A Pre-Filtering Method to Improve Watermark Detection Rate in DCT Based Watermarking

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Abstract: *In image processing pre-processing is used for preparing or improving performance of operations. In order to improve performance of extraction algorithms in Discrete Cosine Transform (DCT) based watermarking method, a new pre-filtering method is proposed in this paper. Enhancement filters are applied to the watermarked image as pre-filtering before running watermark extraction algorithms in DCT based method. These filters are based of mixture of two filters: Unsharp and Laplacian of Gaussian (LoG). Distinction of watermarked part and unwatermarked part is increased by these filters; thus, the watermark information could be extracted with more accuracy. To show the effectiveness of the proposed method, different types of attacks are applied on typical DCT based algorithms. Experimental results show that extracted watermark has better quality than previous method.*

Keywords: *Digital image watermarking, watermark detection, DCT based watermarking, unsharp filter, LoG filter.*

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1. Introduction

The watermarking is a method that could solve copyright protection. The purpose of the watermark is to embed some extra information about the digital data without visibly modifying it [2, 15].

Watermark might be invisible and resistant to the intentional or inadvertent changes of the image. It should be robust to the compression, resizing, cropping, filtering, additive noise and enhancement operations. Watermarking methods are normally classified into the spatial domain or the transform domain. Spatial domain techniques are not robust to image compression and other image processing [17]. Transform domain watermarking schemes like Discrete Cosine Transform (DCT) [6, 7, 15] and the Discrete Wavelet Transform (DWT) [10, 18, 20] typically deliver higher image imperceptibly and more robustness to image manipulations.

When designing a watermarking algorithm, trade-offs exist among three parameters: payload, fidelity, and robustness. Data's payload is the number of bits that can be embedded in the digital data; the fidelity is the degradation introduced into the signal; and the robustness is the ability of the watermark to remain readable after innocent or malicious signal processing operations on the watermarked image. These parameters are conflicting with each other, and they should be set to meet the requirements of the application [14].

In this paper, new pre-filtering method is presented for DCT based watermarking methods. These filters applied before watermark extraction. They increase the contrast between the watermarked parts and unwatermarked parts. The watermarked image which could be attacked is enhanced by pre-filtering operations. Then, a watermark is extracted from this modified watermarked image. Experimental results show that proposed method successfully achieves higher robustness against almost all known attacks in DCT based watermarking algorithms.

The rest of the paper is organized as follows: In section 2, some previous studies about pre-processing algorithms are discussed. The proposed method is introduced in detail in section 3. In section 4, the performance on the typical method is evaluated by the experimental results. Conclusions are drawn in section 5.

2. Related Studies

Watermarking methods consist of two principle parts: embedding algorithm and extraction algorithm. Robustness of watermarking methods could be increased by strengthening each of these two parts. There are several methods which are based on probing the most suitable coefficients to embed watermark information: A perceptually optimal quantization matrix for JPEG standard is proposed in [22]. This matrix describes the artifact visibility as a function of DCT frequency, color channel, and display resolution and brightness. In [5], a JND profile is defined for an optimal image sub band coder. This profile code determined which signal is imperceptible and which signal is not imperceptible. Visibility thresholds of the quantization noise are defined for the linear phase 9/7 wavelet filters [23]. A visual model is proposed to determine the image dependent upper bounds on watermark insertion. These models have been used to achieve imperceptible watermark embedding [16]. The goal of these methods is to develop an efficient perceptual model based on a sub band decomposition that is specifically adopted to watermark embedding in the transform domains.

All of these methods suffer from two main drawbacks. First, the embedding algorithm requires too much time. Thus, they cannot be performed for real-time application. Second, most of these techniques cannot be applied on the blind DCT based watermarking algorithms. Watermarking methods need to know the position of the watermark information on watermarked data.

Power of watermarking algorithm could be increased by improving watermark detection reliability. An improved detector is proposed for detection based on thresholds extracted by statistic rules on which the method relies [9]. It extends the traditional schemes by taking into account the similarity diagrams that are widely used, until now, as an evidence of the existence of watermark and its uniqueness. Blurring filters before watermark detection can improve the detection rate [4]. For a watermark which has dominant low frequency content, the application of a blurring filter can serve to improve the detection probability. The reliability of the detector can be improved by applying matched filtering before correlation [8]. This decreases the contribution of the original image to the correlation. Therefore, the watermark can easily recover from watermarked image.

