005

MULTILEVEL WAVELET DECOMPOSITION WATERMARKING TECHNIQUES.

W. A. Wan Adnan[1], S. Abdul-Kareem[2], S. Hitam[1]
[1]Department of Computer and Communication Engineering, University Putra Malaysia
[2]Faculty of Computer Science and Information Technology, University Malaya, Malaysia
Email: wawa@eng.upm.edu.my

ABSTRACT

The merging of computer and communication technologies offers substantial new opportunities for processing and distribution of digital media. Along with powerful software and new devices such as digital cameras, scanners and printers, duplication, distribution, creation, and manipulation of images can be easily and cheaply done. The protection of ownership and the prevention of unauthorized tampering of images are becoming increasingly important concerns to multimedia content owners especially when the content is to be made available through the internet, which is unsecured. Digital watermarking is considered by many a potential solution to this problem. It is a process which embeds some characteristics data in an image in advance which later can be extracted that can be used for authentication or proof of ownership. This paper proposed a combination of spread spectrum encoding of the embedded message and wavelet transform-based invariants for digital image watermarking. Using the proposed method, we investigated the effect of using different values of gain factor at different sub-band of decomposition in such a way that it will not affect the perceptual transparency of the original image. The experimental results show that the imperceptibility and robustness are guaranteed using the proposed technique.

Keywords: *Watermarking, wavelet transform, data embedding.*

INTRODUCTION

Digital images can be easily manipulated and illegally duplicated by using image processing tools which make authentication and proof of ownership difficult. This motivates the research of watermarking which embeds some characteristics data in an image in advance so that authentication and intellectual property protection can be possible after they are modified or changed.

The embedded data is typically imperceptible but can later be detected or extracted to make an assertion about the originality or ownership. Generally, there are two common methods of watermarking: frequency domains[1,2] and spatial domain watermarks[3,4]. Our approach is to transform the image into its frequency domain representation where pseudo-random codes are added to the coefficient of the frequency bands of the Discrete Wavelet Transform(DWT) of an image. DWT-based watermarking methods have been chosen since the current image compression techniques JPEG2000 are based on the wavelet domain.

The algorithm published in [2] adds pseudo Random Noise to the large coefficients of the high and middle frequency bands of the DWT transformed image after performing two-level decomposition using Haar wavelet filters. Although the watermark was invisible, it proved to be fragile against low pass and median filtering. On the other hand, independent component analysis (ICA) combined with DWT and DCT is suggested by [5]. The approximation of the DWT transformed host image is then DCT transformed where the watermark is added. The invisible watermark was easy to detect through ICA however it was not robust enough to survive high pass filtering. The main requirements which should be fulfilled by a watermarking scheme are imperceptibility, security and robustness. In this paper, we only focused on the first two requirement of the scheme namely imperceptibility and robustness.

THE PROPOSED WATERMARKING TECHNIQUE

This section discusses the proposed techniques and includes a brief description of the wavelet transform.

The Discrete Wavelet Transform

The Discrete Wavelet Transform (DWT) provides the time-frequency representation of a given signal. The DWT is defined using a single signal as a basis for representation. The simplest and most popular basis function is the HAAR mother wavelet, which is a simple 2-level signal and is mathematically represented as:

$$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$$

The DWT separates an image into a lower resolution approximation image (LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) detail components. The process can be repeated to compute multiple "scale" wavelet decomposition as shown in figure 1 below:

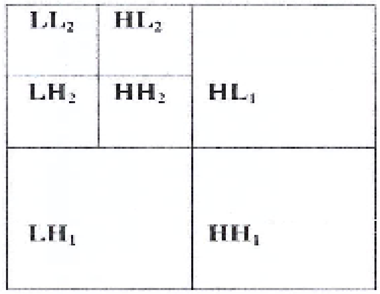

Figure 1. DWT decomposition of image using two-level pyramid

DWT Watermarking Technique

The proposed watermarking in the DWT domain includes two parts: embedding and extracting. The watermark embedding procedure is described below:

