Ownership Identification Using Discrete Wavelet Transform (DWT)-Based LOGO Watermarking

T Mita Kumari
Department Electronics and Communication Engineering
Apex Institute of Technology and Management
Bhubaneswar, Orissa, India
e-mail: mitat2006@gmail.com

Gayadhar Panda
Department of Electrical Engineering
Indira Gandhi Institute of Technology organization,
Sarang, Orissa, India
e-mail gayadharpanda@gmail.com

***Abstract*— In this paper, an efficiently DWT-based watermarking technique is proposed to embed gray-scale logos as watermark in images to attest the owner identification and discourage the unauthorized copying. The method transforms both the host image and watermark into the discrete wavelet domain where their coefficients are fused adaptively based on Human Visual System (HVS) model to hide a higher energy hidden watermark in salient image components. The method repeatedly merges the watermark coefficients at the various resolution levels of the host image which provides simultaneous spatial localization and frequency spread of the watermark to provide robustness against different attacks. From the simulation results it can be observed that proposed method is robust to wide variety of attacks, such as image compression, linear or non-linear filtering, noise addition, image resizing, cropping, and image enhancement, etc**.

***Keywords*—Digital watermark, discrete wavelet transform, HVS characteristics,**

I. Introduction

Copyright protection of multimedia content is nowadays an all increasing demand especially with the drastic expands of Internet and web-based services. The cryptography has a long history of application to multimedia security, but the undesirable characteristics of providing no protection to the media once decrypted has limited the feasibility of its widespread use. In response to these challenges, digital watermarking techniques have been developed. Digital watermarking is a technique for inserting imperceptible secret information (the watermark) into an image, which can be later extracted or detected to prove the owner identification of the data and discourage the unauthorized copying. All the watermarking techniques aim at satisfying two basic requirements [1]: watermark perceptual invisibility, and watermark robustness against image modification by different attacks while preserving a desired image quality. The attacks include image compression, linear or non-linear filtering, noise addition, image resizing, cropping, and image enhancement, etc. In general, watermark embedding and retrieval should have low complexity because for various applications, real time watermarking is desirable.

Watermarking techniques are distinguished in two classes according to the domain where embedding is performed: the spatial domain methods, and the transform domain methods. The earlier watermarking techniques are almost spatial based approach. In spatial domain the watermark is embedded into the host image by directly modifying the pixel values, i.e. simplest example is to embed the watermark in the least significant bits (LSBs) of image pixels [2]. Spatial domain watermarking is easy to implement and requires no original image for watermark detection. However, it often fails under signal processing attacks such as filtering, cropping and compression and having relative low-bit capacity. Besides, the fidelity of the original image data can be severely degraded since the watermark is directly applied on the pixel values.

In contrast to the spatial-domain-based watermarking, frequency-domain based techniques can embed more bits of watermark and are more robust to different attacks, because when image is inverse transformed watermark is irregularly distributed over the image. Transform domain scheme includes DFT [3] (Discrete Fourier Transform), DCT [4]-[8] (Discrete Cosine Transform), DWT [9]-[14] (Discrete Wavelet Transform). However, embedding watermark in host image by DFT is suffering from the JPEG attacks. Although embedding watermark in host image by DCT is more robust than that of by DFT, the DWT has number of advantages over the DCT, because DWT provides both time and frequency localization, and different resolution levels. Thus, DWT based watermarking algorithms can effectively utilize the characteristics of HVS (Human Visual System) to attain good trade-off between robustness and imperceptibility. So, DWT based watermarking algorithms have gained more interest among the watermark researchers.

In most previously proposed wavelet based watermarking techniques [9]-[11], the watermark is a random sequence of bits, and can only be detected by employing detection theory. Detection involves retrieving the watermark by subtracting the original image from the watermarked image. Therefore, an experimental threshold value is chosen and compared to a sharp peak in the cross-correlation coefficient to determine whether the image is watermarked. However, it has been suggested that visually meaningful watermark like logos may improve the trustworthiness of identification or security based on data embedding in the eyes of nontechnical arbitrators [12]-[14]. The presentation of a recognizable mark is much more convincing than a numerical value and allows the opportunity to exploit the human visual system's ability to recognize a pattern.

