A Robust Digital Watermarking using Discrete Wavelet Transform in Chrominance Channel

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***Abstract*—A wavelet-based digital watermarking scheme is presented in this paper. The watermark signal is embedded into HLn of LLn-1 transformed sub-band of original chrominance channel host image using coefficients scaling technique. In the extraction process, the average filter is applied to predict original dwt coefficients in HLn-1 sub-band. Then, the watermark logo is recovered by subtracting the coefficients predicted from the embedded coefficients, without original image needed. The obtained results show significant improvement in terms of quality and fidelity of extracted signal. Also, the improvements in terms of robustness by the proposed method work effectively against various common image-processing-based attacks especially against compression attacks.**

***Index Terms*—discrete wavelet transform, digital watermarking, chrominance channel, image processing based attack**

I. Introduction

The copyright of digital media protection becomes an important topic nowadays, due to one main characteristic of digital multimedia which is the ease of copying and redistributing without losing quality. To resolve the copyright protection problem for multimedia data, many watermarking schemes are proposed and discussed.

We can classify watermarking methods into frequency and spatial domain based watermarking. In the spatial domain, watermark embedding can be accomplished easily by modifying the image pixels directly. For instance, [1], [2] and [3] also proposed the watermarking schemes in spatial domain by using spatial correlation of colors, RST-resistant method and independent component analysis, respectively. However, there are many arguments about robustness against compression attacks e.g. JPEG2000 and JPEG compression standard. In contrast, in the frequency domain based approach, it is obvious that the robustness against compression attack is much better than spatial domain based.

Moreover, frequency domain watermarking strongly helps increasing the imperceptibility, security, and robustness. Therefore, presently, most of image watermarking methods are in the transform domain. For example, M. K. Samee et al. [4] presented reversible watermarking scheme for images by using *CMDA* based in wavelet domain. In addition, [5] and [6] proposed watermarking algorithms in frequency domain using discrete wavelet transform. They applied discrete fractional Fourier transformation *DWT* and Region of Interest (ROI) technique, respectively.

In this paper, we present a wavelet-based digital watermarking scheme by applying some spatial domain techniques to improve the performance of extracted watermark signal. The coefficient scaling method is proposed to adjust area before embedding which will be explained more in section 2. Then, in section 3, the experimental results are shown and discussed. The conclusion is finally drawn in section 5.

II. Proposed Watermarking Scheme

This proposed watermarking scheme consists of two processes those are the embedding process and the extraction process. In addition, we also present some techniques to transform the color channel and the sizes of watermark image and host image before performing the operations. The detail of the embedding process and sub-processes are given next.

A. Pre-processing Operation of Host Image

The host image is first pre-processed before embedding with the following steps;

Step 1: The original *RGB* host image I with n by n pixels is converted to YC_bC_r color space, the chrominance channel, C_r is selected to use in this process.

$$C_r = \left\{ Cr_{(i,j)} \mid 1 \le i \le n, 1 \le j \le n, 16 \le Cr_{(i,j)} \le 240 \right\}$$

Then, the host image C_r is decomposed into n levels using discrete wavelet transform. The HL_n of LL_{n-1} transformed sub-band is selected for watermarking embedding.

$$[a_n, q_n, b_n, r_n] = dwt(LL_{n-1}) \tag{1}$$

where a_n, q_n, b_n, r_n is wavelet coefficient value of LL_n ,HL_n LH_n and HH_n sub-band, respectively.

