# Extraction of Serial Numbers on Bank Notes

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***Abstract*—The study of RMB (renminbi bank note, the paper currency used in China) serial number recognition draws more and more attention in recent years, for reducing financial crime, improving financial market stability and social security. The accuracy of RMB recognition relies heavily on the extraction, which is a challenging problem due to background variations and uneven illumination. In this paper, we present a new system that extracts the RMB characters directly from scanned RMB images. First, two different techniques, namely skew correction and orientation identification are used to detect the region which contains RMB serial number. Then the detected text region is binarized by a combined thresholding technique. After that, a local contrast average method is introduced to extract the RMB characters from the binarization result. The experiments demonstrate that the proposed binarization method outperforms other well-known methods. For character extraction, we report an overlap-recall rate of 79.68% and an overlap-precision rate of 98.10% respectively.**

***Keywords—image binarization, combination technique, local contrast, RMB serial number extraction***

## I. INTRODUCTION

Document images often suffer from their complex background that renders the character extraction a challenging task. However, the problem of character extraction is critical in many applications such as vehicle license plate recognition [1], automatic bank check processing [2], recognition of historical document images [3], etc. Numerous character extraction approaches have been developed for different types of applications in these years, however, little research has been done on extraction of serial number on bank note.

In this paper, we present a new approach of RMB (renminbi, the bank note used in China) serial number extraction from original scanned RMB images which have complicated background and uneven illumination. The RMB serial number includes 10 printed characters designed uniquely and used as the identification of RMB. High reliability of automatic RMB serial number recognition system can improve social security, reduce financial crime and stabilize financial market. Fig. 1 shows the serial numbers in the scanned image.

(a) (b)

Fig. 1. (a) See-through image and (b) reflection image of RMB

Scanned original RMB images are captured by the contact image sensor (CIS) installed in the money counting machine. Both a see-through image and a reflection image are obtained in a single pass of the scanning process. The see-through (Fig. 1(a)) image includes complex security texture information from both sides of the currency while the reflection image (Fig. 1(b)) provides either the image side containing clean serial numbers without complex background or the other side excluding serial numbers. However, in order to extract the RMB serial number by scanning the paper currency only once without considering the input side, the serial number can only be extracted from the see-through image which is a much more difficult problem.

Given a RMB image, the proposed approach first extracts the RMB serial number region through procedures of RMB edge detection and orientation identification. There are some anti-counterfeiting circles located around or overlapping with the RMB serial number. Because these circles have the same gray level and stroke width as the characters, both the stroke-model based extraction method [4] and gray level-based extraction method [5] are not suitable to produce accurate extraction results. Instead of extracting the RMB serial number from gray level image, a novel binarization approach is applied to the serial number region. As a result, we locate the RMB serial number from the binary text region. The proposed binarization technique combines the area-ratio-based and block-contrast-based [6] thresholding methods. It outperforms the background estimation method [7], local maximum-minimum method [8], and super-resolution method [9] which are the winners in the recent Document Image Binarization Contest (DIBCO) 2009 [10] & 2011 [11] and the Handwritten Document Image Binarization Contest (H-DIBCO) 2010 [12].

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(a) (b) (c) (d)

Fig. 2. (a) RMB edge detection, (b) skew correction, (c) RMB security thread, and (d) '100' template

We extract the RMB characters by combining apriori knowledge and block contrast average, and conducting superior performance.

The rest of the paper is organized as follows. Section 2 details the RMB serial number region detection. Text region binarization and character extraction are presented in Sections 3 and 4 respectively. Section 5 summarizes the experimental results. Finally, we conclude our paper in Section 6.

## II. SERIAL NUMBER REGION AND DETECTION

### A. RMB Edge Detection

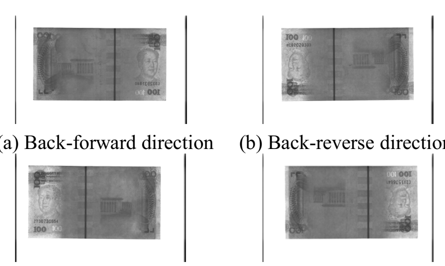
During the RMB scanning process, the paper currency may not be fed straight into the scanner, which causes skewing of the bitmapped image. This effect will dramatically reduce the accuracy of the subsequent processes, such as RMB orientation identification and character extraction. The RMB image should be aligned with the coordinate axes before further operations.

