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Coin Recognition Based on Image Correction and Template Matching

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Abstract: In order to improve the identification efficiency of coins, a coin identification method based on image rectification and template matching is put forward. Firstly, the image of coins is separated from the whole image through background modeling; secondly, according to Fourier transform or Shape features, the image of coins which has been separated is corrected. Lastly, the coins are identified through the template matching aiming at the corrected image. Experimental results show that the proposed method is characterized by high accuracy, strong anti-interference ability and high identification efficiency.

Keywords: Background modeling, image correction, template matching, Coin recognition

I. INTRODUCTION

Coins have advantages of convenient transaction, easy carrying and wear resistance. However, counting coins by hands has a disadvantage of massive labor intensity. In order to improve the efficiency of coin counting, how to automatically count the coins has become a major research target in recent years. Common methods include eddy current testing and image detection. The current mainstream coin detection method is eddy current testing which is based on electromagnetic induction, but it is affected greatly by working environment. The image detection depends on the merits of hardware and algorithm. Compared with the eddy current testing, the image detection is not easy to be affected by the environment.

Mao *et al*. [1] proposed a method of coin recognition algorithm which is based on neural networks. The method trains samples by grasping the invariant moment features of coins to achieve the purpose of identifying coins. However, the accuracy of the identification network is limited by the number of learning samples. Bi *et al*. [2] proposed a method of coin recognition algorithm which is based on ant colony algorithm. The method identifies the coins through cluster analysis based on six feature functions and ant colony algorithm. However, the calculation is large and the efficiency is low. Fu *et al*. [3] proposed a method of coin recognition algorithm based on the histogram of coin images and the shape of coins. However, the former is extremely susceptible to light, whereas the latter can't identify coins.

In order to improve the efficiency and accuracy of coin recognition, taking template matching as the core of coin feature recognition, the accuracy of coin identification is guaranteed by image segmentation which eliminates irrelevant points from the coin image. Furthermore, the direction of the coin's rotation is unified using image correction, which makes coin recognition easier. The experimental results also verify the effectiveness of the proposed method.

II. IMAGE SEGMENTATION OF COINS BASED ON BACKGROUND MODELING

Because the image acquisition environment is different, each image will be affected by different light and noise. If a coin is identified directly, the computation is not only large, but also the recognition results will be disturbed by uneven illumination and noise. The segmentation of coin images by background modeling not only avoids the influence of noise and illumination on coin images, but also eliminates the calculation of irrelevant elements.

2.1 Basic Principle of Background Modeling

Background modeling [4] is often used in object detection, and its basic idea is to detect the foreground image by the background modeling of images. Once the background model is established, the current image is compared with the background model, and the foreground target is determined according to the comparison

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results. The advantage is that the target is not easily lost. The disadvantage is that object shadows can easily be misjudged to be the target.

Because of the acquisition equipment and other reasons, static background modeling method is adopted in this paper, that is, the first few images are taken as the background, and then the background is updated according to the situation.

$$G(x, y) = \left| f(x, y) - I(x, y) \right| \tag{1}$$

where $G(x, y)$ is the gray value of (x, y) point of a foreground image. $f(x, y)$ is the gray value of (x, y) point of a current image. $I(x, y)$ is the gray value of (x, y) point of a background image.

2.2 Connected Region Analysis

The binarized coin image still has a pile of tiny discrete points, which results in the inability to segment the coin. Therefore, it is necessary to remove the discrete points by means of connected region analysis so as to retain the target points.

The common connected region analysis methods include Two-Pass method and seed filling method. The basic idea of seed filling is to take the frontier points as the seed points in the foreground image. If an adjacent point of a seed point is also a point in the foreground image, the two points are marked for a region and taking this point as the seed point to continue to examine its neighboring points. In this paper, eight neighborhood seed filling method is adopted.

III. COIN IMAGE CORRECTION

Although the original coin image has been split into separate images after the background modeling, each individual coin image has different angle error and position error, which is difficult for coin recognition. So it is necessary to carry out image correction.

