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Print-Scan Resilient Watermarking for the Chinese Text Image

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Abstract

Digital text watermarking has been a popular way to discourage illicit reproduction of documents by embedding copyright information into them. This study presents two robust watermarking algorithms for the Chinese text image. One embeds watermark by modulating the character spacings and the other is based on the relative heights of characters in the same text line. In the embedding process, the characters are segmented firstly by projecting the image horizontally and then vertically. And the rough segmentation is refined according to the peculiarity of Chinese characters. Then on the basis of character segmentation algorithm, watermark embedding is achieved by shifting characters up or down (left or right). In the extracting process, pre-process operations such as the binarization and image deskewing algorithm are done first to reduce the impact caused by print-scan operation. Then the messages are extracted by comparing the character spacings or relative heights of characters. Experimental results show that the proposed methods possess high extraction accuracy under the tampering of print-scan operations.

Keywords: *Chinese text image watermarking, Print-scan attack, Character segmentation, Image deskewing, Character spacing*

1. Introduction

Along with the development and widespread of the Internet, text documents could be easily copied and distributed. Thus more and more attention has been paid to illicit access to text images. Digital text watermarking is a technology which prevents copyright piracy by hiding copyright information into digital texts [1-3]. Although the digital text watermarking technologies could be a good copyright protector to the digital texts, the mature techniques of printing and scanning make them invalid when the digital texts are converted to hardcopies and vice versa. Therefore, it is worth proposing print-scan resilient watermarking methods for text images.

There have been a lot of print-scan resilient watermarking researches devoted to images. Hernandez *et al.*, proposed image watermarking methods in the frequency domain (Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT)) [4-6]. Although they can resist print-scan attack effectively, they cannot be adopted directly into text images. Because characters in text images have clean cuts between the foreground and background areas; a slight change of data in the transformation domain would lead to severe distortion of images. In order to verify this, in the experiment part, some text images are tested with the transform domain method but it can hardly succeed.

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Topkara *et al.*, put forward the text image watermarking method based on natural language processing which generally embeds watermark by replacing the equivalent information or voice transformation [7-9]. They are suitable for text images and own strong robustness to print-scan attack, but it is very complex to carry out natural language processing (such as participle processing, polyphone recognition, and syntax and synonyms analysis). In addition, methods that by modulating the structure of Chinese characters [10, 11] and by modifying the strokes of characters [12, 13] have better visual effect but they will lose effectiveness if the content of the document is changed.

Brassil *et al.*, presented the line shift coding and word shift coding for English text images [14-16]. They embed a data by slightly shifting a block of characters vertically or horizontally. Although they have low embedding capacity and need original images when extracting messages, their idea inspires us to design the watermarking method for Chinese text images.

In this study, two print-scan resilient watermarking methods are proposed for Chinese text images. The first one embeds watermark by modulating the character spacings and it performs as shifting the characters left or right. The second shifts characters up or down with modulating relative heights of characters in the same line.

In Section 2, we depict the framework of watermarking algorithms including the embedding and extracting process. Section 3 introduces the character segmentation algorithm in detail, which is a key step of the proposed watermark methods. The binarization and deskewing algorithm is described in Section 4. The experimental results are showed in Section 5. In the end, we make a conclusion in Section 6.

2. Watermark Embedding and Extracting Process

The framework of the watermarking methods is illustrated in Figure 1. In the embedding process, the Chinese characters are segmented firstly with the character segmentation algorithm which is depicted detailedly in Section 3. Then messages are embedded by shifting the characters in two different ways. In the extracting process, in order to minimize noises and deskewing caused by print-scan operation, the scanned text image is firstly processed by binarization and deskewing algorithm. Then characters are segmented with the proposed character segmentation algorithm. At last the messages are extracted by comparing the character spacings or relative heights of characters.

