A SEMI-BLIND WATERMARKING SCHEME FOR IMAGES USING A TREE STRUCTURE

Ersin Elbasi
The Graduate Center, CUNY
365 Fifth Avenue, New York, NY 10016, USA
EElbasi@gc.cuny.edu

Ahmet M. Eskicioglu
Department of CIS, Brooklyn College, CUNY
2900 Bedford Avenue, Brooklyn, NY 11210, USA
eskicioglu@sci.brooklyn.cuny.edu

Abstract **In this paper, we embed the watermark in a tree structure in the Discrete Wavelet Transform domain. For watermark embedding, the two level DWT decomposition of an *N*x*N* gray scale image *I* is computed. The same PRN sequence is embedded into the DWT coefficients higher than a given threshold T_1 in the LL2 and HH2 bands. The watermark is also embedded into the children of DWT coefficients. The original DWT coefficients are replaced by the modified DWT coefficients. The final step is to compute the inverse DWT to obtain the watermarked image *I'*. For watermark detection, the DWT of the watermarked and possibly attacked image *I** is computed. All the DWT coefficients higher than a given threshold T_2 in the LL2 and HH2 bands are selected. Then the sum *Z* of all attacked DWT coefficients multiplied by either the embedded watermark or other random PRN sequence is computed, divided by the length of the PRN sequence. The sum is also computed for the children of modified DWT coefficients. A predefined threshold *T* is chosen for LL2 and HH2 bands and the HH1 band. In each band, if *Z* exceeds *T*, the conclusion is that the watermark is present.**

Index Terms — **DWT, tree structure, semi-blind watermarking, PRN sequence.**

I. INTRODUCTION

A DWT-based semi-blind image watermarking scheme[1] leaves out the low pass band, and embeds a pseudo random number (PRN) sequence (i.e., the watermark) in the other three bands into the coefficients that are higher than a given threshold T_1. During watermark detection, all the high pass coefficients above another threshold T_2 ($T_2 \geq T_1$) are used in correlation with the original watermark. In a recent paper [2], the above idea is extended to embed the same PRN sequence in two bands (LL and HH) using the first level decomposition. In this paper, we embed the watermark in a tree structure in the DWT domain. Figure 1 shows the structure of such a tree.

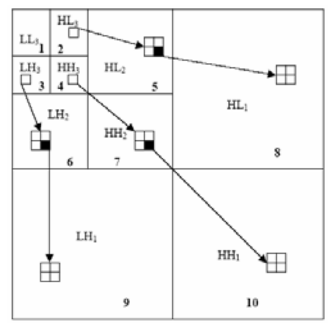


Figure 1. DWT tree structure

One criterion for a classification of image watermarking schemes is the information needed in the detection process. According to this criterion, there are three schemes:

- Non-blind [3,4,5]: Both the original image and the secret key(s) are needed.
- Semi-blind [6,7,8,9,10] : The watermark and the secret key(s) are needed.
- Blind [11,12,13,14]: Only the secret key(s) are needed.

II. EMBEDDING AND DETECTION ALGORITHMS

Watermark embedding

1. Compute the two level DWT decomposition of an *N*x*N* gray scale image *I*.
2. Embed the same PRN sequence into the DWT coefficients higher than a given threshold T_1 in the LL2 and HH2 bands: $T = \{t_i\}$, $t'_i = t_i + \alpha|t_i|x_i$, where i runs over all DWT coefficients $> T_1$.
3. Embed the PRN sequence into the children of DWT coefficients in Step 2.
4. Replace $T = \{t_i\}$ with $T' = \{t'_i\}$ in the DWT domain.
5. Compute the inverse DWT to obtain the watermarked image *I'*.

