WAVELET-BASED DIGITAL WATERMARKING USING HUMAN VISUAL SYSTEM FOR COPYRIGHT PROTECTION

Anuwat Sombun*, Quen Pinngern** and Chom Kimpan***

*Research Center for Communication and Information Technology, Department of Computer Engineering,
Faculty of Engineering, King Mongkut's Institue of Technology Ladkrabang, Thailand.
(Tel : +66-2-737-3000 Ext. 3334; Email : s3061607@kmitl.ac.th)
**Research Center for Communication and Information Technology, Department of Computer Engineering,
Faculty of Engineering, King Mongkut's Institue of Technology Ladkrabang, Thailand.
(Tel : +66-2-737-3000 Ext. 3334; Email : kpouen@kmitl.ac.th)
***Department of Science Program in Computer Science, Sripathum University JaktuJak Bangkok, Thailand
(Tel : 66-1-985-6653; E-mail: kkchom@kmitl.ac.th)

Abstract: This paper presents a wavelet-based digital watermarking technique for still images. The digital watermarking considering human visual system (HVS) to increase the robustness and perceptual invisibility of digital watermark. The watermarking embedding is modified discrete wavelet transform (DWT) coefficients of the subbands of the images. The human visual system is number of factors that effect the noise sensitivity of human eyes that is considered to increase the robustness and perceptual invisibility of digital watermark. The watermark detection is blind watermark (original image is not required). Experimental results successful against attacks by image processing such as add noise, cropping, filtering, JPEG and JPEG2000 compression.

Keywords: Wavelet, Watermark, Human Visual System, Copyright Protection, Correlation.

1. INTRODUCTION

The rapid development of computer and internet, the digital multimedia reproduction and distribution are becoming extremely easier and faster. However, it has been pirate copyrighted digital multimedia products. The digital watermarking [1] represents a viable solution to the above problem, since it make possible to declare the ownership of the digital multimedia. The digital watermark is embedded a watermark into digital multimedia products for detecting and tracing copyright violation.

Several digital watermarking algorithms [2] have been proposed with different contributions. These contribution can be categorized according to their casting/processing domain, signal type of the watermark, and hiding position. Two processing domain categories, the spatial domain and the frequency domain watermarking, have been proposed. The spatial based approached the simplest example is to embed the watermark in the least significant bits (LSBs) of image pixels. These technique still have relative low bit capacity and are not resistant enough to lossy image compression and other image processing. The frequency domain based technique can embed more bits of watermark and more robust to attack. Several methods have been processed in frequency domain such as DFT, DCT and DWT.

In this paper, we propose a wavelet-based watermarking algorithm [3] that is not required the original image for detected the watermark. The watermark is a binary pseudo-random sequence that is added to the DWT coefficients of the subbands of the image. Watermark casting is performed by exploiting the masking characteristics of the Human Visual System (HVS), to ensure watermark invisibility. The model for estimating the sensitivity of the eye noise is used to adapt the watermark strength to the local content of the image. The watermark has been added to the three detail subbands levels of DWT coefficients image that is improving watermark robust against to high compression, where other method marking only higher frequency subbands or lower level subbands are not very performance.

2. WATERMARKING PROCESS

2.1 Watermark Embedding

The Wavelet based algorithm uses explicitly the HVS [4] to exploit the human eye's limitation to embed strong watermark, maintaining perceptual invisibility. The principal advantage of use the HVS, consists of adapting the watermark to the image, so that it gives strongest watermark energy to embed in the certain image area in which the HVS is not perceived.