- Initially, third level Haar wavelet decomposition is performed to produce a sequence of detailed images, corresponding to the horizontal, vertical and diagonal details at each of the three level of the discrete wavelet decomposition as shown in figure 1.
- A secret key is used to generate PN sequence.
- In each of the 3 level of decomposition of the specific detailed coefficient in the sub-bands , pn-sequence x_i is added when an associated value of the watermark = 0

  using equation $V_i' = V_i + \alpha x_i$ $1 \le i \le N$ where N is the length of the watermark, V_i denotes the corresponding DWT coefficients of the original image at each of the resolution level and V'_i denotes the DWT coefficients of the watermarked image respectively. x_i is the pn sequence generated from a uniform distribution of zero mean and unit variance and α is the gain factor. The value of α used is not necessary be the same at each of the level of decomposition.
- The corresponding third level inverse DWT is computed to form the watermarked image.

The watermark extraction is performed by performing third Haar wavelet decomposition of the watermarked image and key-based detection of the watermark location. PN sequence is regenerated based on the earlier key used for embedding. The correlation between each of the 3 level of decomposition of the specific detailed coefficient and the PN sequence is calculated. If the correlation exceeds the mean correlation of each of the 3 level of decomposition of a particular sequence a "1" is recovered otherwise a zero. The recovery process is repeated until all bits of the watermark have been recovered.

The cryptographic security of the methods described above lies in the key that is used to generate pseudo-random numbers which is to be embedded at the selected image coefficients.

Performance Metrics

A watermarking scheme is usually evaluated based on two critical performance metrics:

i. imperceptibility i.e watermark should be invisible and

ii. robustness to incidental distortion such as signal processing, and attacks intended to remove the watermarks

As for the imperceptibility measures Peak Signal to Noise Ratio (PSNR) is a widely used measure of similiarity between the original and the watermarked image since it is easy to compute and analytically tractable. PSNR is defined as

$$PSNR = 20\log_{10}\left(\frac{255}{RMSE}\right) \tag{1}$$

where RMSE is the square root of Mean squared error(MSE) between the original and distorted images.

$$\text{MSE} = \frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N}\left[\hat{f}(m,n) - f(m,n)\right]^2 \tag{2}$$

where (M,N) is the size of host image f and $\hat{f}$ is the watermarked image

To evaluate the robustness against certain attacks, a watermarked image is first subjected to that distortion and a test image is then extracted from the altered image. The correlation between the test image which is the extracted watermark and the original watermark is computed using the equation below to show its robustness.

$$Correlation = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} I(i,j)I'(i,j)}{\sum_{i=1}^{N}\sum_{j=1}^{N}[I(i,j)]^2} \tag{3}$$

where I represent the original watermark and I' represent the extracted watermark. The value of correlation determines how closely the original resembles the extracted watermark where a value of 1 indicates that they are identical.

RESULTS AND DISCUSSION

The 384 x 384 brain image (Figure 2) is used as the host image to demonstrate the effectiveness of the proposed method while Figure 3 is used as the watermark. The watermark is embedded at each of the three level of the specified detailed sub band of decomposition. PSNR and correlation as defined earlier are used as the performance indicator Various values of gain factor α are used for each level of decomposition in order to investigate the effect on the perceptual quality of the host images and also on the extracted watermark.

