A Robust Watermarking Algorithm Based on Image Normalization and DC Coefficients

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Abstract

Digital watermarking algorithms are prune to different attacks. Of these geometric attacks are recognized as one of the strongest attacks for digital watermarking technology. Normalization watermarking algorithm is resistant to geometrical distortions and DC coefficients are perceptually most significant and more robust to many unintentional attacks (signal processing) and intentional attacks (unauthorized removal). In this paper we propose a robust non-blind watermarking algorithm based on DC coefficients and normalization. By applying discrete wavelet transformation technique (DWT) followed by block based Discrete Cosine Transformation (DCT) technique, DC components are obtained. The cover image is normalized using normalization algorithm in different frequency bands using wavelet decomposition and then block based DCT is applied. In the DC coefficients of the sub-band of the image, watermark is embedded. The algorithm resistant to geometrical distortions (rotation, scaling) and different other attacks (histogram equalization, noise) on different contrast images. The quantitative measurements like SNR (Signal to Noise Ratio), MSE (Mean Squared Error), RMSE (Root Mean Squared Error) and PSNR (Peak Signal to Noise Ratio) are tabulated.

Keywords: *Digital Watermarking, Normalization, Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT).*

1. Introduction

Generally information could be hidden either by directly modifying the intensity value of pixels or frequency coefficients of an image. The former technique is called spatial domain technique and later is called frequency domain technique. In transform domain casting of watermark can be done in full frequency band of an image or in specific frequency band such as in low frequency band or in high frequency band or in middle frequency band. If perceptually insignificant coefficients are selected for embedding then the watermark may be lost by common signal processing operations. Geometric attacks are thought of as one of the most dangerous attacks in the digital watermarking world. Although several watermarking schemes that handle geometric attacks have been introduced each of them has problems. A little distortion such as rotation, scaling, translation, shearing, change in aspect ratio [1] can defeat most of the existing watermarking algorithms. Geometrical robustness problems persist due to the ease of performing rotation, scaling, and translation (RST) attacks on images without much quality compromise. A RST invariant domain watermark offers robustness against rotation, scaling, and translation attacks using invariant domains. This paper describes a digital image watermarking method that resists rotation, scaling, aspect ratio, histogram equalization, jpeg, noise attacks. The method exploits normalization. J' Ruanaidh and T. Pun [2] are the first to suggest a Fourier-Mellin transform based watermarking scheme to handle geometric attacks, such as rotation, scaling and translation (RST).The algorithm seems workable theoretically, but proved to be difficult in implementation. C. Y. Lin and M. Wu, etc [3] proposed an improvement to the implementation difficulty [2] by embedding the watermark into a 1-dimensional signal obtained by projecting the Fourier-Mellin transformed image onto log-radius axis. Such algorithm can embed only one bit information, i.e. presence or absence of the watermark, and the implementation is still a headache and far from practical application. Pereira and Pun [4] proposed an approach to embed a template into the DFT domain besides the intended watermark. Moment based image normalization has been used in computer vision for pattern recognition for a long time [5].Parameters of affine geometric attacks are estimated through the detection of template. The scheme handles flipping, scaling and rotation attacks, and it is only used to embed 1-bit information. Thus determining the place of watermark is a conflict between robustness and fidelity and it is purely application dependent.