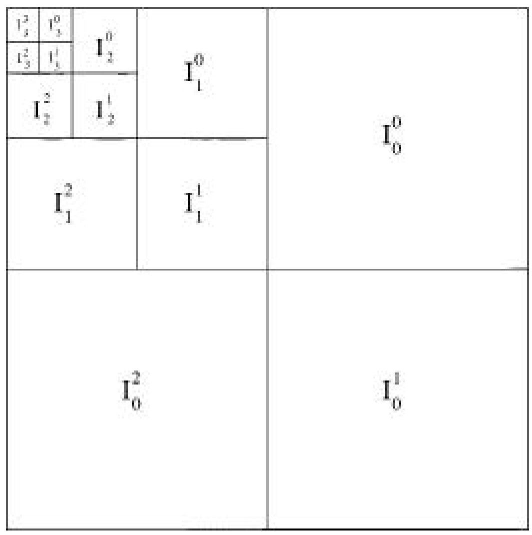


Fig. 1 The decomposition of an image in four levels of DWT.

In embedding process, the original image decomposed through DWT in four levels using Daubechies-6 filter is illustrated in Fig.1. In each level there are one compressed and three detail matrices. we denote I_l^θ is l-th level matrix with the direction θ, where l is {0, 1, 2, 3} and θ is the direction {0, 1, 2}. The watermark, consisting of a pseudorandom sequence generated by normal distribution with zero mean and unit variance, is then insert by modifying the wavelet coefficients at the high and middle frequency bands of the DWT of an image, sub-bands coefficients are then modified according to the Eq (1).

$$\overset{*\theta}{I_l}(i,j) = I_l^{\theta}(i,j) + \alpha w^{\theta}(i,j) x^{\theta}(i,j) . \quad (1)$$

where :

$I_l^{\theta}(i,j)$ is original wavelet coefficients of θ- the matrix in level l.

$\overset{*\theta}{I_l}(i,j)$ is marked coefficient of θ-the matrix in level l.

$x^{\theta}(i,j)$ is the pseudo random sequence .

α is a parameter accounting for watermark strength.

$w^{\theta}(i,j)$ is weighting function, which considers the sensibility of the image for the noise .

θ is the orientation.

2.2 Visual Masking

In order to embed watermark into the image. The weight function is considered to increase the robustness and perceptual invisibility of digital watermark. The weight function is created from the wavelet coefficient and HVS [4]. In their paper [4], a quantization of the DWT coefficient for the image compression is proposed. We use the modified quantization model based on HVS [5] in watermark embedding, according to the local noise sensitivity of the eye. In particular, the following considerations have been taken in to account.

- The eye is less sensitive to noise in high resolution bands, and in those bands having orientation of 45°(i.e.,θ =1 bands in our case; see Fig 1).
- The eye is less sensitive to noise in those areas of the image where brightness is high or low
- The eye is less sensitive to noise in highly textured areas but, among these, more sensitive near the edges.

The quantization step as the product of three terms.

$$q_l^{\theta}(i,j) = \Theta(l,\theta)\Lambda(l,i,j)\Xi(l,i,j)^{0.2} \quad (2)$$

where the first term is:

$$\Theta(l,\theta) = \begin{Bmatrix} \sqrt{2} & if & \theta = 1 \\ 1 & otherwise & \end{Bmatrix} \begin{Bmatrix} 1.00 & if & l = 0 \\ 0.23 & if & l = 1 \\ 0.16 & if & l = 2 \\ 0.10 & if & l = 3 \end{Bmatrix} \quad (3)$$

takes into account how the sensitive to noise changes depending on the band that is considered (in particular depending n the orientation and on the level do detail) . The second term is:

$$\Lambda(l,i,j) = \frac{1}{256} I_3^3\left(1+\frac{i}{2^{3-l}}, 1+\frac{j}{2^{3-l}}\right) \quad (4)$$

estimate the local brightness based on the grey level values of the low pass version of the image.

Finally, The third term:

$$\Xi(l,i,j) = \sum_{k=1}^{3-l}\frac{1}{16^k}\sum_{l=0}^{2}\sum_{x=0}^{1}\sum_{y=0}^{1}\left[I_{k+l}^{\theta}\left(y+\frac{i}{2^j}, x+\frac{j}{2^k}\right)\right]^2 +$$

$$Var\left\{I_3^3\left(1+y+\frac{i}{2^{3-l}}, 1+x+\frac{j}{2^{3-l}}\right)\right\}_{\substack{x=0,1\\ y=0,1}} \quad (5)$$

gives a measure of the activity of texture in the neighborhood of the pixel. In particular, this term is composed by two contributions. The first is the local mean square value of the DWT coefficients in all detail sub-bands at the coarser levels, while the second is the local variance of the low-pass sub-bands, both this contributions a computed in small 2x2 neighborhood corresponding to the location (i , j) of the pixel.