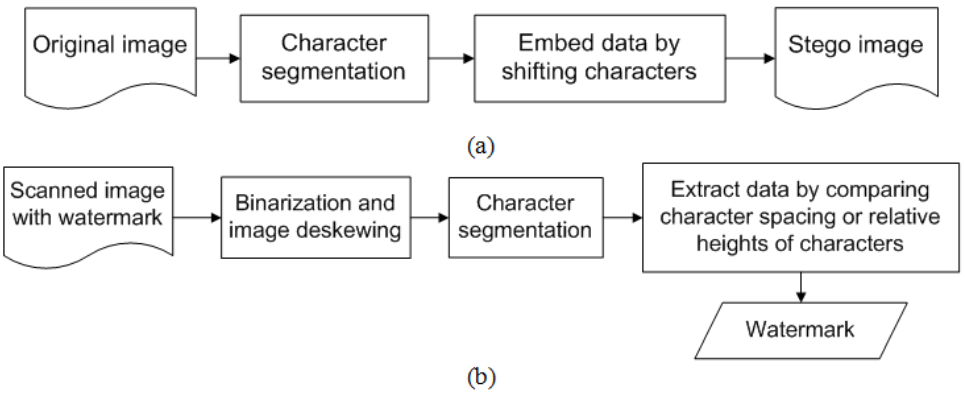


Figure 1. Framework of proposed methods, (a) Watermark embedding, (b) Watermark extracting

2.1. Watermarking Algorithm by Modulating the Character Spacings

In this part, the main idea of the embedding method is modulating the character spacing. In a Chinese text document, the character spacing is the space between two neighbor characters in the same text line. The paper margins do not belong to the character spacing. As shown in Figure 2, the length of the character spacing is measured as the number of pixels and denoted as c_1 to c_{12}. The total length of the valid character spacing L in one line is calculated as

$$L = \sum_{i=1}^{n} c_i \tag{1}$$

Where c_i (i=1, 2, 3, ⋯, n) denotes the length of the ith valid character spacing and n is the total number of the valid character spacings in a text line.

The most important issue before embedding is how to find embeddable text lines and valid character spacings in them. In order to ensure the robustness, we rule that an embeddable text line must have 12 valid spacings at least. The valid spacing is decided by using a threshold T which is got with an iterative method. For the sake of better imperceptibility, the spacing whose value is less than T can be used to embed messages.

2.1.1. Embedding Procedure: The modulation of character spacing performs as shifting the Chinese characters left or right. During the modulation, the L of each line is calculated firstly; and then for each valid line, corresponding L is divided equally into each valid spacing with equation (2). If there is a remainder r, it would be distributed evenly into the first r spacings.

$$l_i = {}^{L}/_{n} \ (i = 1,2, \dots n) \tag{2}$$

Then valid spacings are grouped into two blocks (B_1 and B_2) averagely shown in Figure 2. If the number of spacing is odd, the last one is left out.

Figure 2. Grouping of the character spacings

Let c'_i be the new length of the character spacing after modulation. After embedding, the character spacings in B_1 and B_2 meet the following equations (3) and (4):

embed bit '1': In B_1: $c'_i = l_i + q\left(i = 1,2,\mathbf{1},\frac{n}{\mathbf{2}}\right)$ (3)

In B_2:

embed bit '0': In B_1: (4)

In B_2: $c'_i = l_i + q\left(i = \frac{2}{n} + \mathbf{1}, \frac{2}{n} + \mathbf{2}, \dots, n\right)$

We can see the L in one line remains unchanged before and after modulation. As an empirical study, q is set to $L/2$. It is a tradeoff between the robustness of the watermark and the visual perceptibility of the marked image. The larger the q, the stronger robustness of the watermark we can get; but if the q is too large, the stego image would have more serious distortion.

2.1.2. Watermark Extraction Process: The scanned image is firstly binarized and corrected with the binarization and image deskewing algorithm. Then characters are segmented and the grouping result is obtained by using the same grouping method introduced above. Afterwards, the total length of spacings in different groups is calculated and compared. According to Eq. (3) and (4), if the L in former group is bigger than the latter one, bit '1' is extracted; otherwise bit '0' is extracted.

2.2. Watermarking Algorithm Based on the Relative Heights of Characters

In this method, the height of a character is measured by its position in the vertical direction and its value is equal to the mean of the character's upper and lower boundaries. The main thought of this algorithm is to shift characters and make their height upper or lower than the reference line. The following is the specific embedding procedure.

2.2.1. Embedding Procedure: According to the result of the character segmentation, the bounding box of each character could be determined and the height of each character can be obtained. Subsequently, in each text line the reference line shown in Figure 3 can be located and its value is the average height of all valid characters in the same line.

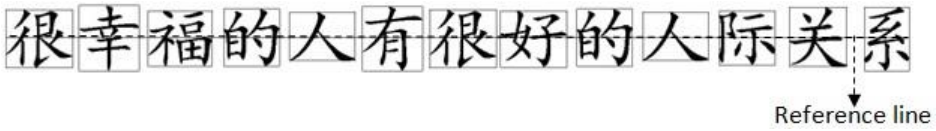


Figure 3. Reference line of a text line

In order to ensure the Imperceptibility, the punctuations and the characters whose heights have big gaps with the reference line cannot be used to embed watermark. In addition, with the purpose of stronger robustness, we only embed the watermark in the text lines that have 10 valid characters at least. Finally, for embeddable text lines, we shift valid characters up or down to make their heights equal to the reference line.

