Performance Analysis of Biorthogonal Wavelet Filters for Lossy Fingerprint Image Compression

S.S.Gornale[1], R.R.Manza[2], Vikas Humbe[2] and K.V.Kale[2]

***Abstract*—** The increasing amount of fingerprints collected by law enforcement agencies has created an enormous problem in storage and transmission [1]. To reduce the increasing demand of storage space and transmission time, Compression techniques are the need of the day. There are many image compression techniques available at present. Wavelet coding is one of the effective techniques for compression and de-noising of image [2] [3]. In wavelet based image coding, a variety of orthogonal and biorthogonal filters have been developed by researchers for signal analysis and compression. The selection of wavelet filters plays a crucial part in achieving an effective coding performance, because there is no filter that performs the best for all images [4]. The Current Compression system uses the biorthogonal wavelet filters instead of orthogonal. Because Orthogonal filters have a nice property of energy preservation where as biorthogonal filters lack of it. Daubechies, Symlet and Coiflet filters having special property of more energy conservation, more vanishing moments , regularity and asymmetry than other biorthogonal filters [5]-[7]. In this paper we have analyze the best biorthogonal wavelet filter out of Daubechies, Symlet and Coiflet for lossy fingerprint image compression. For this, we have applied Daubechies, Symlet and Coiflet Wavelet Transforms (WT) through different orders at 1 to 5 decomposition levels on the fingerprint images. Our results show that the Coiflet4 (4^{th} order) wavelet filter is more suitable for lossy fingerprint image compression and gives a better compression at 5^{th} level.

***Keywords*—** Decomposition, Fingerprint Image Compression, Wavelet Compression, Wavelet Filter.

I. Introduction

THE Federal Bureau of Investigation (FBI) deals with a large collection of fingerprints containing more than 200 million cards and this volume is growing at a rate of 30,000-50,000 new cards per day [8]. Digitization of these cards requires greater storage space, likewise their retrieval and transmission requires longer time. Therefore it is often necessary to compress the image while storing the necessary data for subsequent reconstruction [9]. There are many image compression techniques available for compressing the images, such as DCT, JPEG, Sub-band Coding, JPEG2000, and Wavelet etc, [10]. The common aim of all these techniques is to achieve high compression ratio. But still there is a need to develop and more efficient algorithm for fingerprint images [11]. One of the difficulties in developing compression algorithm for fingerprint is the necessity of preserving minutiae i.e. ridges endings and bifurcations, which are subsequently used in automatic authentication in biometric system identification. Wavelet Thresholding is an effective method of compressing and de-noising the noisy signals, which can prove very effective in de-noising images [12]-[17]. In this paper, we have applied different biorthogonal wavelet filters with different order to fingerprint images. And we are trying to choose the best wavelet filter for compression of fingerprint images

II. Wavelet for Compression

The theory of wavelet analysis has proved to be very important development in the search of more efficient methods of image compression. Like most Lossy image coders, wavelet based image coders are typically comprising three major components. Wavelet filter bank decomposes an image into wavelet coefficients, which are then quantized in quantizer, and finally an entropy encoder encodes these quantized coefficients into out bit stream i.e. compressed image as shown in figure 1.

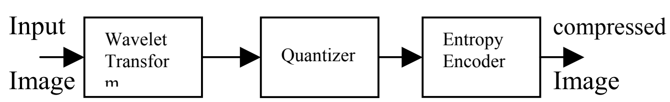

Fig. 1 shows the Lossy Image Coding System

The ability of Wavelet transform is to take into account the Human Visual System (HVS) characteristics and good energy compaction capabilities under transmission and decoding which results the high compression ratio [18],[19]. In addition to these, wavelet transform compression provides a superior image quality at low bit rates. Wavelet analysis can be used to divide the information of an image into approximation coefficients and detail coefficients. The approximation coefficients show the general trend of pixel values, and detail coefficients show the Horizontal (H), Vertical (V), and Diagonal (D) details or changes of the image. The advantage of the wavelet is that often a large number of the detail coefficients turn out to be very small in magnitude. If these

