

Study on Money Number Recognition Arithmetic

Hongli Yu¹ and Yingyong Zou^{1,2}

¹Scientific Research Administrative department, Changchun University

²Intelligent Machine Institute, Harbin University of Science and Technology
yyzou@126.com

Abstract

Money number recognition refers to the money of the currency, the currency and authenticity recognition. Money number recognition system is the kernel module of self-service system, and the major applied range is cash-related equipments. In this paper we design a kind of money number recognition system. The quick positioning of money number is achieved based on gray value accumulation. The edge line of money number area is detected using the least square method. Using geometrical rotation method and gray adjacent interpolation method to realize the number of tilt correction. Based on the character structure characteristic and the imaginary line and character of the point of intersection features, formation recognition judgment tree, realized the character recognition. The simulation experiment indicates that this algorithm has a high recognition accuracy under the condition of rejection.

Keywords: *the paper money, number recognition, recognition algorithm, imaging sensor*

1. Introduction

The serial number on the money is the Recognition of printing qualities, without repeating, so it can be used to identify the identity of money. While in China money circulation field, soft, old and residual paper money is more, the great amount of cash, foreign some money number Recognition product adaptability is bad, often fault practical application, and can't meet the requirements of the banking business[1]. So in recent years the domestic in the fields of study also more, such as shenyang university of research based on DSP money number Recognition system[2], Nanjing university of aeronautics and astronautics developed a based on single chip money number Recognition system[3]. Harbin industrial university developed using contact CIS image sensor for money number Recognition[1]. The main Recognition method is: using the BP network to carry on the character recognition[4], Template matching and neural network combination of character recognition method[5], Based on the moment and wavelet transform method for character recognition, etc[6]. This paper presents a character based on structure characteristics and imaginary lines and character of the point of intersection features, formation recognition judgment tree, realize the money character recognition.

2. Money Number Range Location

All printed material, including text, illustrations, and charts, must be kept within the parameters of the 8 15/16-inch (53.75 picas) column length and 5 15/16-inch (36 picas) column width. Please do not write or print outside of the column parameters. Margins are 1 5/16 of an inch on the sides (8 picas), 7/8 of an inch on the top (5.5 picas), and 1 3/16 of an inch on the bottom (7 picas).

Pinpoint of the money number zone is the key link of money character segmentation and extraction. In the pictures collected by CMOS imaging sensor, money number range only takes up a part, if pretreat, the whole picture and then identify, it has no pertinence, and the data is huge, also waste a lot of time. So if we can in the image preprocessing before determine the number range location, can reduce the amount of data processing, so as to improve the recognition speed number, and based on this, still can further accurate positioning out money the edge of the number. In view of these, this paper proposes a method based on pixel gray value accumulation method to money number range location, a large number of reduced to deal with image data.

Because money number range image background pixel gray value than its surrounding pixel gray value, the sensor output gray value data as a matrix G , then put on the same line of pixel gray value accumulation as the ordinate, can be in number range formation rock bottom, and in number range two edge form two mutation. Confirm the choppy location, the confirm the two horizontal edge, as the formula (1), the functin $S(i)$ means the summation of pixel gray value on line i .

$$S(i) = \sum_{j=0}^M G(i, j) \quad (1)$$

This paper selects the image range is 320 x 480 pixels, $S(i)$ function curve and capture images as shown in figure 1 shows, in rectangular coordinate system in x axis for I , ordinate for on the same line are all pixel gray value and. $S(i)$ curve has two rock bottom, the left bottom corresponding number range, the number and the edge of the gray value and have a mutation, determine the largest around mutation place i value, can determine the character level range.

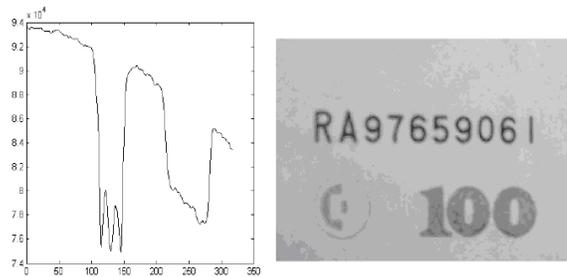


Figure 1. Intercepted Money Scope and Line Pixel Gray Value and Function

3. The spatial Filtering of Money Number Range

Because of CMOS image sensor itself exists the noise source, in the acquisition money image process, will be loaded into the image [7]. Furthermore, during the process of circulating, RMB can be inevitably polluted, these pollutant and the stochastic noise of CMOS may influence the result of character recognition, so, before the character recognition, we need to denoise the money, and it is the foundation character extraction.

