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Image Watermarking with Biorthogonal and Coiflet Wavelets at Different Levels

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ABSTRACT

Image watermarking is the process that embeds data called watermark into the digital image. Purpose of watermarking is to completely recognize a person who applies it and, therefore, marks image as being his intellectual property. Watermarking can be applied using various techniques. One of the best image watermarking techniques is using wavelet transform. It is comparatively new and has many advantages over other techniques. Wavelet transform use a variety of wavelets for decomposition of image. Each has its own technical advantage. The wavelet transform results therefore have the importance, which is dependent on the type of wavelet used and also on the level at which the transform is applied. In this paper, biorthogonal and coiflet wavelets have been used to perform the transform of four standard test images at three different levels of decompositions and their results has been discussed and analyzed. The analyses have been carried out in terms of MSE (mean square error), RMSE (root mean square error), SNR (signal to noise ratio), PSNR (peak signal to noise ratio), MAE (mean absolute error) and E (entropy).This analysis will help to select the best wavelet and most suitable level out of the two wavelets at different levels for watermarking. The results of this study are quite promising.

Keywords: Wavelet Transform, Standard Test Images, Image Watermarking, Decomposition

1. INTRODUCTION

Copyright protection of images has become a major concern with the rapid expansion of the Internet, which contains millions of freely available images. Digital image watermarking has been suggested as a form of copyright protection and is becoming a major player in this field. The digital watermarking technology has been recognized as one of the best and effective method for multimedia copyright protection problems [1, 2]. Watermarking is the process of embedding data into multimedia element such as an image, audio or video file for authentication purposes [3]. This embedded data can later be extracted from, or detected in, the multimedia data for security purposes.

Digital image watermarking can be grouped into two major categories: spatial domain and frequency domain [4]. The frequency domain has an advantage over the spatial domain, as in this, frequency-based schemes "spread the watermark over the whole spatial extent of the image", and is therefore less likely to be affected by attacks [5], and is proved to be more effective with respect to achieving the imperceptibility and robustness requirements of digital watermarking algorithms [6]. Commonly used frequency-domain transforms include the Discrete Wavelet Transform (DWT), the Discrete Cosine Transform (DCT) and Discrete Fourier Transform (DFT). However, DWT [7] has been used in digital image watermarking more frequently due to its excellent spatial localization and multi-resolution characteristics, which are similar to the theoretical models of the human visual system [8].

2. DISCRETE WAVELET TRANSFORM

The DWT (Discrete Wavelet Transform) process the image by dividing it into four non overlapping multi resolution sub bands LL1, LH1, HL1 and HH1. The sub-band LL1 represents the coarse-scale DWT coefficients while the sub-bands LH1, HL1 and HH1 represent the fine-scale of DWT coefficients. To obtain the next coarser scale of wavelet coefficients, the sub-band LL1 is further processed until some final scale N is reached. When N is reached we will have 3N+1 sub-bands consisting of the multi-resolution sub-bands LLN and LHx, HLx and HHx where x ranges from 1 until N.

Most of the image energy is concentrated at the lower frequency sub-bands LLx and therefore embedding watermarks in these sub-bands may degrade the image significantly. Embedding in the low frequency sub-bands, however, could increase robustness significantly. On the other hand, the high frequency sub-bands HHx include the edges and textures of the image and the human eye is not generally sensitive to changes in such sub-bands.

This allows the watermark to be embedded without being perceived by the human eye. The best method is to embed the watermark in the middle frequency sub-bands LHx and HLx where acceptable performance of imperceptibility and robustness could be achieved [9-13]. A three level DWT decomposition of standard 'Lena' image using bior3.7 wavelet is as shown in figure 1.