[2] *Department of Computer Science and IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. India, reamesh_manza@yahoo.com vikashumbe@yahoo.co.in and kvkale91@rediffmail.com*

[1] *Department of Computer Science, University of Pune, Pune. India* shivanand_gornale@yahoo.com

details are very small, they can be set to zero without significantly changing the image. The value below which details are considered small enough to be set to zero is known as threshold. The greater the number of zeros the greater the compression ratio. The amount of information retained by an image after compression and decompression is known as Retain Energy (RE) and this is proportional to the sum of square of the pixel values. If the Retain Energy (RE) is 100% the compression is known as Lossless as image can be reconstructed exactly. This occurs only when the threshold value is set to zero. If there are any changes in the retain energy then the compression is known as lossy [5], [20], [21]. The selection of threshold value is not an easy task; again, this is one of the grand challenges in front of researchers, these thresholding values must be provided in such a manner that there is good initial balance between retaining the images energy while minimizing the number of coefficients needed to represent the image. Wavelet thresholding removes noise by eliminating coefficients relating to some thresholds and turns out to be simple and effective [13], [22], [23]. The Current Compression system uses biorthogonal wavelet filters instead of orthogonal ones. Because orthogonal filters have a property of energy preservation, where as, biorthogonal filters do not preserve the energy. [6].

III. Design Parameters

A. Iteration of Decomposition, Filter order and decomposItion level:

To achieve a high compression rate, it is often necessary to choose the best wavelet filter bank and decomposition level, which will play a crucial role in compressing the images. The choice of optimal wavelets has several criteria. The main criteria are:

a) Support size.
b) Number of vanishing moments.
c) Symmetry.
d) Orthogonality and Biorthogonality of the resulting analysis.

Another criterion of wavelet is its regularity, but greater regularity often does not improve the visual quality [24], [25].

Wavelet transform is a pair of filters. The way we compute the wavelet transform by recursively averaging and differentiating coefficients is called the filter bank, where one is a low pass filter (lpf) and other is a high pass filter (hpf). Each of the filters is downsampled by two. Each of those two output signals can be further transformed. Similarly, this process can be repeated recursively several times, resulting in a tree structure called the decomposition tree. Wavelet transform can be used to analyze or decompose signals and images called decomposition. The same components can be assembled back into the original signal without loss of information called reconstruction or synthesis and the same has been shown in figure 2. The structure of Wavelet can be represented as a four channel perfect reconstruction of filter bank. Now each filter is 2D with subscript indicating the type of filter (HPF or LPF) for separation of horizontal and vertical components. The resulting four-transform components consist of all possible combinations of high and low pass filtering in the two directions. By using these filters in one stage an image can be decomposed into four bands. There are three types of detail of images for each resolution Diagonal (HH), Vertical (LH) and Horizontal (HL).