Step 2: The coefficient values $q_{n(i,j)}$ is scaled between 0-255 by using following equations;

$$q'_{n(i,j)} = -\min(q_n) + q_{n(i,j)} \tag{2}$$

Manuscript received October10, 2012; revised December 22, 2012.
This research work is supported by the Information and Communication Technology Programme, Faculty of Science, Prince of Songkla University.

doi: 10.12720/joace.1.2.99-102

$$q'_{n(i,j)} = q'_{n(i,j)} \times \left(\frac{255}{\max(q_n)} \right) \qquad (3)$$

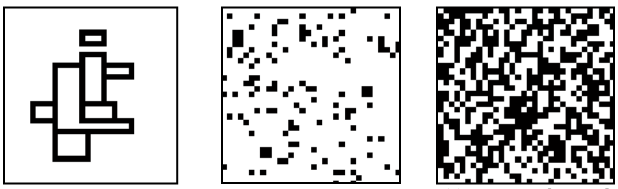
where $q'_{n(i,j)}$ is the scaled coefficient value at position (i,j), $\min(q_n)$ is the minimum value of HL_n sub-band wavelet coefficient and $\max(q_n)$ is the maximum value of HL_n sub-band wavelet coefficient.

B. Pre-processing Operation of Watermark Signal

The watermark signal is first pre-processed with the following steps;

Step 1: watermark pixels are converted from {0,1} to {1,-1} by switching the value of the zero bits to the one bits.

Step 2: The watermark balance and security are improved by using the XOR operation to permute the watermark bits with a pseudo-random bit-stream generated from a key-based stream cipher. The figures of watermark logo after processing the operations are illustrated below:



(a)ICT watermark logo　(*b*) Watermark signal after permuting bits　*(c)* Watermark signal after balancing bits

Figure 1. Watermark logo and processed watermark logos.

C. Embedding Process

The embedding process is started by modifying the dwt coefficient values in the HL_n sub-band $q'_{(i,j)}$, in a line scan fashion. The result $q''_{(i,j)}$ are either additive or subtractive, depending on $w_{(i,j)}$, the result is then adjusted by a scaling factor *s* to control the strength of watermark for the entire HL_n sub-band. The representation of watermark embedding process can be expressed by

$$q''_{n(i,j)} = q'_{n(i,j)} + w_{(i,j)} s \qquad (4)$$

After finished pixel modifications, the embedded coefficient $q''_{(i,j)}$ is scaled back to the previous proportion by using reversal equation:

$$q''_{n(i,j)} = \left(q''_{n(i,j)} \times \frac{\max(q_n)}{255} \right) - \left(\min(q_n) \times (-1) \right) \qquad (5)$$

Then, the final embedding process is applied by using inversed DWT, set *n* equal to decomposition level at the first place. The embedded C_r' is recovered in the last inversed transformation.

$$LL_{n-1}' = idwt\left[a_n, q''_n, b_n, r_n\right] \qquad (6)$$

Finally, we transform the color model back from YC_bC_r to *RGB* at the end of embedding process.

D. The Extraction Process

Step 1: *RGB* color model is transformed to YC_bC_r color model. Next, the transformed C_r is decomposed into *n* levels using discrete wavelet transform. Then, the scaling equation is applied to adjust the coefficients into the right proportion the same as the embedding process.

Step 2: Each original transformed image pixel in the chosen sub-band is predicted from its surrounding scaled coefficient values. The predicted original image pixel $q'''_{(i,j)}$ is calculated by

$$q'''_{(i,j)} = \frac{1}{9} \left(\sum_{m=-1}^{i} \sum_{n=-1}^{j} q''_{(i+m,j+n)} \right) \qquad (7)$$

Step 3: The embedded watermark bit $w'(i,j)$ at a given coordinate (i,j) can then be determined by the following equation

$$w'_{(i,j)} = q''_{(i,j)} - q'''_{(i,j)} \qquad (8)$$

where $w'_{(i,j)}$ is the estimation of the embedded watermark *w* around *(i,j)*.