In the watermark embedding , we choose the quantization step for the DWT coefficient at location (i , j). The weighting function as:

$$w^{\theta}(i,j) = q_l^{\theta}(i,j) \quad (6)$$

It is important to mention that the watermark embedding energy given for α and w^{θ}, we haves fixed α values are 0.02 whereas the weight function w^{θ} provides a adequate value for each pixel of the image. The watermark is embedded in the sub-band first three levels. The Inverse Discrete Wavelet Transform is obtain the watermarked image.

2.3 Watermark Detection

Watermark detection is accomplished without referring to the original image. The correlation is computed between the watermark to be tested for presence and the marked coefficients Eq (7). The value of the correlation is compare to a threshold to decide if the watermark is present or not.

$$\rho = \sum_{\theta=0}^{2}\sum_{i=1}^{M}\sum_{j=1}^{N}\overset{*\theta}{I_l}(i,j)x_l^{\theta}(i,j) . \quad (7)$$

An optimum threshold is theoretically set to minimize the probability of false positive detection. The value of this threshold depend on the variance of the DWT coefficient of the watermarked image, and can thus be computer a-posteriori [6].To determine watermark is present in the image, the correlation value ρ is compared by T_ρ, if $\rho > T_\rho$ then the image is marked by the code, but if $\rho < T_\rho$ is not marked by code.

The Threshold values T_ρ calculation following Eq (8):

$$T_p = 3.97\sqrt{2\sigma_{\rho B}^2} . \quad (8)$$

In the practice the estimation of $\sigma_{\rho B}^2$ is given by Eq (9):

$$\sigma_{\rho B}^2 \approx \frac{1}{(3MN)^2}\sum_{\theta=0}^{2}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(\overset{*}{I_l^{\theta}}(i,j)\right)^2 . \quad (9)$$

where :

M, N is sizes of the DWT coefficients of the subbands of the image.

3. EXPERIMENTAL RESULTS

In order to confirm that the proposed image watermarking is effective, we have applied the presented technique on some benchmark images. We describe experimental results using the standard image "Lena" (512x512 pixel, 8 bits/pixel) shown in Fig. 2(a). Fig. 2(b) shows the watermarked image in first three levels of DWT. Fig. 3 illustrates the absolute value of difference between the original image and watermarked image.

(a) (b)

Fig.2 (a) original image "Lena" (b) watermarked image.

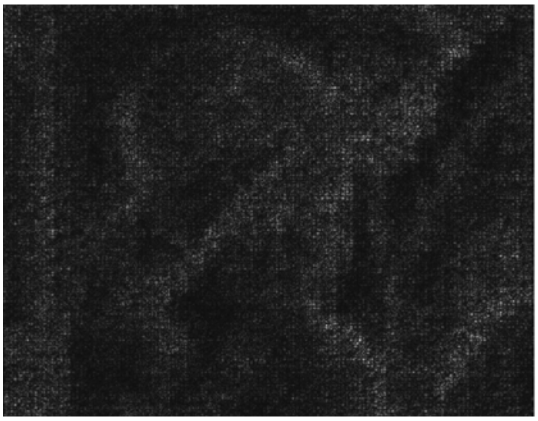


Fig. 3 absolute value of difference between the original image and watermarked image.