With the similar idea of the first algorithm, characters in the same line are divided equally into 2 or 4 groups. If bit '0' is embedded, characters in the former group are shifted with their heights higher (lower) than the reference line and the latter group remains unmoved; otherwise if '1' is embedded, the latter group is shifted and the former group is kept unchanged.

According to the idea of relative heights of characters, the larger the relative height, the stronger robustness the watermark will acquire; however, if the relative height is too large, it would cause severe visual distortion. In order to balance the robustness and visual perceptibility of the watermark, the shifting pattern is made like a shape of a letter 'n'. For example, characters in Figure 4 are denoted as a_i (i=1, 2, ⋯, 5). The character a_3 is shifted 3 pixels up; a_2 and a_4 2 pixels up and a_1 and a_5 1 pixel up.

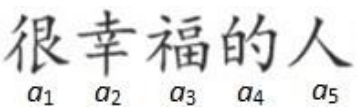


Figure 4. Example of shifting pattern

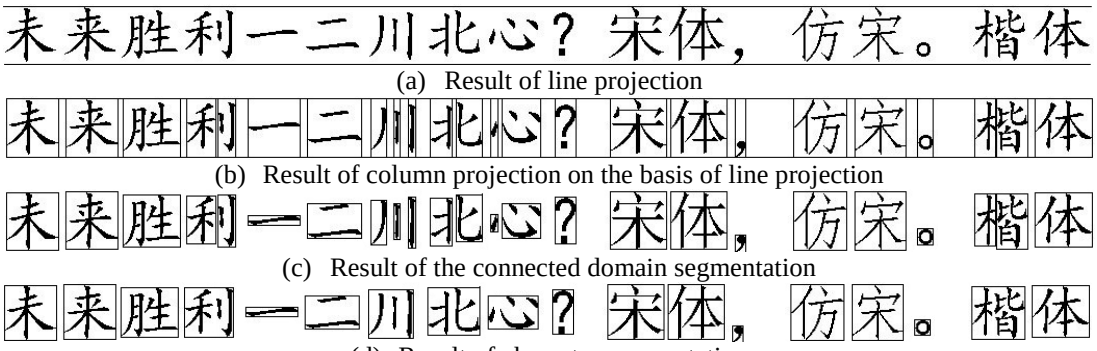
2.2.2. Extracting Procedure: The extracting method is the inverse process of the embedding phase. On the basis of the character segmentation operation, the bounding box of each character is got. Then divide the characters into 2 or 4 groups. According to the embedding phase, we can see the sum of the heights of characters in different groups indicating their difference after watermarking. So the hiding dates could be extracted just by computing and comparing the sum of the heights in different groups.

3. Character Segmentation

As described above, the embedding method is realized by shifting the characters up or down (left or right). So, precise character segmentation is very important to the watermarking algorithm. In this study, on the basis of connected domains, the Chinese character segmentation algorithm is mainly composed of the segmentation of connected domains and the merging of the connected domains. The particular process is in the following steps.

3.1. The Segmentation of Connected Domains

Firstly, the results of the line segmentation of a text image are got by projecting the image horizontally shown in Figure 5(a). On the basis of line segmentation, by projecting each text line vertically, the rough segmentation of each connected domains is obtained shown in Figure 5(b). According to the rough connected domain, the accurate left and right boundaries are gained. And then by projecting the each connected domain horizontally again, the minimum and maximum ordinate point can be located, which is the exact upper and lower bounds of the connected domain. So, the exact segmentation of connected domains is received shown in Figure 5(c).



(a) Result of line projection

(b) Result of column projection on the basis of line projection

(c) Result of the connected domain segmentation

(d) Result of character segmentation

Figure 5. Procedure of connected domain segmentation

3.2. The Merging of Different Kinds of Connected Domains

As we all know, most of the Chinese characters have a characteristic of square shape. And the aspect ratio R of majority characters' bounding boxes is almost equal to 1. So, the

merging operation is achieved according to aspect ratio R of the connected domains. The concrete segmenting process is as follows:

Step 1. Compute R_1 of the selected connected domain Q_1;

Step 2. Get Q_2 by merging Q_1 and its adjacent connected domain and compute R_2;

Step 3. Compare R_1 and R_2 and the connected domain whose R is closer to 1 would be segmented into a separate Chinese character;

Step 4. Reselect the next connected domain and goto step 1.