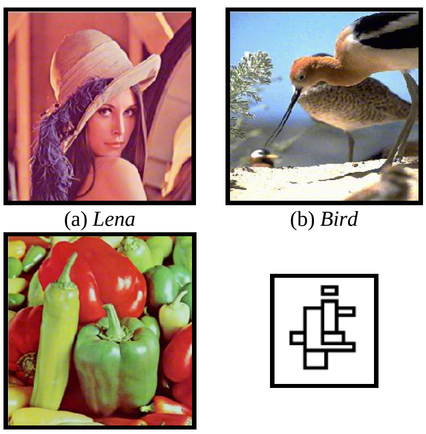
Step 4: Since $w_{(i,j)}$ can be either 1 and -1, the value of $w'_{(i,j)} = 0$ is set as a threshold, and its sign is used to estimate the value of $w_{(i,j)}$ as follows:

$$w'_{(i,j)} = \begin{cases} 0 & , q'' - q''' < 0 \\ 1 & , q'' - q''' \geq 0 \end{cases} \qquad (9)$$

III. EXPERIMENTAL RESULTS

A. Experimental Settings

In the following experiments, three standard color images, namely '*Lena*', '*Bird*', and '*Pepper*' with the size of 256×256 pixels were used as the original images. We also used the 32x32 pixels black & white image containing a logo *'ICT'* as a watermark signal as shown in Fig. 2. In addition, *Haar* wavelet filter were selected and used in discrete wavelet transform. The level of wavelet decomposition (*n*) and was set to 3.



(a) *Lena*　(b) *Bird*　(c) *Pepper*　(d) *PSU ICT*

Figure 2. The Original testing images and the watermark logo.

B. *Evaluation Method*

In all experiments, we evaluated the quality of watermarked image by measuring its *PSNR* (Peak Signal-to-Noise Ratio). The following equation defines the PSNR value:

$$PSNR(dB) = 20\log_{10}\frac{255\sqrt{3MN}}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(B'_{(i,j)}-B_{(i,j)})^2}} \quad (10)$$

where M and N are the numbers of row and column of the images; $B_{(i,j)}$ and $B'(i,j)$ are the original host image bit and the retrieved watermark image bit at coordinate (i,j). Note that the higher the *PSNR* value, the better the quality of watermarked image.

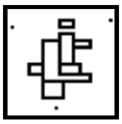
Furthermore, Normal Correlation (*NC*) value was measured to evaluate the quality of extracted watermark. The calculation of *NC* value can be expressed by:

$$NC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} w_{(i,j)} w'_{(i,j)}}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(w_{(i,j)})^2}\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(w'_{(i,j)})^2}} \quad (11)$$

C. *Embedding and Extraction Performance*

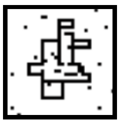
In this experiment, the performance of the proposed method was evaluated in terms of the quality of watermarked image and extracted watermark. Note that we tested the performance of the extracted watermark image by fixing a *PSNR* value around 31. Then, the *NC* value was evaluated. The obtained results are shown in Fgi. 3.

(a) Lena at *PSNR* = 31.05 db



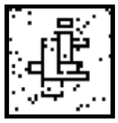
(b) Extracted signal *NC* = 0.9983

(c) Bird at *PSNR* = 31.68 db



(d) Extracted signal *NC* = 0.9832

(e) Pepper at *PSNR* = 31.20 db



(f) Extracted signal *NC* = 0.9815

Figure 3. The resultant watermarked image and its extracted signal.

D. *Robustness against Image Processing based Attacks*

Finally, the robustness of the proposed watermarking method was evaluated by applying six different types of attack. The NC values from the attacked images were then computed and compared. A list of the attacks in the experiment consisted of additive Gaussian distributed noise with zero mean at various variances, JPEG compression at various percentage, the salt and pepper noise at various densities, the blurring attack at theta = 11 and various length and the contrast adjustment attack at various contrast scaling factors. The experimental results are illustrated in table I and table II.

