

Effect of Locations of using High Boost Filtering on the Watermark Recovery in Spatial Domain Watermarking

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Abstract

Generally, High Boost filter is used to emphasize high frequency components representing the image details without eliminating low frequency components representing the basic form of the signal. The dissimilarity between the watermark and unwatermarked parts of the image are increased by this filter. Thus, watermark could be recovered significantly better by recovery algorithm. In this paper, a comparison is taken place between the effects of different places of performing High Boost filter on the reliability of the recovery methods in spatial domain image watermarking. This filter is convolved in two different places in the watermark extraction algorithm; before running the watermark extraction and before calculate the correlation in the middle of extraction. This paper concentrate to conclude which of these places is more proper to convolve this filter. A classic correlation based method is used as a representative of spatial domain watermarking. Several experiment are done to show which one of this places is more proper for performing proposed filter.

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

1. Introduction

The watermarking has been proposed as an appropriate solution for copyright protection methods for digital data. Different watermarking methods embed a watermark with some extra information about the digital media without visibly modifying them¹. Digital watermarking methods are consisting of two parts; embedding and extracting algorithms. In the embedding algorithm, the watermark is embedded in digital media with a special method. And the embedded watermark is recovered from the watermarked image in extracting algorithm.

Resistant and imperceptibility are two important factors in watermarking algorithm, and these properties are incompatible with each other. The imperceptibility means that how much the media quality is changed by the embedded watermark; and the robustness is the ability

to recover the watermark after common or malicious signal processing operations. These incompatible parameters should be set to meet the requirements of the application^{2,3}.

Generally watermark is embedded in the spatial domain or in the transform domain. The watermark is embedded straight forward in the pixels of the host image in the spatial domain methods. But, these methods are not robust to image common image processing operation⁴. Although the filters capability are used to increase the power of recovery algorithm^{3,5,6}, Transform domain watermarking methods take advantage of the transform domain properties to embed the watermark. These methods usually use the Discrete Cosine Transform (DCT)^{7,8} and the Discrete Wavelet Transform (DWT)^{9,10}. These methods typically are more imperceptible and robustness to common image processing operation.

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Many researchers have tried to increase the power of watermarking algorithms. Several of these researchers concentrate on finding most suitable places for watermark embedding, and the others have studied the enhancement algorithm to increase power of watermark retrieval algorithms.

In the first method, there are attempts to use human visual system characteristics to choose appropriate for resistance and transparency. These techniques generally utilize the frequency-domain characteristics to detect the most proper locations to embed the watermark. These methods are commonly applied on frequency domain watermarking techniques. There are several methods which are based on probing the most suitable coefficients to embed watermark information⁴. These approaches utilize a perceptually optimal quantization matrix¹¹, Just Noticeable Difference (JND)^{12,13}, wavelet filter¹⁴, and Human Visual System (HVS)¹⁵⁻¹⁷, for probing the most suitable coefficients to embed the watermark information.

However, in the second methods, researchers try to make watermark information more visible to the recovery algorithms. Therefore, these approaches could increase the capability of recovery algorithms. The goal of these methods is to boost watermark detection rate by an efficient and simple model based on image enhancement, edge detection and noise magnifying methods^{3,4}.

An improved detector is proposed for detection based on thresholds extracted by statistic rules on which the method relies¹⁸. Application of blurring filter for increasing the possibility of detection of watermark is proposed by Braudaway¹⁹. They use blurring filters for a watermark with a dominant low frequency content to improve the detection probability. Since the content of image might interfere with the watermark, especially in the low-frequency parts, the reliability of the detector could be improved by applying matched filtering before correlation⁶. This decreases the influence of the original image to the correlation. Therefore, the watermark could easily be recovered from watermarked image.

Hafiz proposed an approach to blind watermark detection for spread spectrum by using of Independent Component Analysis theory²⁰. It uses the theory of Independent Component Analysis (ICA) and detects the watermark with a blind source separation method. The watermark information is considered as noise for the watermarked image in its spatial domain. This noise is magnified before executing recovery algorithm, and then recovers the watermark information by adjusting the extracted

data from the frequency domain according to the global minimum method²¹. A pre-processing method is proposed that exploit a combination of noise boosting and filtering to facilitate recovering the watermark from watermarked image in the DCT-based watermarking algorithm^{3,5}.

In this paper, a comparison is made between effects of different locations of utilizing High Boost filter on increasing power of recovery algorithms in the spatial domain methods. The dissimilarity between the watermark and the original image are increased by this filter. Thus, the watermark could be removed from the modified watermarked image meaningfully better. This filter is applied before running watermark extraction procedures, and before taking the correlation between the extracted block and pseudo random noise, in correlation based method. Several experiments are done to show that which of these locations is proper for convolving High Boost filter in the spatial domain based watermarking.

