Robust Text Image Watermarking Algorithm Based on Odd-even Quantization

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Abstract

This paper presents the high-capacity blind text watermarking algorithm that is robust to print and scan operations and this method based on the odd-even quantization. First, segment the binary images of Chinese text characters. And the text image is segmented into the embedded part, adjust part, and dislodge part. After segmentation, the quantization function is built on the basis of invariables during printing-scanning. Construct odd-even quantization make sure the number of watermarking embedded. The watermark is embedded through the strategy of flipping pixels at the boundaries of characters. This method exploits human visual masking characteristics to reduce the degree of the text image distortion. Experimental results indicate the watermarking embedded method base on odd-even is robust to common attacks and has good visual effect. The extract of watermarking realized blind detection.

Keywords: *robust method, text image watermarking, odd-even quantification, print-scan*

1. Introduction

With the popularization of Internet and the development at full speed of the multi-media technology, more and more governments have begun to create and distribute con-tracts and other important documents directly in digital form. The copyright protection of text image works has already become a hot issue and needs strong digital watermarking scheme which can guarantee the authenticity and integrity of these text image works. However, most of text image works are spread through print-and-scan, which can disrupt the watermark.

Text image embedding capacity depends on the works redundant data, such that it cannot be perceived by the human senses [1-4]. But text images do not have enough redundant data, the conventional frequency-domain watermarking schemes [5-6] do not have good visual effect and have low-capacity. Instead, better visual results can be obtained by flipping pixel in each text character, but such scheme has low embedding capacity. It depends on the number of characters in text images directly. Thus, it is necessary to improve the embedding capacity for individual characters.

This paper presents a high capacity text watermarking algorithm that can resist attacks of print-and-scan. Through the experiments, we prove that the proposed algorithm has better imperceptibility and visual effect, and strong robustness.

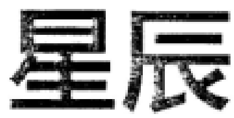
This paper is organized as follows: Section 2 describes the fundamental theory about the scheme of this paper. Section 3 describes the high capacity text image algorithms for watermark embedding and extraction. Section 4 presents the experimental results in order to evaluate the robustness and visual effect of the proposed algorithm in this paper. Finally, the main conclusions are summarized in the last section.

2. Invariants During Printing and Scanning

2.1. Invariants in printing and scanning

Figure 1 shows the same text images before and after printing and scanning. This process will import random noise [7] and it can be described as convolution process approximately. With this assumption, reference [8] and [9] concluded that the pro-portion of the pixels in single character and the average number of pixels among all characters remain invariant among printing and scanning. We use this invariant as the foundation of our high capacity algorithm.

(a)



(b)

Figure 1. Comparison of original text (a) with printed-and-scanned text (b)

2.2. Data hiding in character boundaries

Text image only has the pixel value 0 or 1, few pixel changes would lead to the perceivable distortion in visual effect. Therefore, most watermarking strategies only flipped the boundary pixel of the characters. In order to keep the visual effect, Wu and Liu have identified the pixels flipped strategy. In this strategy, first we define a function f(x) for 3 × 3 window centered on each boundary pixel x as Figure 2 shows, and we only modify the simple boundary points [10].

y_1	y_8	y_7
y_2	x	y_6
y_3	y_4	y_5

Figure 2. Boundary pixel points of pixel x

The model of binary image is mainly shown as Figure 3. The score of boundary points impact visual effect in a binary text image according to the Ref. [10]. As show in Table 1, lower scores indicate that pixel can be changed with large visual distortion. In our scheme, we use the pixel whose score is higher than 0.1.

The pixel to be flipped must comply with the flipping strategy. When the white boundary points need to be flipped, the process flips the types 51W, 6W, 71W, and 72W, and then flips the types 4W and 32W. When the black boundary points need to be flipped, the process flips the type of 11B, 12B, 2B, and 31B, and then flips the types 4B and 52B. In order to improve the visual effect, the point could not be flipped when a neighboring pixel of the same color has been flipped. The strategy does not degrade the visual quality of the final embedded image.

