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An Image Watermarking Scheme based on Image Visual Activity for Copyright Protection

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Abstract

In this paper, a digital watermarking technique for copyright protection or ownership identification of digital media is introduced. In the proposed scheme, a novel classifier is employed to measure the visual activity of the image blocks. The proposed approach utilizes the level of visual activity within the host image and modifies the intensities of some pixels in image blocks accordingly. The described technique, is an invisible, image watermarking technique in the spatial domain and the experimental results show that the watermark can be extracted properly under image processing and destroying operations

1. Introduction

The age of digital multimedia has brought many advantages in the creation and distribution of image content but the ease of copying and editing also facilitates unauthorized use, misappropriation, and misrepresentation. In the recent years the field of image watermarking has attracted researchers because of its use to provide protection against illegal copying or tempering. Image watermarking has been proposed as a successful means to ensure the ownership of electronic documents and hence enforcement of electronic copyright. At a glance it is the insertion of copyright information into the image data in such a way that the added information may be visible or invisible and yet resistant to image alteration.

Digital watermarking is designed to insert a meaningful signature, called a watermark, directly into a digital host image to register the ownership. Then, the watermark can be extracted when the ownership of the image needs to be identified. The watermark in the watermarked image can be either visible or invisible. Generally, the watermark should maintain certain requirements, such as:

- Imperceptibility to human eyes,
- Robustness to common image processing operations and malicious attacks,
- Unambiguousness to ownership and copyright identification,
- Security and key against unauthorized parties,
- Capacity for embedding maximum information

Some of these requirements may conflict with each other and thereby introduce many technical challenges. For example, imperceptibility and capacity may conflict with robustness. Therefore, a reasonable compromise is required to achieve better performance for the intended applications [1].

Methods for watermarking can be categorized as spatial domain methods and frequency domain methods according to, whether embedding of watermark is done in spatial or in frequency domain. *Non-oblivious* method requires the original data to be present at the detector and *oblivious* methods do not require the original data [2]. A *robust watermark* should be stuck to the image or document such that a pirate willing to remove the watermark will not succeed unless they destroy the image too much to be of commercial interest. In the frequency domain, it is mainly performed by embedding a spread spectrum sequence in the Fourier or Discrete Cosine Transform (DCT) domain coefficient [3]. In spatial domain, methods can be mainly classified as Least Significant Bit (LSB) based, block based, statistical, and feature point based.

In this paper, we will propose an invisible, *non-oblivious* image watermarking technique in the spatial domain that is robust to common image processing operations such as low-pass filtering and JPEG compression. The proposed approach utilizes the level

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of visual activity within the host image and modifies the intensities of some pixels in image blocks accordingly. The proposed system combines the fundamental study on the modification of pixel intensities reported in [4] with a novel scheme on measuring the image visual activity, presented in [5] and further enhances the modification of the pixel intensities. If the visual activity of the block is large (e.g., an edge block), the intensities can be changed greatly without introducing any distortion to human eyes. On the other hand, if the visual activity is small (e.g., a uniform block), the intensities can only be tuned slightly. The rest of this paper is organized as follows. In Section 2 the proposed scheme is presented. Experimental results and analyses are given in section 3, followed by conclusions in section 4.

2. The Proposed Algorithm

The proposed watermarking scheme is composed of three stages; i) a block classification stage, ii) casting a binary watermark into a grey-level host image, and iii) detecting the watermark to identify the ownership. The watermark used is a visually meaningful binary image rather than a randomly generated sequence of bits. Thus, human eyes can easily identify the extracted watermark. In fact, embedding a watermark in the least significant bits of a pixel is less sensitive to human eyes. However, the watermark will be destroyed if some common image operations such as low-pass filtering are applied to the watermarked image. Therefore, to make the embedded watermark more resistant to any attack, the watermark must be embedded in the more significant bits. This will introduce more distortion to the host image and conflicts with the invisible requirement. To meet both invisible and robust requirements, we will modify the intensities of pixels and this modification is not noticeable to human eyes. In addition, to prevent tampering or unauthorized access, the watermark is first permutated into scrambled data [4]. In the following subsections, we will first describe the classifier, followed by embedding process and then the extraction process.