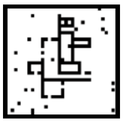
TABLE I. ROBUSTNESS AGAINST COMPRESSION ATTACKS

Attack Types	***Lena***	***Bird***	***Pepper***
Non-attacked Average *PSNR* = 31.5dB	0.9983	0.9833	0.9702
JPEG Image Quality= 90%	0.9956	0.9765	0.9610
JPEG Image Quality= 80%	0.9933	0.9725	0.9558
JPEG Image Quality= 70%	0.9928	0.9645	0.9448
Salt&Pepper Noise density = 0.01	0.9983	0.9804	0.9708
Salt&Pepper Noise density = 0.04	0.9933	0.9564	0.9593

TABLE II. ROBUSTNESS AGAINST VARIOUS SPATIAL DOMAIN ATTACK TYPES

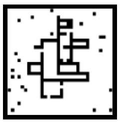
Attack Types	***Lena***	***Bird***	***Pepper***
Blurring *Theta* =11 *Len* =8	0.9928	0.9668	0.9564
Blurring *Theta* =11 *Len* =2	0.9972	0.9816	0.9690
Brightness Adjustment 10%	0.9983	0.9782	0.9702
Brightness Adjustment 80%	0.9972	0.8939	0.9673
Contrast Adjustment 10%	0.9983	0.9833	0.9702
Contrast Adjustment 80%	0.9866	0.8802	0.9662

(a) JPEG 75%



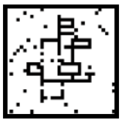
(b) Extracted signal *NC* = 0.9810

(c) Salt&Pepper Attack with Noise density = 0.04



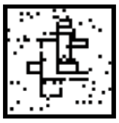
(d) Extracted signal *NC* = 0.9804

(e) Blurring Attack with *Theta* = 0.04, *Len* = 6



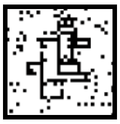
(f) Extracted signal *NC* = 0.9702

(g) Brightness Adjustment 35%



(h) Extracted signal *NC* = 0.9622

(i) Contrast Adjustment 35%



(j) Extracted signal *NC* = 0.9489

Figure 4. The resultant watermarked image and its extracted signal.

IV. CONCLUSION

This paper has described a scheme for digital watermarking based on discrete wavelet transform. In the proposed method, the embedded watermark logo can be recovered without accessing to the original image by applying *DWT* in the Chroma blue channel (C_b). Also, the coefficient scaling technique is proposed to improve the variances between the coefficient values. In the extraction process, the mean filter is used to recover the watermark bits. The experimental results have shown the strength in every types of attack including the non-attacked cases. Especially in the JPEG compression attack, even though the original image is compressed about 50%, the extracted watermark signal is still clearly readable with a high NC value.

ACKNOWLEDGMENT

This research work is supported by the Information and Communication Technology Programme, Faculty of Science, Prince of Songkla University.

REFERENCES

[1] A. Hajisami, A. Rahmati, and M. Babaie-Zadeh, "Watermarking Based on Independent Component Analysis in Spatial Domain," *International Conference on Computer Modeling and Simulation (UKSim)*, 2011, pp. 299-303.

[2] Y. T Lin, C. Y. Huang, and G. C Lee, "Rotation, scaling, and translation resilient watermarking for images," *Image Processing (IET)*, 2011, pp. 328-340.

[3] B. Surekha and G. N. Swamy, "Digital image ownership verification based on spatial correlation of colors," in *Proc. Conference on Image Processing*, 2012, pp. 1-5.

[4] M. K. Samee and J. Gotze, "CDMA based blind and reversible watermarking scheme for images in Wavelet domain," in *Proc. International Conference on Systems, Signals and Image Processing*, 2012, pp. 154-159.

[5] Y. Chen, W. Yu, and J. Feng, "A digital watermarking based on discrete fractional Fourier transformation DWT and SVD," in *Proc. 24th Chinese Control and Decision Conference*, 2012, pp. 1383-1386.

[6] R. Keshavarzian, "A new ROI and block based watermarking scheme using *DWT*," in *Proc. 20th Iranian Conference on Electrical Engineering*, 2012, pp. 1323-1328.

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