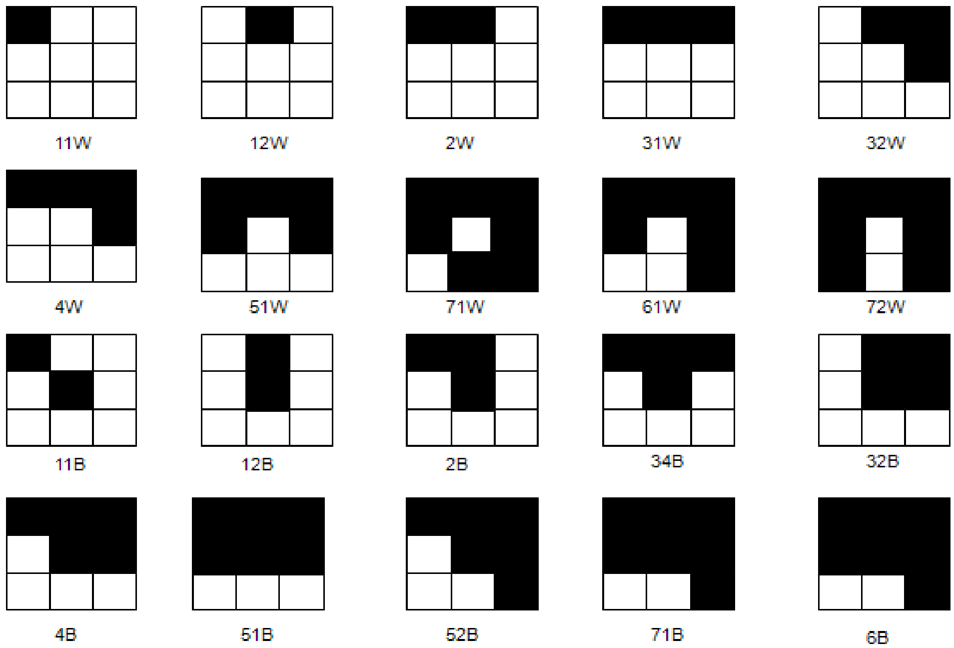


Figure 3. Model of boundary point

Table 1. Scores for the boundary points of a binary image

template	11W	12W	31W	4W	51W	71W	6W	52W
score	0.01	0.01	0	0.62	0.38	0.38	0.8	0
template	2W	32W	72W	11B	12B	2B	31B	
score	0.125	0.38	0.25	0.38	0.25	0.38	0.38	
template	32B	4B	51B	52B	6B	71B	72B	
score	0	0.625	0	0.8	0.125	0.01	0.01	

3. Proposed Watermarking Algorithm

3.1. Embedding of watermark

First, the process segments the binary text image into the characters. The segmentation process of the text image is shown as Figure 4.

Figure 4. Segmentation of the text image

Character with little pixels should not be flipped, otherwise it would influence the visual effect. Thus, characters with fewer pixels are not embedded watermark. In order to keep the ratio of black and white pixels invariant, we divide the whole text image into the embedded part, adjust part and dislodge part. The number of the pixels flipped in the adjust part should be the same as the number of the pixels flipped in the embedded part. We define A as the embedded part, B as the adjust part, and C as the dislodge part of text image and suppose the pixels in parts A and B are in a single character image. And then, we compute the average value for all the pixels in a character image as follows:

$$m = 1/(N_A + N_B + N_c)\left(\sum_{i=1}^{N_A} x_i + \sum_{i=1}^{N_B} y_i + \sum_{i=1}^{N_c} c_i\right) \tag{1}$$

1. Segment each character image into four parts and process the pixels in each block. The segmentation process is shown as Figure 5.

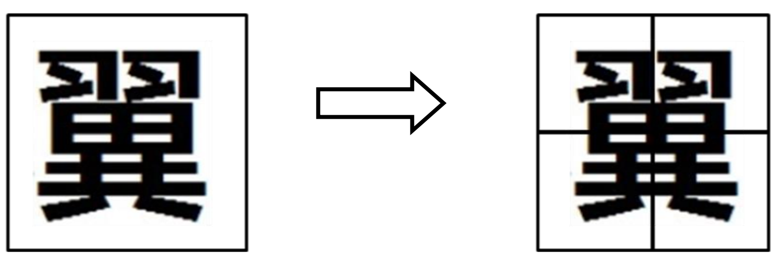


Figure 5. Segmentation of the character

2. For a watermark comprising the binary sequence $w_1, w_2 ... w_{N_A}$, where the value of w_i is zero or one, set the value of x_i to $\tilde{x}_i$ such that the value of $\tilde{x}_i$ is an odd or even multiple of k (k > 0) which is the closest selected step length. The quantization process is expressed as formula (2) and (3):

