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An Effective Method of 1-D Bar Code Image Identification*

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***Abstract*—This paper proposes a new approach to achieve angle correction for images with arbitrary rotated bar code. A new projection curve based bar code reading method and a new global and local based Euclidean distance decoding algorithm are proposed. The proposed method is effective for identifying bar code images which are low-resolution, non-uniform illuminated, photographed remotely, noisy or slightly blurry, and it is especially suitable for recognizing low-resolution, severely noisy, and small-scale bar code image. Also, this method has the virtue of real-time, robustness and high recognition rate, etc. Experimental results using some international UPC-A bar code library show that the proposed algorithm delivers substantial improvements when compared with some latest methods.**

***Index Terms*—bar code image; Radon transformation; projection curve;**

I. INTRODUCTION

With the advancement in economy, science and technology, people's consuming attitudes are changing quickly. It will bring buyers great convenience if they are able to keep abreast of the authenticity and sale price of the merchandise and relevant information. However, current identification of bar code mainly uses bar code scanning devices, and the laser readers used commonly are expensive and inconvenient to carry. Therefore, we hope to use our cell phones or other electronic devices with camera to take pictures of the bar code on merchandise, and then obtain the relevant information about the merchandise from the Internet through mobile network or wireless network. This requires the recognition of bar code image to apply the knowledge related to computer vision field. Unfortunately, because the conditions are not good while we take a picture of bar code images using cameras in current cell phones or other electronic devices, bar code images are usually low-resolution, severely noisy, and with poor quality, which bring us a great deal of difficulty in identification.

Based on the one-dimensional bar code image recognition method, many scholars have made lots of intensive studies and proposed a lot of approaches, which have made great contributions to the 1-D bar code image identification. Most of the early methods focus on the precise localization of stripe edges. For example, first-order differential equation method [1], Fourier transform method [2], and so on. However, it is difficult to precisely localize the edge of each stripe, when the bar code image is severely affected by noise and the stripe edges which are often superimposed on each other. A method is proposed in [3] that firstly processes the image using adaptive binarization method, and then uses most similar approach for template matching method, based on the standardized bar code. Kresic-Juric and others [4] firstly find possible edge values by derivation of the gray value along the scanning line, and then use Hidden Markov Model for decoding. Although this method is only used in laser scanners, it works rather well. Tekin and Coughlan [5] proposed a method that uses Bayesian model for bar code image identification, and does not require precise localization of strike edges. They proposed variable strike based model, and used Bayesian framework to solve the above problem. Gallo and Manduchi [6] proposed a new bar code recognition algorithm, which identifies bar code image based on grayscale images and variable template. With high recognition rate, this algorithm have made great contributions to the improvement of strike identification algorithm. However, this approach requires accurate localization of the front and rear edges of the bar code, and it could not identify correctly if the localization of the edges are inaccuracy.

In this paper, we propose a new bar code identification approach that can be used to identify bar code image taken from mobile phones or other terminal electronic devices. Since our approach does not require the image binarization processing or the edges localization, it has high recognition rate for bar code images which are low-resolution, severely noisy, non-uniform illuminated, photographed remotely, or blurry slightly. Finally, we do experiments using some international public bar code libraries, and compare them with some commercial software and the latest proposed research methods.

II. THE ALGORITHM FOR ALIGNING ANGLE OF BAR CODE

To increase flexibility of taking photos, this paper presents a new method for recognizing bar code taken from different angles, which is based on Radon Transformation. Radon Transformation is the line integral of some function $f(x, y)$ along a set of lines from plane that contains the function. It