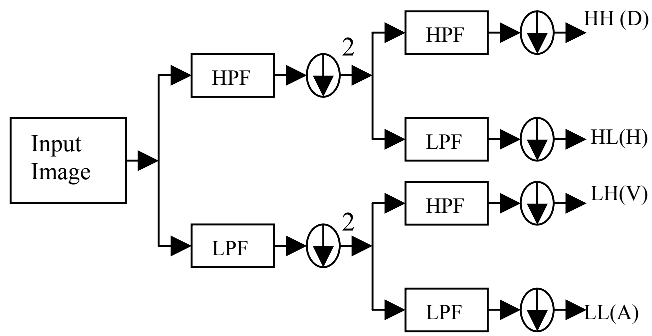

Fig. 2: Analysis of 2-D DWT shows one stage filter

The operations can be repeated on the low low (LL) i.e. on approximation band using the second identical filters bank [26]. The decomposition process can be iterated, with successive approximations being decomposed. However, in practice, more than one decomposition level is performed on the image data. Successive iterations are performed on the low pass coefficients (approximation) from the previous stage to further reduce the number of low pass coefficients. Since the low pass coefficients contain most of the original signal energy, this iteration process yields better energy compaction. The quality of compressed image depends on the number of decomposition. Compression of an image can be obtained by ignoring all coefficients less than the threshold value. If we use decomposition iteration, it will be more successful in resolving DWT coefficient because Human Visual System (HVS) is less sensitive to removal of smaller details. Decomposition iterations depend on the filter order. Higher order does not imply better image quality because of the length of the wavelet filter. This becomes a limiting factor for decomposition. Usually, Five levels of decompositions are used in current wavelet based image compression [27]-[29]. The maximum levels of Decomposition of any image can be determined by using the formula

Maximum Levels of Decomposition = $\log_2 x_{max}$

Where x_{max} is the maximum size of given image.

IV. Methodology

To determine the effect of good filter we have perform operations on Daubechies, Symlet and Coiflet filters belonging to biorthogonal families with their different orders. To do this we have used fingerprint image 1_1.tif of size 374x388 taken from FVC2002 database [23]. These biorthogonal wavelets families at 1 to 5 levels with varying threshold values are applied to the image. For every threshold value, this transform gives different compression ratio. This analysis is determined on the basis of 2-D wavelet analysis technique. In this technique the retain energy (RE) and number of Zeros (NZ) are noted after the compression, and these are calculated by the fallowing formula.

$$RE = \frac{100*(vn(ccd,2))^2}{(vn(originalsignal))^2}$$ and

$$NZ = \frac{100*(ZCD)}{numberofcoefficients}$$

Where ***vn*** is the vector norm, ***ccd*** is the coefficients of the current decomposition and ***zcd*** is the number of zeros of the current decomposition [5].

V. Result and Discussion

Image compression and decompression depends on NZ and RE. In this paper we have applied Daubechies, Symlet and Coiflet transforms with different orders from 1^{st} to 5^{th} level. We found that at first level of all three transform for all orders the NZs are similar. It shows that compression ratio is same as at first level of all different orders of these three transforms. Further we found that for all orders of these transforms if level increases the NZs are also increases. It means, to get high compression ratio we have to select highest level. In Daubechies transform, the highest compression ratio is achieved at 10^{th} order with 5^{th} level, whereas, in case of Symlet, it is achieved at 8^{th} order with 5^{th} level and in Coiflet, the highest compression ratio is achieved at 4^{th} order with 5^{th} level. We compared these three transforms for fingerprint image compression, and we found that Coiflet is best suited for fingerprint image compression, because it gives highest compression ratio among these three transforms in 4^{th} order with 5^{th} level. So our result shows that the Coiflet is more suitable for fingerprint image compression. The same has been shown in table and graph.

VI. Conclusion

Daubechies, Symlet and Coiflet filters having special property of more energy conservation, more vanishing moments, regularity and asymmetry than other biorthogonal filters therefore in this paper we have applied Daubechies, Symlet and Coiflet transforms with different orders to fingerprint images of FVC2002 database. We determined NZ and RE at different orders from 1^{st} to 5^{th} level. If NZs are more, then compression ratio is also more. We found that to get highest compression ratio, the order and level must be high. We have compared these three transforms and their order as well as levels, and found that Coiflet is most suitable for fingerprint image compression, because it gives more NZs at 4^{th} order with 5^{th} level. Hence for fingerprint image compression Coiflet transform is most suitable.

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VII. References

[1] Shohreh Kasaei, Mohamed Deriche, Boualern Boash, "A Novel Fingerprint Image compression technique using Wavelet packets and Pyramid Lattice Vector Quantization", *IEEE Tran. on Image Processing* Vol.11.No.12. , Dec-2002, PP. 1365-1378

[2] Dilmaghani, Dr. A Amadian, N. Maleki "Choice of wavelet filter for medical image compression and approximation", *Proc. of the 2nd joint EMBS/BMES conference Houston, TX*, USA, 2002, PP 1059-1060.