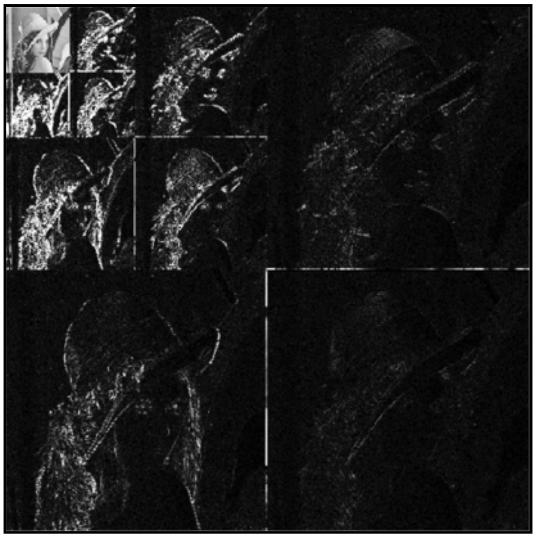

Fig.1: Three Level Decomposition of Lena Image using Bior 3.7

3. PROPOSED ALGORITHM FOR WATERMARKING

The watermarking algorithm which is used to embed the watermark in the host image is as follows:

- **Step 1:** Read in cover host image and watermark image.
- **Step 2:** Reformulate the watermark image (image which is to be inserted into host image) into vector of zeros and ones.
- **Step 3:** Apply the DWT to decompose the cover host image into four non overlapping multi resolution sub bands LL1, HL1, LH1, and HH1, i.e., find the level 1 DWT decomposition of the image.
- **Step 4:** Generate a pseudorandom sequence, PN_0, which is to be embedded in various components of the image. This sequence can be embedded into any of components, i.e., horizontal component, vertical component, diagonal component or any combination of these three components of the image. The pseudorandom sequence is embedded in the image if the watermark bit is zero. The watermark is embedded using the equation 1:

$$Y = X + k * PN_0 \quad (1)$$

  where X is the intensity value matrix of the original host image, Y is the modified intensity value matrix and k is the scaling factor which is set to be fixed at value 2 (k=2).

- **Step 5:** Save the modified intensity value matrix as the watermarked image.
- **Step 6:** Compare the original and watermarked image against various perceptibility parameters.

4. RESULTS AND DISCUSSIONS

(a)

(b)

(c)

Fig. 2 Standard test images (a) Lena, (b) Barbara, and (c) House

The watermarking algorithm is implemented on three standard test images, (a) Lena, (b) Barbara and (c) House a as shown in figure 2. The Size of the test images 'Lena' and 'Barbara' is 512× 512, while 'House' is 256×256. The watermark image which is inserted in the images is shown in figure3. The size of the watermark is 50×20.

The watermark embedding algorithm remains the same but it is repeated with different parameters. The various parameters which are altered in this algorithm are (i) Level of DWT decomposition, three different levels are used Level 1, 2 and 3 (ii) wavelet which is used for DWT decomposition, two wavelets are used (a) biorthogonal 3.7 (bior3.7) and (b) coiflet 5 (coif5). At all the levels of DWT decomposition watermark is inserted in the H component of the image only.

Fig.3: Watermark Image

(a)

(b)

Fig. 4: Watermarked Images (a) Lena and (b) Barbara using Wavelet 'bior3.7'at Level 1

Watermarked images of Lena and Barbara using wavelet bior 3.7 at level 1 are as shown in figure 4. The various perceptibility parameters taken into consideration are (i) Mean Square Error (MSE) (ii) Root Mean Square Error (RMSE) (iii) Signal to Noise Ratio (SNR) (iv) Peak Signal to Noise Ratio (PSNR) (v) Mean Absolute Error (MAE) and (vi) Entropy (E). MSE for two images X (original image) and Y (watermarked image) is defined in equation 2. Where m, n are the dimensions of the image X. $X(i, j)$ and $Y(i, j)$ are intensity value of the image X and Y at pixel (i, j) respectively. RMSE can be evaluated using the equation 3.

$$MSE = \frac{1}{m*n}\sum_{i=1}^{m}\sum_{j=1}^{n}\left[X(i,j)-Y(i,j)\right]^2 \qquad (2)$$

$$RMSE = \sqrt{MSE} \qquad (3)$$

MSE and RMSE for the image should be as low as possible. Lower the values of MSE and RMSE better is the perceptual quality of the image.