The weaknesses of the existing algorithms include:

1. Some of these existing techniques are not designed for image and video watermarking algorithm.
2. Most of the existing techniques are a part of watermarking extraction algorithms.
3. None of the existing watermarking schemes are robust to all the attacks.
4. Some of the existing techniques are designed to improve detection of watermark, which is in the form of additive pseudo-random noise patterns.

To tackle these problems, a novel pre-filtering scheme based on a combination of noise boosting and edge enhancement filter is proposed in this paper.

3. Proposed Pre-Filtering Method

In this paper, combination of two filters is used to increase power of watermark extraction algorithm in watermarking schemes. These filters are Sharpening and Laplacian of Gaussian (LoG) filters. The Pre-filtering procedure is represented in Figure 1, followed by a detailed explanation. In this section, these filters are introduced in and brief description to them is given in the below. Also, a reason and motivation of performing these filters is explained.

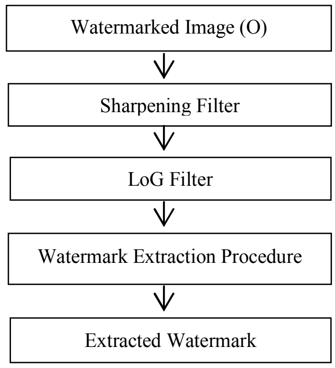


Figure 1. Proposed pre-filtering approach.

3.1. Sharpening Filter

Image sharpening falls into a category of image processing called spatial filtering. In contrast to smoothing operations, image sharpening has the goal to enhance the details specially the high spatial frequency components of the image [12, 19]. Sharpening filters bring out detail by increasing the contrast of pixels next to one another. Image sharpening falls into a category of image processing called spatial filtering. One can take advantage of how quickly or abruptly gray scale values or colors change from one pixel to the next. First order operators which using first derivative measurements are particularly good at finding edges in images. In contrast to smoothing operations, image sharpening has the goal to enhance the details specially the high spatial frequency components of the image [12, 19].

The unsharp filter is a simple sharpening operator which derives its name from the fact that it enhances edges (and other high frequency components in an image) using a procedure which subtracts an unsharp, or smoothed, version of an image from the original image. The unsharp filtering technique is commonly used in the photographic and printing industries for crisping edges [11].

A sharp image can be obtained by high pass filtering of a blurred image. Alternatively, subtracting a blurred version of the image from the original image may also lead to the sharpening of the image. As the name suggests the unsharp masking technique is used for crisping the edges. Such a technique is used in the printing industries. A signal proportional to the unsharp or low pass filtered version of the original noisy image is subtracted from the image, such that the resulting image $g(m, n)$ is a crisp high-contrast image [1]. Unsharp masking produces an edge image from an input image $f(x,y)$ as equation 1:

$$g(x,y) = f(x,y) - f_{smooth}(x,y) \quad (1)$$

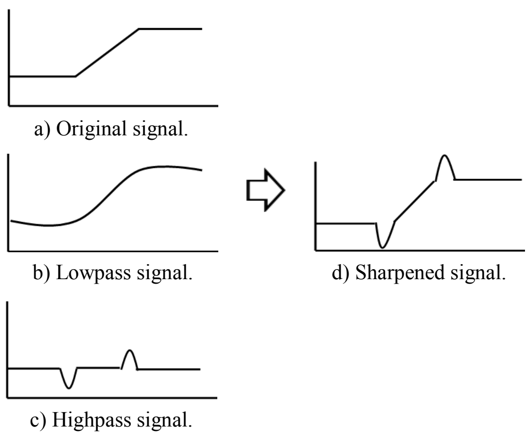
Where $f_{smooth}(x,y)$ is a low pass filtered version of the original image $f(x,y)$.

The operation of the unsharp Sharpening filter can be better understood by examining its frequency response characteristics [1]. If we have a signal as shown in Figure 2-a, subtracting away the low pass component of that signal, yields the high pass, or "edg", representation shown in Figure 2-c. This edge image can be used for sharpening if we add it back into the original signal, as shown in Figure 2-d.