2.1 Block Classification

A novel classification scheme has been developed for classifying the image blocks. The classifier employs the residual values of a block and classifies the block according to the distribution of these values. Each block of 4 x 4 pixels is converted into a residual block by subtracting the sample mean from the original pixels. The residual samples are less correlated than the original samples within a block. Here, two of the most important local characteristics of the image block are considered*: central tendency*, represented by the mean value and the *dispersion* of the block samples about the mean, which is represented by the residual values. The challenge here is to analyze the dispersion of the residual values about the mean. This will give us some indication of whether the block is a low-detail or a high-detail block. One way of achieving this is to compare the absolute block distance *(ABD)* of each block with a pre-defined threshold ∂ . The *ABD* of a 4 x 4 block is defined as:

$$ABD(x) = \frac{1}{16}\sum_{i=0}^{3}\sum_{j=0}^{3}\left|x_{i,j} - \bar{x}\right|$$

where $\bar{x}$ denotes the block sample mean value of the block x. The processed block is identified as a uniform block, if it's $ABD < \partial$, otherwise it is classed as an edge block. By forcibly clustering all pixels in an edge block into two groups, a bi-level approximation of the block may be obtained. Only two representative intensities are necessary to specify the bi-level representation. The block representative intensities, denoted by I_{low} and I_{high} are obtained from:

$$I_{low} = \frac{1}{\# x_{i,j} \le \bar{x}} \sum_{x_{i,j} \le \bar{x}} x_{i,j} \quad \text{and} \quad I_{high} = \frac{1}{\# x_{i,j} > \bar{x}} \sum_{x_{i,j} > \bar{x}} x_{i,j}$$

223	225	182	60
223	215	70	56
225	67	63	65
188	66	70	69

a) a uniform block, $\bar{x} = 181$

4	1	1	-3
4	1	1	- 3
4	1	1	-3
4	2	1	-6

b) the residual block, $ABD = 2.5$

94	96	53	- 69
94	86	-59	- 73
96	-62	-66	--64
59	-63	-59	-60

c) An edge block, $\bar{x} = 129$

94	96	53	- 69
94	86	-59	- 73
96	-62	-66	--64
59	-63	-59	-60

d) The residual block, $ABD = 72$

Fig. 1 : A uniform block and an edge block

2.2 Watermark Casting

In the proposed approach, the embedded watermark must be invisible to human eyes and robust to most image processing operations. To meet these requirements, a bit of binary pixel value (0 or 1) is embedded in a block of the host image. Before insertion, the host image is decomposed into 4x4 blocks. The sizes of the host and watermark determine the size of the blocks, so in this paper the size of the host image is 256x256 pixel gray scale images with intensity values between 0 and 255 and the watermark is a 64x64 binary image, so the bits for the watermark are embedded into 4x4 blocks X of the host image.

Depending on the type of a block (edge or uniform), pixels in the block are modified to maximize robustness and guarantee invisibility. The position or block for embedding is selected by a pseudo-random number generator using a seed value *k*. Let X be the selected block, and $x_{\max}$, $x_{\min}$, $\overline{x}$ represent the maximal, minimal, and mean intensities of the block, respectively. Assume that the embedded pixel value b_w is 0 or 1. The embedding process modifies the intensities of pixels in the block X according to the following rules:

If b_w = 1:

for uniform block ;

$$x_{new} = x_{\max} \text{ if } x > \overline{x}$$
$$x_{new} = x + \delta \text{ otherwise}$$

for an edge block;

$$x_{new} = x_{\max} \text{ if } x > I_{high}$$
$$x_{new} = \overline{X} \text{ if } I_{low} \leq x < \overline{x}$$
$$x_{new} = x + \delta \quad \text{otherwise}$$

If b_w = 0:

for a uniform block

$$x_{new} = x_{\min} \text{ if } x < \overline{x}$$

$$x_{new} = x - \delta \text{ otherwise}$$

for an edge block

$$x_{new} = x_{\min} \text{ if } x < I_{low}$$
$$x_{new} = \overline{X} \text{ if } I_{low} \leq x < \overline{x}$$
$$x_{new} = x - \delta \quad \text{otherwise}$$

where x_{new} is the modified intensity and δ is a small value used to tune the intensities. The embedding of the watermark depends on the content of each block. If the block is an edge block, the intensities of pixels will be modified greatly. Otherwise, the intensities are tuned slightly. Thus the proposed algorithm can modify the content of a block. Let blocks X and X_{new} denote the original and watermarked blocks, respectively. The sum of pixel intensities of X_{new} will be larger than that of X if the inserted watermark pixel value b_w is 1. On the contrary, if the inserted watermark pixel value b_w is 0, the sum of pixel intensities of X_{new} will be smaller than that of X.