As we observed, the RMB horizontal edges are parallel to the RMB serial number, therefore, they can be utilized to estimate the skew angle. In our scanned RMB image, the blank area's gray level is 255 (Fig. 2(a)). It facilitates us to detect the RMB edge points by gradient change. Then parameters of the four RMB edge lines can be estimated via Hough transform. The skew correction is performed by rotating the scanned RMB image according to the horizontal edge line's slope. Fig. 2(a) (b) shows the edge detection and skew correction result.

### B. RMB Orientation Identification

Since the RMB serial number is printed at the bottom-left corner of the RMB's front side with a fixed size, if we could identify the orientation of the RMB, the text area can be easily extracted apriori. Actually there are four different possible orientations of the RMB image, namely front-forward direction, front-reverse direction, back-forward direction, and back-reverse direction, as shown in Fig. 3.

Fig. 2(c) illustrates that there is a straight vertical strip with



(a) Back-forward direction (b) Back-reverse direction

(c) Front-forward direction (d) Front-reverse direction

Fig. 3. RMB image orientations


(a) (b) (c)

Fig. 4. (a) Precise RMB character area, (b) area-ratio based binarization map, and (c) block contrast based binarization map

low gray level located in each RMB image which is the metal security thread of RMB. For different RMB orientations, the security thread appears on the left or right half part of the RMB, respectively. According to the location of security thread, we categorize the orientation identification problem into two groups (Fig. 3(a) and Fig. 3(d), Fig. 3(b) and Fig. 3(c)), and the identification problem becomes a binary-category classification issue. A '100' pattern template (shown in Fig. 2(d)) is applied to detect the best matches in four candidate regions, and the matching result reflects the RMB orientation. Based on the RMB image's scanning orientation, we are able to extract the RMB serial number region by the apriori knowledge of serial number's size and location. Fig. 4(a) shows a few examples of extracted serial number region.

## III. BINARIZATION

### A. Combination of Binarization methods

In recent years, a large number of document image binarization techniques have been proposed and some have reported impressive results. However, the RMB serial number region image has the high intensity variation background and complex texture, all the methods mentioned before cannot achieve approving results. Since the serial number characters have a static stroke width and they account for a certain ratio of image area, we present a combined thresholding method by utilizing the character's stroke and area ratio features.

#### 1) Area-Ratio Based Binarization

A more precise character area can be extracted from the gray level RMB serial number region by horizontal and vertical projections, as shown in Fig. 4(a). And we noticed that the proportion of the characters is almost the same in each precise character area. Therefore, these lower gray level pixels could be labeled as foreground by area-ratio based thresholding. The character area proportion *R(t)* is defined as:

$$R(t) = \frac{\sum_{i=0}^{t} hist(i)}{\sum_{i=0}^{255} hist(i)} \qquad (1)$$

where $hist(i)$ is the histogram of the precise character area, $t$ denotes the threshold. We empirically define the $R(t)$ as 15%, so the threshold can be computed iteratively.

Fig. 4(b) shows the binary map produced by the area ratio based method. It relies on a good choice of the area ratio. Because the character area detection has a high precision, and the resulting precise RMB character area images are very similar to each other. A common choice of the area ratio is reasonable in this case and produces remarkable results.

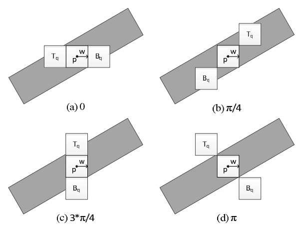



Fig. 5. Block contrast of 4 directions

### 2) Block Contrast Based Binarization

From our observation, the character stroke orientation can be quantized into four directions. The main idea of the block contrast based binarization approach is that: the pixels on the stroke have a lower gray level than the pixels beyond it. Since the feature is insensitive to noise, block average is applied to represent the central pixel's intensity.