The result of the character segmentation is shown in Figure 5(d). During the merging there are the following conditions need to be considered.

(1) **The connected domains of L-R structure character.** Many L-R structure Chinese characters are segmented into 2 separate parts according to the domain segmentation such as '利' in Figure 5(c). So in this case, the method mentioned above could be used directly.

(2) **The punctuations and some characters whose *R* is not close to 1.** The aspect ratio of many punctuations such as "？", "。", characters such as "—" does not meet the feature of R . In this case, our solution is to distinguish them before the merging operation. Then they can be identified and segmented immediately by the feature of position coordinates.

(3) **Chinese characters whose internal spacing is bigger than common ones.** The most typical example of this case is the '川'. In this case, they just be identified and segmented according to an empirical threshold.

4. Image Binarization and Deskewing Algorithm

4.1. Image Binarization Algorithm

The proposed watermark algorithms are achieved with binary images. After binarization, the image becomes simple and has small amount of data, which is benefit to the further processing of the image [17, 18]. Besides, the operation also helps us to remove some noises caused by print and scan operations. If the scanned image is not a binary one, we process it to a binary image with the following iterative binarization algorithm. The specific algorithm is shown in Alg. 1

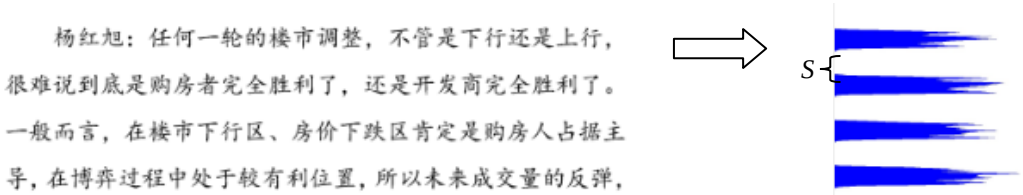
Algorithm 1 The procedure of binarization algorithm

Require: T_{max}(T_{min}): the maximum (minimum) gray value in a Chinese text image,
Calculate T_{max} and T_{min} of a image and then set $T = T_{max} + T_{min}$;
Use T to divide the image into 2 groups and calculate the average gray value T_1, T_2 in each group;
while T_1,T_2 has changed
$T = (T_1 + T_2)/2$;
Use T to divide the image into 2 groups and recalculate T_1, T_2 in each group;
end while
We can get the threshold T and then use it to binarize the image.

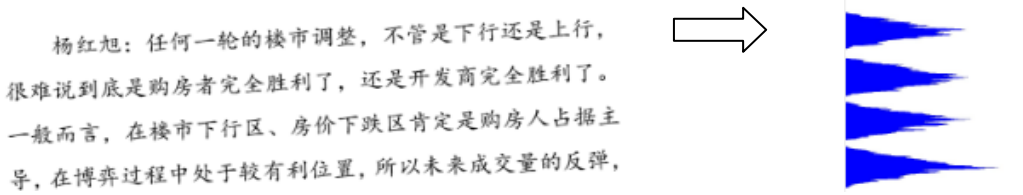
4.2. Image Deskewing Algorithm

Print-scan operation would inevitably introduce image tilt and small tilt could lead to wrong detection especially for the method based on relative height of characters. So it is particularly important to execute the image deskewing algorithm before the detection operation.

When projecting the image with different inclination horizontally, the sum of the inter-line blank spacing S presents different results shown in Figure 6. Experiments show that the smaller the incline angle of the image, the bigger the value of S. Based on this phenomenon, we propose an image deskewing algorithm with the sum of the inter-line blank spacing shown in Alg. 2.



(a) Horizontal projection of correct image



(b) Horizontal projection of tilt image

Figure 6. The horizontal projection of the correct image and tilt image

Algorithm 2 Procedure of deskewing algorithm

Require: I: the Chinese text image, S_r (S_l): the S after rotating I clockwise (anticlockwise), S_a (S_b): the S after (before) rotating I , A: the rotation angle, P: a given precision,

```
    Load the image I and project it horizontally and then calculate S;
    Rotate I clockwise and anticlockwise and calculate its corresponding Sr and Sl;
    if Sr > Sl
        the tilt correction is upright; Sb = Sr;
    else
        the tilt correction is leftright; Sb = Sl;
end if
  while A >= P
    rotate I with angle A in correct direction; then calculate Sa;
      while Sa > Sb
        Sb = Sa ;
          keep rotating I in right direction with angle A and recalculate Sa ;
        end while
    if Sa <= Sb
      reduce A;
    end if
  end while
   if A < P
      we can get the tilt angle W;
 end if
```

In order to evaluate the proposed deskewing algorithm, 10 different text images are tested with it. The images are rotated 0.4° clockwise and anticlockwise respectively and then their tilt angles are calculated by using the algorithm. The result is presented in Table 1 and it indicates that the scope of the error is within 0.00547°.