A more common way of implementing the unsharp mask is by using the negative Laplacian operator to extract the high pass information directly, which may result in a better high contrast image. This operation is shown in Figure 3. Laplacian is also referred to as high emphasis filter, where the high frequency components are emphasized while retaining the low frequency components of the image. Any gradient function may be used, but in this paper unsharp mask is used for producing an edge image of this type. This mask is shown in equation 2:

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix} \tag{2}$$

This is simply negative, discrete Laplacian filters. The enhancement sharpens the edges but also increases noise, in case of attack free noise is the watermarked pattern.



a) Original signal.

b) Lowpass signal.

d) Sharpened signal.

c) Highpass signal.

Figure 2. The operation of the unsharp sharpening filter on a signal.

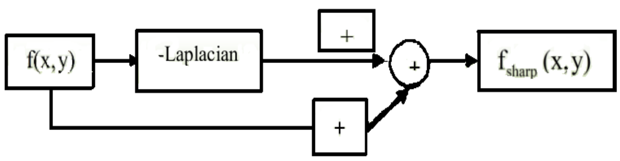


Figure 3. Spatial sharpening, an alternative definition.

The main aim in image sharpening is to highlight fine detail in the image, or to enhance detail that has been blurred (perhaps due to noise or other effects, such as motion). With image sharpening, we want to enhance the high-frequency components; this implies a spatial filter shape that has a high positive component at the centre. Distinction between the watermarked and unwatermarked part of image becomes more explicit by unsharp filter. Thus, watermarked bits can be extracted with more accuracy than without this filtering.

3.2. Gaussian of Laplacian Filter

The Laplacian is a 2D isotropic measure of the 2^{nd} spatial derivative of an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection [1, 11]. The operator normally takes a single gray level image as input and produces another gray level image as output. The Laplacian $L(x, y)$ of an image with pixel intensity values $I(x, y)$ is given by equation 3:

$$L(x,y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \tag{3}$$

This can be calculated using a convolution filter. Because Laplacian is a second derivative measurement on the image, they are very sensitive to noise. To counter this, the image is often Gaussian smoothed before applying the Laplacian filter. This Pre-filtering step reduces the high frequency noise components prior to the differentiation step.

In fact, since the convolution operation is associative, we can first convolve the Gaussian smoothing filter with the Laplacian filter, and then convolve this hybrid filter with the image to achieve the required result. This procedure has two advantages: The LOG kernel can be pre-calculated in advance so only one convolution needs to be performed at run-time on the image [21].

Laplacian operator is susceptible to noise. To reduce the noise susceptibility, LOG operator can be used. LOG first performs the Gaussian smoothing, which is followed by the Laplacian operation. It is less susceptible to noise because Gaussian function reduces the noise and the resultant Laplacian mask minimizes the probability of detection of false edges [1]. The 2D LOG function centred on zero and with Gaussian standard deviation σ has the form equations 4 and 5:

$$h_g(n_1, n_2) = e^{-\frac{n_1^2 + n_2^2}{2\sigma^2}} \tag{4}$$

$$h(n_1, n_2) = \frac{(n_1^2 + n_2^2 - 2\sigma^2)\, h_g(n_1, n_2)}{2\pi\sigma^6 \sum_{n_1}\sum_{n_2} h_g} \tag{5}$$

In these equations n_1 and n_2 are the numbers of rows and columns in the filter. Default value for h is 5 and for σ is 0.6. A smaller σ for the Gaussian will increase the noise, but the sharpening effect will be increased. On the other hand, using a larger σ for the Gaussian will reduce the noise, but the sharpening effect will be reduced. The LOG operator calculates the second spatial derivative of an image. This means that in areas where the image has constant intensity (i.e., where the intensity gradient is zero), the LOG response will be zero.

The first stage of the filter uses a Gaussian blur to blur the image in order to make the Laplacian filter less sensitive to noise. If we run the Laplacian filter on a noisy image, the result is an edge image with many small edges that detract from the larger more meaningful edges. Other blur filters could also be used prior to the Laplacian filter, but the Gaussian blur is more commonly used for this process.

In areas where the image is basically uniform, the LOG will give zero. Wherever, a change occurs, the LOG will give a positive response on the darker side and a negative response on the lighter side. This means that at a reasonably sharp edge between two regions of uniform but different intensities, the LOG response will be: Zero at a long distance from the edge; positive just to one side of the edge; negative just to the other side of the edge, and zero at some point in between, on the edge itself.