A novel robust wavelet based gray-scale logo watermarking technique is presented in this paper, where both the host image and watermark are transformed into the DWT domain and their coefficients are fused according to series combination rule that take into account contrast sensitivity characteristics of the HVS [15]. The method repeatedly merges the watermark coefficients at the various resolution levels.. To show the validity of the proposed method, the watermarked images are tested for different attacks. The significant advantage of our proposed method is that watermarking process is adaptive and depends on the local host image characteristics at each resolution level. Moreover, the watermark is embedded strongly in more salient components of the image.

The remaining sections of this paper are organized as follows. The proposed algorithm is described in section two. Then the results with discussion of simulation study are provided in section three. Finally some conclusions are drawn and future works are suggested in section four.

II. The proposed Algorithm

Throughout our discussion, we use $X(m,n)$ to denote the host image and $w(m,n)$ the watermark. The watermark is visually recognizable gray scale image. The size of the watermark is $N \times N$. It is required that the size of the watermark in relation to the host image be "small". We assume, without loss of generality, that the watermark is smaller than the host by a factor of 2^M, where M is an integer greater or equal to 1.

A. *Watermark Embedding Method*

The watermark embedding technique is comprised of the 4 main stage discussed below.

Stage 1:

The host image and the watermark are transformed into the wavelet domain. We perform the L^{th} level DWT of the host image. The value of L is equal to $M+1$. We denote the k^{th} detail image component at the l^{th} resolution level of the host by $X_{k,l}(m,n)$, where $k=1,2,3$ represents the frequency orientation corresponding to the horizontal, vertical and diagonal image details, $l=1,\dots,L$ the resolution level and (m,n) particular pair spatial location index at the resolution l .The gross approximation is represented by $X_{4,L}(m,n)$ where the subscript "4" is used instead of k to denote the gross image approximation at resolution L.

Similarly, the first level DWT of the watermark w is performed to produce $N_{wx} \times N_{wy}$ dimensional detail and approximation sub-images denoted by $w_{k,1}(m,n)$ where $k=1,2,3,4$.

Stage 2:

The each sub-images of the host are segmented into non-overlapping $N_{wx} \times N_{wy}$ blocks. We denote the segments by $X^i_{k,l}(m,n)$ where $i=1,2,\dots,2^{2(M+1-l)}$ is the total number of blocks at each frequency orientation k and resolution l.

The salience, S (which is numerical measure of perceptual importance) of each of the localized blocks is computed using information about the HVS model based on contrast sensitivity. The value of the salience determines the strength of the watermark to embed in the particular $N_{wx} \times N_{wy}$ coefficient image block. For this paper we assume the well known model given by Dooley [23]. We extend the model to two dimensional using the same approach as [24]. The resulting contrast sensitivity for a particular pair of spatial frequency is given by:

$$C(u,v) = 5.05 e^{-0.178(u+v)} (e^{0.1(u+v)} - 1) \quad (1)$$

Where $C(u,v)$ is the contrast sensitivity matrix and u, and v are the spatial frequencies. The salience of each block is defined as:

$$S(X^i_{k,l}(m,n)) = \sum_{\forall(u,v)} C(u,v) \left| F^i_{k,l}(u,v) \right|^2 \quad (2)$$

Where $F^i_{k,l}(u,v)$ the normalized discrete Fourier is transform of the image component $X^i_{k,l}(m,n)$; $F^i_{k,l}(u,v)$ is normalized such that it has unit energy (i.e. $\left\| F^i_{k,l}(u,v) \right\|^2 = 1$). The proposed method presented relies on the contrast sensitivity of the HVS to determine the importance of the information.