Watermark detection

1. Compute the DWT of the watermarked and possibly attacked image I^*.
2. Select all the DWT coefficients higher than a given threshold T_2 in the LL2 and HH2 bands.
3. Compute the sum $Z = \frac{1}{M}\sum_{i=1} y_i t_i^*$, where i runs over all DWT coefficients higher than a given threshold T_2 in the LL2 and HH2 bands, and M is the length of the PRN sequence, $\{y_i\}$ represents either the real watermark or a fake watermark, $\{t_i^*\}$ represents the watermarked and possibly attacked DWT coefficients.
4. Compute the sum $Z = \frac{1}{M}\sum_{i=1} y_i t_i^*$ for the children of modified DWT coefficients in Step 3.
5. Choose a predefined threshold $T = \frac{\alpha}{2M}\sum_{i=1} |t_i^*|$ for LL2 and HH2 bands and the HH1 band.
6. In each band, if Z exceeds T, the conclusion is that the watermark is present.

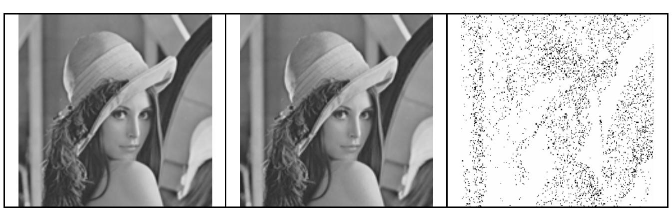
III. EXPERIMENTS

In our experiments, we used the parameters in Table 1.

Table 1. Scaling factor α and threshold T

Parameters/Bands	LL	HH
α	0.01	0.75
T_1	50	65
T_2	60	75

The 512x512 original test image, the watermarked image, and their difference are shown in Figure 2.



Original Lena   Watermarked Lena PSNR = 41.07   The difference

Figure 2. Embedding two watermarks into an image

Matlab was used for all attacks. The chosen attacks were JPEG compression, resizing, adding Gaussian noise, low pass filtering, rotation, histogram equalization, contrast adjustment, gamma correction, and cropping. The attacked images and the Matlab attack parameters are shown in Figure 3.

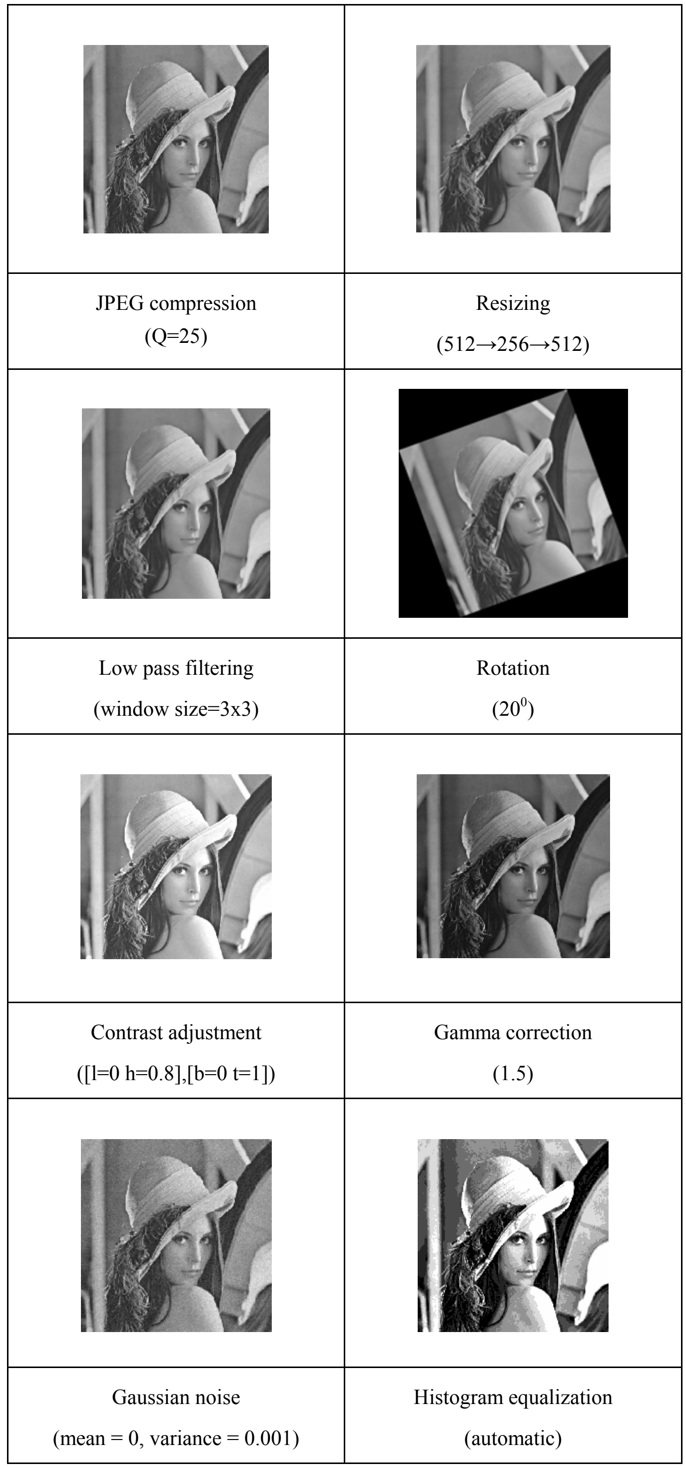
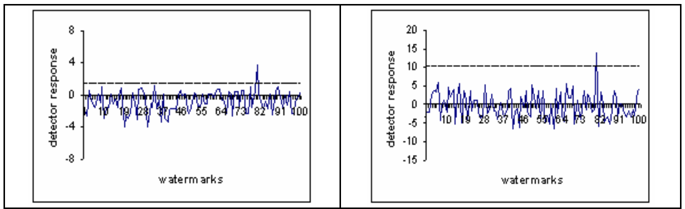