Figure 4 shows the response of 1D LOG filter to a step edge. The left hand graph shows a 1D image, 200 pixels long, containing a step edge. The right hand graph shows the response of a 1D LOG filter with Gaussian=5 pixels. By itself, the effect of the filter is to highlight edges in an image.

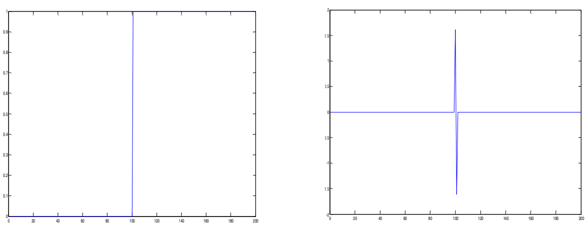


Figure 4. Illustrates the response of the LOG to a step edge.

3.3. Motivation of Utilization of Proposed Pre-Filtering

Combination of the explained process preforms a special kind of edge enhancement operations, which separate watermarked and un-watermarked parts of image. Therefore, performing pre-filtering operation on the watermarked image; which may be attacked, makes details of watermarked image (watermark information) to become more manifest. It means that watermark information which is different from the image background becomes recognizable straightforwardly to the procedure of watermark extraction. Thus, the presented method is better than the Pre-filtering technique which its goal is facilitating watermark insertion, because it is simple, blind, and could applied in the real time.

4. Experiment Results

In order to evaluate the effectiveness of the proposed Pre-filtering method, a typical DCT based is used [13]. The proposed pre-filtering process is applied on the watermarked image before performing extraction procedure. To show the efficiency of the proposed approach on these methods, three standard grayscale images with different contents of size 512×512 are used in our experiments, as shown in Figures 5-b and 5-d. Pepper is used as a representation of image with low spatial frequency, Barbara as a representation of image with average spatial frequency, and Baboon as a representation of image with high spatial frequency. In this experiment, a 32×32 binary image, as shown in Figure 5-a is taken as the watermark of images. Several experiments are done to evaluate the effectiveness of the presented watermarking algorithm. The performance of the watermarking methods is investigated by measuring their imperceptible and robust capabilities. For the imperceptible capability, a quantitative index, Peak Signal-to-Noise Ratio (PSNR), is employed to evaluate the difference between an original image O and a watermarked image $\overline{O}$. For the robust capability, the Mean Absolute Error (MAE) measures the difference between an original watermark W and the corresponding extracted one $\hat{W}$. The PSNR and the MAE are, respectively, defined by equations 6 and 7, respectively:

$$PSNR(O,\overline{O}) = 10\log_{10}\frac{255\times 255}{\dfrac{\sum_{i=0}^{I-1}\sum_{j=0}^{J-1}\left(\left\|O_{ij}-\overline{O}_{ij}\right\|\right)^2}{I\times J}} \tag{6}$$

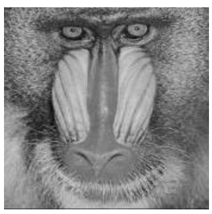
and

$$MAE(W,\hat{W}) = \frac{\sum_{i=0}^{S-1}\left\|w_i-\hat{w}_i\right\|_1}{|W|} \tag{7}$$

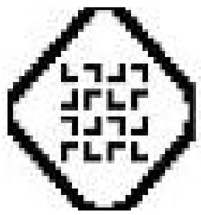
Where $\|.\|_1$ and $|.|$ stand for the $L1$ norm, and the number of components of a vector, respectively.

a) Pepper image.

b) Barbara image.



c) Baboon image.



d) The watermark.

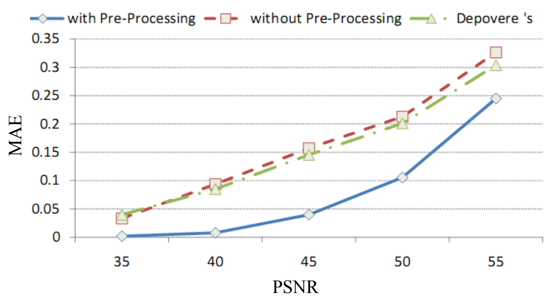
Figure 5. Images used in the experiments.

A larger PSNR indicates that the watermarked image $\overline{O}$ more closely resembles the original image O, meaning that the watermarking method makes the watermark more imperceptible. Generally, if PSNR value is greater than 35dB the watermarked image is within acceptable degradation levels, i.e., the watermarked is almost invisible to human visual system. Higher PSNR values reveal that the watermarked image $\overline{O}$ more resembles its original version O.

