41.2	41.13	41

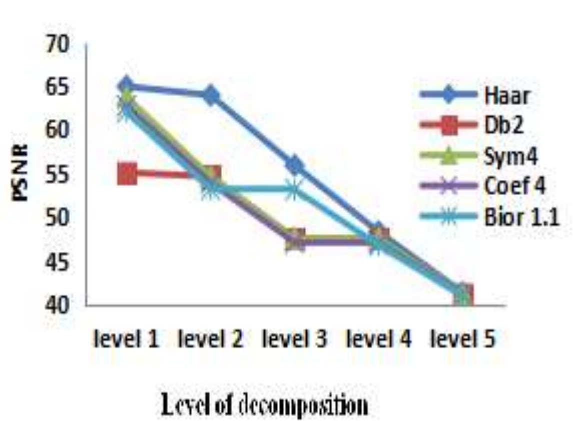


Fig. 8: Comparison of PSNR at Different level of Decomposition for different wavelets of wavelet family.

Table 5. Comparision Table of CR at Different level of Decomposition for different wavelets of wavelet family.

CR% At	Haar	Db2	Sym4	Coef 4	Bior 1.1
level 1	105.27	77.57	101.49	99.45	96.26
level 2	87.05	74	74	68.58	62.41
level 3	75	52.42	55.42	46.82	50.31
level 4	56.9	51.39	51.39	46.51	42.95
level 5	40.55	35.95	35.95	32.11	29.28

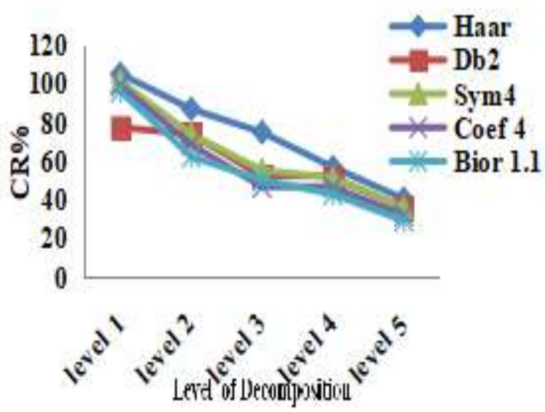


Fig. 9: Comparision of CR at Different level of Decomposition for different wavelets of wavelet family.

Conclusion

From the above data it is seen after the comparative study that PSNR, CR and MSE values of Haar wavelet are most appropriate among all the results obtained. So, we have found in the present data that Haar wavelets gives the best compression of the MRI image of the brain. As well as we also want to say that it is not sure that Haar wavelet always gives the best compression results on all type of medical images. Further study is required for other types of medical images.

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