[3] K.V. Kale, R.R. Manza, S.S. Gornale, Vikas Humbe, "Noisy and Noiseless Fingerprint Image Compression Using Wavelet", *IT Review, Journal of Information Technology and Computer Science,* Vol. 1 No. 1, 2005, PP. 46-50.

[4] Subhasis Saha & Rao Vemuri "Analysis based adaptive Wavelet filter selection in Lossy image coding schemes", *ISCAS-2000-IEEE International Symposium on Circuits and systems* May-28-31,2000, Genewa, Switzerland.

[5] Wavelet Toolbox users Guide, www.mathworks.com

[6] Bryan E. Usevitch "A Tutorial on Modern Lossy Wavelet Image Compression: Foundations of JPEG 2000", *IEEE Signal Processing Magazine*, September 2001.

[7] John D. Villasenar, Benjamin Belzer and Judy Liao "Wavelet Filter Evaluation for image compression", *IEEE Transactions on Image Processing*. Vol. 4. No. 8, 1995.

[8] G. A. Khuwaja and A.S.Tolba, "Fingerprint Image Compression" *Kuwait University*, Kuwait

[9] Ramesh Manza, S. S. Gornale, Vikas Humbe and K.V.Kale, "Noisy and Noiseless fingerprint Image Compression using Wavelet Packet", *Proceedings of International Conference on Cognition and Recognition* Dec-22-23, 2005, PP. 885-890.

[10] Milan Sonka, Roger Boyle "*Image processing Analysis and Machine Vision*", international Thomson Computer press-1996.

[11] Karen Lees "Image compression using Wavelets", *Report of M.S.* 2002

[12] Subhasis Shaha "Image Compression from DCT-Wavelets: A review" *ACM student's magzine*-2000.

[13] D.L. Dohono, "De-noising by soft thresholding", *IEEE Tran. on Information Theory*, No. 3, 1993 PP. 933-936.

[14] S. Grace Chang, Bin yu and M. Vattereli, "Adaptive wavelet thresholding for image denoising and compression", *IEEE Tran. on Image Processing*. Vol No. 9, 2000, PP. 1532-1546.

[15] G.Panda, S.K.Meher and B Majhi "De-nosing of corrupted data using Discrete Wavelet Transform", *Journal of CSI* Vol.30 No. 3, 2000.

[16] A. Buades, B Coil, J. M. Morel, "A review of Image De-noising algorithms with new one", *Multiscale model, simulation* Vol. 4 No. 2. 2005, PP. 496-530.

[17] S. Grace Chang, Bin yu and M. Vattereli, "Spatially adaptive wavelet thresholding with context modeling for image de-noising", *IEEE Tran. on Image Processing*. Vol No. 9, 2000, PP. 1522-1530.

[18] J. Azpiorc-Leehan, R Leder. J-F Lerallut "Quantitative and Qualitative Evaluation of filter characteristics for Wavelet packet compression for MR images", *IEEE Proc. of Int. Conf. of the EMBS*, CA, USA, 2004.

[19] K.P.Soman, K.Ramchandran "*Insight into a Wavelets from Theory and Practice*", PHI New Delhi-2004

[20] R. C. Gonzalez, R. E. Woods, "*Digital Image Processing*" Second Edition, Pearson Education, 2004.

[21] Khalid Syood "*Introduction to data compression*" Second Edition, Morgan Kaufman publisher, 2003.

[22] M.Thiyagrajan, B.Santhi "Wavelet De-noising in image Analysis", *Proc. of Int. Conf. of Systematics, Cybernetics, Informatics*, 2004.

[23] FVC2002: *Fingerprint Verification competition*-2002.