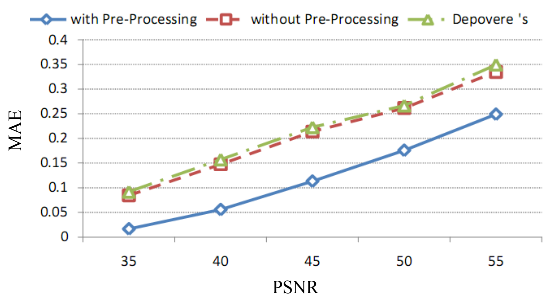
A lower MAE means that the extracted watermark $\hat{W}$ resembles the original watermark W more closely. The robustness of a watermarking method is assessed by comparing $\hat{W}$ with W, where $\hat{W}$ is extracted from the watermarked image $\overline{O}$ which is further degraded by attacks. If a method has a lower $MAE(W, W^*)$, it is more robust.

The watermarking performance of the proposed method is compared to Depovere's method [8]. To investigate the robustness of these methods, several attacks are implemented on the watermarked image, including JPEG compression, Gaussian filtering, adding salt and pepper noise, image scaling. The presented method and experiments are implemented using MATLAB.

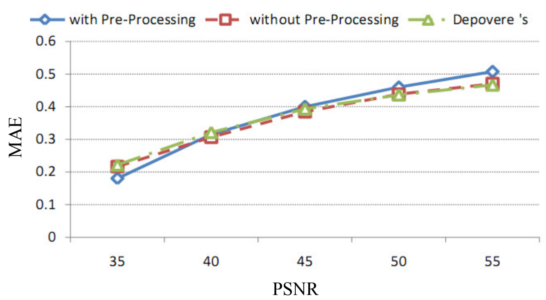
The watermarked image $\overline{O}$ is obtained following the completion of the watermark embedding procedure. The watermark information is embedded with PSNR 30, 35, 45, 50 and 55dB in the watermarked images. Then Pre-filtering method which is described in section 3 is performed on these watermarked images. The output of this Pre-filtering method is an input of extraction procedure. MAE between the original W and the extracted watermark $\hat{W}$ is calculated for all the watermarked images with different PSNRs.



a) MAE value from watermarked image of Peppers.



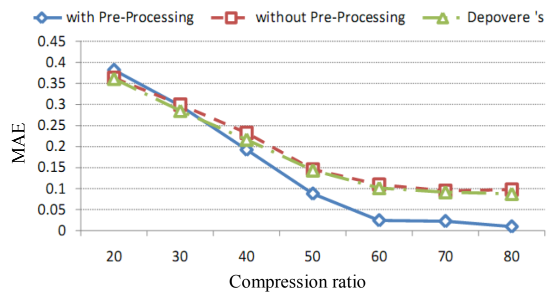
b) MAE value from watermarked image of Barbara.



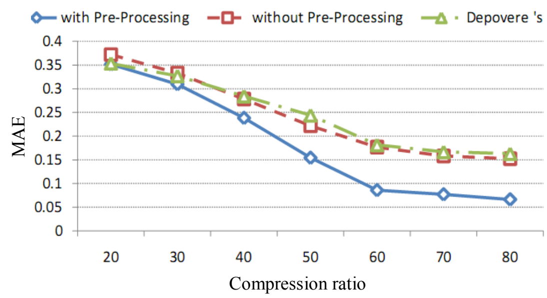
c) MAE value from watermarked image of Baboon.

Figure 6. The experimental results for the case of attack free in DCT based method.

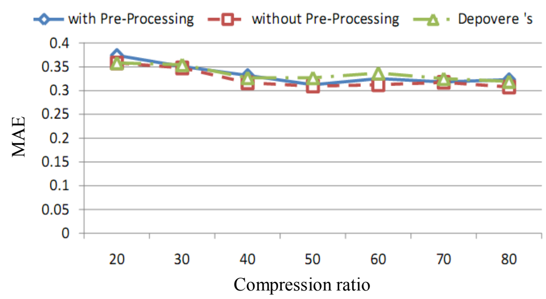
The performance of the proposed method is compared with Depovere's method and with the normal result of watermarking algorithm when Pre-filtering is not carried out on them. Figure 6 provides the quantitative results in terms of the PSNR and the MAE. Results show that the presented method definitely makes the watermark W more robust compared with when no Pre-filtering is done on the watermarked images and when the Depovere's method is done by applying matched filtering before correlation. Depovere's method less improves the detection probability in the DCT based methods. But, efficiency of presented Pre-filtering method is proven by comparing the results of extracted watermark of our method with others in schemas of MAE compared in Figure 6.



a) MAE value from watermarked Peppers image.