The modified block of pixels, X_{new}, is then positioned in the watermark image in the same location as the block X, of pixels from the original host image. By using the offset δ, those pixels which it modifies will have a small random noise component, however with a nonzero overall mean value. The random nature of this tuning helps to prevent a visible blocking effect while still contributing to the shift of the overall mean of the block of pixels. This also contributes to the robustness of the algorithm to some of the image filtering processes while also reducing the blocking. The filtering that might be performed on the watermarked image may reduce the variance of the noise; however, given its nonzero mean, the average may still be preserved at a higher level for a given block.

2.3 Watermark Detection

The extraction of a watermark is similar to the embedding process while in a reverse order. In the proposed algorithm, the extraction of a watermark must make reference to the original host image. First, we use the seed value, *k*, to generate a sequence of positions or blocks where the watermark is embedded. For each selected position, let X and X_{new} represent the corresponding blocks of the original host image and watermarked image, respectively. Compute the sum of pixel intensities, S_o and S_w, of X and X_{new}. The retrieved watermark bit value b_w is determined by the following rule:

$$b_w = 1 \text{ if } S_w > S_o,$$
$$b_w = 0 \text{ if } S_w < S_o$$

The extracted watermark bit values $b_w's$, are then inversely permutated to get the reconstructed watermark.

3. Simulation results

We have evaluated the performance of the proposed coding scheme through a computer simulation. The computer simulation has been carried out, using a set of 256 x 256, 8-bit intensity, grey-level standard images as the host images. The watermark is a visually meaningful binary image of size 64x64. Fig. 2 and Fig. 3(a) show the host image and the binary image, respectively. The effectiveness of the classification scheme, which extracts the uniform blocks from the edge blocks of the host image is illustrated in Fig. 4.

Fig. 5 shows the watermarked image that is derived by embedding the watermark image in the host image. From Figs. 2 and 5, we can not distinguish these two images since they look almost the same. Fig. 3(b) shows the reconstructed watermark, we can see that it is the same as Fig. 3(a). The similarity of these two images is quantitatively measured by the normalized cross correlation defined as:

$$NC = \frac{\sum_i \sum_j x_{i,j} x_{i,j}^{/}}{\sum_i \sum_j [x_{i,j}]^2},$$

where $x_{i,j}$ and $x_{i,j}^{/}$ represent the pixel values at location *(i, j)* in the original and extracted watermark images, respectively. To show the robustness of the algorithm under JPEG compression, the watermarked image was first compressed and then the watermark was extracted form the compressed image. The normalized cross correlation value NC was found to be 98.15 %. Fig. 6 shows the PSNR of the watermarked image for different choice of threshold ∂. A bigger threshold results in less number of uniform blocks and a lower PSNR.

Finally, to show the robustness of the proposed algorithm under JPEG image compression, we first compress the watermarked image and then extract the watermark from the compressed image. Fig. 7 shows the compressed image with a compression ratio of 5.28 and the corresponding extracted watermark. The normalized cross correlation value *NC* is 95.36%. Finally,

4. Conclusions

In this paper, we have proposed an image watermarking scheme which utilizes the visual activity level of the image host to modify the contents of the image block. The choice of threshold ∂ is very crucial and determines the population of uniform and edge blocks, which in turn affects the quality of the processed image. Results show that the proposed technique is robust to common image operations such as JPEG compression.

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Fig. 2 : Original 256x256 host image

Fig. 4 : Population of different types of blocks

□ : uniform : 71% ▒ : edge : 22% ■ :mixed : 7 %

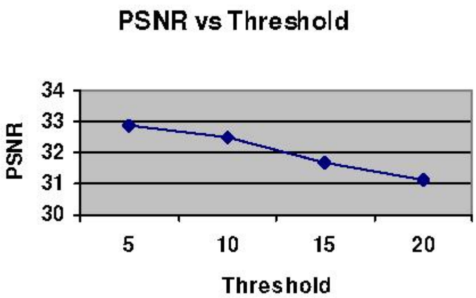

Fig. 6 : PSNR of watermarked image for different threshold

(a) **(b)**

Fig. 3 : 64x 64 images
(a) : Original watermark
(b) : Extracted watermark

Fig. 5 : Watermarked image

(a) (b)

Fig. 7 : Result of applying JPEG to Fig. 5

(a) JPEG compressed image with *CR = 5.30*
(b) Extracted watermark with *NC= 95.36 %*