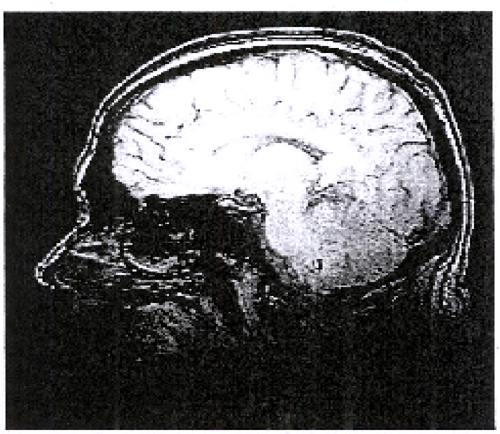

Figure 2 The cover image

Figure 3 The watermark

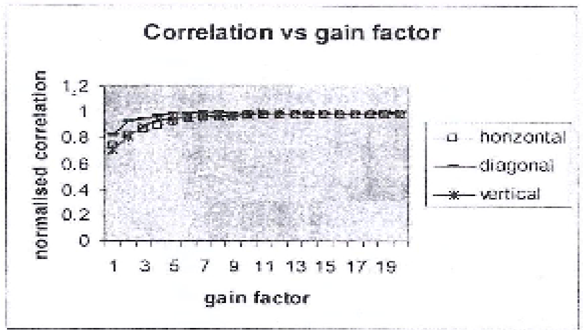

Figure 4 The correlation of the watermark with various value of gain factor at the 3rd level of decomposition.

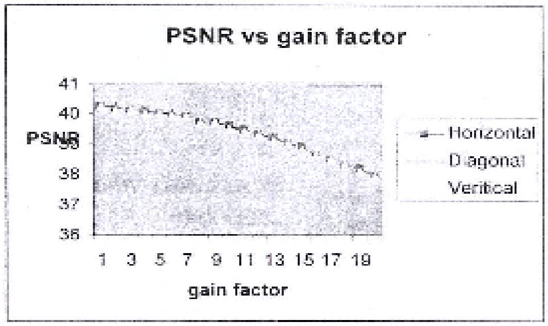

Figure 5 The PSNR of the watermarked image with various values of gain factor at the 3rd level of decomposition.

Figure 4 and 5 are the results obtained when the gain factor is fixed to 8 at the 1st level and 2nd level of decomposition with varying values at the 3rd level. The figures clearly shows that the value chosen for the gain factor effects the PSNR and correlation coefficient. From figure 4, it can be seen that the higher the value of α, the better will be the correlation but figure 5 shows that the PSNR decreases with the increase of α. However, there is no significant difference in PSNR when embedding the watermark in any of the detailed sub bands. Therefore α should be chosen such that it will give high perceptual quality of the watermarked image and also the extracted watermark resembles the original watermark. To test for robustness against compression, gain factor equals to 8 at the 3rd level of decomposition is chosen since that value gives a high PSNR and correlation based on figure 4 and 5.

Table 1 *PSNR for the watermarked and correlation for the retrieved watermark after the watermarked image undergoes compression with the various value of quality factor.*

Quality Factor	PSNR(dB)	Correlation
100	40.2	1
90	39.5	1
80	39.2	0.995
70	38.5	0.984
60	38.4	0.980

A comparative evaluation of the distortions induced by applying the embedding schemes and JPEG compression with different quality factors is presented in Table 1. The results show that correlation of more than 0.98 is obtained for retrieved watermark and PSNR greater than 38 for the watermarked image. These suggest that the watermark display a high immunity to compression without sacrificing the image quality.

CONCLUSION

In this paper, we have introduced a watermarking technique in the Discrete Wavelet Transform(DWT) which is implemented using MATLAB software. The PSNR and the correlation values which are used for performance measure show that different values of gain factor has to be taken into consideration when embedding at different level of wavelet decomposition.

REFERENCES

[1] Houng-Jyh Wang, Po-Chyi Su and C.-C. Jay Kuo "Wavelet-based Digital Image Watermarking" *Journal of Optics Express*, Vol. 3, No. 12, pp.491-496, December 1998

[2] X. Xia, C. Boncelet, and G. Arcee, "A multiresolution watermark for digital images," in Proc. IEEE int. Conf. Image Processing 1997(ICIP' 97), vol.1, Santa Barbara,CA, Oct 1997, pp 548-551

[3] R.B Wolfgang, E.J.Delp, A watermark for digital images
Proceedings., International Conference on Image Processing 1996. Volume: 3 , 16-19 Sep 1996
Page(s): 219 -222 vol.3

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

[5] Ju liu, Xiangang Zhang, Jiande Sun and Miguel Angel Lagaunas, "A Digital Watermarking Scheme Based on ICA detection", Proceedings of the 4th International Symposium on Independent Component Analysis and Blind Signal Separation (ICA2003), April 2003, Nara, Japan.