Wavelet-Based Digital Image Watermarking Using Level Adaptive Threshold

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Abstract: - In this paper, we propose a method of digital watermarking for still image using multi-stage discrete wavelet transform which does not require the original image for watermark detection. The watermark, generated by pseudo-random sequence with a normalized distribution of zero mean and unit variance, is added to all high-frequency coefficients which are above a level adaptive threshold. By comparing the correlation between the wavelet coefficients of a possibly corrupted watermarked image and the watermark with a threshold, the embedded watermark can be detected. Experimental results show that the embedded watermark is robust against various signal processing and compression attacks.

Key-Words: - Digital Watermarking, Discrete Wavelet Transform, Level Adaptive Threshold

1. Introduction

The growth of new imaging technologies has created a need for techniques that can be used for copyright protection of digital images. Copyright protection involves the authentication of image content and/or ownership and can be used to identify illegal copies of a (possibly forged) image. One approach for copyright protection is to introduce an invisible signal known as a digital watermark in the image.

There are two different ways to retrieve the watermark from the watermarked image. One needs the original image to recover the watermark and the other can recover the watermark without the original image. In both ways, their techniques can be classified into two categories: spatial domain approach [1] or frequency domain approach [2-5]. The spatial domain watermarking scheme is generally fast and simple, but it does not guarantee that the watermarking would be robust against noises and JPEG compression as a frequency domain method. Many schemes have found that watermarking in the frequency domain is more robust to common image processing operation. Several watermarking in frequency domain already had been proposed. These methods hide data into the frequency domain of an image using the discrete cosine transform (DCT)[2,3], the discrete wavelet transform (DWT) [4,5]. Cox et al. [2] proposed a secure spread spectrum watermarking method for embedding a watermark in the perceptual significant portion of the image in order to provide greater robustness. Hsu et al. [3] proposed a block based on DCT watermarking approach, the watermarking is visually recognizable pattern such as an image of seal with Chinese characters. The image is first divided into any blocks and DCT is performed on each block. The watermark is then embedded by selectively modifying the middle frequency of DCT coefficients, since the embedded watermark is an image. Xia et al. [4] introduced a multiresolution watermarking for digital images based on diiscrete wavelet transform. The watermark which is a Gaussain noise with zero-mean and unit-variances is inserted into the large coefficients at the high and middle frequency bands of image. Dugad et al. [5] proposed a technique using wavelet transform that does not require the original image for the watermark detection. In the method, the watermark is inserted into the all high frequency subbands.

In this paper, we propose a technique in frequency domain approach by analyzing the robustness of the watermarked images based on the Discrete Wavelet Transform (DWT) and does not require the original image for watermark detection. Furthermore, we discuss the threshold value used to determine whether the watermark is present or not. Finally, we will investigate the limitations of the watermarking techniques and discuss further research issues.

2. The Proposed Algorithm

2.1 Watermark Insertion

Figure 1 shows a block diagram of the watermark insertion. We decompose an original image I until the scale N and obtain multiresolution representation (MRR) LH_n, HL_n, HH_n (n = 1,2,…, N) and multiresolution approximation (MRA) LL_N.

To find the perceptually significant wavelet coefficients for each subband, the threshold value is calculated according to the decomposition level. For example in the 2 level decomposition , the largest coefficient C_1 for 1-level subbands (LH_1 ,HL_1, HH_1) is selected and the threshold T1 is calculated by equation (1) and T2 for the subsequent levels are respectively calculated using the same procedure.

$$T_i = 2^{\lfloor \log_2 C_i \rfloor - 1} \qquad (1)$$

where i is the decomposition level and $\lfloor X \rfloor$ represents the largest integer which is not greater than X. The watermark is embedded only to the selected coefficients.

The watermark **X** is generated by the pseudo random sequence whose probability law has a normal distribution of zero mean and unit variance. The watermark is then inserted into the image by:

$$V_i^{'} = V_i + \alpha |V_i| x_i \qquad (2)$$

where i runs over all DWT coefficients > T_i. V_i and $V_i^{'}$ denote respectively the DWT coefficient of the original and watermarked image and α is a scaling parameter. Finally, we reconstruct the watermarked image I' using the inverse DWT.