The rest of the paper is organized as follows. In section 2, High Boost filter is described in details. A typical correlation based method is introduced as a representative of spatial domain watermarking in section 3. Section 4 presents the experimental results to demonstrate the performance of this scheme on the classical method. Conclusions are drawn in Section 5.

2. High Boost Filter

In this paper, Gonzales definition is used for High Boost filter²¹.

High boost filtering can be implemented with one pass using either of the two masks shown in equation (1), (2). Note that, when $A=0$, high-boost filtering becomes "standard" Laplacian sharpening. As the value of A increases past 1, the contribution of the sharpening process becomes less and less important. Eventually, if A is large enough, the high-boost image will be approximately equal to the original image multiplied by a constant.

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

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & A+8 & -1 \\ -1 & -1 & -1 \end{bmatrix} \quad (2)$$

One of the principal applications of High Boost filtering is when the input image is darker than desired.

By varying the boost coefficient, it generally is possible to obtain an overall increase in average gray level of the image, thus helping to brighten the result.

In this paper, a standard type of High Boost filter is used. It is shown in the 3×3 convolution matrix looks as follows:

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix} \quad (3)$$

3. 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 16×16 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 16×16 blocks of the host image. If we donate X as the matrix of the block, then embedding is done as equation (4):

$$x = \begin{cases} x + \alpha * PN_0 \text{ watermark_bit} = 0 \\ x + \alpha * PN_1 \text{ watermark_bit} = 1 \end{cases} \quad (4)$$

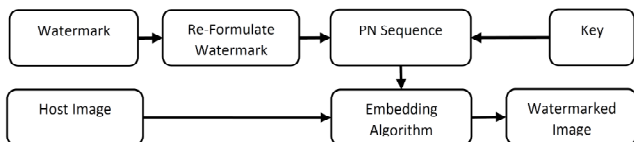


Figure 1. The watermark embedding process.

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. Recovery method is the same as embedding one, and filtering is convolved before running extraction and before calculate the correlation on each block to better separate watermark information from host image. The watermark extraction procedure is shown in Figure 2, and described in details in the following steps.

- Step 1:Applying High Boost filter as shown in the equation of (3) 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.

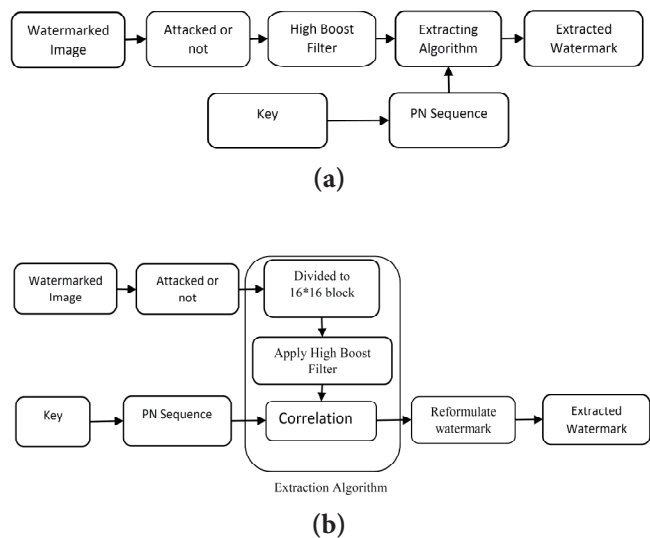


Figure 2. (a) The watermark extracting with applying High Boost before performing extracting algorithm. (b) The watermark extracting process with applying High Boost in the middle of extracting algorithm.

4. Experimental Result

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 ure 3(a)–(c). Pepper is used as a representation of image with low spatial frequency and 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 3(d) is taken as the watermark of images. The effect of the High Boost filters 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, Normalized Cross-Correlation (NC) measures the difference between an original watermark W and the corresponding extracted one. If a method has higher NC, it is more robust. The PSNR and the NC are, respectively, defined by equation 5 and 6; respectively,

$$PSNR(O, \bar{O}) = 10 \log_{10} \frac{255 \times 255}{\sum_{i=0}^{I-1} \sum_{j=0}^{J-1} \left(\|O_{ij} - \bar{O}_{ij}\| \right)^2} \quad (5)$$

$I \times J$

$$NC = \frac{\sum_{i=1}^{M_1} \sum_{j=1}^{M_2} W(i, j) \cdot W'(i, j)}{\sqrt{\sum_{i=1}^{M_1} \sum_{j=1}^{M_2} [W(i, j)]^2} \sqrt{\sum_{i=1}^{M_1} \sum_{j=1}^{M_2} [W'(i, j)]^2}} \quad (6)$$

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

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 High Boost filter which is described in section 2 are performed on these watermarked images which may be attached by the method presented in section 3. NC between the original W and the extracted watermark W' is calculated for different PSNR. To compare the effect of different places of preforming proposed filter, 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 Visual Comparisons

Table 1 shows visual comparisons between the effects of different position in convolving High Boost filter with watermarked image in the correlation based watermarked. These results have been gain form Pepper’s image which watermarked with PSNR 40. As shown in the Table 1, although preforming the High Boost filter before correlation improve the trustworthiness of watermark retrieval of typical correlation based watermarking method, But, convolving the High Boost filter before running extraction slightly is better than it. These improvements in the case of scaling and blurring attacks are more significant than the others. From these experimental results, we could find that the convolving High Boost filter before running recovery algorithm is more applicable.