3.1 Image Correction Based on Fast Fourier Transform

Fourier transform [5] is to change the signal from time domain to frequency domain, and then study the spectrum structure and change regulation of signal. But there is no time domain in the image, so the Fourier transform in image processing is to transform the spatial domain into frequency domain.

Fourier transform formula is as follows:

$$F(u,v) = \frac{1}{N} \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x, y) \exp[-j2\pi(ux + vy) / N] \tag{2}$$

where $F(u, v)$ is the frequency domain signal at u and v frequencies after Fast Fourier Transform. $f(x, y)$ is the gray value of (x, y) point of an image. N is the width and length of an image.

In the Fourier transform, the frequency represents the speed of the gray change of an image, so the noise and the edge belong to the high frequency signal, and the main part of the image belongs to the low frequency signal.

The correction of coin images mainly uses the characteristics of numbers and letters. They have directionality in the low frequency signals of the spectrum. By Fourier transform, the rotation angles of numbers and letters can be obtained.

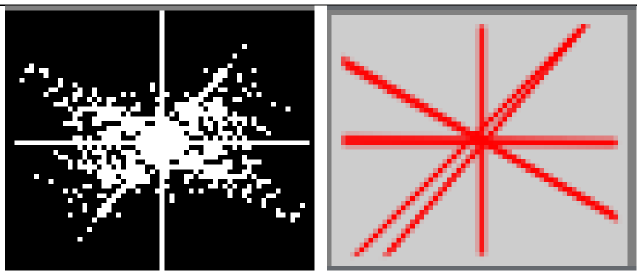

Fig 1: Fourier transformed images

The correction process is as follows: firstly, the central image of coins is selected, and the spectrogram is obtained after Fourier transform. Secondly, a high amplitude signal graph is obtained by threshold processing. Finally, the suspected rotating line is detected by Hof line detection.

The straight line drawn in Figure 1 has 5 bars besides the coordinate axis, which needs to be further screened to obtain a true rotation line. The straight line Hof transform is used to vote for the highest straight line passing through the origin. Finally, the corrected image is obtained by rotation transformation. The yellow line in Figure 2 is the selected rotating line.

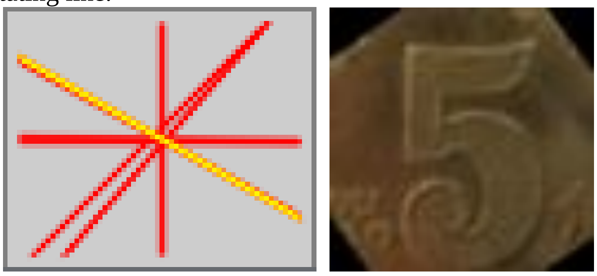

Fig 2: Fourier corrected images

The advantage of Fourier transform in image correction is that it is almost unaffected by illumination. Furthermore, it is characterize by small errors and wide range of applications. Its disadvantage is that the corrected image obtained from the rotating line may be corrected in different directions.

3.2 Image Correction Based on Shape

Image correction based on shape is mainly based on the outline of digits in the coin. First, edge detection is needed to obtain a rough outline. Then, the rotation angle is determined according to the contour feature to obtain the corrected image.

Fig.3: Corrected images based on shape

In Fig 3, the noise of the original image is removed through Gauss filter. Secondly, the image contour is obtained through edge detection [6].Then, only the lines on both sides of the number 1 are detected according to the rotation principle of the lines on both sides of number 1 in the coin. Finally, rotate the lines which are screened and meet the conditions to obtain the corrected images.

Image correction based on shape has advantages of a smaller error, strong anti noise and not being affected by light intensity. But the correction must obtain different shape features from different types of coins. The quality of the correction also depends on whether the captured features are distinct.

3.3 Image Correction Based on Projection Histogram

Although the above two correction methods can effectively correct the coin front image with digits, it is difficult to correct the coin reverse image with complicated texture. Therefore, a coin image correction method based on projection histogram is proposed in this paper.

The image correction based on projection histogram is completed mainly according to the letters and Chinese characters around the coin center. First of all, select letters and Chinese characters around coin core through edge detection as shown in Fig 4. Secondly, project the letters and Chinese characters on the X axis to obtain the histogram. Finally, the histogram is analyzed to achieve the coin rotation angle.