2.2 Watermark Detection

The watermark detection process is showed in Figure 2. It is composed of DWT of watermarked image. We choose all the high-pass coefficients selected and find the threshold for each level and correlate them with the original copy of the watermark..

We calculate the correlation z between the DWT coefficients of the corrupted watermarked image and a possibly different watermark Y is computed as

$$z = \frac{1}{M} \sum_i |\hat{V}_i| y_i \qquad (3)$$

If the similarity value is greater than a threshold value S in equation (3), it is possible to determine whether a given watermark is present.

$$S = \frac{\alpha}{2M} \sum_i |\hat{V}_i| \qquad (4)$$

where M is the number of coefficients where the watermark is inserted.

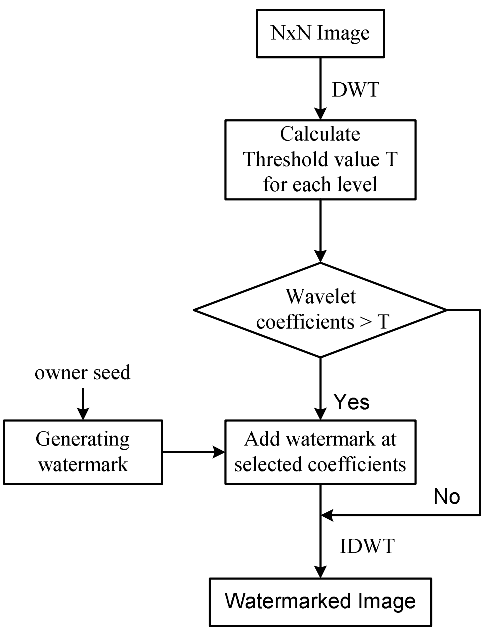

Figure 1: Watermark insertion process

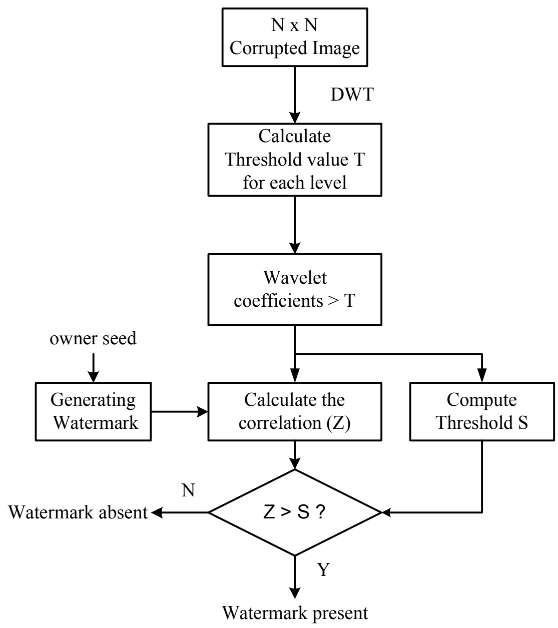

Figure 2: Watermark detection process.

3. Experimental Results

Figure 3(a) shows the original "Lena" image and Figure 3(b) shows the watermarked image with parameter $\alpha = 0.2$, the wavelet filter used is Daubechies 8 with $N = 2$. We can see that the watermark image is not distinguishable from the original image. Figure 3(c) illustrates the absolute value of difference between the original image and the watermarked image. We see that most of the watermark is added in edge regions of the image. Figure 3(d) shows the response z of the watermark detector to 1000 randomly generated watermarks. The dotted line showed the threshold S, we find that the positive response to the correct watermark is much stronger than the response to incorrect watermarks.