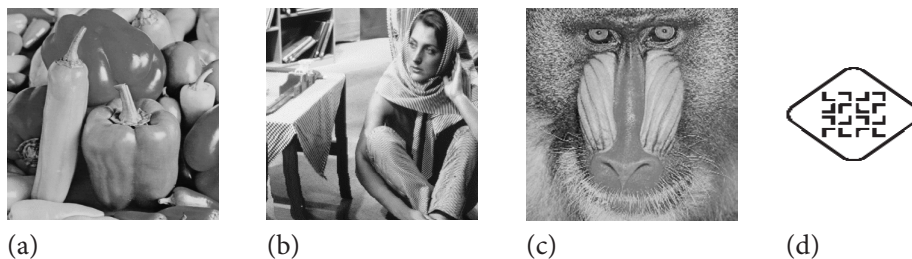

















Figure 3. (a) The original Pepper image; (b) the original Barbara image; (c) the original Baboon image; (d) the original watermark.

Table 1. Visual comparison between the extracted watermark from the peppers watermarked image with PSNR = 40

| | Attack | | | | |
|-------------------------------|---|---|---|---|---|
| | Attack Free | Jpeg compression (50%) | Scaling (50%) | Salt and Pepper Noise (10%) | Blurring (Gaussian With $h = 5$, and $\sigma = 1$) |
| Without Filtering |  |  |  |  |  |
| High Boost before Extraction |  |  |  |  |  |
| High Boost before Correlation |  |  |  |  |  |

4.2 Results for the Pepper Image

In the second experiment, the results of performing High Boost filter on Pepper image as a representation of image with low spatial frequency are presented. The goal of this section is to show the effect of different position of convolving this filter on a typical low spatial frequency image. As it is shown in the Table 2, results are meaningfully augmented by utilizing this filter in both of places for in compare with normal retrieval. Utilizing proposed filter before extraction algorithms is more effective to the attacked image with jpeg compression, scaling and blurring attacks. However, in the noise addition attacks, utilizing High Boost filter before calculating the correlation better increases the results. As it shown in this table, performing High Boost filter before recovery algorithm shows better improvement in the values of NC. For example, in scaling attack on image with PSNR 40 as a high invisible watermarked image, NC performs 0.027 much better than utilized this filter before calculating the correlation, and in the case of jpeg compression attack improvement is 0.02 in term of NC. Therefore, for low spatial frequency, using the High Boost before running

extraction is more suitable than utilizing it before taking the correlation.

4.3 Results for the Barbara Image

In the third tests, the results of using High Boost filters on Barbara as a representation of image with average spatial frequency is shown. As shown in Table 3, results are significantly enhanced by utilizing proposed filter with the Barbara image in both position compared to normal recovery. Convolving High Boost filter before recovery algorithms is more successful to the attacked image with jpeg compression, scaling and blurring attacks. However, in the noise addition attack, using High Boost filter before taking the correlation better recovers the results. Applying High Boost filter before recovery algorithm shows better improvement in the values of NC. For example, in blurring attack on image with PSNR 40 as a high imperceptible watermarked image, NC performs 0.02 much better than applying this filter before taking the correlation. Therefore, for average spatial frequency, convolving the High Boost before executing retrieval is more proper than using it before taking the correlation.

Table 2. Comparison in term of NC between the recovered watermark from the peppers watermarked image with different methods

| Pepper Image | PSNR | Attack | | | | |
|-------------------------------|------|-------------|------------------------|---------------|-----------------------------|--|
| | | Attack Free | Jpeg compression (50%) | Scaling (50%) | Salt and Pepper Noise (10%) | Blurring (Gaussian with $h = 5$, and $\sigma = 1$) |
| Without Filtering | 30 | 0.9928 | 0.9274 | 0.8383 | 0.9154 | 0.8635 |
| | 35 | 0.9743 | 0.8547 | 0.7856 | 0.8298 | 0.8105 |
| | 40 | 0.9280 | 0.7464 | 0.7280 | 0.7336 | 0.7530 |
| High Boost before Extraction | 30 | 1 | 0.9967 | 0.9496 | 0.9961 | 0.9763 |
| | 35 | 1 | 0.9608 | 0.9168 | 0.9875 | 0.9481 |
| | 40 | 0.9974 | 0.8476 | 0.8596 | 0.9070 | 0.8904 |
| High Boost before Correlation | 30 | 1 | 0.9948 | 0.9330 | 0.9980 | 0.9749 |
| | 35 | 1 | 0.9512 | 0.8905 | 0.9862 | 0.9439 |
| | 40 | 0.9974 | 0.8257 | 0.8318 | 0.9185 | 0.8744 |