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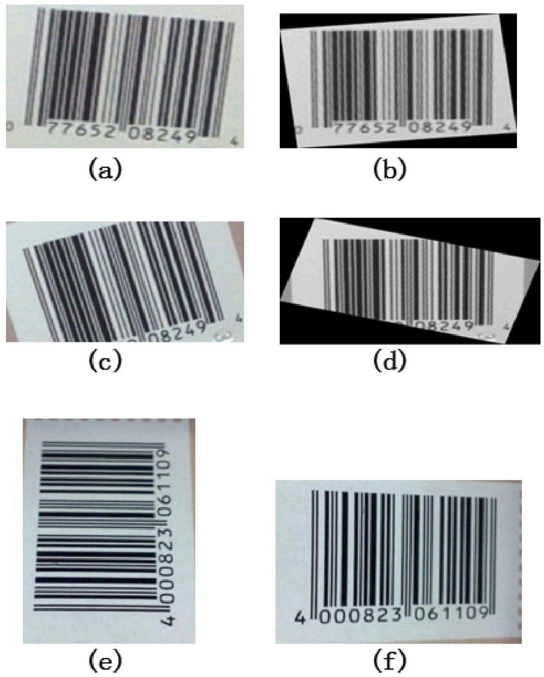

Fig. 1. Images (a) (c) (e) are the original images, and (b) (d) (f) are those after Radon transform and angle correction.

is defined as follows.

$$R_\theta(x') = \int_{-\infty}^{+\infty} f(x'\cos\theta - y'\sin\theta, x'\sin\theta - y'\cos\theta)dy', \quad (1)$$

where

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}.$$

Actually, when $f(x, y)$ represents an image matrix, the result of Radon transform is the projection of the image matrix along arbitrary direction θ.

Note that there exist a lot of marginal points along different vertical directions of bar code, since a bar code image consists of a series of black stripes and white stripes. Firstly, Radon transform is applied to get projection of the image from different angles; then difference values of projection data are calculated. The direction with the maximum difference value is the vertical direction. Finally, rotation operation is applied to correct the image. The images in Fig. 1 show examples of bar code images which are taken from different angles.

III. The Identification Method Based on Bar Code Projection Curve

A. Bar code projection

We calculate the mean of the bar code over the vertical direction which is so-called bar code projection [7]. We can not only solve the identification problems due to low resolution or blur of the bar code which is unsolvable by binarization method, but also decrease the influence of noise on bar code identification effectively by vertical projection. The gray value curve chart after using the bar code projection method is shown in Fig. 2. It can be seen that extreme points of the curve locate somewhere near the intermediate position of the stripes of the bar code. Thus we can roughly localize the intermediate position of the stripes by vertical projections over the bar code image.

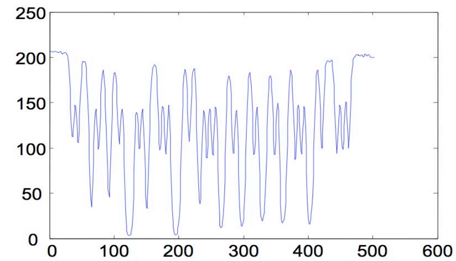

Fig. 2. Bar code projection curve.

B. Localization of extreme point at the endpoint

In this proposed algorithm, all of the extreme points are localized firstly. Then the location of entire bar code is discovered by localizing the first and the last extreme points whose gray values are much smaller than left and right preserved region.

The extreme points extracted from bar code curve can be defined as $e = (e_1, e_2, ..., e_l, ..., e_r, ..., e_n)$, and $L(i)$ denotes the gray value at i-th extreme point. These points are processed literately. If the gray value of one extreme point is smaller than 0.85 times of the mean of extreme points from itself to the λ-th point on the left of it, it is regarded as the first extreme point, or endpoint, in bar code area (λ is always from 10 to 15). The other endpoint can be localized in the similar way from right to left. The mathematical formulation is defined as following [6](2)(3):

$$e_l : L(e_l) < 0.85 \frac{\sum_{i=e_l-\lambda}^{e_l-1} L(i)}{\lambda}, \quad (2)$$

$$e_r : L(e_r) < 0.85 \frac{\sum_{i=e_r+\lambda}^{e_r+1} L(i)}{\lambda}. \quad (3)$$

This algorithm can help us localize the first and last extreme points. Other 57 extreme points in bar code projection curve can be localized after that. The algorithm aims to eliminate the interference of noise in preserved region and localize 59 extreme points accurately. The accuracy of extreme point localization depends on the precision of endpoint's location. The identification error is always resulted by extreme point localization error. So it is decisive for the performance and stability of entire bar code identification system.