The robustness capability is very critical for watermark. We tested the robustness of watermarking with some attacks such as median filter, cropping, and JPEG compression. Figures 4 and 5 show the results of watermark detection after 50% cropping and smoothing with 5x5 median filter respectively. The robustness against JPEG compression is illustrated in Figure 6 with quality factors of 10%. We see that in all cases the detector responses are still well above the threshold.

4. Conclusions

In this work, we developed a perceptual watermark insertion scheme which searches the perceptually significant wavelet coefficients. The watermark sequence is embedded into selected significant coefficients by using level-adaptive threshold to provide a higher tolerance to various attacks. Moreover, the fidelity of the watermarked image can be adjusted by using the weighting factor alpha of the embedded watermark energy. A blind watermark retrieval technique was proposed and analyzed. It was demonstrated by experiments that the proposed algorithm can provide an excellent protection under various attacks.

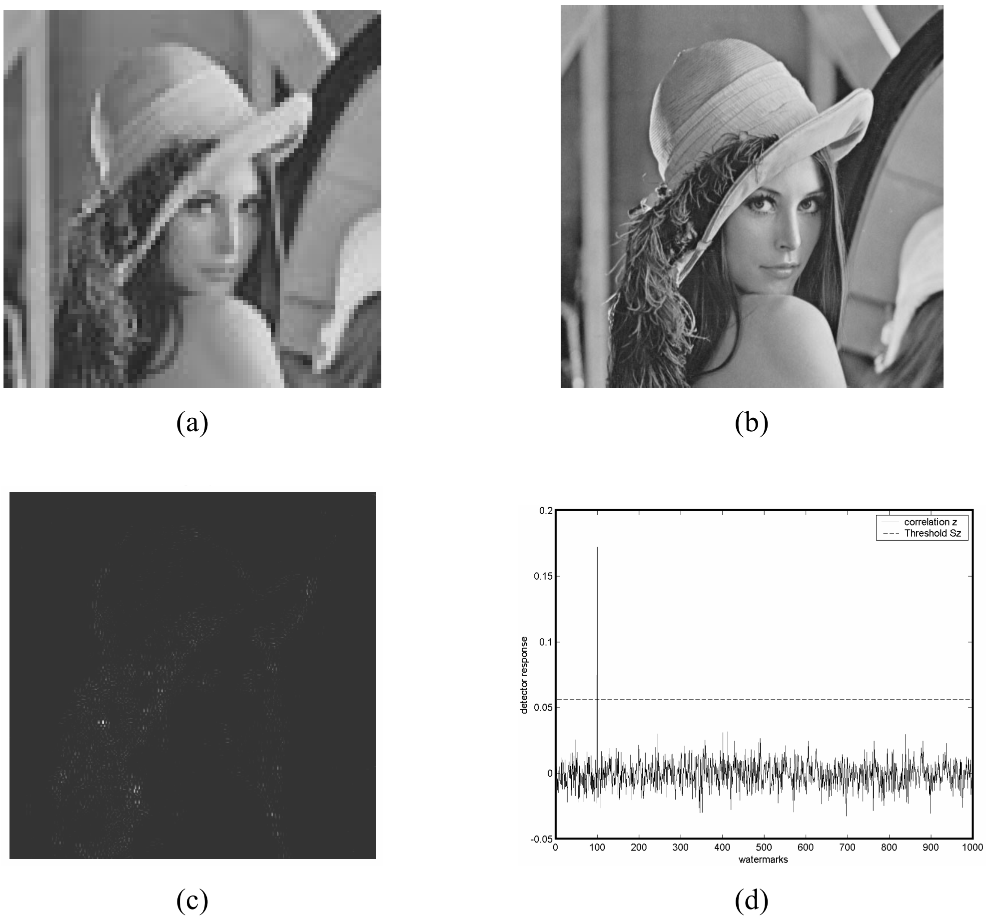

Figure 3: (a) Original image. (b) Watermarked image. (c) Difference of images (a) and (b). (d) Corresponding detector response

