Implementation and Comparison of Watermarking Algorithms using DWT

Bushra Jamal
M.Tech. Student
Galgotia's College of Engineering & Technology
Greater Noida, U.P., India

Athar Hussain
Asst. Professor
School of Engineering, Gautam Buddha University
Greater Noida, U.P., India

ABSTRACT
Robustness is an essential requirement of watermarking schemes so that they can sustain several intentional or unintentional image processing attacks. For such a robust watermarking algorithm, watermark will be embedded into the third level wavelet coefficients of an image that is decomposed by using DWT technique. In this paper the third level watermarking scheme is proposed by three different algorithm and the obtained results are then compared so as to find out that which algorithm performs better under a particular condition. In present study the third level enhanced watermarking scheme for two DWT based watermarking techniques namely alpha blending technique and CDMA-DWT based watermarking scheme is also proposed. The results obtained by these two techniques are further compared and analyzed.

Keywords
Digital watermarking, Discrete Wavelet transform, Insertion, Extraction, Watermark, PSNR, MSE, Alpha Blending

1. INTRODUCTION
The rapidly growing field of digitized images, video and audio has urged the need of copyright protection, which can be used to produce evidence against any illegal attempt to either reproduce or manipulate them in order to change their identity. Digital watermarking is a technique providing embedded copyright information in images. In digital watermarking an imperceptible signal "mark" is embedded into the host image, which uniquely identifies the ownership. After embedding the watermark, there should be no perceptual degradation. These watermarks should not be removable by unauthorized person and should be robust against intentional and unintentional attacks. Digital watermarking techniques have wide ranging applications [1, 2, 3] such as copy protection, tracking, tamper proofing, broadcast monitoring, covert communication etc. Digital watermarking schemes can be broadly classified into four categories, namely, Secure [4], Robust, Semi-fragile and Fragile [5]. Early watermarking schemes worked in the spatial domain, where the watermark is added by modifying pixel values of the host image [6]. Generally, spatial domain watermarking is easy to implement from a computational point of view, but too fragile to resist numerous attacks. In order to have more promising techniques, researches were directed towards watermarking in the transform domain, where the watermark is not added to the image intensities, but to the values of its transform coefficients [7]. Then to get the watermarked image, one should perform the transform inversely. Some of the transform based watermarking techniques used the Discrete Cosine Transform (DCT). The wavelet transform is another type of the transform domain. Wavelet based transform gained popularity recently since the property of multiresolution analysis that it provides. Discrete Wavelet Transform (DWT) is most commonly used wavelet transform. DWT is the most effective and easy to implement techniques in watermarking. DWT has been used in digital image watermarking more frequently due to its excellent spatial localization and multi-resolution characteristics. The biggest issue in DWT-based image watermarking is how to choose the coefficients to embed the watermark. The most common approaches include modifying the largest DWT coefficients in all decomposition levels or quantizing certain DWT coefficients in different levels and scales.

2. WAVELET TRANSFORM
The wavelet transform decomposes the image into three spatial directions, i.e. horizontal, vertical and diagonal. Hence wavelets reflect the properties of HVS more precisely. Wavelet Transform decomposes an image into a set of band limited components which can be reassembled to reconstruct the original image without error.

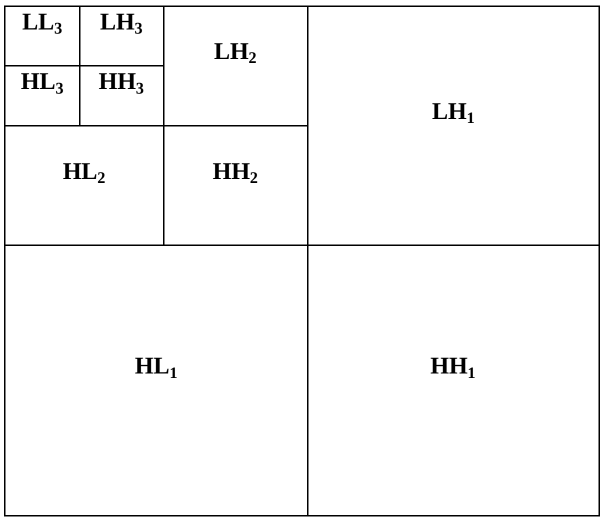

Figure 1: Three Level 2-dimensional DWT model

As pointed out in [7], wavelet-based watermarking methods exploit the frequency information and spatial information of the transformed data in multiple resolutions to gain robustness. Wavelet Transform is computationally efficient and can be implemented by using simple filter. Magnitude of DWT coefficients is larger in the lowest bands (LL) at each level of decomposition and is smaller for other bands (HH, LH and HL). The larger the magnitude of the wavelet coefficient the more significant it is. Watermark detection at lower resolutions is computationally effective because at every successive resolution level there are few frequency bands involved. High resolution sub bands helps to easily locate edge and textures patterns in an image.

