Digital Image Watermarking using Wavelet Transform

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ABSTRACT

In this paper, we introduce a robust multiresolution watermarking algorithm for copyright protection of digital images. By adapting the watermark signal to the wavelet coefficients, the proposed algorithm is highly image adaptive and the watermark signal can be strengthen in the most significant parts of the image. As this property also increases the watermark visibility, we have used the human visual system to prevent perceptual visibility of embedded watermark signal. Experimental results show that the proposed algorithm preserves the image quality and is robust against most common image processing distortions. In this work, multiple watermark addition is defeated easily. Furthermore, the hierarchical nature of wavelet transform allows for detection of watermark at various resolutions, resulting in reduction of the computational load needed for watermark detection based on the noise level. The performance of the proposed algorithm is shown to be superior to that of other available schemes reported in the literature.

Keywords: *Watermarking, Wavelet transform, embedding algorithm, detection algorithm, human visual system.*

1. INTRODUCTION

Multimedia services have witnessed a spectacular growth in recent years. This progress has created an ever-increasing need for techniques that can be used to support some security issues such as copyright protection, copy protection, fingerprinting and authentication.

In this paper, we are especially concerned with copyright protection of digital images. Digital watermarking is a method that can be used to address this issue. In this means, the digital watermarking is considered as a way of embedding the copyright information (watermark) into an image such that the watermark data is perceptually invisible and robust.

Algorithm robustness is important from different point of views. In copyright protection an algorithm should be robust against all kinds of removal attacks including common signal processing distortions which an image encounters during transmission, and malicious removing attacks.

In this regard, many different types of approaches have been reported in the literature. Some of them simply work in spatial domain. At present, these algorithms are not in wide use; since their general robustness does not seem adequate. Some other algorithms use different types of 2-D image transforms to embed their watermark signal more robustly. Amongst these the discrete cosine transform-based and wavelet-based algorithms seem to be more promising. The wavelet-based algorithms have shown to be much more robust and perform greater perceptual invisibility than others [1, 2, 3]. Some wavelet-based algorithm have been designed to embed the watermark signal into the lower level subbands. Most of them do not consider the fact that embedding watermark in higher-level subbands makes the algorithm much more robust due to quality degradation.

In this paper, we present a robust multiresolution image watermarking method with application to copyright protection of images. This method explicitly exploits the human visual system to guarantee that the embedded watermark is imperceptible. The proposed algorithm saves the image quality in spit of changing all wavelet coefficients of original image. In order to support algorithm robustness, the proposed algorithm is highly image dependent.

We have described our proposed watermark embedding and detection algorithm in Section 2. The experimental results are given in Section 3, followed by conclusion expression in Section 4.

2. ALGORITHM DESCRIPTION

2.1. Proposed Watermark Embedding Algorithm

The block diagram of the proposed image adaptive watermarking algorithm is shown in figure 1. As this figure shows, our proposed watermarking algorithm consists of three main steps. In the first step, we decompose an image into its n-level wavelet decomposition coefficients. As Daubechies 9/7 is in wide-use in most image processing works, we have also chosen to use this filter as our basis function (there are many references which support this idea from theoretical point of view, some proof can be find in [4,5,6]).
In the second step, the watermark embedding step, the wavelet coefficients are used to embed the watermark strongly in perceptually most significant parts of the original image. Let $\tilde{I}, W, W^*$ denote the wavelet coefficients of the original image, the original watermark, and the weighted watermark, respectively. So we have:

$$w^*(x, y) = \tilde{i}(x, y) \times w(x, y) \qquad (1)$$

As equation (1) shows, W^* is highly image dependent and its weights increase significantly in the perceptually important parts of the original image.
Subsequently, we employ a thresholding procedure to encounter the properties of human visual system. In this procedure, we use the threshold level of noise visibility in different bands of wavelet decomposition of the image [4] to keep the watermark level under the threshold of visibility.
Then, the watermark signal is added to the original image to construct the wavelet coefficients of the watermarked image. Then we have:

$$\tilde{\tilde{I}} = \tilde{I} + W^{**} \qquad (2)$$

where $\tilde{\tilde{I}}$ denotes the wavelet coefficients of the watermarked image and W^{**} denotes the thresholded version of the original watermark signal.
In the third step, the inverse wavelet transform of the watermarked image is computed to produce the watermarked image in spatial domain.
Obviously, although we have changed all wavelet coefficients of the original image, our weighting function and its subsequent thresholding schemes are designed in such a way that it provides us with a robust algorithm, which preserves image quality very well.