The watermark is embedded only in B percent of the most salient detail image blocks at each resolution level and orientation using the following equation:

$$X^{w,i}_{k,l}(m,n) = X^i_{k,l}(m,n) + \alpha^i_{k,l} \beta^i_{k,l} w_{k,l}(m,n) \quad (3)$$

Where $X^{w,i}_{k,l}(m,n)$ are the watermarked DWT coefficients, and $\beta^i_{k,l}$ is given by:

$$\beta^i_{k,l} = \sqrt{\frac{S(X^i_{k,l}(m,n))}{\max S(X^i_{k,l}(m,n))}} \quad (4)$$

For the remaining blocks, we set

$$X^{w,i}_{k,l}(m,n) = X^i_{k,l}(m,n) \quad (5)$$

Where $\alpha^i_{k,l}$ are positive real numbers that determine a trade-off between the imperceptibility and robustness against attacks at each of the resolution levels. The value of $\alpha_{k,l}^{i}$ is set in a different way to that in [16].

The value of $\alpha_{k,l}^{i}$ is adaptively changed according to the resolution level. The value of $\alpha_{k,l}^{i}$ ranges between 5% and 75% of the mean value of the detail image blocks. For each resolution levels, the value of $\alpha_{k,l}^{i}$ is set such that lower value for higher resolution level and correspondingly higher value for next lower resolution levels. The fraction within the square root is a relative measure that gives greater weight judiciously to the embedded watermark in more salient host image regions.

A similar merging procedure is used to embed the watermark approximation coefficients $w_{4,1}(m,n)$ into the host image approximation block $X_{4,L}^{i}(m,n)$. The watermark is embedded in all blocks. The value of $\alpha_{4,L}$ is set between 1% and 5% of the mean value of the approximate image block to ensure imperceptibility. The larger the magnitude of $\alpha_{k,l}$, the more robust and visible the watermark; the ranges of value suggested provide an appropriate trade-off for most photographic images. Similarly, the larger the value of *B*, the greater the number of coefficient blocks in which the watermark is embedded at each resolution level which also comes at the expense of increased visibility; simulation results shows that a range of *B* between 25 and 75 allows for appropriate marking.

Stage 3:

The corresponding L^{th} level inverse DWT (IDWT) of the fused image components $X_{k,l}^{w}(m,n)$ is computed to form the watermarked image.

B. *Watermark ExtractingMethod*

The objective of the extraction process is to reliably obtain an estimate of the original watermark from a possibly distortion version of the watermarked image X_w. The reconstruction process requires knowledge of the original host image X. The watermark is extracted from the possibly corrupted watermarked image using the host image, by applying the inverse procedure at each resolution level to obtain an estimate of the watermark. The estimates for each resolution level are averaged to produce an overall estimate of the watermark. The normalized correlation coefficient r was used to measure the robustness of the extracted watermark against different attacks.

III. Simulation Results and Discussions

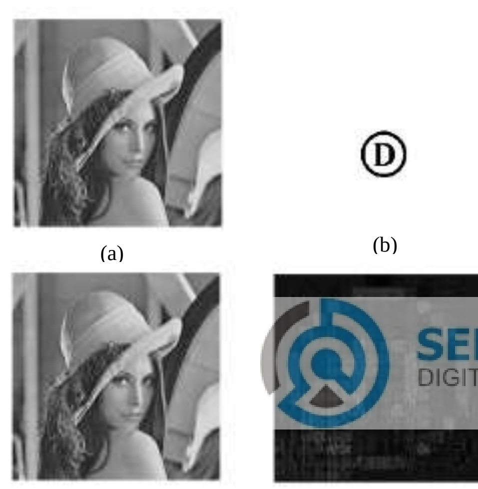
For simulations, we take Lena image of size 512×512 as the host image shown in Fig. 1(a) and watermark is visually recognizable gray-scale image of size 32×32 shown in Fig. 1(b). To form the watermark, the DC value is first subtracted from the watermark image and then made its variance value to 1, before watermark image is used for simulation. We chose $B=75$, $L=5$; and α value was set to 60, 40, 20, 10, and 5 percent of mean value of detail image blocks for lower resolution level to higher resolution level respectively, and α value was set to 1% of approximate image blocks in our simulation. The PSNR value of watermarked image is 38.2485 as shown in Fig. 1(c), and is perceptually identical to the original host and watermark can be exactly extracted. Eight time's magnified absolute difference between the original and the watermarked image is shown in Fig. 1(d) . Because of the adaptive and localized nature of our embedding routine the watermark takes on characteristics similar to the host image itself. The resulting watermarked image is corrupted using one of many common distortions which we discuss in the subsequent section.