SNR measures are estimates of the quality of the reconstructed image compared with an original image. The fundamental idea is to compute the value which reflects the quality of the reconstructed image. Reconstructed image with higher metric are judged as having better quality. SNR can be defined as in equation 4.

$$SNR = 10*\log_{10}\left[\frac{1}{MSE*m*n}\sum_{i=1}^{m}\sum_{j=1}^{n}\left(X(i,j)\right)^2\right] \qquad (4)$$

Although, in fact, traditional SNR measures don't equate with human subjective perception, it is still used as it is easy to compute. Another measure that can be used for comparison is PSNR that can be used using the equation 5.

$$PSNR = 10*\log_{10}\left[\frac{\max\left(\left(X(i,j)\right)^2\right)}{MSE}\right] \qquad (5)$$

PSNR is measured in db. Larger the value of SNR and PSNR are better the watermark conceals [14]. Another parameter to measure the quality of image is standard deviation. For the better the processed image quality, the standard deviation should the bigger. To calculate the standard deviation of the image intensity values, find the mean intensity of the original host image using equation (6), and this is subtracted from the from the intensity of each pixel of watermarked image as shown in equation (7).

$$\mu = \frac{1}{m*n}\sum_{i=1}^{m}\sum_{j=1}^{n}X(i,j) \qquad (6)$$

$$SD = \sqrt{\frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left[Y(i,j)-\mu\right]^2}{m*n-1}} \quad (7)$$

The last parameter is Entropy. The entropy of each watermarked image is compared using equation (8), the better the enhanced image quality, the bigger the entropy. Given a probability distribution $P= (P_1, P_2 .... P_n)$ with $p_i \geq 0$, for i=1, 2……n and $\sum_{i=1}^{n} p_i = 1$, the entropy of P is

$$E = -\sum_{i=1}^{n}(p_i \log p_i) \quad (8)$$

Where, $p_i \log p_i = 0$ by definition for $p_i = 0$. Since P is a probability distribution, the histogram should be normalized before applying the entropy function in equation (8) [15].

The results for Lena image are summarized in table 1. Table 1 shows the various parameters at level 1, 2 and 3 of DWT decomposition. Table 2 shows result for Barbara and table 3 shows values for house test image.

Table 1
Values of Various Parameters for Lena Image at Level 1, 2 and 3

Performance Parameters	*Level 1*		*Level 2*		*Level 3*	
	BIOR 3.7	*COIF 5*	*BIOR 3.7*	*COIF 5*	*BIOR 3.7*	*COIF 5*
MSE	66.1931	52.3628	8.7859E-27	3.29612E-14	1.86808E-26	9.19113E-14
RMSE	8.1359	7.2362	9.37332E-14	1.81552E-07	1.36678E-13	3.03169E-07
SNR	24.2737	25.2916	303.0439979	177.301832	299.7605073	172.8407629
PSNR	29.6458	30.6637	308.4160748	182.6739089	305.0693766	178.1496322
SD	45.9301	45.7803	45.20554341	45.2055434	47.85378512	47.85378509
E	7.5483	7.5817	7.347919364	7.347919364	7.45821921	7.455923605

Table 2
Values of Various Parameters for Barbara Image at Level 1, 2 and 3

Performance Parameters	*Level 1*		*Level 2*		*Level 3*	
	BIOR 3.7	*COIF 5*	*BIOR 3.7*	*COIF 5*	*BIOR 3.7*	*COIF 5*
MSE	66.19308	52.36275	8.24275E-27	9.6094E-14	1.74452E-26	1.49087E-13
RMSE	8.13591	7.23621	9.07896E-14	3.0999E-07	1.3208E-13	3.86118E-07
SNR	24.03541	25.05331	303.082811	172.4165667	299.8267667	170.5091308
PSNR	29.61058	30.62848	308.6579818	177.9917375	305.4019375	176.0843016
SD	55.20998	55.08499	54.60774957	54.60774955	54.60774957	54.60774953
E	7.67309	7.64571	7.634352508	7.63309863	7.636689871	7.633331367

