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Optimizing of Spatial Domain Watermark Recovery Algorithm by Laplacian Filter

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Abstract

In this paper, impact of a Laplacian filter in better watermark recovery in the spatial domain watermarking algorithms has been investigated. A Laplacian filter is an enhancement filter, this filter could be utilized to optimize extraction of the watermark information in spatial domain watermarking. The distinction between the watermark and unwatermarked part is increased by this filter. Thus, watermark could be extracted significantly better by the watermark recovery algorithm. To show effectiveness of Laplacian filter on the spatial domain watermarking algorithms, it is applied on a typical correlation based method. Several experiments are done to show that performance of correlation based watermarking algorithm is improved by applying this filter before watermark extraction procedure.

Keywords: Laplacian Filter, Digital Image Watermarking, Correlation Based Watermarking, Spatial Domain Watermarking.

1. Introduction

In recent years, Digital watermarking is one of the most important techniques for the copy right protection. In this techniques, some extra information in the form of watermark is embedded invisibly in the digital media [1-2].

In the design of the watermarking algorithm always, there are two important item that they should be considered: robustness and imperceptibility. The imperceptibility means that how much the embedded information make reductions in signal quality; 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 have conflict with each other [3].

The Watermarking methods could be categorized into the spatial domain or the transform domain. The watermark is embedded directly in the pixels of the host image in the spatial domain techniques. Although, these methods are not robust to image common image processing operation [4-5], they have high imperceptibility. Some methods [6-7], utilized the filters capability to better extract the watermark. Transform domain watermarking schemes benefit properties of the transform domain to embed the watermark. These methods usually use the Discrete Cosine Transform (DCT) [8-9] and the Discrete Wavelet Transform (DWT) [10-11]. These methods typically are more robustness to image manipulations.

Several methods are proposed to augment the performance of algorithms watermarking. Most of these method concentrate on finding most suitable place for embedding watermark. Human visual system (HVS) [12-13], just noticeable difference (JND) [14-15] and optimal quantization matrix are used as techniques for finding most proper place [16]. These methods are commonly utilizing the characteristics of in frequency domain to detect suitable place. On the other hand, these method need some extra time to process digital media. Thus, they are not suitable for the real time application [17].

However, small research are done to augment the watermark recovery algorithm. The purpose of these method are to boost watermark detection rate by an efficient and simple model. Consequently, these approaches could increase the resistance and the imperceptibility of watermarking algorithms. On the other hand, these methods could apply and used in real time.

The watermark information is considered as noise for the watermarked image in its spatial domain. This noise is magnified before detection, and then recovers the watermark information by adjusting the extracted data from the frequency domain according to the global minimum method [18]. A preprocessing method is proposed that exploit a combination of Laplacian and Laplacian of Gaussian filtering to improve recovering the watermark from watermarked image in the DCT-based watermarking algorithm [3, 17]. They prove that performing these filter before watermark recovery in the DCT based watermarking could significantly increase chance of watermark recovery. Application of High Boost and unsharp masking filters in boosting the detection of watermark in show in [5, 7]. They show that performing this filter before and in the middle of watermark extraction procedure could significantly augment the results.

In this paper, a Laplacian filter is applied before watermark extraction to increase the probability of detection of watermark in the correlation based watermark recovery algorithms in the spatial domain methods. This filter could assistance the recovery algorithm to discriminate between the watermark and the host image. Thus, the watermark information could be removed from the altered watermarked image significantly better. This filter is applied before executing watermark extraction procedures in the spatial domain watermarking method. Different Experiments are done to show the impact of applying Laplacian filter in the spatial domain based watermarking.

2. MATERIALS

2.1. Second-order headings

Laplacian filter is one of the sharpening filters. The principal objective of sharpening filter is to highlight and enhance detail in the image that has been blurred. Uses of image sharpening to vary and include applications ranging from electronic printing and medical imaging to industrial inspection and autonomous guidance in military systems.

Laplacian filter could be obtained by first and second derivative. In most applications, the second derivative is better suited than the first derivative for image enhancement because of the ability of the former to enhance fine detail. For this, and for reasons of simpler implementation and extensions, in this paper, the second derivative is used as enhancement.