2.2. Proposed Watermark Detection Algorithm

In the watermark detection step, the wavelet representations of the received image and the original image are both computed. Then, the wavelet coefficients of the original image are subtracted from the wavelet coefficients of the received image (to extract the existing watermark from the received image). This by, we have obtained the thresholded version of embedded watermark (W^{**}). Furthermore, as in [7,8] the thresholding error is modeled as an additive Gaussian noise. Here, we have considered the probability distribution function of extracted watermark to have the same probability distribution function as the original watermark (W). Consequently, we can now simply use the *Cox* similarity model [7] to determine whether or not the existing watermark is the initially inserted signal.
In the next section, we will give our experimental results to prove our claims regarding the image quality and the algorithm robustness.

3. EXPERIMENTAL RESULTS

In order to evaluate our proposed algorithm we have run our algorithm on a large database of colored images. After running the quality and robustness tests on the images, we have compared the performance of our proposed algorithm with that of the most common algorithms reported in the literature. Here, due to the space constrains, we have just shown the results for the Lena image.

In the first test, we have presented the original images and their watermarked versions to 100 people of different ages and have asked them to compare the quality of the original and watermarked images. The result is listed in Table 1.

Then we have produced several random watermarks and have compared their watermark detection performance. Fig. 3 shows a typical response of our watermark detection algorithm to 1000 randomly generated watermarks in which only one matches the watermark that is really present in the received image. As this test shows, the algorithm false positive rate is very low and the correlation parameter due to the correct watermark is much stronger than the response to incorrect watermarks. It is worth mentioning that comparing to other algorithms [8,9,10], in our algorithm, the obtained peak of the correlation parameter and the differences between computed positive and negative correlation values are much higher. This in turn causes the proposed algorithm to be much more robust against additive noise and other artifacts.

Then we tested our algorithm against additive Gaussian noise. The results, shown in Fig. 4, clearly show that the robustness of the algorithm against the additive noise is satisfactory. We have also tested our watermark detection performance using just a limited number of wavelet decomposition bands. Fig. 5 shows the result.

We then tested our algorithm robustness against different types of compression algorithms (with various levels of compression ratios). The experiments showed that even with the compression ratios of lower than 0.12 bpp (67:1) the proposed detection algorithm is able to detect the embedded watermark signal correctly.

To test the robustness against geometric distortions, we can easily claim that as in our detection algorithm we have also access to the original image most kinds of geometric distortions, such as scaling and rotation, can be defeated easily. However, we tested our algorithm robustness against cropping by cropping different parts of images by different sizes and tested our detection algorithm performance for the cropped images. The experimental results showed that our proposed algorithm overcomes the cropping distortion for cropped part of up to half of the image size.

Finally, we compared our algorithm results with the results given in [3, 8, 9, 10] and our algorithm showed to have much better performance in most cases.

4. CONCLUSION

An adaptive and efficient multiresolution algorithm for copyright protection of digital images was presented. We have shown that although the algorithm adds the watermark to all the wavelet coefficients of the original image, but by taking advantages of the visibility level of noise in different bands of discrete wavelet decomposition of the image, we have preserved our watermarked image quality very well.

The algorithm is highly image adaptive, which in turn guarantees a satisfying level of robustness against different kinds of image processing distortions such as image compression, geometric distortions, and noise addition.

In the cases where the noise level of the received image is not very high, only a few bands of wavelet decomposition are needed to detect the watermark which, in turn, results in reduction of the algorithm computational load efficiently.

Finally, the experimental results showed that, compared to other available algorithms, our proposed algorithm performs in a very good level of robustness in addition to preserving the image quality.

5. REFERENCES

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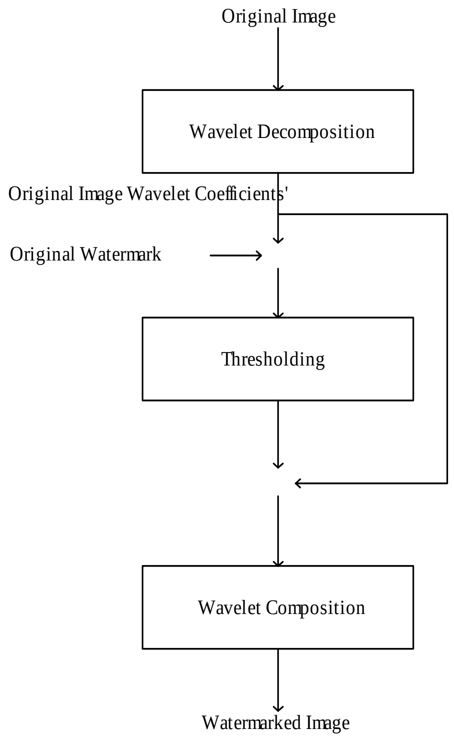
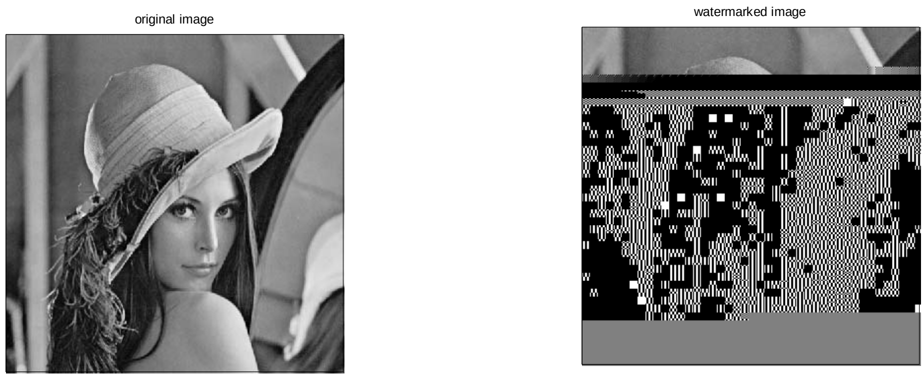