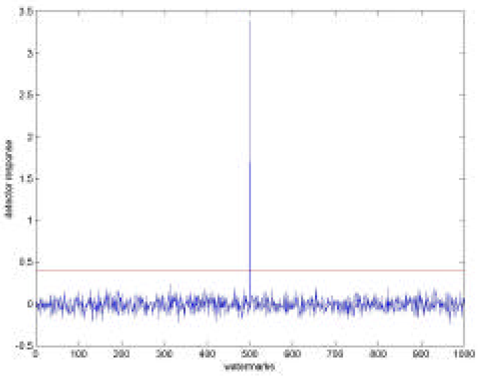
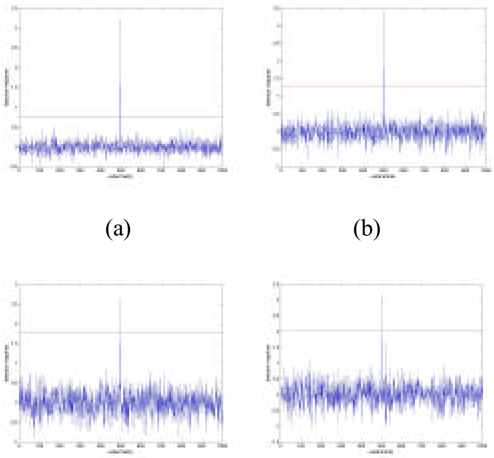


Fig. 4 The corresponding detector response to 1000 randomly generated watermarks.

The response of the watermark detector to 1000 randomly generated watermarks is show in Fig. 4. The vertical line shows the threshold T_ρ in Eq (8) because no attack we find that the positive response to the correct watermark (i.e. no.500) is much stronger than the response to incorrect watermarks.

Our experiments have demonstrated the robustness of the watermark against other attacks, in particular gaussian noise addition, cropping, geometrical distortion, luminosity modification , multiple watermark embedding and compression.

We also evaluated robustness of the algorithm introducing Gaussian noise to watermarked image. The noise density addition to watermarked image used from 10% to 40%. In the Fig. 5, we can observe that he detector detect watermark correctly

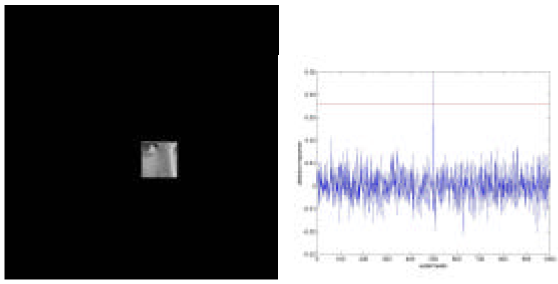


(a) (b)

(c) (d)

Fig. 5 The detector response to 1000 watermarks addition Gaussian noise with density (a) 10% (b) 20% (c) 30% (d) 40%.

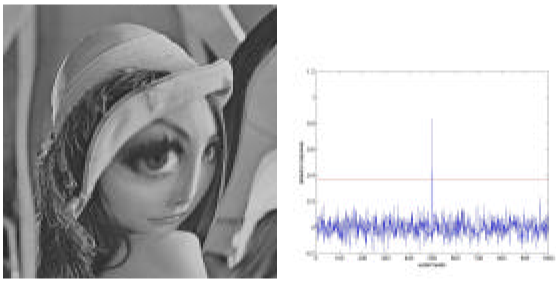
The cropping of a part of the image of the watermarked image is show in Fig. 6. We can cropping to 64x64 pixels.



(a) (b)

Fig. 6 (a) Cropping 64x64 pixels watermarked image (b) The detector response to 1000 watermarks for cropping to 64x64 pixels.

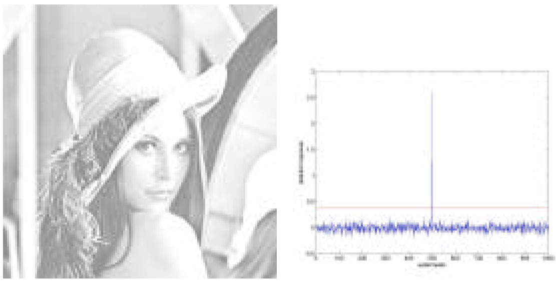
The geometrical distortions were applied to the watermarked image as show by Fig. 7



(a) (b)

Fig. 7 (a Geometrical distortion watermarked image (b) The detector response to 1000 watermarks for distortion.