For each pixel $p$ in the RMB serial number region, the classification of foreground (indicated by 1) or background, is defined by the following thresholding operation:

$$f(p) = Max_{d=0}^{3} f_d(p) \tag{2}$$

$$f_d(p) = \begin{cases} 1, & C_{Top}(p) > T \ AND \ C_{Bottom}(p) > T \\ 0, & otherwise \end{cases} \tag{3}$$

$$C_{Top}(p) = \frac{Avg_{q \in T_q}(q)}{Avg_{p \in M_p}(p)} \tag{4}$$

$$C_{Bottom}(p) = \frac{Avg_{q \in B_q}(q)}{Avg_{p \in M_p}(p)} \tag{5}$$

Here, $d = 0, 1, 2, 3$ refer to four directions $\{0, \pi/4, \pi/2, 3\pi/4\}$, the pixel $p$ will be labeled 1 if one of the $f_d(p)$ is 1; $T$ is a block contrast threshold, empirically set as 1.2; $C_{Top}(p)$ refers to the contrast between top and middle blocks, and $C_{Bottom}(p)$ refers the contrast between bottom and middle blocks; $M_p$ is a $(2W + 1)$ square, centered by $p$; $T_q$ and $B_q$ are two $(2W + 1) * (2W + 1)$ block windows that are $(2W + 1)$ pixel away from $p$, in opposite directions (Fig. 5); $W$ is defined as half the width of the character stroke.

The proposed block contrast based threshold approach makes use of the stroke width information, limits the interferences like circles, wrinkles, and smudge, tends to provide a binary image without considering the pixels intensity (Fig. 4(c)).

### 3) Combination

We take the intersection of the two aforementioned binarization maps as the combined result. Pixel is labeled foreground by examining both methods. Since the area-ratio method does not consider the stroke texture characteristic and the block contrast based method does not regard pixel intensity, the combination method can correct a few false foreground pixels, and provide a more precise classification.

## B. Post Processing

The binary quality derived from the combination can be further improved by post processing. First, the text components which are smaller than three pixels are removed based on the hypothesis that the real serial number components are usually composed of more than three pixels. Then, by horizontal and vertical projections, we obtain the precise RMB character area from the binary image. Labeling all the outside pixels background will help to remove the false circles from the foreground, and facilitate subsequent character extraction procedures. Furthermore, we design eight logic operators to detect and remove single pixel artifacts along the character stroke, such as concavities and convexities [13]. Fig. 7(i) shows the binarization result after post processing.

# IV. CHARACTER EXTRACTION

Once the final binarization result is produced as described in previous sections, we extract the RMB serial number from the binary image by procedures of horizontal character extraction and vertical character extraction.

## A. Horizontal Character Extraction

In horizontal character extraction, each RMB character's left and right boundaries are located. Specifically, we use a bounding rectangle to indicate the outline of characters, the width of each character rectangle is estimated by the apriori knowledge of character's width and the height of each character rectangle is equal to that of the precise RMB character area. Algorithm 1 states the horizontal boundary extraction procedure for each character in the serial number. Fig. 6(a) shows the character horizontal extraction result.

**Algorithm 1** Character horizontal extraction

**Require:** binary image
**Ensure:** Character horizontal boundaries
1: Character boundaries pre-estimation: locate the character bounding rectangle according to apriori knowledge.
2: Calculate the center of gravity (centroid) of the character rectangle, and center the rectangle to x-direction centroid.
3: Examine the left and right margins of the rectangle
**if** the width of left margin equals to the right **then**
go to step 4
**else** center the character rectangle by equalizing the left and right margins, then return to step 2
**end if**
4: Narrow the character bounding rectangle by removing the left and right margins.

## B. Vertical Character Extraction

Due to the remaining circle fragments distributing around or overlapping with the first three characters, the *Y* direction character extraction is more complicated than *X*. First, we center the character bounding rectangle according to y-direction centroid. Then, local contrast average method is applied on the detection of first three characters' top and bottom boundaries. The boundary is derived from the maximum local contrast average value of the neighborhood:

$$y = arg\ max_{y \epsilon W}\ C(y) \tag{6}$$

where $C(y)$ denotes the local contrast average at $y$, $W$ refers to the search area which belongs to $[y_b - \omega, y_b + \omega]$, $y_b$ is the initial boundary and $\omega$ indicates the search range. For the top and bottom boundaries, local contrast average values are defined as follows:

$$Top\ boundary: \quad C_{top}(y) = \frac{Avg_{btm} - Avg_{top}}{Avg_{btm} + Avg_{top} + \varepsilon} * Avg_{btm} \tag{7}$$

$$Bottom\ bounary: \quad C_{btm}(y) = \frac{Avg_{top} - Avg_{btm}}{Avg_{btm} + Avg_{top} + \varepsilon} * Avg_{top} \tag{8}$$

