Print and Generation Copy Image Watermarking Based on Spread Spectrum Technique

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Abstract. After a watermarked image is printed, copied several times and scanned, the watermark usually cannot be extracted rightly, as well as distorted by noise. In this paper, a spread spectrum technique was introduced to image watermarking which can be applied to print and generation copy. The watermarking message is modulated by the key-dependent pseudo-random sequences to produce a spread spectrum signal. The watermark is embedded into the cover image by modifying the gray value of each pixel. The cover image is not needed when the watermark is detected. The watermark is estimated exploiting the properties of HVS(Human Visual System) and extracted through the same key-dependent 2D sequences. Experimental results show that the scheme can resist print, generation copy and scan process.

1 Introduction

Watermarking techniques allow embedding information into digital media. The technologies are becoming more focus. An amount of algorithms have been proposed to hide data into multimedia [1]. But most of the commonly used watermark applications are referred to digital watermarking. While many important, long-lived documents are still available only on paper and most office activities still involve with paper documents. Current technology, however, has made some problems easier, such as leaking of information and counterfeit paper documents. These dishonest actions can be discouraged by enabling office equipment to check embedded watermarks of the documents.

Today the print, generation copy and scan processes are commonly used for image reproduction and distribution. It is popular to transform images between the digital format and the printed, generation copied format. Several articles can be found for printed-and-scanned image, e.g., [2]. But it didn't mention generation copy. This paper introduces spread spectrum technique[3] to image watermarking and this method is useful for the watermarking applications mentioned above, especially for printed and generation copied watermarked image. It can resist print, at least 2-generation copy and scan process[4]. In this method, watermarking message is modulated by the key-dependent pseudo-random sequences to produce a spread spectrum signal. The watermark is embedded into cover image in spatial domain exploiting the properties of HVS. The cover image is not needed when the watermark is detected.

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After print, generation copy and scan process, the correlation between estimated watermark and original key-dependent 2D sequences is computed.

In Section 2, we describe the watermark embedding method. Watermarking detection process is given in Section 3. In Section 4, we give the experimental results and discuss the validity of the method and future work.

2 Embedding Process

Figure 1 shows the watermarking embedding system. First, the watermark message is encoded as a signal. Second, the signal is modulated by the key-dependent pseudo-random sequences to yield a spread spectrum signal. Finally, the modulated signal is added to the cover image exploiting the properties of HVS to obtain the watermarked image.

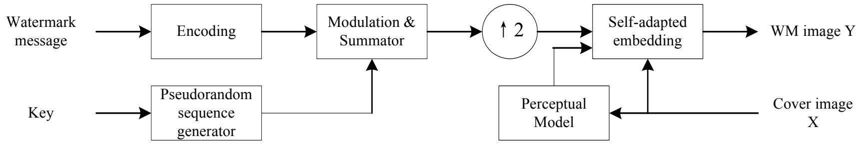

Fig. 1. Watermark embedding system

2.1 Watermark Generation

For getting a high correlation at watermark detection process, we generate watermark signal by spread spectrum technique. Suppose $b = \{b_i \mid b_i \in \{0,1\}, i = 1,2,\cdots L\}$ is a binary sequence that represents watermark information. We map each "0" bit of the sequence b to "-1", yielding a new binary polar sequence of {-1,1}, $b' = \{b_i' \mid b_i' \in \{-1,1\}, i = 1,2,\cdots L\}$. Afterward every b_i' is modulated by one sequence of modulation sequences set which were defined as $p = \{p_k(x,y) \mid k = 1,2,\cdots,L\}$, where $p_k(x,y)$ is a real number sequence according to Gaussian distribution $N(0,1)$ and it was generated by the key. In our experiments, the size of $p_k(x,y)$ is settled to 128×128 (a quarter of the cover image).

So the watermark signal will be

$$w(x,y) = \sum_{i=1}^{L} b_i' p_i(x,y) \tag{1}$$

After interpolate the watermark signal $w(x,y)$, we can get the final watermark W, which is the same size with the cover image.