Table 3
Values of Various Parameters for House Image at Level 1, 2 and 3

Performance Parameters	*Level 1*		*Level 2*		*Level 3*	
	BIOR 3.7	*COIF 5*	*BIOR 3.7*	*COIF 5*	*BIOR 3.7*	*COIF 5*
MSE	65.2383	52.8093	9.8020E-27	4.3147E-14	2.1572E-26	1.0417E-13
RMSE	8.0770	7.2670	9.9005E-14	2.0772E-07	1.4687E-13	3.2275E-07
SNR	25.1097	26.0276	3.0334E+02	1.7691E+02	2.9992E+02	1.7308E+02
PSNR	29.4229	30.3409	3.0765E+02	1.8122E+02	3.0423E+02	1.7739E+02
SD	46.7272	46.5895	4.6022E+01	4.6022E+01	4.6022E+01	4.6022E+01
E	7.2334	7.1818	6.4971E+00	6.4971E+00	6.4971E+00	6.4971E+00

All the values are computed by implementing the algorithm in Matlab7.0. Results are analyzed by generating their graphs in Matlab7.0. Various graphs are shown in figures 5 to 13. Figures 5, 6 and 7 show the performance comparison of 'bior3.7' and 'coif 5' wavelets for watermarking in Lena image at levels 1, 2 and 3 respectively. Figures 8, 9 and 10 show the performance comparison of 'bior3.7' and 'coif 5' wavelets for watermarking in Barbara image at levels1, 2 and 3 respectively. Figures 11, 12 and 13 show the performance comparison of 'bior3.7' and 'coif 5' wavelets for watermarking in House image at levels1, 2 and 3 respectively. In figures 5 to 7 that for image Lena, 'coif 5' wavelet gives better results than 'bior 3.7' at level 1 while it is vice –versa at level 2 and level 3. It is also shown that out of the three levels, level 2 gives best results.