$$\mathrm{fix}(\frac{x}{mK}) \tag{2}$$

$$\mathrm{fix}(\frac{x}{mK})+1 \tag{3}$$

3. Then, compute the value for the flipped black pixels $\Delta x_A{}'$, for each of four parts which are segmented from each character image in the embedded part A. Next, compute the value of Δ_i for all pixels changed in the embedded part.

4. In order to keep the total number of pixel constants, some flipped pixels in the embedded part must be flipped back in the adjust part. The number of adjusted pixels is computed as follows:

$$\sum_{i=1}^{N_B} \tilde{y}_i - \sum_{i=1}^{N_B} y_i = -\Delta_i \tag{4}$$

5. If the number of flipped pixels is greater than zero, flip the corresponding number of white boundary points. If the number of flipped pixels is less than zero, flip the corresponding number of black boundary points. The embedding process of watermark is shown as Fig. 6.

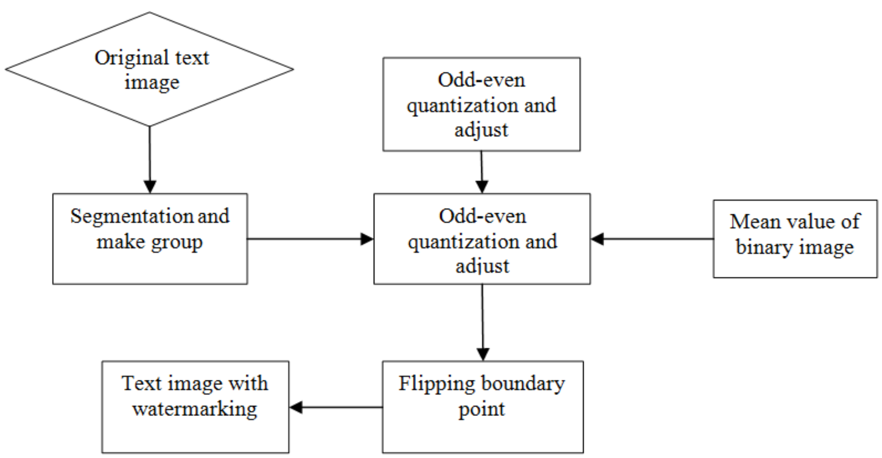


Figure 6. Embedding process of watermark

3.2. Extraction of watermark

The proposed scheme allows blind extraction of the watermark as follows:

1. Segment the watermarked text image to identify all character images that are in the embedded part, adjust part, and dislodge part.

2. Segment each character image into four parts and process the pixels in each four character image.

3. Compute the number of black pixels in each character image A and B, which are $\tilde{x}_1, \tilde{x}_2, \ldots \tilde{x}_{N_A}$ and $\tilde{y}_1, \tilde{y}_2 \ldots \tilde{y}_{N_B}$. Compute the average value for the entire character image as follows:

$$\tilde{m} = 1/(N_A + N_B + N_c)\left(\sum_{i=1}^{N_A} \tilde{x}_i + \sum_{i=1}^{N_B} \tilde{y}_i + \sum_{i=1}^{N_c} \tilde{c}_i\right) \tag{5}$$

4. Extract the watermark of each single character image: if the value of $\tilde{x}/(K\tilde{m})$ is an even number, then the watermark bit is zero, otherwise it is one. The process of odd and even quantization can be described as follows:

$$\frac{\tilde{x}}{\tilde{m}K} = \begin{cases} odd \\ even \end{cases} \tag{6}$$

The extraction process of watermark is shown in Figure 7.