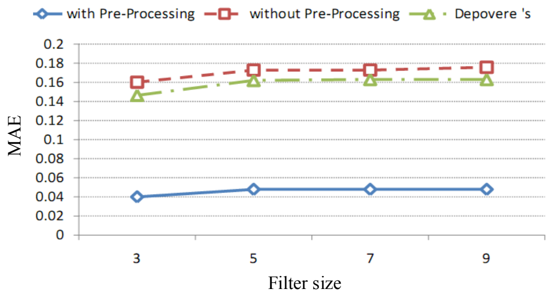
b) MAE value from watermarked Barbara image.



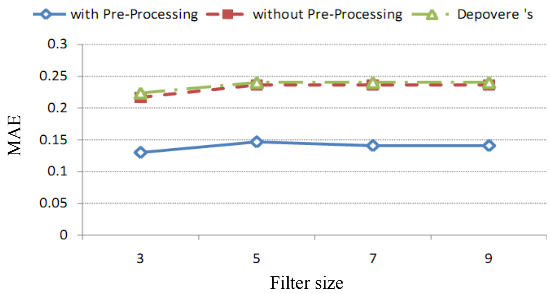
c) MAE value from watermarked Baboon image.

Figure 7. The experimental results in terms of the MAE in which watermarked images further manipulated by the JPEG compression attacks in DCT based method.

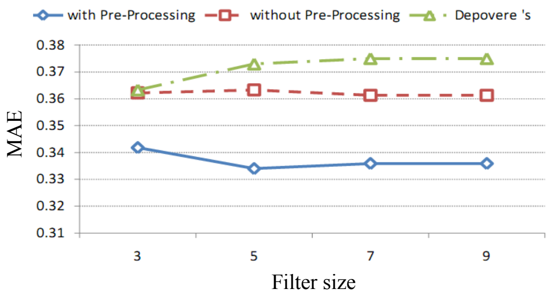
Different attacks are done on the watermarked image. These are JPEG compression, blurring, scaling and additive noise. These attacks are done with different parameters on three sample images. The results achieved from executing proposed Pre-filtering method and previous approach are shown in the Figures 7-10. The result in Figure 7-c shows less improvement because of proposed approach could not distinguish between the watermarked and watermarked parts.



a) MAE value from watermarked Peppers image.

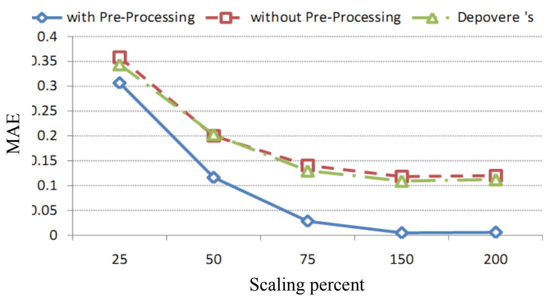


b) MAE value from watermarked Barbara image.

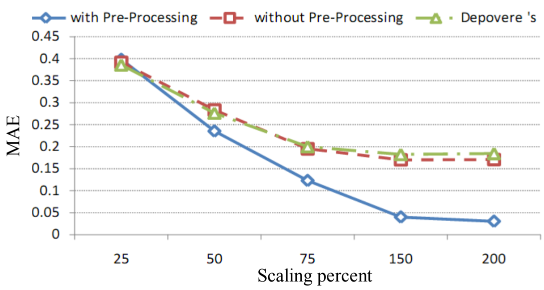


c) MAE value from watermarked Baboon image.