In [6] the image is divided into many block of size 8x8 and it is block transformed using DCT technique. These transformed blocks are randomly shuffled to decor relate and to spread the watermark across the entire image. The mid band blocks are selected from the permuted blocks to embed watermark. In [7] the cover is decomposed into four bands. The high frequency band is inverse transformed to obtain high frequency image and it is SVD decomposed to embed watermark by modifying high frequency components. Results show that the system is withstanding certain attacks including geometric attacks. In [8] Image is transformed by DWT technique to K level. The middle frequency band LH and HL are SVD transformed and watermark is hidden. Similarly in low frequency and high frequency band the watermark is embedded using distributed discrete wavelet transform method (DDWT). In [9], three level decomposition of DWT is applied on image to get ten bands of frequencies. All ten bands of frequency coefficients are SVD transformed to embed watermark. A new watermarking scheme for images based on Human Visual System (HVS) and Singular Value Decomposition (SVD) in the wavelet domain is discussed. Experimental results show its better performance for compression, cropping and scaling attack. In [10] two level decomposition of DWT is applied to transform an image into bands of different frequency and a particular band is selected and converted into blocks of size 4x4 for embedding data. Each of those the blocks are SVD transformed and watermark is hidden into diagonal matrix of every block. The similarity between the original watermark and the extracted watermark from the attacked image is measured using the correlation factor NC. The algorithm shows that when DWT is combined with SVD technique the watermarking algorithm outperforms than the conventional DWT algorithm with respect to robustness against Gaussian noise, compression and cropping attacks. Based on the review performed many works are existing for embedding watermark by combining DWT and SVD technique for intensity images. In the proposed work the image the image is first normalized using BNA algorithm and the watermark is embedded in the DC components of transformed image. In order to increase the robustness, the low frequency band can be selected. But to increase the capacity of the watermark full band can also be used. The selected band is divided into block of size 4x4 which in turn DCT transformed to obtain only DC coefficients. These DC coefficients are SVD transformed to embed watermark in singular values.

2. Watermarking Algorithm

In this paper, we implement a normalization algorithm (BNA) [11] based watermarking in DWT and DCT.

2.1 Normalization Algorithm

The NA [11] consists of two components. The first is a Rotate and Scale (RnS) step that rotates the signal by a fixed angle θ followed by scale normalization. The second component is the computation of the orientation indicator index (OII) defined below. The algorithm iterates repeatedly the RnS and OII steps. After a finite number of iterations, the signal corresponding to the maximum value of the OII is chosen as f^{θ}.

1. Rotate and Scale (RnS):
In this step, the signal is rotated by a angle θ and is scaled to the normalized the size by {1/α , 1/β }, where α and β are the dimensions of the region of support for the signal f(x, y), and are defined as

$$\alpha = \left| max_x\{x: f(x,y) \neq 0\} - min_x\{x: f(x,y) \neq 0\} \right| \tag{1}$$

and

$$\beta = \left| max_y\{y: f(x,y) \neq 0\} - min_y\{y: f(x,y) \neq 0\} \right| \tag{2}$$

If *f(x, y)* is the input to the RnS step, the outcome $f(x_d, y_d)$ is obtained by a coordinate transform,

$$\begin{bmatrix} x_d \\ y_d \end{bmatrix} = \begin{bmatrix} 1/\alpha & 0 \\ 0 & 1/\beta \end{bmatrix} \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \tag{3}$$

2. Orientation Indicator Index (OII):
OII [1] of *f(x,y)* is defined as

$$OII_f = \sqrt{\mu_x{}^2 + \mu_y{}^2} \tag{4}$$

Where

$$\mu_x = \int_R (x - g_x)^3 . f(x,y)\,dxdy$$

$$\mu_y = \int_R (y - g_y)^3 . f(x,y)\,dxdy$$

(g_x, g_y) is the center of the mass for *f(x,y)* ,and defined as

$$g_x = \int_R x . f(x,y)\,dxdy \tag{5.a}$$

$$g_y = \int_R y . f(x,y)\,dxdy \tag{5.b}$$

3. BNA Algorithm

The BNA[1] is slightly different version from [12].Because of the periodic property of OII, a full rotation interval of θ = [0,2π] is time consuming and not necessary. Other orientations with max OII can be find by adding multiple π /2.

The NA algorithm used in this paper is summarized as following.