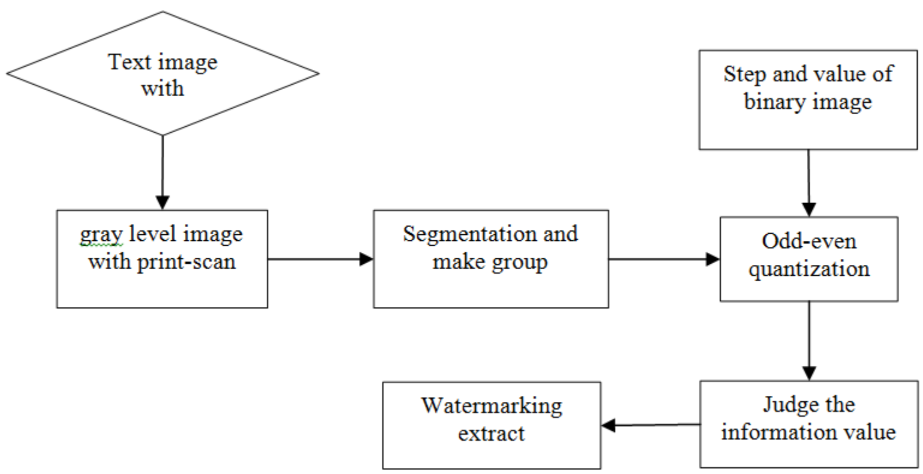


Figure 7. The extraction process of watermark

3.3. Performance evaluation

Performance evaluation of watermarking system mainly focuses on the imperceptibility and robustness of watermark. There is no standard and objective method to evaluate the visual effect. In this paper, we evaluate the performance of the algorithm by the visual effect subjectively, and compute the bit error rate (BER) to estimate the robustness of the watermarking.

4. Results and Discussion

A binary text image with 64 Chinese characters consists of three parts: the dislodge part of 8 character images, the adjust part of 14 character images, and the embedded part of 42 character images. The algorithm segments the embedded part into three sections and embeds a random sequence three times. Four bits of the watermark are embedded in each character image, and the length of the step is 0.067.

In this paper, we embedded the number sequence three times, and extract the watermarking three times, The final result depends on the chance of 0 0r 1. This method could improve the robustness.

In contrast with the scheme proposed in Ref. [10] where a single bit is embedded in each character image, our scheme can embed four bits, as shown in Figure 8.

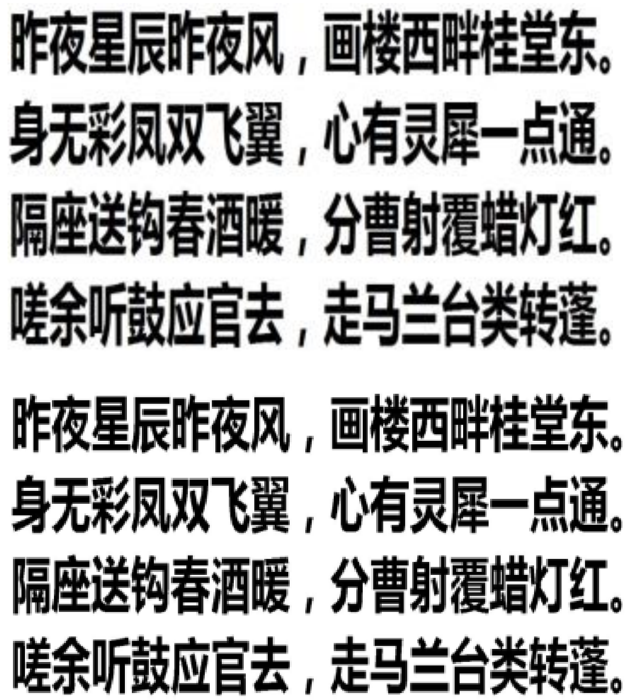


Figure 8. Compare of Embedded one bit and four bits in single character image

After embedding four bits watermark into a character image, the watermarked image has not been greatly distorted. Thus, the proposed method in this paper has the embedding performance four times higher than the scheme proposed in Ref [10]. As show in Figure 9, when compared with the original text, the text image with four bit watermarking has little influence on the visual effect.

Figure 9. The part comparison of original text and embedded watermark text

As shown in Figure 9, except that some characters have changes such as coarsening or thinning of individual strokes, it has good visual effect. We can conclude that the embedded watermark is sufficiently imperceptible.