In this paper, Gonzales definition is used for Laplacian filter [19]. It can be shown that the simplest isotropic derivative operator is the Laplacian, which, for a function (image) $f(x, y)$ of two variables, is defined as.

$$\nabla^2 f = \frac{\nabla^2 f}{\partial^2 x^2} + \frac{\nabla^2 f}{\partial^2 y^2} \quad (1)$$

Because derivatives of any order are linear operations, the Laplacian is a linear operator. In order to be useful for digital image processing, this equation needs to be expressed in the discrete form. There are several ways to define a digital Laplacian using neighborhoods. Taking into account that we now have two variables, we use the following notation for the partial second-order derivative in the x-direction:

$$\frac{\nabla^2 f}{\partial^2 x^2} = f(x+1, y) + f(x-1, y) - 2f(x, y) \quad (2)$$

and, similarly in the y-direction, as

$$\frac{\nabla^2 f}{\partial^2 y^2} = f(x, y+1) + f(x, y-1) - 2f(x, y) \quad (3)$$

The digital implementation of the two-dimensional Laplacian in equation (4) is obtained by summing these two components:

$$\nabla^2 f = [f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1)] - 4f(x, y) \quad (4)$$

This equation can be implemented using the mask shown in equation (5).

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix} \quad (5)$$

In this paper a special implementation of the Laplacian is used:

$$\nabla^2 f = 8f(x, y) - \left[\begin{array}{l} f(x-1, y-1) + f(x-1, y) + f(x-1, y+1) + f(x, y-1) \\ + f(x, y+1) + f(x+1, y-1) + f(x+1, y) + f(x+1, y+1) \end{array} \right] \quad (6)$$

This equation can be implemented using the mask shown in equation (7).

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix} \quad (7)$$

Because the Laplacian is a derivative operator, its use highlights gray-level discontinuities in an image and deemphasizes regions with slowly changing gray levels. Background features can be “recovered” while still preserving the sharpening effect of the Laplacian operation simply by adding the original and Laplacian images.

2.2 Motivation of Laplacian filtering

The goals of this research were to show the effectiveness of performing typical Laplacian filtering on performance of spatial domain watermarking method. This filter is applied on attacked watermarked image before execution of the watermark extraction algorithm. This filter process applies a special kind of edge enhancement operations, which separate watermarked and un-watermarked parts of image. This filter helps that watermark information, which is different from the image background, becomes recognizable to the watermark extraction procedure.

3. METHODS

In this paper, a typical spatial domain watermarking method is used [7]. It is correlation based watermarking using block processing in the spatial domain.

3.1 Watermark Embedding Algorithm

The watermark embedding process is represented in Figure 1., followed by a detailed explanation.

Step 1: Divide the host image into 16 x 16 blocks.

Step 2: Re-formulate the watermark image into a vector of zeroes and ones.

Step 3: Generate two uncorrelated pseudorandom sequences by a key. One sequence is used to embed the watermark bit 0 (PN_0) and the other sequence is used to embed the watermark bit 1 (PN_1). Number of elements in each of the two pseudorandom sequences must be equal to the number of block.

Step 4: Embed the two pseudorandom sequences, PN_0 and PN_1, with a gain factor α in the 16x16 blocks of the host image. If we donate X as the matrix of the block, then embedding is done as equation (8):

$$X' = \begin{cases} X + \alpha * PN0 & watermark_bit = 0 \\ X + \alpha * PN1 & watermark_bit = 1 \end{cases} \quad (8)$$

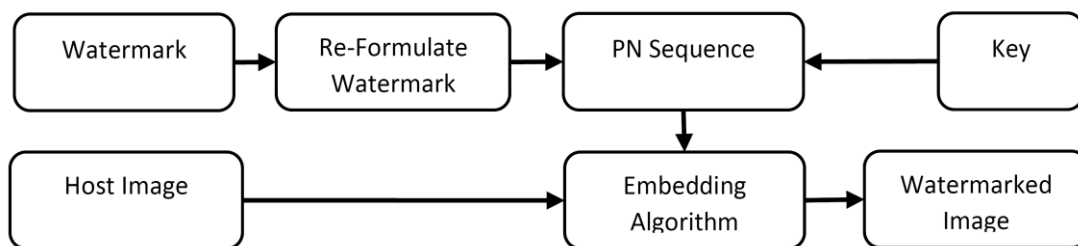


Figure 1. The watermark embedding process

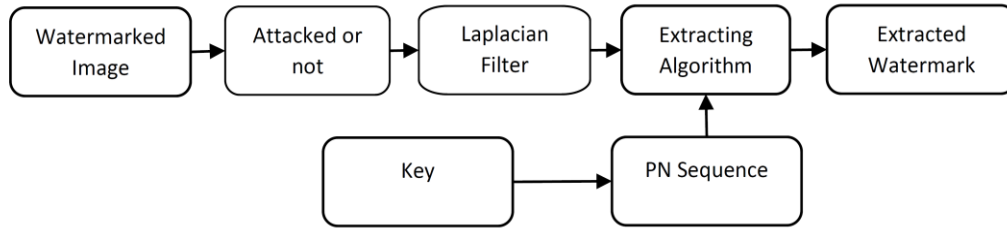


Figure 2. The watermark extracting with applying Laplacian before performing extracting algorithm.