[24] Raghuveer M. Rao, Ajit. S. Bopardikar, "*Wavelet Transform: Introduction to theory and applications*", Second Edition, Addison Wesley , 2005.

[25] S. Raut, "Orthogonal Vs Biorthogonal Wavelet for image compression", *M. S. Thesis*, Blacks Burg Vrginia, 2003.

[26] Sonja Grigic, Mislav Grigic, Branko Zovko-Cihlar, "Performance Analysis of Image Compression using Wavelets", *IEEE Transactions on Industrial electronics* , Vol.48. N0. 3, June 2001, PP.682-695.

[27] Michael B. Martin, A.E.Bell at.el. "Applications of Multiwavlelet to image compression", *MS thesis, Virgina Polytechnic Institute and State University,* June-1999

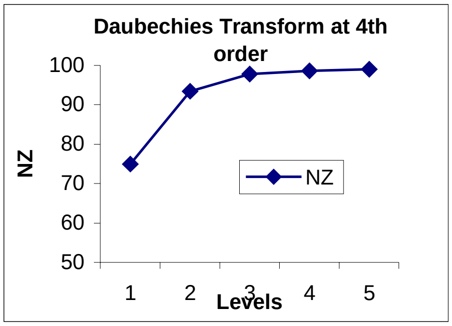
[28] Sonja Grigic, et. al. "Optimal Decomposition for Wavelet image Compression", *First International Workshop on Image and Signal Processing and Analysis*, June 14-15, 2000, Pula, Coatia.

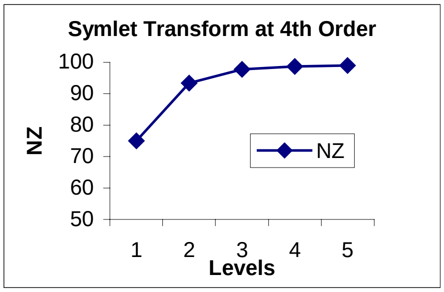
[29] Geeta S. Rao "*Wavelet Analysis and Applications*", New Age International Publisher, 2004.

TABLE I

SHOWS THE DB, SYMLET AND COIFLET TRANSFORMS WITH RETAIN ENERGY (RE), NO. OF ZEROS (NZ) WITH ORDER AND LEVELS.

Wavelet Order	No. of Levels	Daubechies Transform		Symlet Transform		Coiflet Transform	
		RE	NZ	RE	NZ	RE	NZ
1	1	99.33	75.00			99.81	75.00
	2	97.46	93.72			98.46	93.53
	3	97.27	97.27			97.67	97.67
	4	97.69	97.69			98.36	98.37
	5	97.82	97.83			98.72	98.72
2	1	99.81	75.00	99.81	75.00	99.95	75.00
	2	98.37	93.63	98.37	93.63	99.08	93.25
	3	97.64	97.64	97.64	97.64	97.73	97.73
	4	98.26	98.26	98.26	98.26	98.73	98.73
	5	98.54	98.54	98.54	98.54	99.19	99.19
3	1	99.91	75.00	99.91	75.00	99.96	75.00
	2	98.73	93.53	98.73	93.53	99.32	92.97
	3	97.75	97.75	97.75	97.75	97.63	97.63
	4	98.48	98.48	98.48	98.48	98.80	98.80
	5	98.82	98.82	98.82	98.82	99.32	99.33
4	1	99.94	75.00	99.94	75.00	99.97	75.00
	2	99.00	93.44	98.97	93.44	99.44	92.71
	3	97.80	97.79	97.80	97.80	97.47	97.47
	4	98.63	98.63	98.63	98.63	98.78	98.78
	5	99.02	99.02	99.03	99.03	99.35	99.35
5	1	99.96	75.00	99.95	75.00	99.97	75.00
	2	99.14	93.34	99.13	93.34	99.52	92.45
	3	97.78	97.78	97.79	97.79	97.76	97.19
	4	98.71	98.71	98.72	98.72	98.73	98.67
	5	99.13	99.13	99.14	99.14	99.45	99.20
6	1	99.96	75.00	99.96	75.00		
	2	99.21	93.25	99.22	93.25		
	3	97.75	97.75	97.75	97.75		
	4	98.76	98.76	98.77	98.77		
	5	99.21	99.21	99.22	99.22		
7	1	99.96	75.00	99.97	75.00		
	2	99.29	93.15	99.29	93.15		
	3	97.72	97.72	97.72	97.72		
	4	98.80	98.80	98.79	98.79		
	5	99.26	99.26	99.27	99.27		
8	1	99.97	75.00	99.97	75.00		
	2	99.37	93.06	99.36	93.06		
	3	97.69	97.69	97.69	97.69		
	4	98.81	98.81	98.82	98.82		
	5	99.30	99.30	99.32	99.32		
9	1	99.97	75.00				
	2	99.39	92.97				
	3	97.63	97.63				
	4	98.81	98.81				
	5	99.31	99.31				
10	1	99.97	75.00				
	2	99.43	92.88				
	3	97.56	97.56				
	4	98.80	98.80				
	5	99.32	99.32				