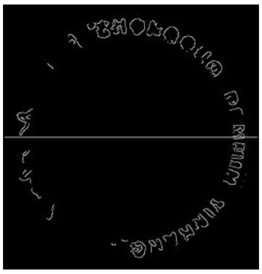

Fig 4: Letters and numbers after edge detection

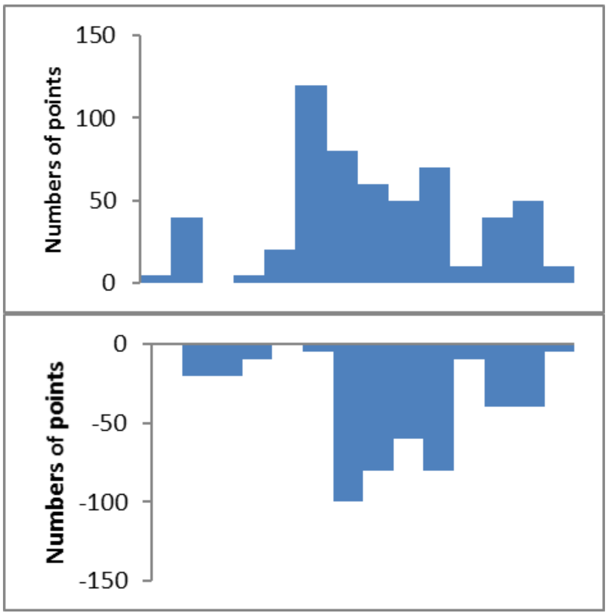

Fig 5: Projection histogram of *x*-axis

Fig 5 is a histogram by projecting the numbers and letters on X axis. Fig 5 is divided into projection histogram of positive number and negative number. The positive projection histogram only records the number of white spots above the *x* axis and is marked as positive. Negative projection histogram only records the number of white spots below the *x* axis and is marked as negative.

From Fig 5, it can be seen that the points are mainly concentrated in the right half. From counterclockwise, the rotation direction of the points is from the lower right part of the peak, goes through several troughs and low peaks and reaches the upper middle of the peak before the end. The rotation direction of the coin illustrates the rotation process of the coin. By the rotation direction of the points and the end position of the peak, the rotation angle of a coin can be calculated as

$$\theta = \arccos(\frac{t-a}{R}) - \theta_0 \tag{3}$$

where t is the end position of the peak, a is the abscissa of an image's centre, R is the radius of the coin and θ_0 is the offset angle. Because the corrected image has an inclination error, an offset angle should be subtracted. θ is the actual rotating angle of the coin.

Table1: Comparison of accuracy for different correction methods

Methods	Fourier	Shape	Projection
Accuracy	0.88	0.94	0.99
Error of angle	±2°	±1°	±4°

Table 1 gives the correct comparison of different correction method. From the table, it can be seen that the correct rate of image correction based on projection histogram is higher than the other two methods; however the correction error is larger. The maximum angle error allowed in the template matching is 7°, and the method is within the acceptable error range.

IV. FEATURE RECOGNITION BASED ON TEMPLATE MATCHING

Template matching is the most important part of coin recognition, and the recognition accuracy will be affected by image correction and segmentation. But the effect of template matching will be directly related to the quality of recognition and the length of time. In order to improve the efficiency of the recognition method, template matching is applied in this paper.

Template matching of coins [7] needs to be considered from two aspects of accuracy and calculation. In terms of accuracy, the normalized correlation coefficient matching method is chosen. The similarity of normalized correlation coefficient matching method is

$$R(x,y) = \frac{\sum_{x'=0}^{m-1}\sum_{y'=0}^{n-1}(T'(x',y')\cdot I'(x+x',y+y'))}{\sqrt{\sum_{x'=0}^{m-1}\sum_{y'=0}^{n-1}T'(x',y')^2 \cdot \sum_{x'=0}^{m-1}\sum_{y'=0}^{n-1}I'(x+x',y+y')}} \tag{4}$$

$$T'(x',y') = T(x',y') - 1/(m\cdot n)\sum_{x''=0}^{m-1}\sum_{y''=0}^{n-1}T(x'',y'') \tag{5}$$

$$I'(x+x',y+y') = I(x+x',y+y') - 1/(m\cdot n)\sum_{x''=0}^{m-1}\sum_{y''=0}^{n-1}I(x+x'',y+y'') \tag{6}$$

where $T(x, y)$ is the gray value of template image's point (x, y), $I(x, y)$ is the gray value of input image's point (x, y), m and n represent the length and width of the template image, respectively, and $R(x, y)$ is the similarity of the input image's point (x, y).