1) Recentering: Recenter $f^d(x, y)$ with respect to the center of mass (g_x, g_y) defined by eq .5.
2) Scale normalization: Compute {α, β} from equation eq. 1,2, and scale the pixel coordinates (x, y) to (x/α, y/β).
3) Calculate OII for each rotated position
4) Iteration: Repeat steps 3 and 4 for rotation interval θ = [0, π /2].
5) Normalization: Selects the signal corresponding to the maximum value of the OII, and stores it as $f^d(x,y)$

2.2 Discrete Cosine Transform

DCT is another important transformation technique which is widely used due to its energy compaction and decorrelation properties. DCT technique is faster than discrete Fourier transform since the bases are cosine function for the former technique and complex function for the later technique The transformed matrix consists of both AC and DC coefficients. If the DCT technique is applied on block of size NxN then it is called block DCT. In DCT transformed block the left top corner element is called as DC coefficient which is perceptually significant and the remaining coefficients are called AC coefficients which are perceptually insignificant. These coefficients are zigzag scanned to obtain frequency components of an image in decreasing order. These DC and AC components are modified to embed watermark in it [7][13]. Equ. 1 and 2 are used for taking transformation and inverse transformation of an image.

2.3 Discrete Wavelet Transform

DWT is a transformation technique is used to represent an image in a new time and frequency scale by decomposing the input image into low frequency, middle and high frequency bands. The value of low frequency band is the averaging value of the filter whereas the high frequency coefficients are wavelet coefficients or detail values. [4]. The DWT can be used to decompose image as a multistage transform. In the first stage, an image is decomposed into four subbands LL1, HL1, LH1, and HH1, where HL1, LH1, and HH1 represent the finest scale wavelet coefficients, while LL1 stands for the coarse level coefficients, i.e., the approximation image. Fig.1 shows the one level wavelet decomposition of an image [14].

LL	LH
HL	HH

Figure 1: One level decomposition

2.4 Watermarking Scheme

a. Find the normalized image using BNA algorithm as described in section 2.3.
b. Apply DWT to decompose of an image into various frequency bands.
c. Divide the middle frequency band and apply DCT. Divide DCT transformed band into smaller blocks of size 4X4.
d. Extract the DC coefficients $\delta_{i,j}$ from every DCT transformed blocks.
e. Modify the DC coefficients with the watermark coefficients W i,j .

$$\widetilde{\delta_{i,j}} = \delta_{i,j} + \alpha\ W_{i,j}$$

f. Replace the original DC's $\delta_{i,j}$ by the modified DC's $\widetilde{\delta_{i,j}}$ in each block. Then apply inverse DCT and inverse DWT.

Figure 2: Watermark Embedding

g. Step b to step f is repeated for hiding watermark in other bands of a cover image.
h. Inverse wavelet transformation technique is applied to get the watermarked.
i. Restore the watermarked image to the original orientation and size.

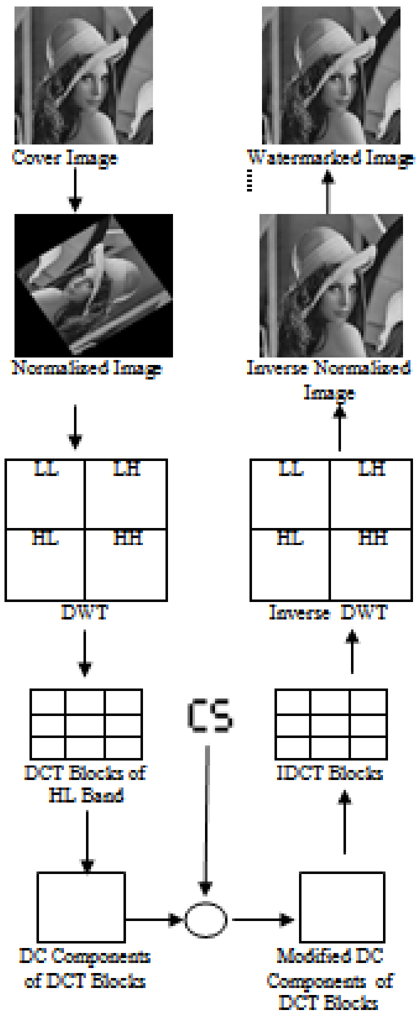

Figure 2: Watermark embedding

2.5 Decoding Procedure

Find the normalized image of watermarked image using BNA algorithm.

a. Apply DWT to decompose of watermarked image into various frequency bands.
b. Divide the middle frequency bands and apply DCT. Divide DCT transformed band into smaller blocks of size 4X4.

c. Extract the DC coefficients $\widetilde{\delta_{i,j}}$ from every DCT transformed blocks.
d. Modify the DC coefficients with the watermark coefficients W I,j .

e. $$W_{i,j} = (\widetilde{\delta_{i,j}} - \delta_{i,j})/\alpha$$

f. Reconstruct the watermark image. In the proposed method, to extract the watermark from all frequency bands, it uses original cover image. So, this algorithm is can be classified as non-blind watermarking technique.