3.2 Watermark Extracting Procedure

The typical correlation based algorithm is a blind watermarking algorithm, and thus the original host image is not required to extract the watermark. Extraction algorithm is the same as embedding one, and filtering is used before applying it to better separate watermark information from host image. The watermark extraction procedure is shown in Fig. 2, and described in details in the following steps.

Step 1: applying proposed filter as shown in the equation of (2) for Laplacian filter, on the watermarked image.

Step 2: Divide watermarked image that could be attacked or not into 16×16 blocks.

Step 3: Regenerate the two pseudorandom sequences (PN_0 and PN_1) using the same key which used in the watermark embedding procedure.

Step 4: For each block in the watermarked image calculate the correlation between the element and the two generated pseudorandom sequences (PN_0 and PN_1). If the correlation with the PN_0 was higher than the correlation with PN_1, then the extracted watermark bit is considered 0, otherwise the extracted watermark is considered 1.

Step 5: The scrambled watermark is reconstructed using the extracted watermark bits.

4. Experimental Results

To compare the efficiency of the proposed filter on correlation based methods, three standard grayscale images with different contents of size 512×512 are used in our experiments, as shown in Figure 3. (a)-(b). Pepper is used as a representation of image with low spatial frequency and Barbara as a representation of image with average spatial frequency. In this experiment, a 64×64 binary image, as shown in Figure 3.(c) is taken as the watermark of images. The impact of the Laplacian filter is investigated by measuring imperceptible and robustness of watermarked image. 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. For the robust capability, the Mean Absolute Error (MAE) measures the difference between an original watermark W and the corresponding extracted one. If a method has lower MAE, it is more robust. The PSNR and the MAE are, respectively, defined by equation 9 and 10; respectively,

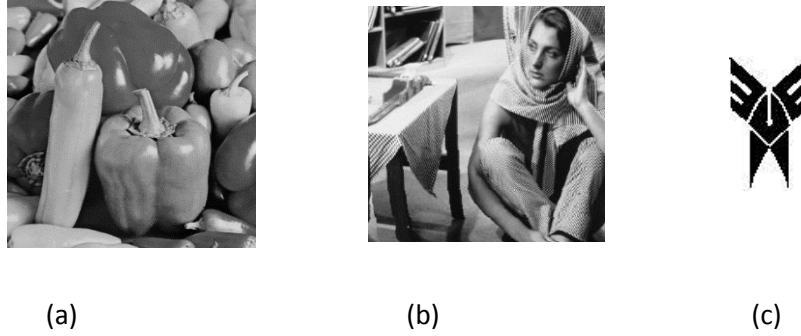


Figure. 3. (a) The original Pepper image; (b) the original Barbara image; (c) the original watermark.

$$PSNR(O, \bar{O}) = 10 \log_{10} \frac{255 \times 255}{\sum_{i=0}^{I-1} \sum_{j=0}^{J-1} \left(\left\| \begin{matrix} O_{ij} \\ \bar{O}_{ij} \end{matrix} \right\| \right)^2} \quad (9)$$

$I \times J$

$$MAE(W, \hat{W}) = \frac{\sum_{i=0}^{S-1} \|w_i - \hat{w}_i\|_1}{|W|} \quad (10)$$

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

Performance of the proposed method is compared to previous method [6]. The algorithm was tested on Peppers and Barbara standard test images. The watermarked image O is obtained following the completion of the watermark embedding procedure. The watermark information is embedded with PSNR 30, 35, and 40 dB in the watermarked images. Then Laplacian method which is described in Section 2 is performed on these watermarked images which may be attached. This filtered image is used as an input of extraction procedure. MAE between the original W and the extracted watermark W' is calculated for different PSNRs. The performance of the proposed method is compared with Depovere method and with the default results when no processing is done on the correlation based watermarking algorithm. In the Depovere method, for each block in the watermarked image, at first a high boost filter is applied on them and then, correlation between the filtered block and the two generated pseudorandom sequences (PN_0 and PN_1) is computed. To show the robustness of these methods, the efficacy of the algorithm is tested by several attacks, including JPEG compression, image scaling, adding Salt and Pepper noise, Gaussian filtering. The presented method is implemented using MATLAB.