C. Analysis of the bar code projection curve

The location between the white stripes and black stripes can be obtained through processing the bar code projection

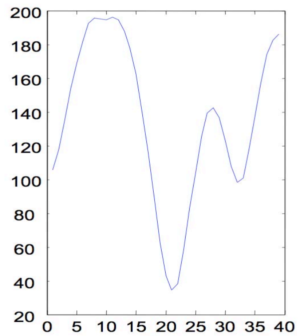

Fig. 3. Bar code character curve.

curve. Even though the obtained bar code image is blurred, the extreme point of the projection curve still lies in the location between the white stripe and black stripe, while it has the problem that the variation of the values in the projection curve is small, since the contrast of the blurred images is smaller compared to the clear images. That is the reason why the method mentioned above is steady. It is hard to localize the edges of the stripes in the image accurately. As shown in Fig. 2, there are cases that the values of the pixels lie within a certain range which help to identify the character of bar code. For example, as showed in Fig. 3, the ratio of the widths of the stripes is close to 3:2:1:1 in consideration to the area between the two horizontal lines. This ratio corresponds to the character 0. Hence, the identification of the bar code character can be realized by localizing interval of edge values in the bar code projection curve.

D. Localization of edge pixel regions for bar code image

In this paper, there are two steps to localize the edge pixel regions of bar code image. The first step is the preliminary localization of bar code image's edge pixels regions, and the second step is the accurate localization.

(1) Preliminary localization of edge pixels regions of bar code image

According to the knowledge of bar code image's edge pixels, the edge pixel regions must locate in the area which consists of all extreme points. Assume that $e = (e_1, e_2, e_3, e_4, e_5, e_6)$ represents 6 extreme points in Fig. 3, where $e_{\min} = (e_1, e_3, e_5)$ denotes 3 local minimum points, and $e_{\max} = (e_2, e_4, e_6)$ denotes 3 local maximum points. Let e_R represent the edge pixel region we want to know, and the e_R has to match all of the following conditions, as shown in (4),

$$e_{low} = \max(e_{\min}), e_{high} = \min(e_{\max}), \quad e_{low} < e_R < e_{high}, \tag{4}$$

where e_{low} represents the minimum of all the local minimum points, and e_{high} represents the maximum of all the local maximum points. By further study of the bar code curve chart, we can learn that the edge pixel regions must be localized in the area between each pair of adjacent local minimum and maximum points. So we can use the following way to make further localization of the region. Firstly, the pixel values between the adjacent minimum and maximum are sorted in ascending order, and the mean value(can be called low mean for convenience) of the first 50 percent pixel values in the sorted sequence can be denoted by u_b and the mean value(can be called high mean for convenience) of the last 50 percent can be denoted by u_w. Pixels whose values are smaller than u_b, are considered to belong to black stripe, and pixels whose values are larger than u_w, are considered to belong to white stripe. The variance is denoted as σ^2. Assume that $u_b = (u_{b1}, u_{b2}, u_{b3}, u_{b4}, u_{b5})$ denotes the 5 low means and $u_w = (u_{w1}, u_{w2}, u_{w3}, u_{w4}, u_{w5})$ denotes the 5 high means mentioned above. The minimum of the u_w can be denoted by $u_{w\min}$, and the maximum in u_b whose value is less than $u_{w\min}$ is denoted as $u_{b\max}$. In the end, we can obtain the preliminary localized region e_R, in the form (5) as follows,

$$\max(u_{b\max}, e_{low}) < e_R < \min(u_{w\min}, e_{high}). \tag{5}$$

(2) Accurate localization of edge pixel regions for bar code image

Bar code image's edges are the regions where pixel values increase or decrease greatly. Hence, in this paper, further localization of the edge pixel region is made firstly in the gradient domain of the bar code image. In the beginning, we do difference operation for the image, which is shown in (6) as follows,

$$Diff\_im(i) = im(i+1) - im(i-1), \quad 2 \le i \le n-1, \tag{6}$$

where im denotes the gray value of bar code image which is between adjacent maximum point and minimum point, and $Diff\_im$ denotes the gray value of bar code image which is obtained after difference operation.