Figure 1: Proposed watermark embedding algorithm.

Table 1: Subjective test run on different watermarked images.

Quality / Image	Excellent	Very Good	Good	Fair	Poor
Lena	88	12	0	0	0
Mandrill	94	5	1	0	0
Dessert	86	10	4	0	0
Peppers	8	82	10	0	0
Squares	5	26	49	15	5



(a) **(b)**

Figure 2: (a) Original Lena image, (b) Watermarked Lena image.

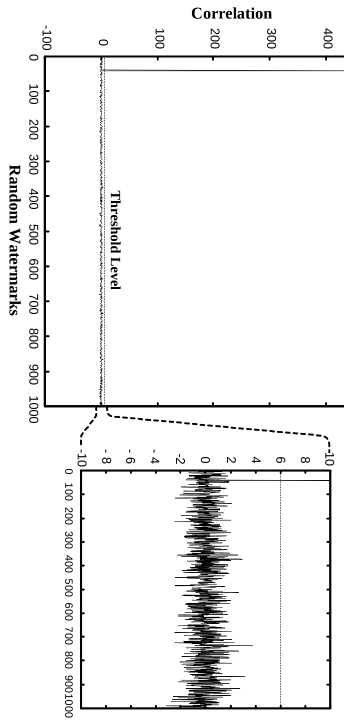


Figure 3: Watermark detector response to 1000 randomly generated watermarks. The threshold level is drawn for ease of comparison.

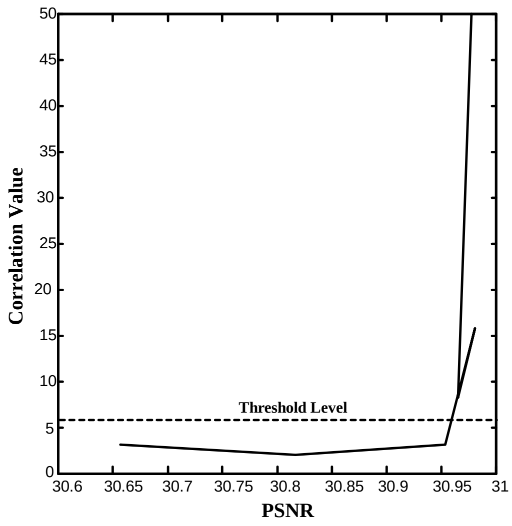


Figure 4: Watermark detector response against different levels of additive Gaussian noise.

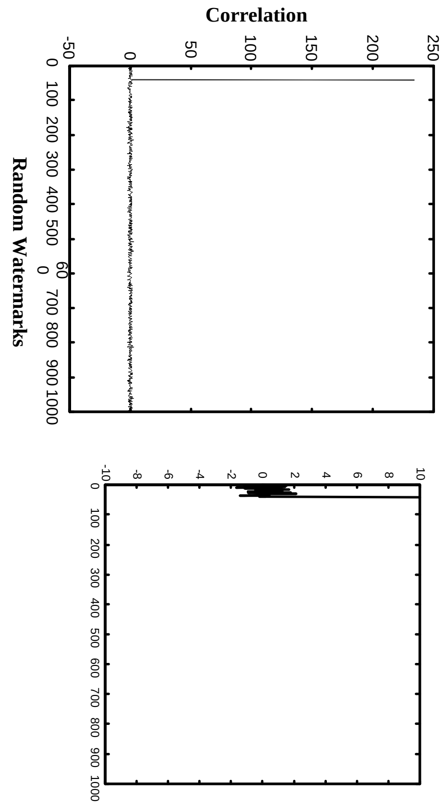


Figure 5: Watermark detector response to 1000 randomly generated watermarks using just the lowest resolution bands as detector input.