4.1 Comparison in the case of Attack Free

In the first experiment, we compared the effect of Laplacian filter on watermarked image, which is not attacked, with Depovere's method and normal extracted watermark (without filtering). The results are shown in form of a line chart in the Figure 4. The results show significant improvement in compare with the normal one. Although, the results show that the Depovere method is performed as similar as the proposed method.

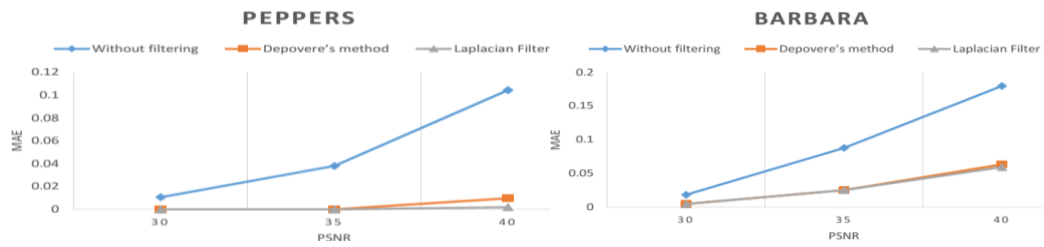


Figure 4. The experimental results in terms of the MAE in which watermarked images did not manipulated by the attacks in correlation

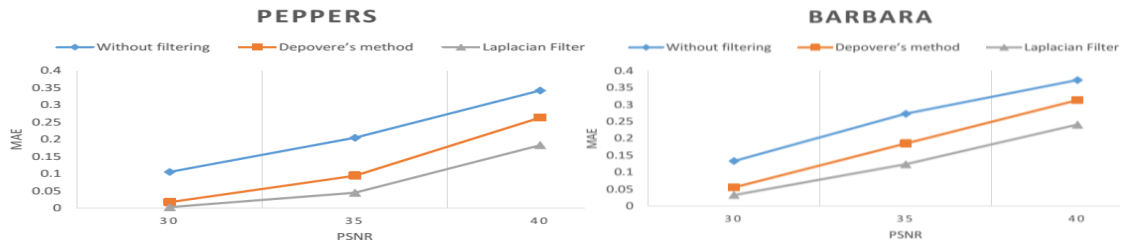


Figure 5. The experimental results in terms of the MAE in which watermarked images further manipulated by the 50% JPEG compression attack on correlation based method.

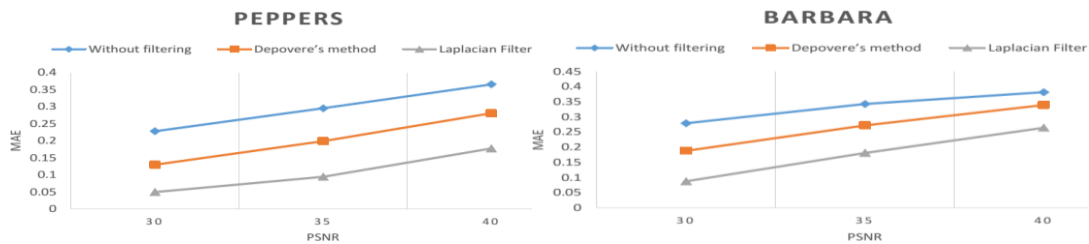


Figure 6. The experimental results in terms of the MAE in which watermarked images further manipulated by the 50% scaling attack on correlation based method.

4.2 Comparison in the Case of JPEG Compression Attack

In the second experiment, we wanted to find out how the proposed algorithm improves the robustness of correlation based method when 50% jpeg compression attack is applied to the watermarked image. The results achieved from executing Laplacian filtering, and Depovere method are shown in the Figure 5. As shown in this figure, although, the watermark retrieval performance is improved by Depovere method, but these results are become better by the proposed filter. Generally, it is believed, if the watermarked image has a higher PSNR, the watermark embedded into the image is more imperceptible. This figure also shows that, the watermark is recovered with more accuracy in compare with the previous method when the watermark is embedded in the host image with high PSNR.