A. *Robustness Against JPEG Lossy Compression*

Table I. lists the Peak Signal to Noise Ratio (PSNR) of watermarked image, extracted watermark image, and Correlation values between original watermark and extracted watermark in the case that the watermarked images are attacked by JPEG compression for different compression ratios. The result shows that the correlation coefficient between extracted watermark and original watermark is still high, even under the high compression ratio.

B. *Robustness Against AWGN Noise*

The method was tested its robustness for additive white Gaussian noise (AWGN). Table II. shows the result for Gaussian noise for different SNR values. The result shows that, although the watermarked image is overwhelmed by the noise, the extracted watermark images are still recognizable.



(a) (b)

(c) (d)

TABLE I.

RESULTS FOR JPEG LOSSY COMPRESSION

Compression Ratio	14.1203	17.1107	26.3879	48.813
PSNR after attack in dB	33.7658	33.1849	31.3219	27.1000
Extracted watermark				
Correlation	0.9248	0.9104	0.8772	0.6493

TABLE II.

RESULTS FOR AWGN NOISE

SNR in dB	30	20	10	5
PSNR after attack in dB	33.7592	25.4267	15.6330	10.6487
Extracted watermark				
Correlation	0.9716	0.7449	0.2744	0.1526

C. Robustness Against Filtering

The proposed method was tested its robustness against mean, and median filtering of different order. The result was shown in table III., and IV. for mean, and median filtering respectively. The result shows that, although the watermarked image is highly degraded by the filtering operation, the extracted watermarks are still visually recognizable.

D. Robustness Against Image Resizing

Table V. shows the results for resizing watermarked images. The images were scaled down in size by a factor of F using bilinear interpolation and were resized to their original dimension before watermark extraction. Visible degradation occurs for high value of F due to resolution adjustment, but result shows the watermark can still be detected.

TABLE III.

RESULTS FOR MEAN FILTERING

Order of the Filter	3	5	7	9
PSNR after attack in dB	31.5014	28.1423	26.2512	24.9909
Extracted watermark				
Correlation	0.8017	0.7142	0.6191	0.5493

TABLE IV.

RESULTS FOR MEDIAN FILTERING

Order of the Filter	3	5	7	9
PSNR after attack in dB	34.6702	31.2839	29.2549	27.9760
Extracted watermark				
Correlation	0.9462	0.8646	0.7943	0.7273

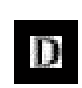
.TABLE V.

RESULTS FOR IMAGE RESIZING

Scaling down factor F	2	4	8	16
PSNR after attack in dB	33.2717	28.6293	25.0777	21.9551
Extracted watermark				
Correlation	0.9119	0.8719	0.8243	0.5682

TABLE VI.

RESULTS FOR IMAGE CROPPING

% of image area cropped	50	25	12.5	6.25
PSNR after attack in dB	6.9056	8.9909	12.1919	15.1084
Extracted watermark				
Correlation	0.1389	0.3477	0.5058	0.5234

E. Robustness against Image Cropping

Table VI. shows the effect of image cropping on watermark extraction. For watermark extraction, the portion of the watermarked image cropped out was replaced with the zero value. Although 50% of the image area cropped out, the extracted watermark is still visually recognizable.

IV. CONCLUSION

The work in this paper, primarily focus on to provide good trade-off between perceptual quality of the watermarked image and its robustness to different attacks. For this purpose, we have proposed a fusion based watermarking technique in discrete wavelet domain by incorporating contrast sensitivity based human visual system model. The watermark is a visually recognizable gray-scale logo. Simulations of various attack shows that the scheme is robust to JPEG compression, AWGN noise, mean, and median filtering, image resizing, and as well as cropping. The future work is to develop watermarking scheme robust to both non-geometric attacks and geometric attacks such as rotation, and affine transforms.

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