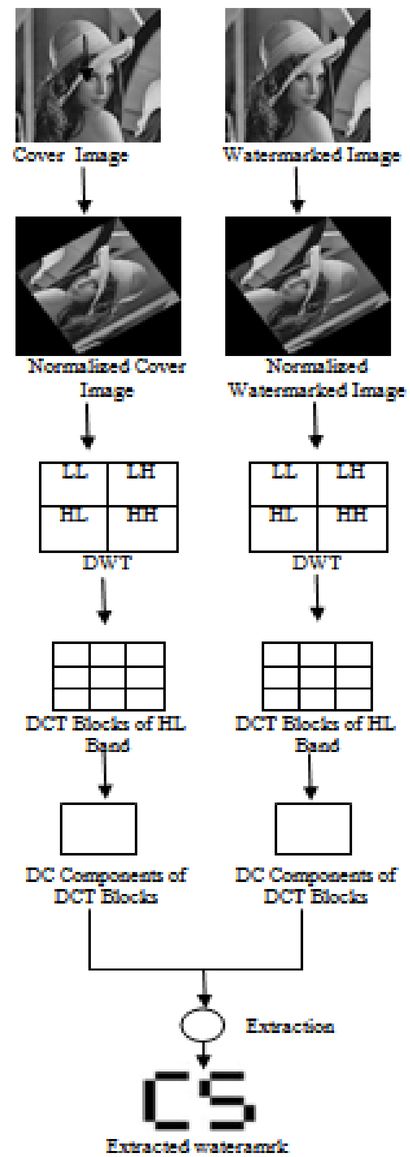

Figure3: Watermark Extraction

3. Results

In this proposed algorithm, Lena, peppers, man images of size 256x256 are taken as test images and the watermark is the CS logo of size 64x64. Embedding intensity value is varied from 0.1 to 1 for all frequency bands. The original images are shown in figure 4 and watermark is shown in figure 5. The watermarked images are shown in Fig 6. Similarly the extracted watermarks are shown in Fig.7.

(a) (b) (c)

Figure 4(a-c): Sample cover images

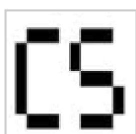

Figure 5: Watermark image

(a) (b) (c)

Figure 6(a-c): Watermarked images

(a) (b) (c)

Figure 7(a-c): Extracted watermarks

In order to test the quality of the extracted watermark and cover data both subjective and objective measurements are used. The objective criteria are measured through (5), (6) and (7), (8).

$$MSE = \frac{1}{M\ X\ N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \left(f(i,j) - g(i,j)\right)^2 \quad (5)$$

$$RMSE = \frac{1}{M\ X\ N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \left(f(i,j) - g(i,j)\right)^2 \quad (6)$$

$$SNR = \frac{\sum_{i=0}^{M-1} \sum_{j=0}^{N-1} g(i,j)^2}{\sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \left(g(i,j) - f(i,j)\right)^2} \quad (7)$$

$$PSNR = 10 * \log_{10}\left(\frac{255^2}{MSE}\right) \quad (8)$$

The SNR, MSE, RMSE and PSNR values for watermark embedding are shown in Table 1.