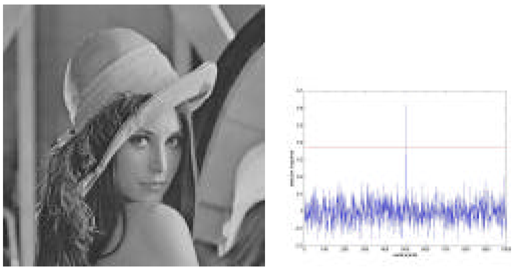
The brightness are applied to the watermarked image, being able to achieve to detect watermark with brightness up to 100% Fig. 8



(a) (b)

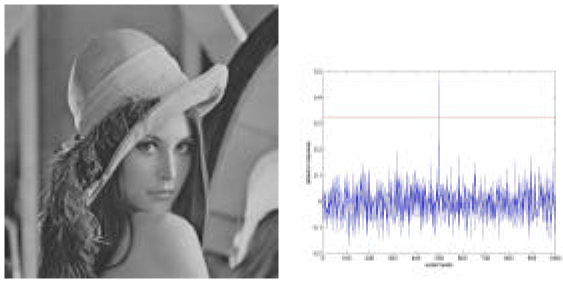
Fig. 8 (a) Brightness to 100% watermarked image (b) The detector response to 1000 watermarks for brightness up to 100%.

Finally, the JPEG and JPEG2000 compression attracted with quality factor 1 and 10% respectively show in Fig. 9 and Fig. 10.



(a) (b)

Fig. 9 (a) JPEG compression watermarked image (b) The detector response to 1000 watermarks for JPEG compression quality factor 1.



(a) (b)

Fig. 10 (a) JPEG2000 compression watermarked image (b) The detector response to 1000 watermarks for JPEG2000 compression quality factor 10%.

4. CONCLUSIONS

This paper presents techniques for embedding a digital watermark into image based on the wavelet transform. The algorithm embeds the watermarking code by modifying the coefficients of the DWT of the image which improving performance with respect to existing algorithms is obtained by masked the watermark according to the characteristics of the human visual system (HVS). This technique allow us to insert watermark in a higher level sub-band with an appropriate energy resulting in a watermarked image that has greater invisibility but is still robust. The technique has to be robust to the JPEG and JPEG2000 and image processing operation. Further research, focuses on developing the watermark detection method for improving the robustness of the propose algorithm to other aspects of attack such as rotation and scaling.

REFERENCES

[1] R.G. van Schyndel, A.Z. Tirkel, N.R.A. Mee, C.F. Osborne, " A digital watermark", Proceedings of the International Conference on Image Processing, November, 1994, Austin, Texas, vol. 2, pp. 86-90

[2] Raymond B. Wolfgang, Edward J. Delp, "A watermarking for digital images," Proceedings of the International Conference on Image Processing, Lausanne, Switzerland, 16-19 September 1996 vol. III, pp.219-222.

[3] R. Dugad, K. Ratakonda, and N. Ahuja, "A new wavelet-based scheme for watermarking images", Proc. IEEE ICIP'98, Oct. 1998.

[4] A. S. Lewis and G. Knowles, "Image compressin using the 2-D wavelet transform," IEEE Trans. On Image Processing, vol. 1, pp. 244—250, April 1992.

[5] M.Barni, F. Bartolini, and V. Cappellini, A. Lippi, A. Piva, "A DWT-based algorithm for spatio-frequency masking of digital signatures," Proceedings of SPIE vol. 3657, Security and Watermarking of Multimedia Contents, Electronic Imaging'99, San Joes, CA, January, 1999.

[6] A. Piva, M Bani, F. Bartolini, and V. Cappellini, "Threshold Selection for Correlation-Based Watermark Detection," Workshop on intelligent communications,1998, pp. 67-72.