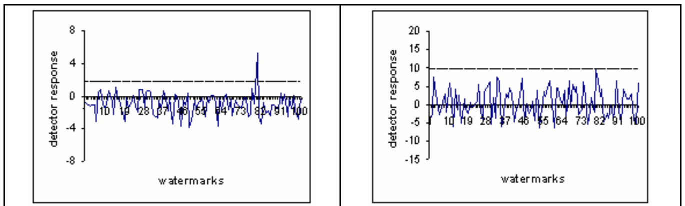
Figure 3. Attacks on watermarked Lena

In Figures 4-13, we display the detector responses for the real watermark, and 99 randomly generated watermarks. In each figure, the correlation with the real watermark is located at 80 on the x-axis, and the dotted line shows the value of the threshold.



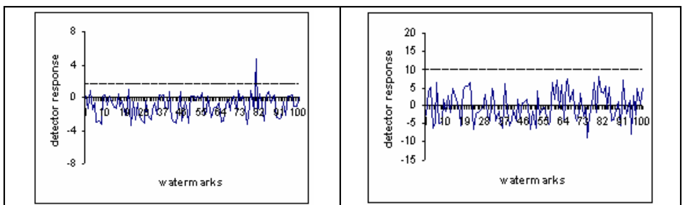
LL band (T=1.415)	HH band (T=10.236)

Figure 4. Detector response for unattacked watermarked Lena



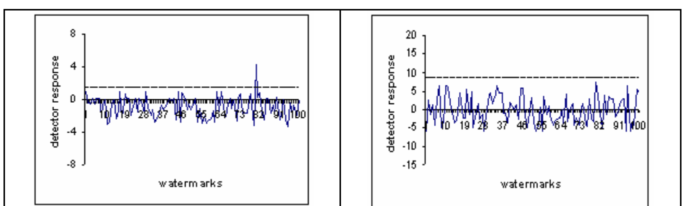
LL band (T=1.752)	HH band (T=9.747)

Figure 5. Detector response for JPEG compression: Q=25



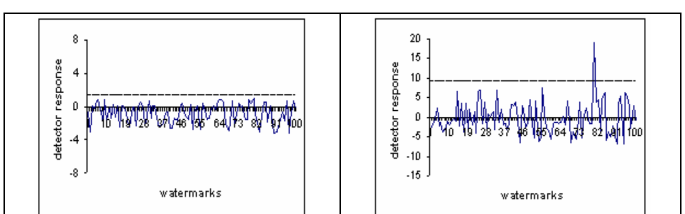
LL band (T=1.752)	HH band (T=9.997)