4.3 Comparison in the Case of Scaling Attack

In the third experiment, we wanted to find out how much the proposed algorithm improves the robustness of correlation based method when the watermarked image is attacked by 50%. The results achieved from executing Laplacian filtering, and Depovere method are shown in the Figure 6. As shown in this Figure, although, the watermark retrieval performance is improved by Depovere

method, but these results are become well by the proposed filter. This Figure also shows that, the proposed method has a best performance in compare with the previous methods when the watermark is embedded in the host image with high PSNR.

4.4 Comparison in the case Salt and Peppers Noise Attack

In the fourth experiment, we wanted to find out how the proposed algorithm improves the robustness of correlation based method when 10% Salt and Pepper noise attack is applied to the watermarked image. The results achieved from executing Laplacian filtering, and Depovere method are shown in the Figure 7. As shown in this figure, although, the watermark retrieval performance is improved by Depovere method, but these results are become better by the proposed filter. This Figure also shows that, the watermark is recovered with more accuracy in compare with the Depovere method when the watermark is embedded in the host image with higher PSNR.

4.5 Comparison in the case Blurring Attack

In the fifth experiment, we try to find out how the proposed algorithm improves the robustness of correlation based method when Gaussian Blurring (with $h=5$, and $\sigma = 1$) attack is applied to the watermarked image. The results achieved from Laplacian filtering, and Depovere method are shown in the Figure 8. In this case, the proposed method significantly shows more improvement at the watermark recovery. This figure also shows that, the watermark is recovered with more accurateness in compare with the Depovere method when the watermark is embedded in the host image with higher PSNR.

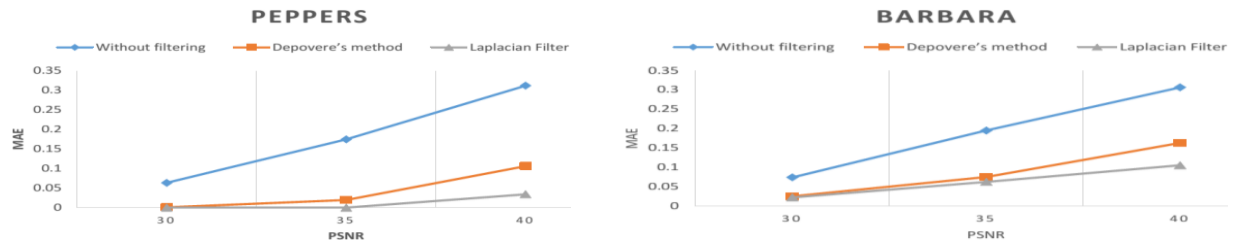


Figure 7. The experimental results in terms of the MAE in which watermarked images further manipulated by 10% salt and pepper attack on correlation based method.

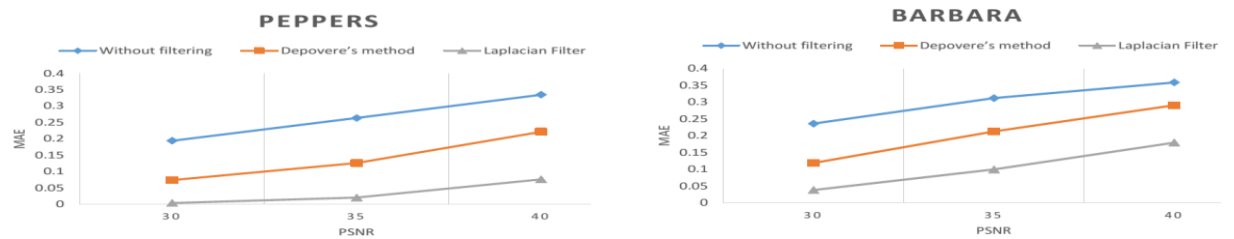


Figure 8. The experimental results in terms of the MAE in which watermarked images further manipulated by Gaussian Blurring with $h=5$, and $\sigma = 1$ attack on correlation based method.

5. Conclusions

In this paper, a new application of Laplacian filter is presented to achieve more imperceptibility and robustness in the spatial domain based watermarking methods. The dissimilarity between watermarked part and unwatermarked part of host image is increased by Laplacian filter. Then, this enhanced watermarked image is used as an input image watermark extraction's process. The proposed method helps details of watermarked image become perceptible. Several experiments are

done to show that presented filtering method could considerably raise power of spatial domain watermarking method. Effectiveness of the proposed filtering method is tested by comparing its result with another filtering method, which proposed by Depovere's, in the term of MAE. The watermark is 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 noticeable.

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