Table 1. The test result of the deskewing algorithm

samples	-0.4°	0.4 °	samples	-0.4°	0.4 °
1	-0.403238	0.397195	6	-0.401785	0.396123
2	-0.401759	0.400577	7	-0.400000	0.405286
3	-0.400330	0.401637	8	-0.394530	0.398770
4	-0.400352	0.403878	9	-0.403960	0.397799
5	-0.402768	0.396494	10	-0.400115	0.400686

5. Experiment Results

5.1. Comparison of Different Watermarking Methods

We compared the advantages and disadvantages of different kinds of the watermarking methods in Table 2. Methods base on transform domain have strong robustness but they are not suitable for text images [6, 19]. Zou *et al.*, proposed an Inter-word Space Modulation scheme which is robust to printing, copying and scanning but this technique is specifically for English texts [20]. Brassil *et al.*, proposed three data hiding methods; they have good visual perceptibility but low embedding capacity [14]. Although method based on natural language processing possesses good imperceptibility and has strong robustness but it is very complicated to carry out the natural language process. The proposed methods are suitable for Chinese text images and the process of embedding and extracting is simple and efficient to implement. Besides, they offer robustness to print-scan attack.

Table 2. Comparison among different methods

Methods	Embedding capacity	Robustness	Weakness
Transform domain	—	Print-scan	Suitable for natural images
Line/word shifting	0.5bit/line	Little to print-scan	Low embedding capacity, need original image when detecting
Word space modulation	1bit/line	Print-scan-copy	For English text images
Based on natural language processing	—	Print-scan	Need complex pretreatment
Proposed	1.5bit/line	Print-scan	Little robustness to copy

5.2. Algorithm Tests

In order to verify the performance of the proposed method, the extraction accuracy and the embedding capacity of four methods was compared. The first one embeds data by adjusting the coefficient of the 3-level DWT (Discrete Wavelet Transform) [6]. And the two of the rest are presented in our study. The last one is the combination of the two proposed methods.

We used a HP LaserJet M1536dnf MFP to print and scan the hardcopy documents with resolution of 600 dpi. A 60-page Chinese text document was used to test the methods respectively. The documents were formatted in different fonts (“Song typeface”, “Regular script”, “Imitation song”) and sizes (16pt and 15pt). The extraction result is shown in Table 3. The results apparently indicate that the method with transform domain is not suitable for the text image while the proposed method possess strong robustness to the print-scan attack. The

result of embedding capacity is presented in Table 4. From the table, we can see the embedding capacity is enough to hide copyright information and it lies on the font size of the text to some extent.

Table 3. The extraction accuracy result by using different methods

Method	Font (%)		
	Song typeface	Regular script	Imitation song
Modulating character spaces	99.67	99.61	100
Shifting characters up or down	99	100	100
Combination of above two methods	99.71	100	100
DWT	48.92	51.67	51.5

Table 4. Comparisons of the embedding capacity of different methods

Watermarking method	Pages	Average document page sizes(KB)	Average embedding capacity(byte)
Modulating character spaces	60	30	30
Shift characters up or down	60	26	30
Combination of above two methods	60	26	30
DWT	60	27	–

6. Conclusions and Future Works

In this paper, we propose two watermarking algorithms which can be employed in Chinese text images. One embeds watermark by modulating the character spacings; the other one is on account of the relative height of characters and it completes data hiding by shifting characters with their height higher or lower than the reference line. In the extracting process, pretreatment such as binarization, image deskewing and character segmentation were adopted firstly. Then, messages are extracted by comparing the sum of character spacings or relative heights of characters. Experimental results indicate that they hold much better robustness against print-scan attack and have good visual perceptibility.

In current digital age, the images are likely to be printed and scanned for many times. So, it is necessary to put forward the watermarking method robust to multiple printing and scanning. In addition, we plan to improve the watermarking algorithm and make it robust to copying attack.

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