There are various advantages of using discrete wavelet transform [8] such as

- It understands the HVS more closely than the DCT.
- Wavelet coded image is a multi-resolution description of image. Hence an image can be shown at different levels of resolution and can be sequentially processed from low resolution to high resolution.
- DFT and DCT are full frame transform, and hence any change in the transform coefficients affects the entire image except if DCT is implemented using a block based approach. However DWT has spatial frequency locality, which means if signal is embedded it will affect the image locally. Hence a wavelet transform provides both frequency and spatial description for an image.

Wavelet transforms use wavelet filters [9] to transform the image. There are many available filters, although the most commonly used filters for watermarking are:- Haar Wavelet Filter, Daubechies Orthogonal Filters, Daubechies Bi-Orthogonal Filters, Symlet wavelets. Each of the filters decomposes the image into several frequencies. Single level decomposition gives four frequency representations of the images.

3. PROPOSED WATERMARKING ALGORITHMS

Based on DWT technique, three watermarking algorithms are proposed as follows. The proposed algorithms are divided into two parts, watermark embedding and watermark extraction. In both algorithms firstly the gray scale host image is taken and 2-D, 3-level DWT (Discrete Wavelet Transform) is applied to the image which decomposes image into low frequency and high frequency components. In the same manner 2-D, 3-level DWT is also applied to the watermark image which is to be embedded in the host image. The wavelet used here is the wavelets of daubecheis. After decomposition, formulae's of embedding and extraction are applied respectively based on which certain results are obtained that will show the efficiency of all proposed algorithms.

3.1 Watermarking formulae

In this scheme the watermarking will be done by embedding the watermark into the cover image on the basis of certain weight values [10]. Here the watermark is multiplied by a weight factor and is added to the third level decomposed components of cover image. For doing this the watermark is resized to the size of third level wavelet coefficients of cover image. Addition is performed on all the wavelet coefficients of third level approximation component of cover image. Similarly watermark is recovered by subtracting coefficients of cover image from the watermarked image. It's embedding and extraction formulae are stated below.

For embedding: $WMI = CI + C * WM;$

Where, CI contains 3rd level wavelet coefficients of original cover image, C is the weight of watermarking and WM contains 3rd level wavelet coefficients of watermark image to be embedded.

For extraction: $RW = WMI - CI$

Where, WMI contains wavelet coefficients of watermarked image, CI contains 3rd level wavelet coefficients of original cover image.

3.2 CDMA-DWT based watermarking scheme

One of the most straightforward techniques is to use a CDMA sequence in the detail bands according to the equation given below [11].

$$IW_{u,v} = \begin{cases} W_i , + \alpha\, |W_i| xi & u,v \in HL, LH \\ W_i & u,v \in LL, HH \end{cases}$$

To detect the watermark we generate the same pseudo-random sequence used in CDMA generation and determine its correlation with the two transformed detail bands. If the correlation exceeds some threshold δ, the watermark is detected. Its embedding and extraction algorithms are stated below.

3.3 Alpha blending formulae

In this technique two scaling parameters are opted for watermarking [12]. The decomposed components of the host image and the watermark are multiplied by a scaling factor and are added. Since the watermark embedded in this scheme is perceptible in nature or visible, it is embedded in the low frequency approximation component of the host image.

Watermark Embedding formulae:

$$WMI = k * (LL3) + q * (WM3)$$

Where, LL3 is 3rd level wavelet coefficients of original cover image, WM3 is 3rd level wavelet coefficients of watermark image to be embedded, k and q are scaling parameters.

Watermark Extraction formula:

$$RW = WMI - k * (LL3)$$

Where, WMI contains wavelet coefficients of watermarked image, LL3 contains 3rd level wavelet coefficients of original cover image. Performance is measured on the basis of following parameters.

$$PSNR = 10\, log_{10} \left(\frac{255^2}{MSE}\right) dB$$

4. EXPERIMENTAL RESULTS

The following results are presented according to their qualitative and quantitative evaluation of the reconstructed watermarked images and recovered watermarks from those watermarked images. For all 3 techniques same gray scale images of size 256×256 are used so that comparison can be easily made and a better conclusion can be drawn that which algorithm will give best results at what point and their respective working range for the same natural images. Here Lena image is used as original cover image, the reason for using this image is mainly due to its feature of carrying all frequencies and bird image is used as watermark that will be embedded into the third level wavelet coefficients of Lena image.