Table 3. comparison in term of NC between the extracted watermark from the Barbara watermarked image with different methods

| Barbara Image | PSNR | Attack | | | | |
|-------------------------------|------|-------------|------------------------|---------------|-----------------------------|--|
| | | Attack Free | Jpeg compression (50%) | Scaling (50%) | Salt and Pepper Noise (10%) | Blurring (Gaussian with $h = 5$, and $\sigma = 1$) |
| Without Filtering | 30 | 0.9875 | 0.9072 | 0.8033 | 0.9170 | 0.8332 |
| | 35 | 0.9400 | 0.8044 | 0.7549 | 0.8077 | 0.7762 |
| | 40 | 0.8608 | 0.7054 | 0.7214 | 0.7198 | 0.7336 |
| High Boost before Extraction | 30 | 0.9967 | 0.9762 | 0.9135 | 0.9763 | 0.9502 |
| | 35 | 0.9842 | 0.8969 | 0.8521 | 0.9384 | 0.8882 |
| | 40 | 0.9446 | 0.7835 | 0.7849 | 0.8497 | 0.8187 |
| High Boost before Correlation | 30 | 0.9967 | 0.9715 | 0.8976 | 0.9789 | 0.9481 |
| | 35 | 0.9836 | 0.8865 | 0.8307 | 0.9419 | 0.8751 |
| | 40 | 0.9500 | 0.7682 | 0.7611 | 0.8458 | 0.7990 |

4.4 Results for the Baboon Image

In the fourth experiment, the results of applying High Boost filter on Baboon image as a representation with high spatial frequency are shown. Results are considerably augmented by convolving of the High Boost filter with the watermarked image in both locations in compare with standard retrieval (Table 4). Convolving proposed filter before retrieval algorithms is more effective in case of jpeg compression and blurring attacks and to somewhat in the scaling attack. However, in the noise addition attack, using proposed filter

before taking the correlation better increases the results slightly. Therefore, for high spatial frequency, convolving the High Boost before running recovery and before taking the correlation, have the same performance.

5. Conclusions

In this paper, comparison is made between the effects of different locations of using High Boost filter on the watermarked image in increasing the power of watermark recovery algorithms. The High Boost filter is convolved

Table 4. comparison in term of NC between the extracted watermark from the Baboon watermarked image with different methods

| Baboon Image | PSNR | Attack | | | | |
|-------------------------------|------|-------------|------------------------|---------------|-----------------------------|--|
| | | Attack Free | Jpeg compression (50%) | Scaling (50%) | Salt and Pepper Noise (10%) | Blurring (Gaussian With $h = 5$, and $\sigma = 1$) |
| | 30 | 0.9993 | 0.9696 | 0.8291 | 0.9403 | 0.8677 |
| Without Filtering | 35 | 0.9743 | 0.8883 | 0.7534 | 0.8385 | 0.7843 |
| | 40 | 0.9330 | 0.8206 | 0.7176 | 0.7783 | 0.7425 |
| High Boost before Extraction | 30 | 1 | 0.9875 | 0.9148 | 0.9928 | 0.9716 |
| | 35 | 0.9888 | 0.9312 | 0.8340 | 0.9500 | 0.9011 |
| | 40 | 0.9674 | 0.8550 | 0.7806 | 0.8976 | 0.8525 |
| High Boost before Correlation | 30 | 1 | 0.9855 | 0.9083 | 0.9941 | 0.9621 |
| | 35 | 0.9915 | 0.9265 | 0.8349 | 0.9540 | 0.8966 |
| | 40 | 0.9688 | 0.8547 | 0.7780 | 0.9049 | 0.8448 |

with watermarked image in two locations; before running retrieval algorithm, and in the middle of retrieval and before taking the correlation. Several tests are done to investigate which of these locations is more suitable for enhancing spatial domain watermarking method. Efficiency of the methods is tested by comparing its results with each other in the term of NC. The watermark is extracted after common image processing attacks with higher NC value by using High Boost filter before retrieval algorithm. Especially, performance is increased better in case of blurring filter, jpeg compression and scaling. The images with high frequency results are almost identical. However, results of performing High Boost filter before taking the correlation is better than applying filter before executing recovery algorithm, in the case of salt and pepper noise. Therefore, we suggest to use High Boost filter before running watermark retrieval algorithms in the spatial domain watermarking algorithm.

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