The methods of denoising the diagram are linear smoothing, self-adaption smoothing and nonlinear smoothing, *etc.* Considering the advantages and disadvantages of all kinds of noise and the recognition algorithm needs, based on the median filtering method [8].

The window shape and size of two dimension median filtering have great influence on the effect of filtering, different picture material and application requirement always use different window shape and size. Figure 2 are respectively choose 3 by 3 square window, 3 by 3 cross

Windows, 1 x 3 linear window and 5 x 5 square window check the number code line on the effect of the filter. 5 x 5 square window after filtering character is more ambiguous, several other difference is not obvious, but after binarization, 3 by 3 square window, the window effect is better, both between basic no difference. The more data the window has, the larger the operand is. Can be calculated for the same image filtering 3 by 3 square window is about 3 by 3 cross window need 4 times of time, so this paper use 3 by 3 cross template filter.

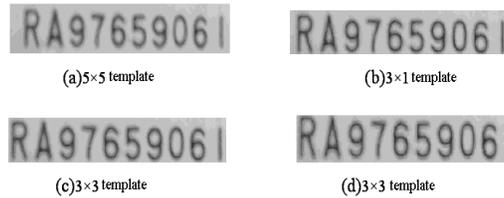


Figure 2. The Filtering Effects of Different Kinds of Masterplate

4. The Binarization Treatment of Money Image

Image binarization is to separate target gray level image from background by setting threshold. During the process of choosing the threshold, is the threshold is too low, the money number will be treated as background spot, and the number will be break, or even disappear; in the threshold is too high, the background and character will be linked together, and it is difficult to identify. In order to select a threshold automatically, this thesis attempts to use an iterative method. The steps are as follows.

- (1) Select an initial estimate for T (This thesis the intermediate value between the maximum luminance one and minimum luminance one in the bankmoney image).
- (2) Using the T -divided image. This will produce two groups of the pixel: the luminance value more than T consist of $G1$, while the luminance value less than T consist of $G2$.
- (3) Calculate the average luminance value μ_1 and μ_2 between $G1$ and $G2$.
- (4) Calculate a new threshold value:
- (5) Repeat steps (2) to step (4), until the difference of T in successive iterations is smaller than the pre-specified parameters T_0

This thesis selects $T_0=1$, after cruciform template filter by 3x3 square template and 3x3 cross-shaped, the original image is calculated iteratively, and the obtained threshold values are 160 and 159 respectively. The binarization effect by two template filtering respectively is shown in figure 3. Wherein (a) is a cross-shaped template, (b) is the effect after the square template binarization processing.

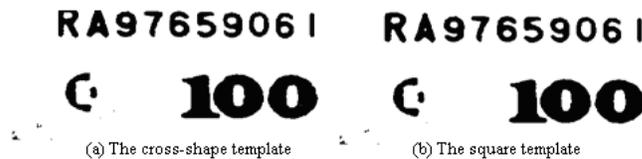


Figure 3. Binarized Image

5. Characters Segmentation

After positing the number range, you need to further extract a single character to identify bankmoney numbers. Whether the extracted character can keep all of the information of the

original character after number range accurate positioning, the key lies in character segmentation: if division range is too small, reserved character information will be less, which will be not easy to identify and even be misrecognized and rejected; if division range is too large, although the information of the original character is retained, its near character information will also be segmented in, interfering the characters to be identified, which also can lead to misrecognition and rejection.

As the Recognition object of this article is printed, the character spacing is large, noise is also smaller, thus a method which is similar to the vertical projection can be selected, with the imaginary vertical line. In a pixel for step length, move straight lines from left to right, and when the straight line and the character have no intersection point, it can be considered to be the dividing line between two characters. Use this method, until ten characters are segmented out. Character segmentation effect is shown in Figure 4.



Figure 4. Character Segmentation Effect

6. Character Recognition

After character segmentation, this paper uses a method combining character strokes of Chinese character characteristics, the structure characteristics knowledge and imaginary lines and character node characteristics to identify the bill number of the letters and numbers grouped.

6.1. Analysis of the Structural Characteristics of the Sharacter

This paper mainly uses the feature amount of the following two characters to identify all the characters:

(1) A combination of the number of times of the intersection of the imaginary straight line with the character dissimilarity. Straight translations in the article abide by the following rules: a horizontal line gradually pans down from the top of the character, the vertical line gradually pans right from the left end of the character, with step size of a pixel. The number of the point of intersection of the straight lines and the character is judged by the following method: when the straight line goes from the background range by characters and then comes back to the background range, it can be said that straight line intersects with the character once. Such as character "W", its maximum intersection number with the horizontal straight line is 4. The number of combinations of these intersections form a feature amount of the character.