The reason why normalized correlation coefficient matching method can accurately describe the correlation between the template image and the input image is that it applies statistical correlation coefficients. The correlation coefficients is

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}} \tag{7}$$

namely

$$r = \frac{Cov(x,y)}{\sqrt{D(x)}\sqrt{D(y)}} \tag{8}$$

where $Cov(x, y)$ is covariance for variables x and y, $D(x)$ and $D(y)$ are respectively variance of variable x and variable y and r is the correlation coefficient.

On the other hand, an optimization algorithm for local feature template matching is considered in terms of calculation quantity.

Regular template matching requires nearly tens of millions iterative matches to complete and it takes nearly a second, which is totally unsatisfied for industrial coin detection. Therefore, on the premise of guaranteeing accuracy, the strategies of hierarchical search and local feature matching are adopted.

The process of hierarchical search strategy is: First of all, it starts matching from the top of the small size image to get some regions with high degree of similarity. Then, from the next layer, it matches these high similarity regions to get some regions with higher degree of similarity. Finally, the process repeats itself to match the original image. The essence of hierarchical search is also a first-rough-then-precise process, which avoids matching some regions with low correlation.

In fact, template matching is very sensitive to deformation, rotation, size and so on. Although hierarchical search reduces the calculations to some extent, it also lays a lot of hidden dangers at the same time. Therefore, it is necessary to select a number of stable and undeformable local features instead of global features for template matching. Fig 6 gives a template and its matching result.

Fig.6: Template matching result

V. EXPERIMENTAL RESULTS AND ANALYSIS

The steps for identifying multiple coins are as follows: (1) separate multiple coins from a background image; (2) correct a single coin image; (3) identify coins.

In order to segment coins from the background image, a background modeling method is adopted. The segmented image is analyzed by the connected region, and the number of coins can be calculated without error.

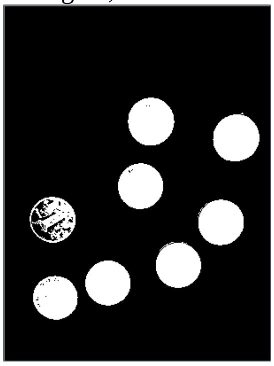

Fig 7: Coins are split from background

After correcting the segmented coin images, these images are recognized by template matching.

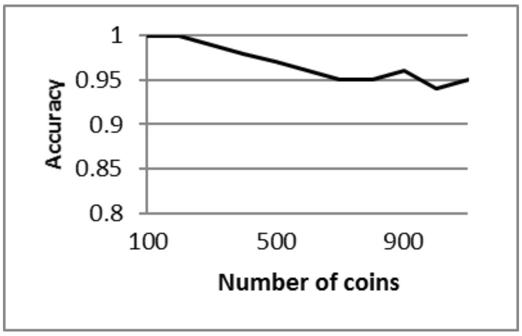

Fig 8: Relationship between accuracy and number of coins

In order to improve the accuracy rate, a template library which is composed of several templates is selected. As seen in Fig 5, the correct rate of coin recognition is stable at 95%.

VI. CONCLUSION

In order to solve the problem of low efficiency of traditional coin recognition, a coin recognition method based on image correction and template matching is proposed in this paper, which can effectively improve the accuracy of coin recognition and reduce the execution time of traditional coin recognition algorithm. This paper firstly introduces the basic principle of image segmentation based on background modeling, and then describes the principle of image correction methods, and the advantages and disadvantages of each method. Finally a new template matching algorithm is put forward. The experimental result verify the validity of the proposed coin recognition method.

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