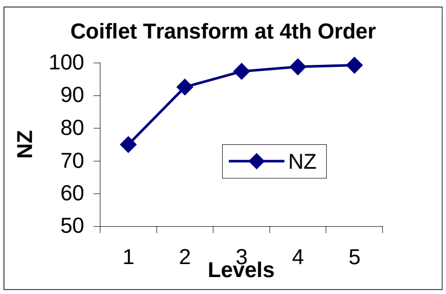


Fig. 3: Daubechies, Symlet and Coiflet transforms at 4th order and its five levels shows the increasing No. of Zeros (NZ)

Karbhari V. Kale, . He is Member of IEEE and Member of IEEE-SA (2005). He has born at Aurangabad in 1962, he has done M. Sc. in Physics (Electronics) in 1987, MCA, in 1994 and Ph. D. in 1997 from Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, India. His areas of interest are Image Processing, Neural Network, Biometrics, Bio-informatics, Software Engineering and ICT.

Presently he is Professor and Head of Dept. of Computer Science and Information Technology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. He has published more than 50 research papers in national and international conferences and journals. He has also conducted various workshops, seminars and conferences.

Prof. Kale is associated as Fellow of IETE, Life Member of IAPR, CSI & IPA. Recently he has honored “VIJAY SHREE” by IIFS, New Delhi.

Ramesh R. Manza, he has completed M. Sc. (Computer Science) in 1998 from Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, India. He has also passed UGC-NET and SET exam. He is also a Life Member of IETE. His areas of interest are Image Processing, Neural Network, Biometrics, Microprocessor and ICT.

Presently, he is working as Lecturer at Dept. of Computer Science and Information Technology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. He has published more than 25 research papers in national and international conferences and journals.

Shivanand S. Gornale, he has done M. Sc. (Computer Science) in 1995, M. Phil. (Computer Science) in 2003 from Dr. Babasaheb Ambedkar Marathwada University, Aurangabad India and Manonmaniam Sundernar University, Thirenelvelli, TN, India respectively. Currently he is doing Ph. D. in Computer Science at University of Pune, Pune, India. His areas of interest are Image Processing, Biometrics, Computer Graphics and ICT.

Presently he is Lecturer at Dept. of Computer Science, C. B. College, Bhalki, KS, India. He has published 10 papers in national and international Conferences and Journals. He is Life Member of IETE.

Vikas T. Humbe, He has completed M. Sc. Computer Science in 2003 from Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, India. He has published more than 14 papers in National and International Conferences and Journals. His areas of interest are Image processing, Biometrics, Computer Vision and ICT.

Presently he is working as Project Fellow at Dept. of Computer Science and Information Technology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad and doing Ph. D. in Computer Science.