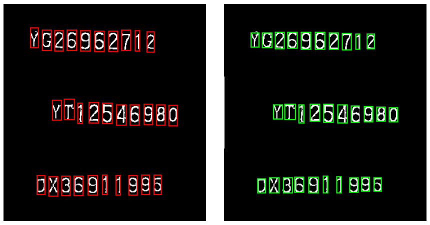



Fig. 6. (a) Horizontal and (b) vertical extraction results

ε is a positive small number that ensures the denominator will not be 0. $Avg_{top}$ and $Avg_{btm}$ refer to the intensity average within top and bottom local neighborhood windows at $y$, respectively. The local neighborhood window has the same width as the character bounding rectangle, and the height is assigned to 5 empirically.

In our scheme, the local contrast average approach eliminates the influence of remaining circle patches to the character vertical extraction through the maximum window average selection rule. It utilizes the block average to suppress the background variation caused by false foreground pixels, and takes advantage of normalization factor to ensure the resulting bounding rectangle is not smaller than the character. The final character extraction result is shown in Fig. 6(b).

## V. EXPERIMENTS AND DISCUSSIONS

### A. Binarization Experimental Results

We compared our binarization approach against several algorithms over the RMB serial number region images which are derived from scanned RMB dataset. These comparison methods include well known Otsu's method [14], Niblack's method [15], Sauvola's method [16], Wolf's method [17], and the top-three methods in DIBCO 2009 & 2011 namely Lelore's method [9], Su's method [8], and Howe's method [18]. The constant k in Niblack's method is set to -0.2 as recommended in the paper. In Sauvola's approach, the window size is designed to 10x10 pixels according to the resolution, and the parameter *k* is set to 0.5. The weighting factor *w* in Wolf's approach is fixed to 0.5. We set the edge detection threshold *T* to 100 in the Lelore's method. The binarization results produced by different methods are shown in Fig. 7.

Many different measures have been proposed to compare the effectiveness of binarization algorithms. We followed the evaluation measures adapted from the DIBCO 2011[11] including F-Measure, Peak Signal to Noise Ratio (PSNR), Distance Reciprocal Distortion Metric (DRD), and Misclassification Penalty Metric (MPM).

TABLE I. BINARIZATION EVALUATION RESULT

| Method | Recall | Precision | F-Measure | PSNR | DRD | MPM |
|---|---|---|---|---|---|---|
| Otsu | 99.82 | 7.15 | 13.35 | 2.10 | 262.48 | 346.98 |
| Niblack | 99.54 | 11.25 | 20.22 | 4.27 | 157.60 | 198.86 |
| Sauvola | 19.05 | 9.96 | 13.09 | 9.19 | 46.81 | 24.34 |
| Wolf | 87.01 | 33.51 | 48.38 | 10.54 | 34.93 | 32.14 |
| Lelore | 79.99 | 71.25 | 75.37 | 16.04 | 8.39 | 8.00 |
| Su | 95.21 | 13.51 | 23.66 | 5.34 | 125.19 | 123.82 |
| Howe | 90.66 | 43.01 | 58.35 | 12.10 | 23.85 | 27.04 |
| Proposed | 61.12 | 95.31 | 74.48 | 17.00 | 5.48 | 0.11 |