Figure 2 Lena image

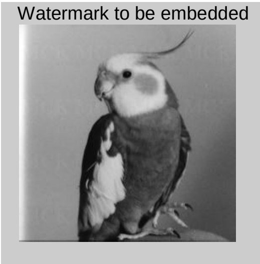

Figure 3 Bird image

4.1 Watermarking formula

Best results of embedding and extraction from this algorithm were obtained at k=0.004 value of weight and as we increases the bit rate of watermark weight values the watermarked image starts getting darker and the recovered watermark almost become invisible. Thus best results from this algorithm are obtained at lower value of weight. Fig. 4 and 5 represents the watermarked image and recovered image from the given scheme. Both images are of 32×32 thus representing third level watermarking.

The range of watermark weight is varied from 0.001 to 7.0 bpp. The resulting values of PSNR, COC and MSE obtained from this algorithm are varied according to the weight of applied watermark.

Figure 4 Level-3 watermarked image at weight=0.004

Figure 5 Level-3 recovered image at weight= 0.004

Table 1 illustrates the resulting values of PSNR, COC and MSE. In embedding process it is observed that as the weight is increased the COC values starts decreasing whereas MSE and PSNR keeps on increasing. In extraction process COC is constant whereas PSNR value is decreasing and MSE is increasing as the weight value is increased.

Table 1 Embedding and extraction results of level 3 in terms of their PSNR, COC and MSE using watermarking formula

k	EMBEDDING			EXTRACTING		
	COC	MSE	PSNR	COC	MSE	PSNR
0.001	0.9150	8.3574e+005	26.7480	0.9664	1.8593e+004	126.0016
0.004	0.9151	8.3616e+005	26.7530	0.9671	1.8483e+004	98.2163
0.007	0.9142	8.3658e+005	26.7580	0.9674	1.8373e+004	86.9644
0.01	0.9151	8.3700e+005	26.7630	0.9670	1.8263e+004	79.7711
0.04	0.9150	8.4122e+005	26.8133	0.9674	1.7187e+004	51.4375
0.07	0.9149	8.4545e+005	26.8635	0.9672	1.6143e+004	39.6187
0.10	0.9148	8.4971e+005	26.9137	0.9674	1.5132e+004	31.8386
0.40	0.9084	9.0865e+005	27.5843	0.9674	4.8099e+003	11.8116
0.70	0.9023	9.3961e+005	27.9195	0.9674	1.8495e+003	28.0984
1.00	0.8898	9.8794e+005	28.4210	0.9673	159.9324	59.7113
4.00	0.6569	1.5948e+006	33.2099	0.9674	1.6482e+005	18.0583
7.00	0.4570	2.4265e+006	37.4067	0.9659	6.5960e+005	15.3831

4.2 Alpha blending technique

For embedding of watermark in the original image the value of scaling factor k is varied from .001 to 7 by keeping q constant and best result is obtained at k=0.1 for all three levels. Fig 5.10 and 5.11 represents both watermarked image and recovered image at k=0.1 at third level.

As the value of k is further increased to 7.0 the watermarked image becomes whiter and finally become invisible. For the process of recovering the watermark from the watermarked image the value of k is kept constant at 0.009 and q is varied from 0.001 to 7.0. For the higher values of q the watermark becomes darker and invisible and as the value of q is reduced best results is obtained. Best result is obtained at q=0.1 for watermark recovery. The resulting values of PSNR, COC and MSE obtained from this algorithm are varied according to the value of scaling factor for original image and watermark image.

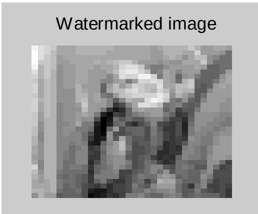

Figure 6 Level-3 watermarked image at k=0.1

Figure 7 Level-3 recovered image at k=0.1

Table 2 illustrates the resulting values of PSNR, COC and MSE for embedding process according to scaling factor values. In this process it is observed that as the scaling factor is increased the COC and PSNR keep on increasing whereas MSE is of variable nature. Best results of embedding and extraction from this algorithm were obtained at 0.1 value of scaling factor.