(2) The strokes of the character features. Stroke of letters and numbers will be divided into two categories: straight strokes and arc strokes, of which arc strokes is divided into the open arcs strokes and closed arc strokes. The so-called open arc stroke refers to the strokes of the arc does not form a closed loop, such as a digital "1", while the stroke of the closed arc forms a closed loop, such as a digital "0". Straight stroke is divided into horizontal strokes and vertical stroke. When the imaginary line intersects with character contains the number of consecutive pixels is greater than a certain threshold value, it is determined that the character here is straight strokes. A continuous straight strokes is considered to be a straight strokes. Only the interval the straight strokes is considered different. The threshold character width

and height can be calculated by the segmentation of characters. The horizontal stroke and vertical stroke threshold respectively take four-fifths of the width and height.

This paper uses the following method to gradually classificcate letters and numbers to form an Recognition decision tree. Each character is a leaf.

(1) First, judged character to be recognized is a number or letter. According to the characteristics of the bill number, the first two characters are letters, and the latter eight characters are numbers.

(2) Then, search the number of the closed loop in the character image to be recognized.

(3) According to the search results to determine the classes which the characters of the closed loop belong to: single closed loop character class, dual closed loop character class and no closed loop character class.

(4) Process them respectively according to the searched class.

6.2A Character Classification

The search of closed loop is actually is the search connected domain in the character image.

(1) There are only two communications domain in the character image of the closed loop, i.e. characters connected domain and background communication domain, Figure 5 (a) in the B and F.

(2) There are four connected domains in the character image of the two closed loop, i.e., a character communication domain and three background communication domains, Figure 5 (b), B1, B2, B3, and F.

(3) There are three connected domain in a closed loop with only one character image, i.e., a character communication domain and two background connected domain, B1, B2, and F in Figure 5(c).

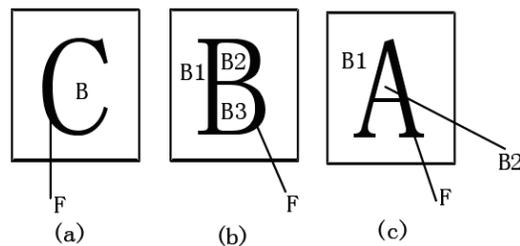


Figure 5. Characters Connected Domain in the Image

The search closed loop implementation steps are as follows:

- (1) Read the binary image.
- (2) Find a background pixels B with pixel gray level value "0".
- (3) Search the connected domain of B, and mark all the pixels in connectivity domain as background 1.
- (4) Traverse the pixel which image pixel gray value is "0".
- (5) When all the "0" pixels have been marked as background 1, the number of closed loop within the image is 0, then go to (11).
- (6) If there is "0" pixel B1 which has not been marked as Background 1, there is a closed loop.

(7) Search the connectivity domain of B1, and mark all the pixels in connectivity domain as background 2.

(8) Traverse the pixel which image pixel gray value is "0".

(9) If the all "0" pixels have been marked as a background 1 or background 2, the image number of closed loop is 1. Then jump to(11).

(10) If there is "0"pixel that has not been marked as background 1 or background 2, the number of closed loop within the image is (2).

(11) End of the search and return to a closed ring number.

6.3. The Secondary Classification of the Character

6.3.1. Closed Loop Characters

When the imaginary horizontal straight line of the character intersects the closed loop, there are three different gray values on a straight line, while when it intersect not closed ring straight line, there is only two gray values. So we can determine whether there is a closed loop somewhere through the number of dissimilarities on the line gray value here. Characters after the first classified change into three categories: closed ring in the upper, closed ring in the lower and closed ring in the middle.

The numbers or letters containing two closed rings can be directly identified as "8" or "B". When closed ring in the lower part, it can be identified as "6"; when it is in the middle, identified as "0"; when in the upper part, identified as "4" and "9". And then, according to the character on whether there is a cross strokes distinguish: cross strokes compared to "4", without cross strokes compared to "9."

Letters with single closed ring: "A", "D", "O", "P", "Q", and R". Letters with closed ring in the upper part: "A", "P" and "R": If no vertical stroke it can be identified as "A"; If there is vertical stroke, it can be identified as "P" or "R". Then make judgment through the intersection number of the horizontal line in the lower part of the closed loop with the character: if the maximum intersecting times is 2, it can be identified as "R"; otherwise, as "P". Letters with closed loop in the middle: "D", "O" and "Q": If there are vertical strokes, it can be identified as "D"; otherwise, "O" or "Q"; when its maximum intersection number with the vertical line is 3, it is identified as "Q"; otherwise, as "O".