By converting the bar code image from the gray value domain to the difference value domain, we can calculate the probability of a pixel value that belongs to the marginal pixel values using (7),

$$P\_Diff\_im(i) = Diff\_im(i)/\max(Diff\_im), \tag{7}$$

where $\max$ is a function used for calculating the maximum value of the difference values, and P_Diff_im is the probability of a pixel value that belongs to the marginal pixel values.

After that, by setting the threshold value λ, we can let all values of P_Diff_im which are larger than λ be the marginal pixel values.

Finally, the minimum and maximum of all marginal pixels which not only meet the initial localization but also meet the marginal differential value, serve as the range of marginal pixels of the stripe.

After we follow the above methods, the width of white stripes and black stripes in the bar code image can be computed using the pixel values of the marginal regions.

IV. The Euclidean distance algorithm based on local and global information

Conventional decoding methods(for example: the width measurement method, the similar edge distance measurement method, etc.), which are simple and quick in calculation, are relatively accurate for clear bar code. However, for some bar code images which are low-resolution, blurry or with inclination angle changing during shooting, certain errors do exist between the real width of bar code stripes and their theoretical values, which result to dissatisfactory identification rate. For these reasons, we propose an Euclidean distance algorithm based on local and global information.

Assume the width of the black and white stripes of the digit character to be decoded is denoted as the vector. The testing bar code encoding vector is $A = (a_1, a_2, a_3, a_4)$, and the standard bar code encoding vector is $R = (r_1, r_2, r_3, r_4)$. We define

$$d(A, R) = \sqrt{\sum_{i=1}^{4} (a_i - r_i)^2} + \lambda \sqrt{\sum_{i=1}^{3} (\sum_{j=i}^{i+1} (a_j - r_j))^2}, \quad (8)$$

where the first part of (8) is mainly based on global Euclidean distance algorithm, which calculates the Euclidean distance between the digit character identified and the standard template. The latter part of (8) is mainly based on local Euclidean distance algorithm, which maps stripes to template with the principle of similar edge distance measurement method. λ is the balance factor which we can adjust the proportion of the global and local approach in the overall process. Using this approach, the correctness of this decoding method is highly enhanced, for the error is greatly compensated.

V. Evaluation of bar code image identification method

In order to assess performance of the bar code identification algorithm which we designed, we need to use some bar code test sets to test our method. Two international bar code libraries have been used in our experiment. The first one is created by Tekin and Coughlan [8]. This bar code library mainly contains 79 UPC-A product bar code images, where some are taken by Nokia N95, some are taken by Nikon Coolpix 4300, and others are obtained from the Internet. All of these 79 bar code images are cut up from the product manually. The founders put these 79 bar codes into two kinds: Clean and Hard. The Clean library contains 44 bar code images, which consist of different resolutions, distortion, non-uniform illumination and small-scale bar code images. While the Hard library has 35 blurred bar code images. Another bar code library was founded by Gallo and Manduchi, which is based on the first library, and another kind of set of bar code images is added [9]. The first set of this library has 62 bar code images taken by Nokia N95, whose resolutions are 1024*768. This set contains bar code images which are motion blurry or focused. The second set of bar code images contains 10 high compressed bar code images, whose resolutions are 640*480. The last set of bar code images has 20 images whose resolutions are 1152*864, and are taken by Nokia 7610. The images in this set are mostly blurred.