Table 3 illustrates the parametric values for extraction process. In extraction process the value of scaling factor k is kept constant whereas the value of another scaling factor q is varied from 0.001 to 7.00. These scaling factors are taken in reversible order for embedding and extraction due to the reason that in alpha blending two images are merged and if have to find out second image from the first image then we need to reverse the process as of embedding that is done over here via scaling parameters.

It is observed that as the scaling factor is increased the COC and PSNR keep on increasing whereas MSE is of variable nature. Here PSNR is increased up to 1.00 value of scaling factor and then drops down. Thus best results from this algorithm are obtained at lower value of weight.

Table 2 Embedding results of level three in terms of their PSNR, COC and MSE according to scaling factor k by alpha blending technique

q	k	EMBEDDING		
		COC	MSE	PSNR
0.009	0.001	0.0591	1.5219e+004	13.3099
0.009	0.004	0.3087	1.4465e+004	13.8177
0.009	0.007	0.4998	1.3731e+004	14.3384
0.009	0.01	0.6288	1.3017e+004	14.8725
0.009	0.04	0.8863	6.9569e+003	21.1380
0.009	0.07	0.9055	2.8634e+003	30.0152
0.009	0.10	0.9104	736.7431	43.5904
0.009	0.40	0.9148	8.7648e+004	4.1980
0.009	0.70	0.9150	3.7124e+005	18.6334
0.009	1.00	0.9151	8.5153e+005	26.9351
0.009	4.00	0.9151	1.6472e+007	56.5590
0.009	7.00	0.9151	5.1761e+007	68.0087

Table 3 Extraction results of level three in terms of their PSNR, COC and MSE according to scaling factor q by alpha blending technique

q	k	EXTRACTION		
		COC	MSE	PSNR
0.001	0.009	0.9649	1.6079e+004	38.9685
0.004	0.009	0.9646	1.6079e+004	38.6263
0.007	0.009	0.9647	1.6078e+004	38.5332
0.01	0.009	0.9650	1.6074e+004	38.6352
0.04	0.009	0.9651	1.6076e+004	38.7002
0.07	0.009	0.9645	1.6075e+004	38.7521
0.10	0.009	0.9648	1.6078e+004	38.4074
0.40	0.009	0.0474	9.3178e+004	38.0294
0.70	0.009	0.0344	3.7577e+005	47.9795
1.00	0.009	0.0344	8.5655e+005	68.7425
4.00	0.009	0.0344	1.6482e+007	30.4877
7.00	0.009	0.0344	5.1776e+007	28.4108

4.3 CDMA-DWT based watermarking scheme

Here again the range of scaling factor is varied from 0.001 to 7.0 and best result in terms of watermarked image is obtained at k=7. Best results for this algorithm are obtained at k=7. Fig. 8 shows the image at k=7.

Figure 8 Level 3 watermarked image at k=7

Table 4 illustrates the resulting values of PSNR, COC and MSE for both embedding and extraction processes according to scaling factor values.

Table 4 Embedding and extraction results of Level 3 in terms of their PSNR, COC and MSE by CDMA-DWT based watermarking scheme

K	EMBEDDING			EXTRACTING		
	COC	MSE	PSNR	COC	MSE	PSNR
0.001	0.9150	198.7045	56.6993	8.1252e-004	1.8503e+004	12.5683
0.004	0.9142	198.8693	56.6863	0.0031	1.8502e+004	12.5687
0.007	0.9147	198.8632	56.6866	0.0016	1.8503e+004	12.5686
0.01	0.9143	198.6798	56.6958	0.0047	1.8504e+004	12.5680
0.04	0.9146	198.8345	56.6881	0.0013	1.8503e+004	12.5684
0.07	0.9144	198.8392	56.6878	0.0175	1.8503e+004	12.5686
0.10	0.9146	198.8362	56.6880	0.0014	1.8503e+004	12.5685
0.40	0.9144	198.6042	56.6996	0.0043	1.8503e+004	12.5683
0.70	0.9146	198.6601	56.6968	0.0018	1.8503e+004	12.5684
1.00	0.9145	198.6661	56.6965	0.0048	1.8502e+004	12.5687
4.00	0.9145	198.8985	56.6848	0.0039	1.8503e+004	12.5686
7.00	0.9141	198.7454	56.6925	0.0037	1.8503e+004	12.5686

4.4 Comparison of Applied Techniques

In table 5 comparison between wavelet based watermarking approach, alpha blending scheme and CDMA spread spectrum technique is given on the basis of PSNR values for their embedding and extraction algorithms respectively and hence will give an estimate of performance that which algorithm will give best results at what point and the working range of each algorithm is clearly specified.