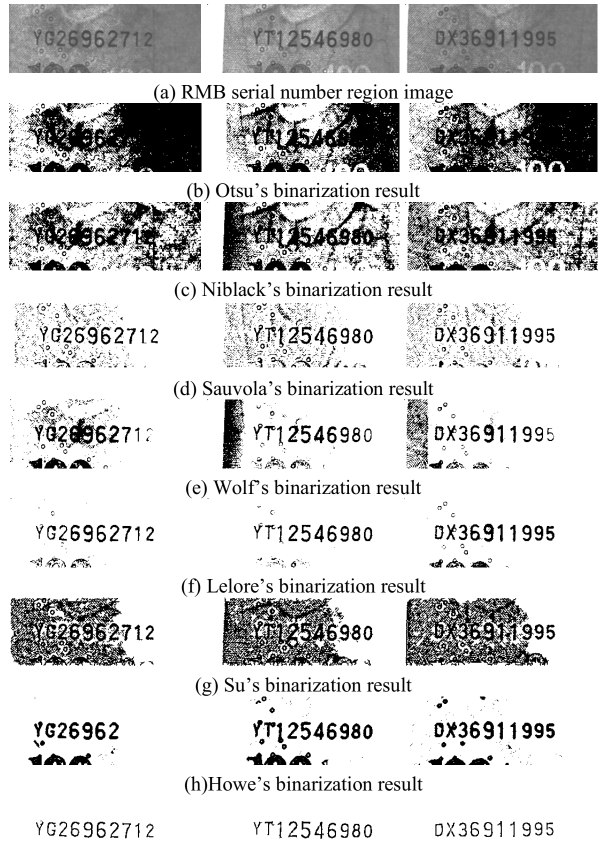



Fig. 7. Binarization of RMB serial number region by different methods

The quantitative evaluation results are shown in Table I. It illustrates clearly that our proposed method produces superior performances than the other seven methods in PSNR, DRD, and MPM, and only slightly lower than Lelore's method in the F-Measure. The Otsu's method cannot solve our problem due to the serial number region image does not present a bimodal histogram pattern. Niblack and Sauvola's method cannot distinguish the difference from noise to text if they have the same image variation. Wolf's method is sensitive to the noise variance and Howe's method is not able to classify the text pixel with low contrast to the background. The method from Su is not suitable to our case, because it assumes the intensity of the character stroke is lower than the noises in the background, which is not satisfied by RMB text region image. Our method outperforms the Lelore's method by utilizing the RMB serial number's distribution characteristic to remove the remaining circles and noises in post processing. Since Lelore's method needs to artificially generate low resolution sequences of the input image and compute their likelihood, our method is much simpler and more efficient.

### B. Character Extraction Results

In order to evaluate the performance of the proposed character extraction approach, we conducted experiments on 500 scanned RMB images which contain 5000 characters.

These images suffer from different types of image degradation including anti-counterfeiting pattern and texture, uneven illumination, smear, and smudge which render the character extraction a challenging task.

We select two representative performance metrics to measure the extraction performance, namely basic overlap based metric (BOM) [19] and ICDAR metric [20], respectively. The BOM is directly defined as dividing the overlap area by the ground truth or detected area:

$$recall = \frac{AreaOverlap}{AreaGT} \tag{9}$$

$$precision = \frac{AreaOverlap}{AreaD} \tag{10}$$

ICDAR metric is computed by dividing the overlapping area by the containing box as:

$$\text{ICDAR}\ metric = \frac{AreaOverlap}{AreaC} \tag{11}$$

In the experiments, our system achieved the overlap-recall of 79.68% and the overlap-precision of 98.10%. The ICDAR metric value is 378.76. The high extraction rate derives from precise binary result and robust extract method. However, there are still some limits in our method. For example, even though the proposed vertical extraction method is efficient dealing with the image contaminated by little noise, it cannot provide the proper result in case of a lot of noise surrounding the character.

## VI. CONCLUSIONS

In this paper, we have proposed a novel system for RMB serial number extraction with complex background and poor illumination. In order to extract the RMB serial number characters from the original scanned RMB bank note, we divide the system into two steps: RMB serial number region detection and character extraction. Firstly, the serial number region is detected through the procedures of RMB edge detection, skew correction, and orientation identification. After that, the pixels in the serial number region are labeled foreground or background according to the combination based thresholding technique. Finally, a local contrast average method is applied to extract the characters from RMB serial number from the binary image. To the best of our knowledge, this is the first systematic work on RMB serial number extraction.

Binarization experiments conducted on a large set of RMB serial number region images demonstrate the efficiency and robustness of proposed method. As for the character extraction, we obtained a promising result of 79.68% overlap-recall rate and 98.10% overlap-precision rate. In the future, more effective methods will be introduced for the RMB serial number extraction, and the character recognition module with classification either on single character level or character string level will be studied based on the extraction results reported in this paper.