2.2 Watermark Embedding

In order to make the watermark as robust as possible and avoid the visible distortion that are introduced by the watermarking process, we consider the scheme on the basis of the utilization of luminance sensitivity function of the human visual system (HVS)[5]. The noise visibility function (NVF) related to the texture masking function is proposed by [6]. The most known form of the empirical NVF is widely used in image restoration applications [8]:

$$NVF(i,j) = \frac{1}{1+\theta\sigma_x^2(i,j)} \tag{2}$$

Where θ is a tuning parameter which must be chosen for every particular image. And to make θ image-dependent, it was proposed to use:

$$\theta = \frac{D}{\sigma_{x_{\max}}^2} \tag{3}$$

Where $\sigma_{x_{\max}}^2$ is the maximum local variance for given image and $D \in [50,100]$ is an experimentally determined parameter.

Using the proposed content adaptive strategy, the final embedding equation is given [8]:

$$y(i,j) = x(i,j) + (1 - NVF(i,j)) \cdot w(i,j) \cdot \alpha \tag{4}$$

Where α denotes the watermark strength. $x(i,j)$ is cover image and $y(i,j)$ is watermarked image. The above rule embeds the watermark in highly textured areas and areas containing edges stronger than in the flat regions.

In the very flat regions, where NVF approaches 1, the strength of the embedded watermark approaches zero. As a consequence of this embedding rule, the watermark information is (nearly) lost in these areas. Therefore, to avoid this problem, we increase the watermark strength in these areas to a level below the visibility threshold by[8]:

$$y(i,j) = x(i,j) + (1 - NVF(i,j)) \cdot w(i,j) \cdot \alpha + NVF(i,j) \cdot w(i,j) \cdot \beta \tag{5}$$

Where β is about 3 for most of real world and computer generated images.

3 Detection Process

Watermark extraction system is shown in Figure 2.

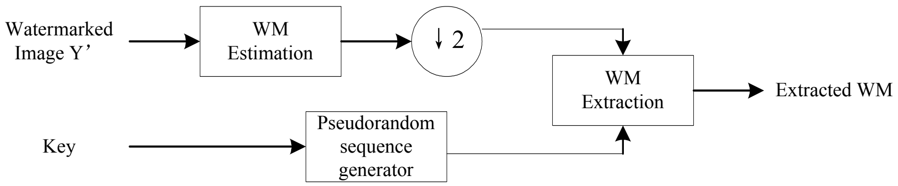

Fig. 2. Watermark extraction system

3.1 Watermark Estimation

According to the MAP criterion, the watermark can be estimated as [7]:

$$\hat{w} = \arg\max_{\tilde{w} \in \Re^N} L(\tilde{w} \mid y) \tag{6}$$

Suppose the cover image and the watermark message are independent identically distributed(i.i.d.), i.e. $x \sim N(\bar{x}, R_X), w \sim N(0, R_W)$. Here, NVF is the output of the perceptual model so we can get

$$\hat{w} = \frac{R_W}{R_W + R_X}(y - \bar{y}) \tag{7}$$

Where we suppose $y \approx \bar{x}$. $\bar{y}$ denotes the local mean of the processed watermark image. $\hat{R}_X = \max(0, \hat{R}_Y - R_W)$ is the maximum likelihood(*ML*) estimation of the local image variance.

In our experiments, for the nice edge preserving properties we estimate local watermarked image mean y by median filtering in the 3×3 neighborhood around the corresponding pixel in the image. We replace the term $\frac{R_W}{R_W + R_X}$ with the value $NVF(y - \bar{y})$ and get a nice result. So watermark estimation as [8]:

$$\hat{w} = NVF(y - \bar{y}) \cdot (y - \bar{y}) \tag{8}$$

3.2 Watermark Extraction

Each watermark message bit detection is performed by calculating cross-correlation between watermarked image and the modulation sequences.

$$\begin{aligned} r_i &=< Y(x,y) * h, p_i(x,y) > \\ &=< W(x,y) * h, p_i(x,y) > + < X(x,y) * h, p_i(x,y) > \\ &=< w(x,y), p_i > + < X(x,y) * h, p_i(x,y) > \end{aligned} \tag{9}$$