6.3.2. No Closed Ring

No closed ring figures include "1", "2", "3", "5" and "7". "1" can be identified according to the vertical stroke; "7" can be recognized when the vertical strokes and characters maximum cross points is 2; "5" can be identified in the upper transverse strokes; horizontal strokes in the lower part can be identified as "2"; Otherwise, it can be identified as character 3. No closed ring letters: "C", "E", "F", "G", "H", "I", "J", "K", "L", "M", "N", "S", "T", "U", "V", "W", "X", "Y" and "Z." These characters can be divided into two categories by whether it contains the cross-strokes. The first category is: "E", "F", "H", "J", "L", "T", "W" and "Z". The second category is: "C", "I", "G", "K", "M", "S", "U", "V", "W", "X" and "Y".

For the first case, there are three transverse stroke for "E"; two transverse stroke for "F" or "Z", it can be distinguished as "F" or "Z" by whether it contains the vertical stroke; The one has one transverse stroke is "L", "T", "J" and "H". If the number of intersections of the straight line is up to 2, it can be identified as "H"; If the transverse stroke is in the lower part, it can be identified as "L", if the transverse stroke is in the upper portion of the character it can be "T"

or "J". And it can be further identified by the points intersected with the vertical line. If the point is up to 2, it can be "J"; or else, it is "T".

For the second case, the one with one vertical stroke is "K" or "I", and the one has the points intersected with the horizontal line up to 2 is "K", or else "I". And the one with two vertical strokes is "M" or "U". It can be identified by its maximum points intersected with the horizontal line. The one has 4 points can be "M", or else "U".

7. Recognition Results and Analysis

This thesis attempts to test sixty pieces of one hundred yuan, and the results are shown in Table 1. According to the test, there are some main reasons for the rejection of the Recognition: the tilt angle of the bill is too big; the pollution of the number range is serious; the number range does not exist actually, the characters are adhered when binarization because of the pollution. Recognition errors are mainly due to the serious contamination of the characters and disruption of the strokes, for example, C and G, J and T. In the case of rejection, the rate of the correct recognition of the bankmoney is 95.92%.

Table 1. Bill Number Recognition Results Tables

| money number | rejection number | correct recognition number | error recognition number |
|--------------|------------------|----------------------------|--------------------------|
| 60 | 11 | 47 | 2 |

8. Conclusion

This thesis attempts to provide a systematic analysis of the performance requirements in bill number recognition system and algorithmic principles, and put forward the proposed fast-positioning bankmoney number accumulation method based on the gray value; Using the iterative method to get the binarization threshold in the number range, and separate the character from the background in a better way; To find out the highest point of a single character in the traversing way, and fit a straight line by the minimum binary method and find the angle of inclination; to achieve the bankmoney number tilt correction by the geometric rotation and gray-neighbor interpolation method; Use the imaginative straight line and no points of the characters in number range as the the dividing line, and cut the single character successfully; Use the combination of the structure, features of the strokes and the imaginative points intersected to select the features of the characters in order to further identify the characters and achieve the rapid Recognition of the bill numbers.

References

- [1] C. N. Wu, "DSP-based Number recognition system and achieve based on DSP", Harbin Institute of Technology, (2004).
- [2] W. Q. Yuan and Y. Zhang, "A Fast Recognition System for Paper Currency Numbers", Computer Engineering, vol.31, no. 24.
- [3] L. Jianye, "Money number recognition system using the MCU", Industrial Control Computer, vol. 15, no. 1, (2002).
- [4] Z. B. Zhang, S. L. Ma and J. Ma, "Application of Wavelet and Neural Network on the Human Face Illumination Compensation", Journal of Jilin University (Science Edition), vol. 43, no. 2, (2004).

- [5] M. Wang, X. H. Huang, W. Wei, *et al.*, “A method of characters in vehicle number plate using pattern match and neural networks”, Journal of Huazhong University of Science and Technology (Nature Science), vol. 29, no. 3, **(2001)**.
- [6] H. L. Shen and Z. N. Li, “A study of number and letter character recognition based on moments and wavelet transform”, Journal of Image and Graphics, vol. 5A, no. 3, **(2000)**.
- [7] Z. Pei and C. M. Guo, “Noise Reduction Technology for Active-pixel Image Sensors”, Semiconductor Optoelectronics, vol.23, no.6.
- [8] D. Wang and S. Zhang, “Application of CCD and Image Technique in the Blade Edge Measurement”, Metrology and Measurement Technique, **(2002)**, no.2.