We performed the experiment to evaluate the embedding capacity with different images. The experimental results for the embedding capacity are shown in Table 2. We made the experimental images with different fonts. The statistic of the experimental results is shown in Table 3.

Table 2. Comparison of capacity

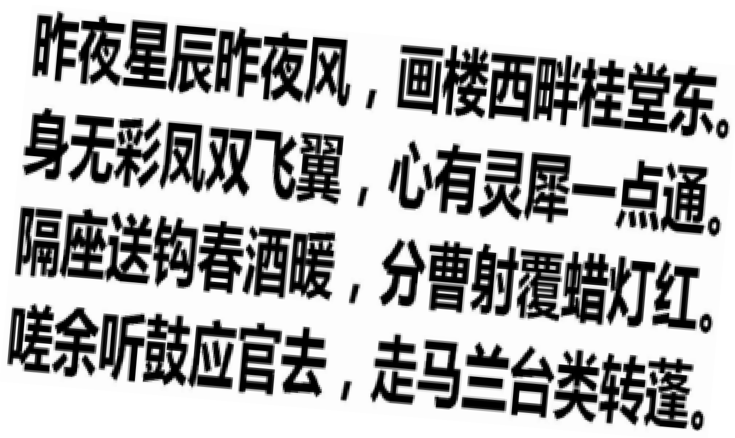
	Proposed algorithm (four bits per character)	**Ref. [10]**
Text 1	140	35
Text 2	398	100

Table 3. Test results for different character fonts

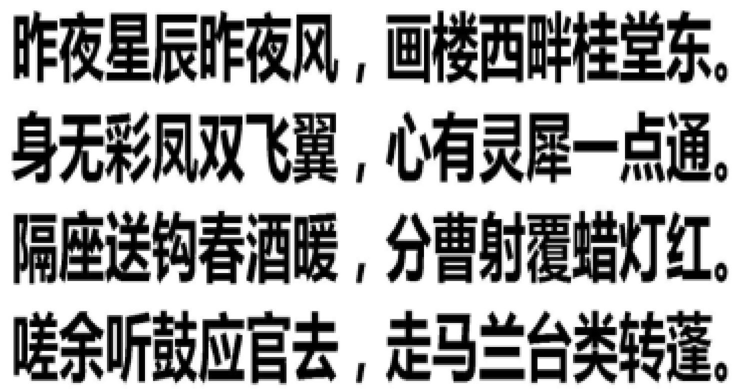
Font	**Number of embedded bits**	**Number of bits extracted**
Kaiti 4	346	342
Songti 4	346	340
Songti 5	346	336

The embedding capacity is four times more than other algorithm in ideal experiment, but in fact the number of some material pixel has decreased, but the loss is very little. The number of extracted data is closed to four times.

The proposed algorithm also can resist rotation attacks, where the image was scanned at an angle, as shown in Figure 10.



(a)



(b)

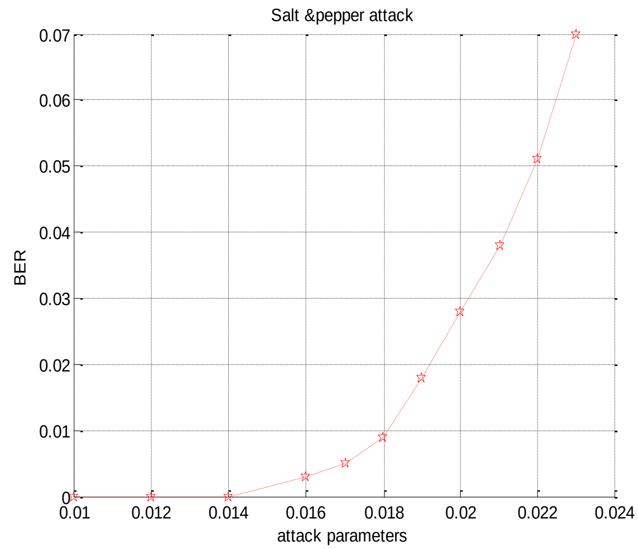
Figure 10. Rotation attack (a) and rectified image (b)

As show in Figure 11, this proposed method could resist many attacks such as salt-and-pepper noise and Gaussian noise, and it has good performance in robustness.