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## REFERENCES

[1] Li-Shien Chen, Yun-Chung Chung, Sei-Wan Chen, “Automatic license plate recognition,” IEEE Transactions on Intelligent Transportation Systems, vol. 5, Issue 1, pp. 42-53, March 2004.

[2] C. Y. Suen, L. Lam, D. Guillevic, etc., “Bank check processing system,” International Journal of Imaging Systems and Technology, vol. 7, Issue 4, pp. 392-403, December 1996.

[3] Itay Bar-Yosef, Isaac Beckman, Klara Kedem, Itshak Dinstein, “Binarization, character extraction, and writer identification of historical Hebrew calligraphy documents,” International Journal of Document Analysis and Recognition, vol. 9, Issue 2-4, pp. 89-99, April 2007.

[4] Xiangyun Ye, M. Cheriet, C. Y. Suen, “Stroke-model-based character extraction from gray-level document images,” IEEE Transactions on Image Processing, vol. 10, Issue 8, pp. 1152-1161, August 2001.

[5] H. Hontani, T. Koga, “Character extraction method without prior knowledge on size and position information,” International Vehicle Electronics Conference, pp. 67-72, 2001.

[6] M. Kamel, A. Zhao, ‘‘Extraction of binary character/graphics images from grayscale document images,’’ Graphical Models and Image Processing, vol. 55, Issue 3, pp. 203-217, May 1993.

[7] Shijian Lu, Chew Lim Tan, “Binarization of Badly Illuminated Document Images through Shading Estimation and Compensation,” International Conference on Document Analysis and Recognition, vol.1, pp. 312-316, September 2007.

[8] Bolan Su, Shijian Lu, Chew Lim Tan, “Binarization of historical document images using the local maximum and minimum,” International Workshop on Document Analysis Systems. pp. 159-166, June 2010.

[9] T. Lelore, F. Bouchara, “Super-Resolved Binarization of Text Based on the FAIR Algorithm,” International Conference on Document Analysis and Recognition, pp. 839-843, September 2011.

[10] B. Gatos, K. Ntirogiannis, I. Pratikakis, “ICDAR 2009 Document Image Binarization Contest (DIBCO 2009),” International Conference on Document Analysis and Recognition, pp. 1375-1382, July 2009.

[11] I. Pratikakis, B. Gatos, K. Ntirogiannis, “ICDAR 2011 Document Image Binarization Contest (DIBCO 2011),” International Conference on Document Analysis and Recognition, pp. 1506-1510, September 2011.

[12] I. Pratikakis, B. Gatos, K. Ntirogiannis, “H-DIBCO 2010 - Handwritten Document Image Binarization Competition,” International Conference on Frontiers in Handwriting Recognition, pp. 727-732, November 2010.

[13] Shijian Lu, Bolan Su, Chew Lim Tan, “Document image binarization using background estimation and stroke edges,” International Journal of Document Analysis and Recognition, vol. 13, Issue 4, pp. 303-314, December 2010.

[14] N. Otsu, “A threshold selection method from gray-level histograms,” IEEE Transactions on Systems, Man and Cybernetics, vol. 9, Issue. 1, pp. 62-66, January 1979.

[15] W. Niblack, “An Introduction to Digital Image Processing,” Englewood Cliffs, New Jersey: Prentice-Hall, 1986.

[16] J. Sauvola, M. Pietikainen, “Adaptive document image binarization,” Pattern Recognition, vol. 33, Issue 2, pp. 225-236, February 2000.

[17] C. Wolf , D. Doermann, “Binarization of Low Quality Text using a Markov Random Field Model,” International Conference on Pattern Recognition, vol. 3, pp. 160-163, August 2002.

[18] N. R. Howe, “A Laplacian Energy for Document Binarization,” International Conference on Document Analysis and Recognition, pp. 6-10, September 2011.

[19] V.Y., Mariano, J. Min, J.H. Park, etc., “Performance evaluation of object detection algorithms,” International Conference on Pattern Recognition, vol. 3, pp. 965-969, August 2002.

[20] Y.F. Pan, C.L. Liu, “Performance Evaluation for Text Localization Algorithms: An Empirical Study,” Chinese Conference on Pattern Recognition, pp. 1-5, October 2010.