International Conference on Information Science and Technology
March 26-28, 2011 Nanjing, Jiangsu, China

QR Code Recognition Based On Image Processing

Yunhua Gu , Weixiang Zhang

***Abstract*— To solve the QR code recognition problem caused by ordinary camera collection, the recognition algorithm based on image processing is put forward in this paper. The whole process including image binarization, image tilt correction, image orientation, image geometric correction and image normalization allows images collected on different illumination conditions, different acquisition angles to be quickly identified. Based on other recognition algorithm, some improvements are presented in the image tilt correction, image orientation, image normalization and so on to speed up the image processing and to achieve more simply. Experiments show that the improved method can enhance the recognition speed of two-dimensional code and accuracy.**

I. INTRODUCTION

On the basis of computer technology and information technology, bar code technology composed by encoding, printing, identification, data acquisition and processing is booming [1]. Compared with bar code, two-dimensional code has significant outstanding advantages in the data capacity, data types, data density and data recovery capability. According to the realization principle, structure and shape differences, two-dimensional code can be divided into linear barcodes and matrix barcodes. And the main application is in logistics management, catering orders, security applications, ticketing system, authentication, business transactions, etc [2~5].

Quick Response Code (QR Code) is one kind of two-dimensional matrix code developed by the Japanese Denso company in September 1994. In addition to the advantages of two-dimensional bar code, it also has features such as ultra-fast response, comprehensive reading, the portable offline application database, more efficiently representation on numbers of letters, characters, images, etc[5]. QR Code increased by 20% than the other two-dimensional bar code on efficiency of the characters representation, its proprietary Chinese model is more suitable for our application.

In practical applications, barcode reading technology will encounter the following difficulties. (1) Together with much of information that is nothing to do with the bar code, the bar code symbols are printed on the packaging of commodities. The condition results in a complex barcode image background. (2) Changes in illumination, resulting in uneven image brightness, increase the difficulty of identification. (3) Acquisition in different angles and distances, coupled with the geometric distortion and flat distortion caused by image capture device, the image of the QR codes will be rotated, zoomed and stretched. To solve the problems above, two-dimensional code image should have a series of image processing before adopting national standards for rapid response code decoding algorithm [6].

Manuscript received January 20, 2011.
Yunhua Gu is with Nanjing University of Information Science and Technology, 219 Ningliu Road, Nanjing China.(phone: 86-25-58731480; fax: 86-25-58731480; e-mail: yhgu@nuist.edu.cn)
Weixiang Zhang is with Nanjing University of Information Science and Technology, 219 Ningliu Road, Nanjing China.(phone: 86-25-58731480; e-mail: zwxscience@163.com)

II. RECOGNITION BASED ON IMAGE PROCESSING

The algorithm for QR code recognition process based on image processing is showed in fig. 1.

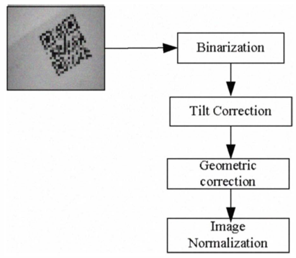

Fig. 1. Recognition Process

A. *Image binarization*

For more practical sense, image acquisition uses a general chat camera and apply camera control program for image acquisition under the intake image pattern. Images collected are converted to grayscale format by gray-scale processing. A good binarization method takes a very important role in the entire bar code identification system. The reference [7] points out that Niblack method is the best method comparing a variety of local threshold algorithm. But it is very difficult to set an appropriate window size on the way, has great influence on the modules, and also takes too much time. The reference [8] used a block thresholds method combined SOM neural network with the Niblack algorithm for binarization. The reference [9] proposes a binarization method based on surface fitting technology using two-dimensional second-order polynomial fitting way to make the QR code background image of the surface fitting, and image segmentation. This method requires that the number of points should be two to three times than the matrix structure and the amount of image fitting in the image segmentation process of the background also need to be determined when selecting the Fitting samples for the image. The reference [10] advises to judge the light intensity by calculating the histogram of gray image bar code, removing noise by median filter and analyzing the peak feature of the histogram. In summary, we choose the global threshold method (OTSU method) in ordinary light condition while a local threshold method (adaptive threshold) is used in the uneven light condition.