For comparing all these proposed techniques the value of k is scaled from 0.001 to 7.0. The working range or we can say the best results in terms of image appearances from wavelet based watermarking formulae lies between 0.001 to 0.004 values of k because as we move further the quality of image drawn from this scheme starts getting changed. Here embedding works till 0.04 value of k but extraction algorithm drawn from this formula does not work at 0.04 as the quality of extracted watermark image starts getting faded off at this value. And as we move further from 0.04 in embedding algorithm the generated watermark image also starts disappearing and only grid starts remaining. Here extraction algorithm gives good recovered watermark image quality before 0.04 value of k.

The proposed three level alpha blending technique gives best results in the range of 0.004 to 0.4 values of k for both embedding and extraction algorithms, thus as we move back to lower values of k i.e. 0.001 then embedding algorithm shows second image as result i.e. parrot image rather than lena image whereas extraction algorithm also shows the same image i.e parrot image. At k= 0.1 this technique gives best results in terms of image quality , i.e both watermarked image and recovered watermark are good. When k=0.4 the results of embedding algorithm starts fading off and image looks whiter whereas the results of extraction algorithm starts getting black. At k=1 results of embedding algorithm becomes white and results of extraction algorithm becomes black.

The proposed CDMA spread spectrum technique gives best results for all values of k taken over here. At k=1 to 7 both embedding and extraction algorithm gives good results as watermarked and recovered images.

Table 5 Comparison of embedding and extraction PSNR of wavelet based watermarking, alpha blending and CDMA spread spectrum

k	EMBEDDING(PSNR)			EXTRACTING(PSNR)		
	Watermarking formula	Alpha blending	CDMA spread spectrum	Watermarking formula	Alpha blending	CDMA spread spectrum
0.001	26.7480	13.3099	56.6993	126.0016	38.9685	12.5683
0.004	26.7530	13.8177	56.6863	98.2163	38.6263	12.5687
0.007	26.7580	14.3384	56.6866	86.9644	38.5332	12.5686
0.01	26.7630	14.8725	56.6958	79.7711	38.6352	12.5680
0.04	26.8133	21.1380	56.6881	51.4375	38.7002	12.5684
0.07	26.8635	30.0152	56.6878	39.6187	38.7521	12.5686
0.10	26.9137	43.5904	56.6880	31.8386	38.4074	12.5685
0.40	27.4167	4.1980	56.6996	3.8272	38.0294	12.5683
0.70	27.9195	18.6334	56.6968	28.0984	47.9795	12.5684
1.00	28.4210	26.9351	56.6965	59.7113	68.7425	12.5687
4.00	33.2099	56.5590	56.6848	18.0583	30.4877	12.5686
7.00	37.4067	68.0087	56.6925	15.3831	28.4108	12.5686

Hence we can say that in all of three algorithms the working range of CDMA spread spectrum technique is more as compared to two other techniques but its extraction algorithm is slow in nature as compared to two other techniques. For embedding algorithm CDMA spread spectrum technique gives high PSNR values whereas for extraction algorithm alpha blending technique gives high values of PSNR.

5. CONCLUSION

In this paper, an exhaustive overall watermarking performance of all the proposed techniques and the conventional methods have been carried out. As the image watermarking aims at providing a balance between perceptibility and robustness of a watermarking algorithm while maintaining the quality of watermarked image, therefore, the effort has been made in this work to optimize the DWT based watermarking efficiency which has been achieved in most of the cases. The overall observations are summarized as:

- Design and implementation of the image watermarking techniques is performed by 3-level DWT as Discrete Wavelet Transform due to its multiresolution property and selective block working capacity provides us much better results as compared to other spatial domain and frequency domain watermarking techniques.

- Comparative analysis of all proposed 3-level DWT based watermarking techniques is made on the basis of performance parameters (MSE, PSNR and COC).

6. FUTURE SCOPE

In this work the digital image watermarking is performed by several algorithms that are based on wavelet transform and this work can be further used in future by the use of Curvelet transform and Shearlet transform in place of wavelet transform for other images such as medical images, satellite images etc.

Some more watermarking techniques may be developed with these transforms for other highly secure data such as banking data, medical data or any other secure data that is of very high priority and should not be easily tampered.

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