Based on the results of our experiments, the algorithm we designed has great practicality and high identification rate. Our algorithm is successful to recognize low resolutions and

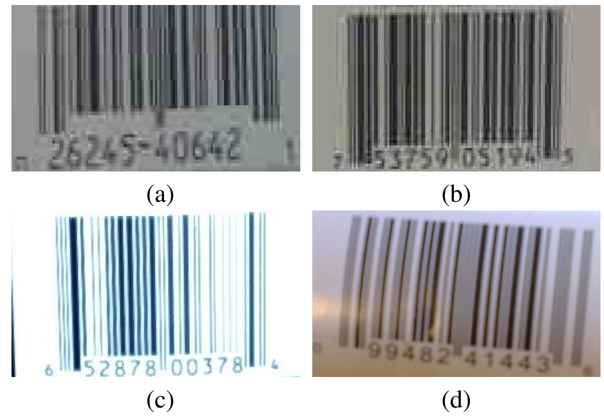

Fig. 4. Examples of four types of bar code image. (a) Low resolutions bar code image. (b) Small-scale bar code image. (c) Bar code image which has overexposed areas. (d) Blurred bar code image.

severely noisy bar code image, as shown in Fig. 4 (a), small-scale bar code images as shown in Fig. 4 (b), regionally overexposed bar code images as shown in Fig. 4 (c), and blurred ones as shown in Fig. 4 (d).

In this paper, we compared our bar code recognition algorithm with those mentioned in [5] and [6], and four commercial software – DataSymbol, DTK, QualitySoft and bcTester, by using the bar code library founded by Tekin and Coughlan. Moreover, we also compared our algorithm with those mentioned in [6] and two commercial software ł-DateSymbol and DTK, by using the bar code library founded by Gallo and Manduchi. All the experiment results on above test set are shown in Fig. 5.

Fig. 5 clarifies the conclusion that in all sets of bar code images, our algorithm is better than other algorithms when processing bar code images that are not very blurred. But when processing the Hard set and the last set of bar code images, our algorithm is not as good as those mentioned in [6], but is better than other algorithms.

VI. Summary and expectation

In this paper, focusing on the problems occurred in bar code images, such as noise, non-uniform illumination, blur, etc., we propose an identification approach based on bar code projection curve. To decode the bar code, we propose a decoding method based on global and local bar code. Finally, experiment results show that our proposed approach has high recognition rate. However, our algorithm is weak to recognize heavily blurry bar code images. Therefore, more works are needed for improvement.

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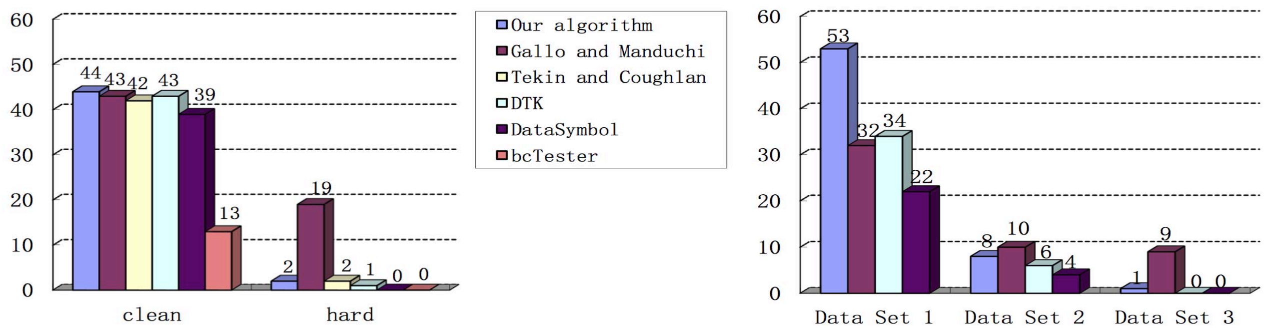

(a) (b)

Fig. 5. Experimental results.

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