Figure 6. Detector response for Gaussian noise



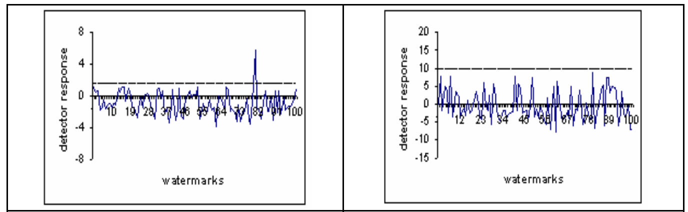
LL band (T=1.498)	HH band (T=8.703)

Figure 7. Detector response for resizing



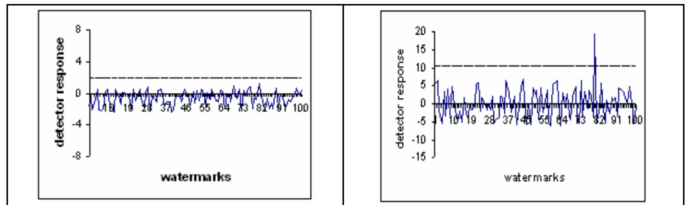
LL band (T=1.462)	HH band (T=9.293)

Figure 8. Detector response for cropping



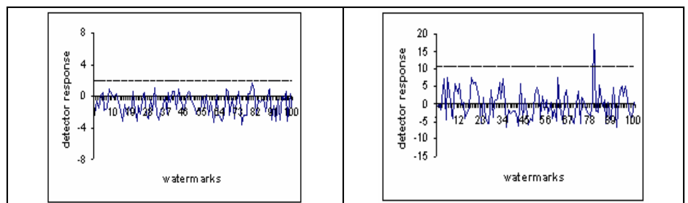
LL band (T=1.624)	HH band (T=9.812)

Figure 9. Detector response for low pass filtering



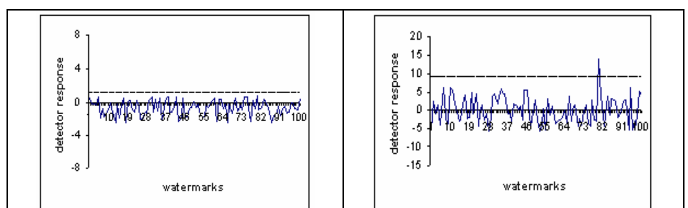
LL band (T=1.882)	HH band (T=10.455)

Figure 10. Detector response for histogram equalization



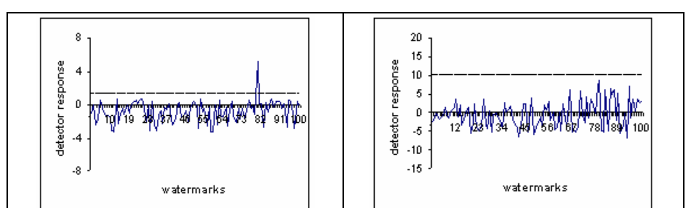
LL band (T=2.029)	HH band (T=10.748)

Figure 11. Detector response for contract adjustment



LL band (T=1.105)	HH band (T=9.138)

Figure 12. Detector response for gamma correction



LL band (T=1.126)	HH band (T=10.126)

Figure 13. Detector response for rotation (20^0)

IV. CONCLUSIONS

We have presented a semi-blind watermarking scheme in the DWT domain using a tree structure.

For one group of attacks (JPEG compression, Gaussian noise, resizing, low pass filtering, and rotation), the correlation with the real watermark exceeds the threshold in the LL bands.

For another group of attacks (cropping, histogram equalization, contrast adjustment, and gamma correction), the correlation with the real watermark exceeds the threshold in the HH bands.