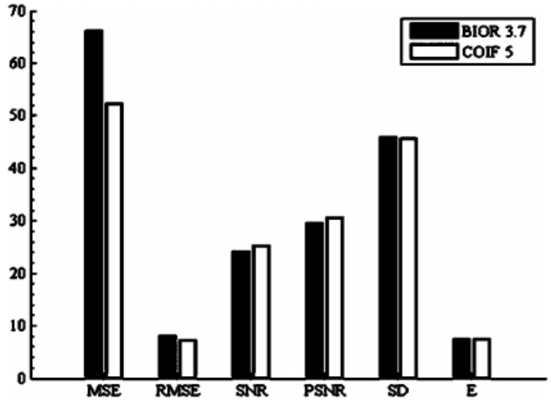

Fig. 5: Performance of Lena Image at Level 1

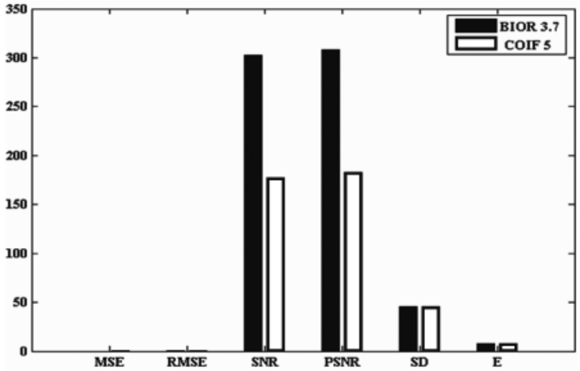

Fig. 6: Performance of Lena Image at Level 2

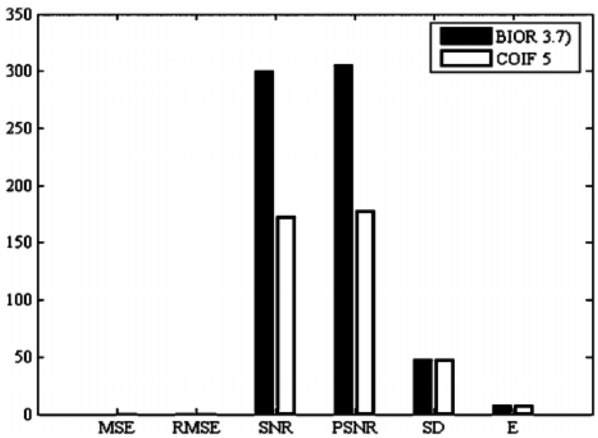

Fig. 7: Performance of Lena Image at Level 3

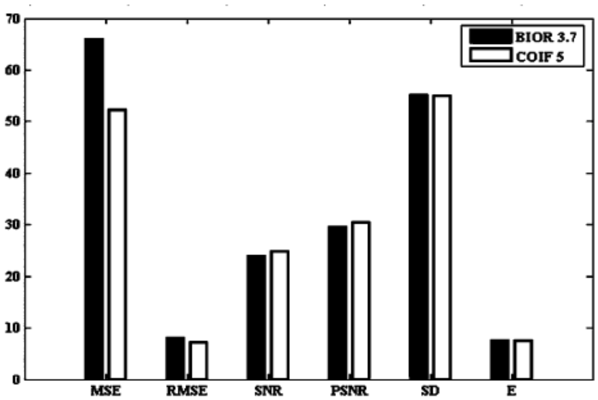

Fig. 8: Performance of Barbara Image at Level 1

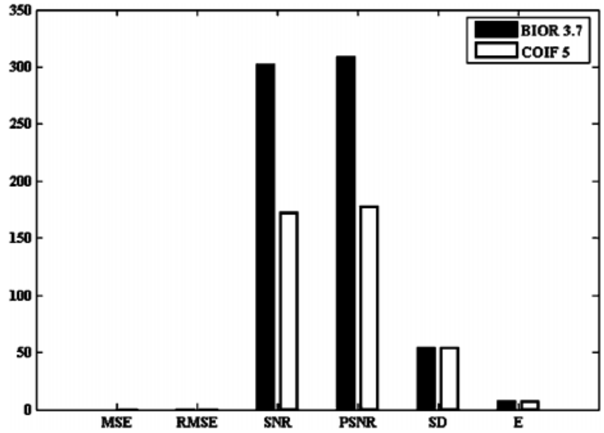

Fig. 9: Performance of Barbara Image at Level 2

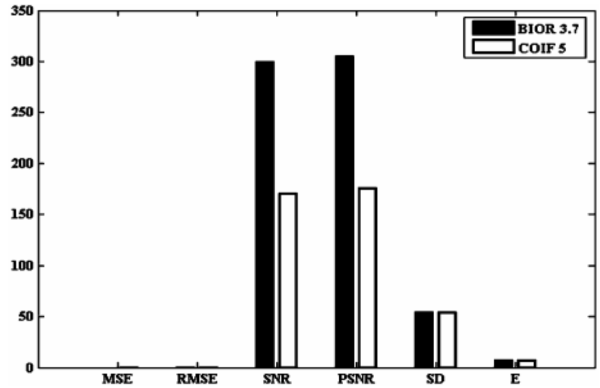

Fig. 10: Performance of Barbara Image at Level 3

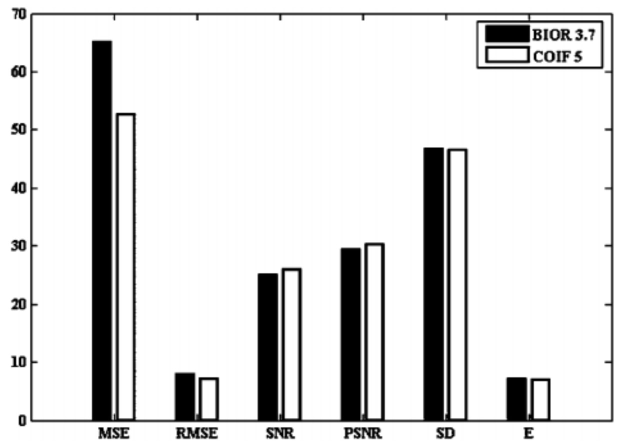

Fig. 11: Performance of House Image Level 1

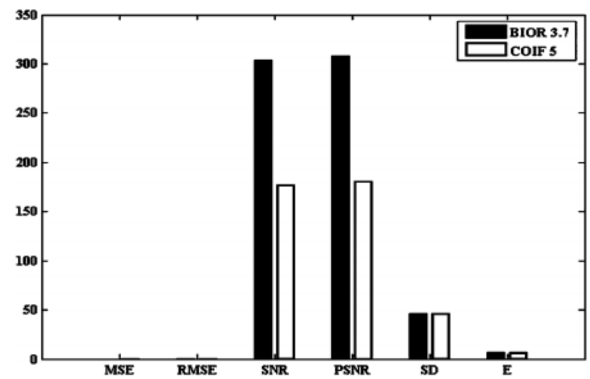

Fig.12: Performance of House Image at Level 2

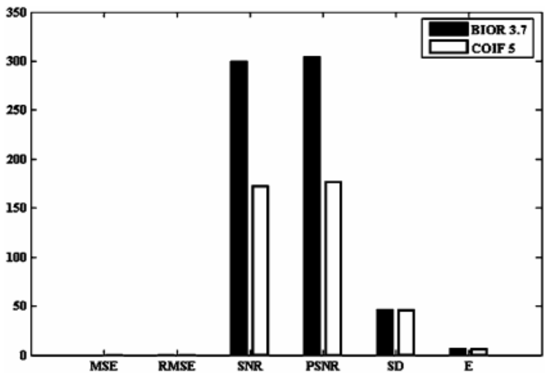

Fig.12: Performance of House Image at Level 3

Figures 8 to 10 shows that for Barbara image, coif 5 wavelet works better than the bior 3.7 at level 1, but, at level 2 and level3, bior 3.7 is better than coif 5. Also, it is observed that level 2 of decomposition gives better result than level 1 and level 3. Figures 11 to 13 shows that for House image, coif 5 wavelet works better than the bior 3.7 at level 1, but, at level 2 and level 3, bior 3.7 is better than coif 5. Also, it is observed that level 2 of decomposition gives better result than level 1 and level 3.

4. CONCLUSIONS AND FUTURE WORK