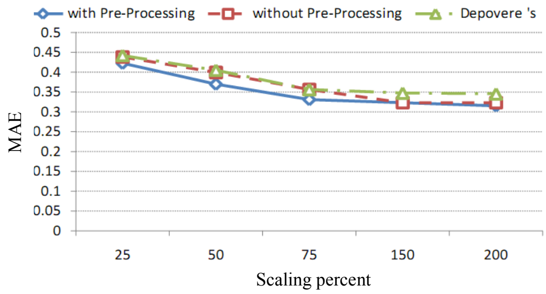
Figure 8. The experimental results in terms of the MAE in which watermarked images further manipulated by the blurring attacks in DCT based method.



a) MAE value from watermarked Peppers image.

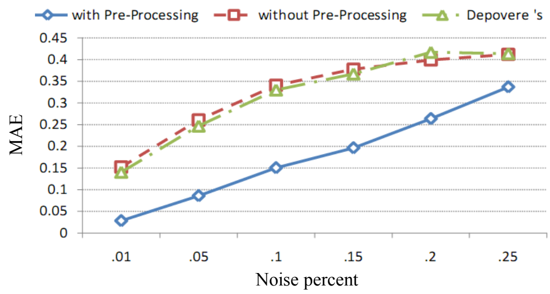


b) MAE value from watermarked Barbara image.

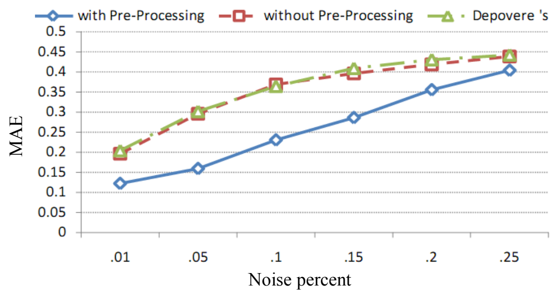


c) MAE value from watermarked Baboon image.

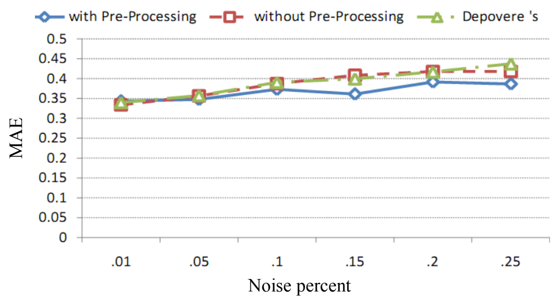
Figure 9. The experimental results in terms of the MAE in which watermarked images further manipulated by the scaling attacks in DCT based method.



a) MAE value from watermarked Peppers image.



b) MAE value from watermarked Barbara image.



c) MAE value from watermarked Baboon image.

Figure 10. The experimental results in terms of the MAE in which watermarked images further manipulated by salt and pepper noise addition attack in DCT based method.

The efficiency of the proposed method in terms of MAE for different attacks is demonstrated in these figures. Watermark detection reliability is improved by the presented method in all figures. The quality of extracted watermark increased meaningfully. Especially in case of enhancement operations with filtering and noise addition, increasing in performance is become more obvious.

Almost, effectiveness of Depovere's method is better than the normal approach for extraction of watermark in DCT based methods. However, as it observed from these figures, the extracted watermark by doing the proposed Pre-filtering on the watermarked image have a better quality against Depovere's method. As shown in part c of these figures, the proposed method could not improve the ability of watermark extraction significantly for high-frequency images. Since the proposed method tries to sharpen and magnify edges in the attacked watermarked image, the probability of detection of watermark becomes higher. This is because, the presented method increases the distinction between watermarked and watermarked part by reinforcement of edges in the attacked image.

5. Conclusions

Many Pre-filtering methods are utilized to improve watermarking strength. In this paper, a new Pre-filtering method is presented to obtain more imperceptibility and robustness watermarking schemes. The distinction between watermarked part and unwatermarked part of host image is increased by the combination of two filters. Then, this enhanced watermarked image is used as a new one which is ready for watermark extraction's procedure. Therefore, proposed method caused details of watermarked image become more manifest. Different experiments have shown that presented Pre-filtering method could significantly boost power of DCT based watermark extracting algorithm in discriminating between watermark and host image in watermarking methods. Effectiveness of the proposed Pre-filtering method is verified by comparing its result with another Pre-filtering method, which uses a sharpening filter as Pre-filtering. For measuring the robustness capability, the MAE measures the difference between an original watermark and the corresponding extracted watermark. The watermarks can be extracted after common image processing attacks with lower MAE value. Especially in case of enhancement operations with filtering and noise addition, increasing in performance is become more obvious.

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