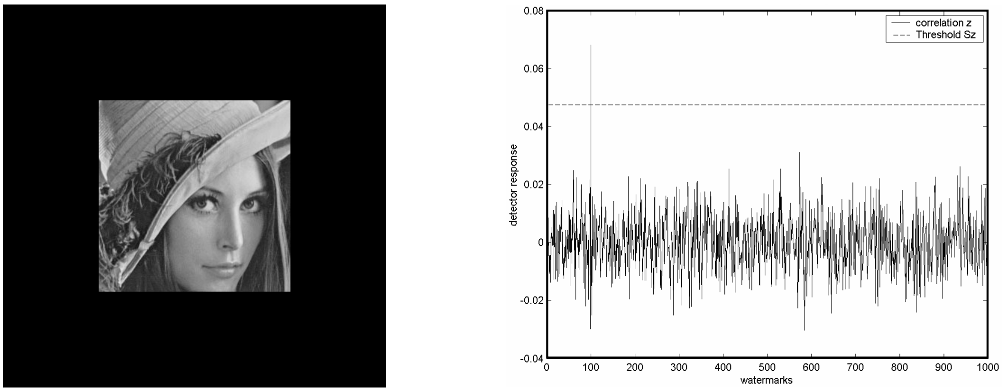

Figure 4: Watermarked image cropping equal to half size (left), and the corresponding detector response (right).

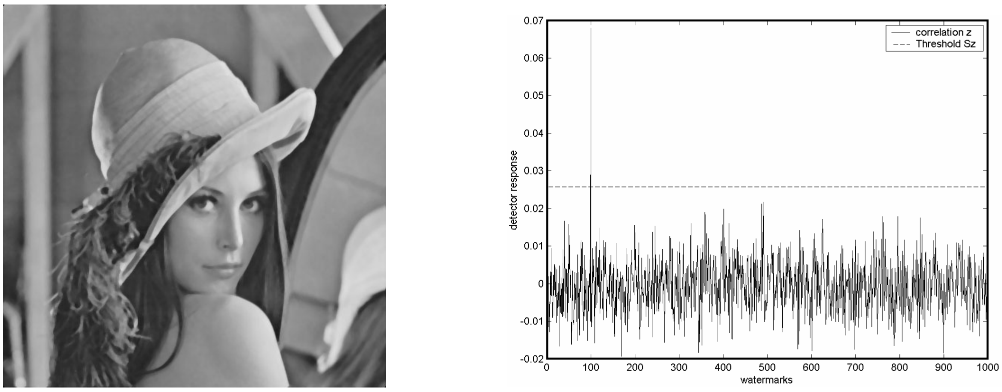

Figure 5: Watermarked image smoothed with 5x5 mean filter (left), and the corresponding detector response (right).

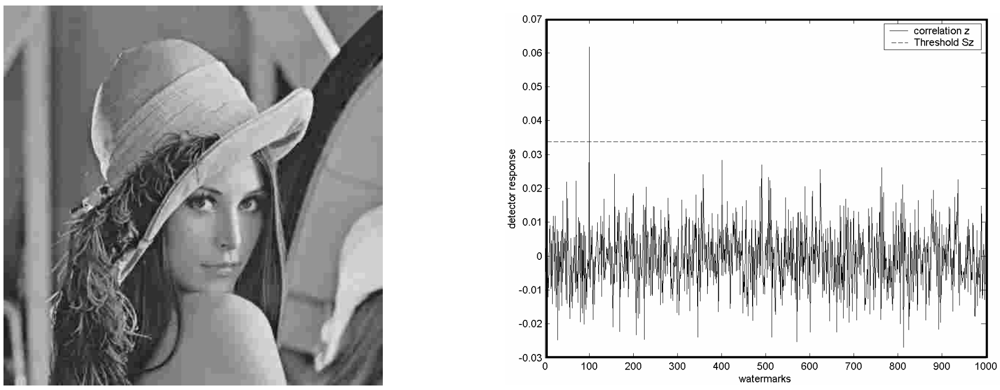

Figure 6: JPEG compression with 10% quality (left), and the corresponding detector response (right).

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