Results are analyzed for finding the best wavelet out of the two wavelets used. Results of all the images shows that, at level 1, coif 5 gives better result than bior 3.7. At level 2 and level 3, bior 3.7 results are better than the results of coif 5. Graphs also show that, the entropy (E) and standard deviation (SD), of the watermarked images, are almost the same for both wavelets at all the levels. It is also observed that at level 1, for both the wavelets, values of SNR and PSNR are approximately the same. For level 2 and level 3 there is a large difference in SNR and PSNR values for the two wavelets used.

It can be easily concluded from the results that the level 2 of DWT watermarking gives better result as compared to level 1 and level 3 for DWT watermarking.

Further research should go towards improving the watermarking program and adding extra functionality. One of these is looking at having multiple watermarks for a single image, so that different parts of the image have a different watermark. There is also the need to further develop the robustness of existing watermarking techniques to combat the ever-increasing attacks on watermarks. The coefficients that are chosen in both techniques can also be investigated to see if choosing different coefficients has an effect on the robustness of the watermark and visual quality.

The work can further be analyzed with other wavelet filters. It can also be extended by considering the effects of higher level of DWT decompositions, i.e., level 4 and level 5 of discrete wavelet transforms. Watermarking can not only be applied on digital images, it can also be applied to audio and video data.

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