Table 1: Watermark embedding (Man)

Frequency Band	k	Measures			
		SNR	MSE	RMSE	PSNR
LL	0.1	1.3316	2.754e+003	52.484	13.7642
	0.5	1.3161	2.761e+003	52.553	13.7528
	1	1.2948	2.802e+003	52.934	13.6901
LH	0.1	-0.0668	26.6574	5.1631	33.9066
	0.5	-0.0852	40.0348	6.3273	32.1404
	1	-0.1007	70.3027	8.3847	29.6951
HL	0.1	-0.0672	26.7334	5.1704	33.8943
	0.5	-0.0847	40.9852	6.4020	32.0385
	1	-0.0995	71.5244	8.4572	29.6203
HH	0.1	-0.0668	26.1553	5.1142	33.9892
	0.5	-0.0864	37.2286	6.1015	32.4560
	1	-0.1022	62.4746	7.9041	30.2078

The SNR, MSE, RMSE and PSNR values for watermark extraction are shown in Table 2.

Table 2: Watermark Extraction (Man)

Frequency Band	*k*	Measures			
		SNR	MSE	RMSE	PSNR
LL	0.1	-43.9509	3.362e+005	579.8931	-7.1022
	0.5	-29.9779	1.624e+004	127.4558	6.0576
	1	-24.0186	6.316e+003	79.4777	10.1599
LH	0.1	-4.9816	2.886e+003	53.7218	13.5618
	0.5	4.1096	2.894e+003	53.7957	13.5498
	1	7.3074	2.958e+003	54.3950	13.4536
HL	0.1	-3.9755	2.857e+003	53.4512	13.6057
	0.5	3.8456	2.901e+003	53.8669	13.5384
	1	7.3965	2.942e+003	54.2422	13.4780
HH	0.1	1.1388	2.984e+003	54.6329	13.4157
	0.5	12.1995	2.986e+003	54.6442	13.4139
	1	14.4298	3.002e+003	54.7945	13.3901

Attacks like Gaussian noise, rotation, Histogram equalization, Contrast increase, contrast decrease and scaling are applied on the watermarked image. The watermark is extracted from the attacked images. The SNR, MSE, RMSE and PSNR values for extraction after applying attacks for embedding strength of 0.5 are shown is Table 3.

Table 3: Watermark extraction after attacks

Band	Attack	Measures			
		SNR	MSE	RMSE	PSNR
LL	Noise	-24.106	6.383e+003	79.8937	10.1145
	Rotation	3.1679	2.584e+003	50.8418	14.0404
	Hist Eq	3.3647	2.608e+003	51.0758	14.0005
	C Inc	3.5755	2.657e+003	51.5432	13.9214
	C Dec	4.2709	2.7067e+003	52.0264	13.8403
	Scaling	2.7894	2.555e+003	50.5516	14.0901
LH	Noise	-3.9794	3.058e+003	55.3006	13.3102
	Rotation	6.5626	2.910e+003	53.9466	13.5255
	Hist Eq	4.1696	2.798e+003	52.9136	13.6935
	C Inc	5.2821	2.867e+003	53.5506	13.5895
	C Dec	6.4701	2.910e+003	53.9481	13.5253
	Scaling	4.6206	2.836e+003	53.2559	13.6374
HL	Noise	-4.6146	3.071e+003	55.4168	13.2920
	Rotation	6.5458	2.905e+003	53.9049	13.5322
	Hist Eq	4.1949	2.800e+003	52.9225	13.6920
	C Inc	6.0581	2.884e+003	53.7029	13.5648
	C Dec	6.5879	2.911e+003	53.9557	13.5241
	Scaling	5.2452	2.855e+003	53.4383	13.6077
HH	Noise	4.9786	3.041e+003	55.1518	13.3336
	Rotation	10.9554	2.977e+003	54.5662	13.4263
	Hist Eq	8.3710	2.951e+003	54.3281	13.4643
	C Inc	10.1274	2.973e+003	54.5250	13.4329
	C Dec	12.2796	2.990e+003	54.6832	13.4077
	Scaling	7.5581	2.932e+003	54.1518	13.4925

4. Conclusions

Algorithm based on Image normalization and DC coefficients is implemented with different embedding strengths. By looking at the results LH, HL bands has shown robustness to the attacks implemented. LL band is the most vulnerable band.

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