In future work, we will use this approach to watermark video sequences such as akiyo, flower garden and tennis.

V. REFERENCES

[1] R. Dugad, K. Ratakonda, and N. Ahuja, "A New Wavelet-Based Scheme for Watermarking Images," *Proceedings of 1998 International Conference on Image Processing (ICIP 1998)*, Vol. 2, Chicago, IL, October 4-7, 1998, pp. 419-423.

[2] E. Elbasi and A. M. Eskicioglu, "A DWT-based Robust Semi-blind Image Watermarking Algorithm Using Two Bands," IS&T/SPIE's 18th Symposium on Electronic Imaging, Security, Steganography, and Watermarking of Multimedia Contents VIII Conference, San Jose, CA, January 15–19, 2006.

[3] C.-H. Lee and Y.-K. Lee, "An Adaptive Digital Image Watermarking Technique for Copyright Protection," *IEEE Transactions on Consumer Electronics*, 45(4), November 1999, pp. 1005-1015.

[4] I. J. Cox, J. Kilian, T. Leighton and T. Shamoon, "Secure Spread Spectrum Watermarking for Multimedia," *IEEE Transactions on Image Processing*, 6(12), December 1997, pp. 1673-1687.

[5] W. Zhu, Z. Xiong and Y.-Q. Zhang, "Multiresolution Watermarking for Images and Video," *IEEE Transactions on Circuits and Systems for Video Technology*, 9(4), June 1999, pp. 545-550.

[6] A. Piva, M. Barni, F. Bartolini, V. Cappellini, "DCT-based Watermark Recovering without Resorting to the Uncorrupted Original Image, Proceedings of the 1997 International Conference on Image Processing (ICIP '97), Washington, DC, USA, October 26-29, 1997.

[7] R. Dugad, K. Ratakonda, and N. Ahuja, "A New Wavelet-Based Scheme for Watermarking Images," *Proceedings of 1998 International Conference on Image Processing (ICIP 1998)*, Vol. 2, Chicago, IL, October 4-7, 1998, pp. 419-423.

[8] V. Solachidis and I. Pitas, "Circularly Symmetric Watermark Embedding in 2-D DFT Domain," *Proceedings of the 1999 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 1999)*, Vol. 6, Phoenix, AZ, March 15-19, 1999, pp. 3469-3472.

[9] V. Licks and R. Jordan, "On Digital Image Watermarking Robust to Geometric Transformations," *Proceedings of 2000 International Conference Image Processing (ICIP 2000)*, Vol. 3, Vancouver, BC, Canada, September 10-13, 2000, pp. 690-693.

[10] C.-Y. Lin, M. Wu, J. A. Bloom, I. J. Cox, M. L. Miller, and Y. M. Lui, "Rotation, Scale, and Translation Resilient Watermarking for Images," *IEEE Transactions on Image Processing*, 10(5), May 2001, pp. 767-782.

[11] R. Caldelli, M. Barni, F. Bartolini, A. Piva, "Geometric-Invariant Robust Watermarking through Constellation Matching in the Frequency Domain," *Proceedings of the 2000 International Conference on Image Processing (ICIP 2000)*, Vancouver, BC, Canada, September 10-13, 2000, Vol. II, Vancouver, Canada, September 10-13, 2000, pp. 65-68.

[12] S. Pereira and T. Pun, "Robust Template Matching for Affine Resistant Image Watermarks," *IEEE Transactions on Image Processing,* 9(6), June 2000, pp. 1123-1129.

[13] G. C. Langelaar and R. L. Lagendijk, "Optimal Differential Energy Watermarking of DCT Encoded Images and Video," *IEEE Transactions on Image Processing*, 10(1), January 2001, pp. 148-158.

[14] P. H. W. Wong, O. C. Au, and Y. M. Yeung, "A Novel Blind Multiple Watermarking Technique for Images," *IEEE Transactions on Circuits and Systems for Video Technology: Special Issue on Authentication, Copyright Protection and Information Hiding*, 13(8), August 2003, pp. 813-830.