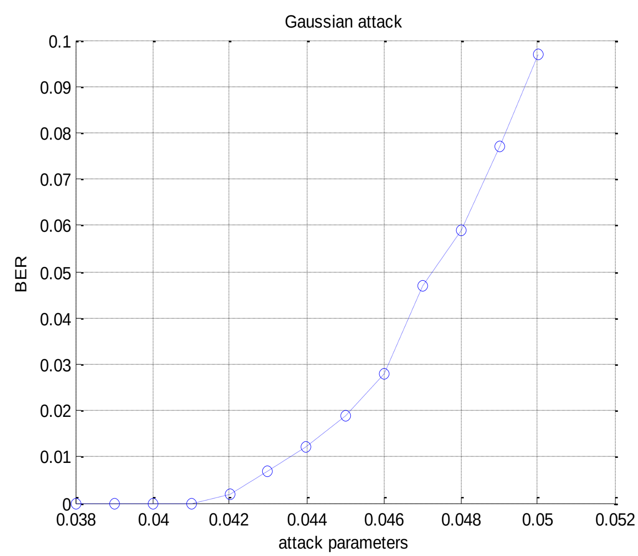
Figure 11. Salt and pepper attack to the image.

As shown in Figure 12, BER value of the extracted watermark depends on the position of each attack. Hence, we performed the experiments by carrying out the attack six times and computed the average BER.

The extracted watermark has low BER after different kinds of attacks. When the image scale ratio was set to 85%, the BER was 0.082 which is quite low.



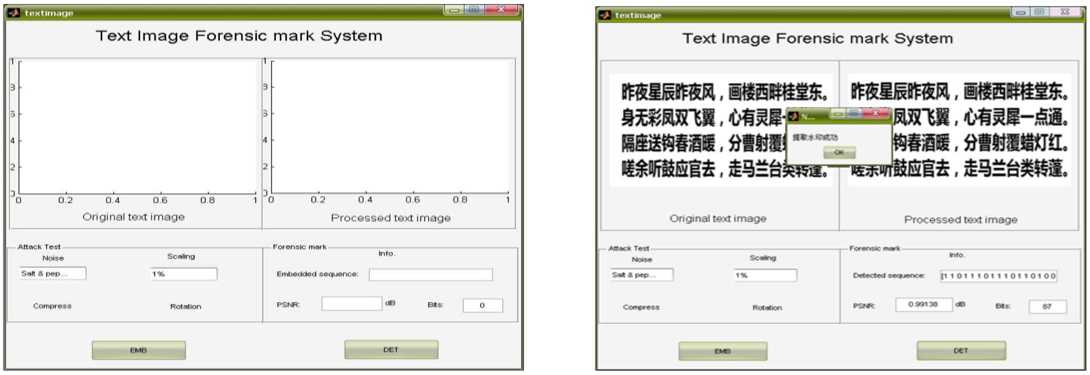
(a)



(b)

Figure 12. Average BER of image with salt-and-pepper (a) and Gaussian (b) noise addition

In order to make the algorithm more practicable, design the high capacity watermarking text image system. The system interface is shown in Figure 13. The system can read the text image in the processing, and display the watermarked text image. System included attack test module and forensic mark module. In the attack test module, users could set the noise attack parameter, scaling parameter, compress parameter, and rotation parameter. System embeds a watermark through the operation of EMB button. In the forensic mark module, users could set the watermarking information, and system could display the PSNR and capacity through the operation of DET button. Function of the system is shown as Figure 13.



(a) (b)

Figure 13. System of text image protection

5. Conclusions

In this paper, we have proposed the high capacity text watermarking algorithm that can resist attacks of print-and-scan in space domain. We combined the algorithm with the pixel flipping strategy. The experimental results presented that the watermarked text image has changed little in visual effect and the proposed method has good performance against attacks such as noise addition, rotation, and scaling. The proposed scheme has the embedding capacity per character four times as high as that of the scheme proposed by Wu and Liu [10]. Thus, the proposed algorithm in this paper achieves higher embedding capacity with little visual effect and has good performance in robustness.

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