Where h denoted the preprocess, including watermark estimation, interpolation and subsample. The first term of above formulation is watermark projection on modulation sequences, and the second term denoted original image projection on modulation sequences. In the above deduction, because p_i is a zero mean pseudo-random sequence, and it is independent of preprocessed image sequence $X(x,y)$, the term on the right tends to be zero. Due to the independency between different modulation sequences, we get:

$$\begin{aligned} r_i &=< w, p_i > \\ &=< \sum_{j=1}^{L} b'_j p_j, p_i > \\ &= b'_i \|p_i\|^2 \end{aligned} \tag{10}$$

And every watermark bit is extracted by the sign of r_i:

$$b_i = \begin{cases} 1 & if\ r_i \ge 0 \\ 0 & if\ r_i < 0 \end{cases} \tag{11}$$

4 Experimental Results

A watermark message of 64 bits is embedded into the cover image, whose size is 256×256 pixels. In our experiments, the parameters are $\alpha = 0.5, \beta = 0.2$. The watermark signal $w(x, y)$ is shown in Figure 3(a) and the Figure 3(b) shows the watermark after modulation according to equation (5), that is, $(1-NVF(i,j))\cdot w(i,j)\cdot\alpha+NVF(i,j)\cdot w(i,j)\cdot\beta$

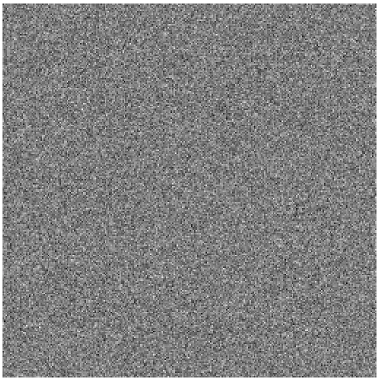

Fig. 3(a). Watermark signal

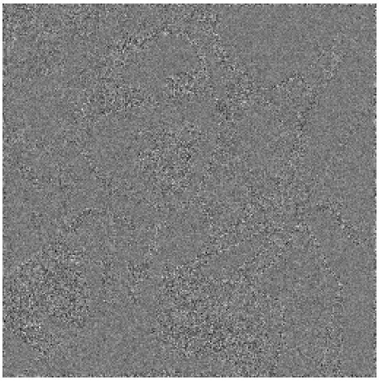

Fig. 3(b). watermark after modulation according to equation (5)

The original(cover) image and watermarked image are shown in Figure 4(a) and Figure 4(b).

Fig. 4(a). Original(cover) image

Fig. 4(b). Watermarked image

The printed watermarked image(0 generation copy) and generation copy watermarked images are shown in Figure 5(a) and Figure 5(b), 5(c), 5(d), 5(e), 5(f).

All of watermark bits can be detected by zero bit error in the 3rd generation copy. Table 1 shows the experiment result with the above original image.

In our experiments, the modulation sequences $p = \{p_k(x, y) \mid k = 1,2,\cdots,L\}$ are chosen from a normal distribution with mean zero, variance one and standard deviation one. And the watermark is embedded in the coordinate domain as a pseudo-random spatial spread modulated sequence. These explain why the watermark can be extracted from the printed and generation copied watermarked images.

Fig. 5(a). Printed watermarked image

Fig. 5(b). The 1st generation copy of the printed watermarked image

Fig. 5(c). The 2nd generation copy

Fig. 5(d). The 3rd generation copy

Fig. 5(e). The 4th generation copy

Fig. 5(f). The 5th generation copy

Table 1. Experiment results

Generation copy	Error bit in 64 bits	BER(%)
0 (only print)	0 bit	0
1^{st}	0 bit	0
2^{nd}	0 bit	0
3^{rd}	0 bit	0
4^{th}	1 bits	1.5625
5^{th}	0 bits	0

Running the test we have successfully extracted the watermark message in the 3^{rd} generation copy image. The test results also show that this method seems to be sensitive to the pixel dithering. We can extract all watermark bits on 5^{th} generation copy but there is one bit error on 4^{th} generation copy image. The possible reasons are the pixel dithering after the image is scanned and/or the error which is introduced when we search the border of the scanned watermarked image. It is, therefore, necessary to consider the enhancement of pixel synchronization and the effects of scanning. Based on the image pixel synchronization problem and the possible effects of scanning, we are going to develop the corresponding commercial schemes to solve it. In the future, we will apply the presented model also for commercial application.

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