B. Tilt correction

When the image is being scanned, the position of QR code often occurs tilt and it needs rotating operation for correction. Researches have been done on this problem. the reference [10] proposed algorithm that hollows out internal points of the bar code, then gets the edge information and peaks and slope detection of bar code with Hough transform over a known point. The references [11] and [12] look for position detection patterns before decoding by using opening operation and closing operation in morphological image processing. The reference [13] uses OTSU method for binarization, extracts edge of QR code via gradient method and uses the Hough transform to locate after decreasing image resolution. However, the recognition rate of these two methods is not high. The reference [14] proposes a quick location method for the QR code symbol using one-dimensional pattern match based on the specific mode of the position detection patterns of the code, and then by Hough transform applied on the edge points of the code, 4 edge lines and 4 vertices are calculated, at last the control-point transform and spatial bilinear interpolation arithmetic are conducted on the code image according to the 4 vertices consisting a square. The reference [15] uses Hough transform, sobel operator to locate the bar code symbol, and then uses space transformation to correct image distortion. However, the boundaries of QR code are not continuous, large errors are made by using of Hough transform positioning. Based on the constraints set by two-dimensional bar code image feature, the reference [16] draws the concept of convex hull in computational geometry into locating bar code through in case of Data Matrix. This algorithm can locate two-dimensional bar code effectively under the distorted or tilted situation.

These methods above can be used to implement image positioning, however, the time complexity is very high in some of them and others are difficult to apply in development. This paper proposes the following strategy for positioning and rotation. Firstly it needs to extract the QR code symbol, and then capture the image region to ensure that the center of the QR code is the center of the new image, this step eliminates the surrounding noise information. Then the rotation angle should be determined, and finally the rotation is carried on with bilinear interpolation.

As shown in fig. 2, QR code contains 3 detection patterns A, B, C with the same size and shape. The detection pattern is composed of three overlapping concentric squares, the black and white of the module's ratio is 1:1:3:1:1. The width of each module allows deviation of 0.5. Based on the size and rotation of QR code symbol have invariant feature, it is very quick to determine the location of detection by looking for areas that meet the approximate ratio of 1:1:3:1:1. According to the character that it can constitute approximate isosceles triangle among A, B, C when the number of appropriate patterns are more than three, the position detection patterns will be ultimately determined. By this step, we can get the center coordinates of A, B, C and QR code symbol. To speed up image processing speed, in practice application, when there is no noise information around the QR code and the shape of it is not changed, the center coordinate of QR code and the coordinates of three vertices(A,B,C) can be calculated by the ranks and arranges scanning method.

Fig. 2. Position Detection

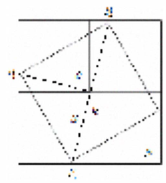

Fig. 3. Rotation Correction

1) When the center coordinate of QR code and the coordinates of feature point are determined, there is the need to determine the angle of rotation. As shown in fig. 3, S square area is the original QR code image; N square is the area after interception. P_1, P_2, P_3 are the three feature points (center point of position detection patterns or QR code vertex),assuming the rotation angle is θ. Calculate Strike distance between three points and find the longest distance, suppose it is P_2P_3.

2) Find the slope of P_2P_3.

$$k = \frac{y_3 - y_2}{x_3 - x_2}$$

3) If $k>-1$ and $k<1$, it requires *a clockwise rotation.*

$$\theta = \arctan((k-1)/(1+k))$$

On the contrary, it needs counter-clockwise rotation,

$$\theta = \arctan(-(k-1)/(1+k))$$

After the center coordinate of QR code determined, to capture its square on the image center to ensure the QR code can all access. The length of the intercepted side is at least

$$NewLength = \sqrt{2} * SourceLength * \sin\theta$$

When the rotated angle is 90 °, the range of areas beyond reaches the maximum. In order to ensure QR code can full access, interception side generally gets its maximum, that is, $\sqrt{2} * SourceLength$.

Because the purpose of rotation coordinates is not necessarily integer coordinates, in order to ensure the image is not distorted, the gray value of purpose pixel needs for interpolation in the image rotation transformation. The frequently-used methods include the nearest neighbor interpolation, bilinear interpolation and tri-linear interpolation [17]. Among them, the nearest neighbor method is very simple, processing time is the shortest, and the real-time performance is very well, but the quality of the result is not high, the process of rotation prone to jagged boundaries. This method is for applications that require high rotation Real-time performance, but less demanding procedures on image quality. The precision of tri-linear interpolation calculation is the highest, through which the processed image is of the best quality and does not appear the case of discrete pixel values. However, compared to the bilinear interpolation method which takes into account the surrounding four coordinates that impacted on floating-point, tri-linear interpolation consider the 16 neighbors that impacted on it, so the time complexity of tri-linear interpolation is very high. Though bilinear interpolation method the results image is of high quality, its texture is quite clear and meets the requirements of most programs. Therefore, the bilinear interpolation is used in image rotation in this paper. In addition, if the coordinates of QR code are not precise enough, the result is not very satisfactory, just as fig. 4 shows.

Fig. 4 is the comparison of three interpolation methods.

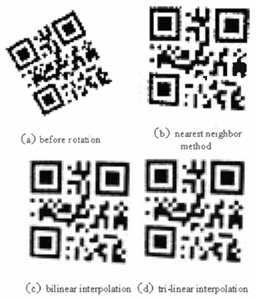

Fig. 4. Comparison of Three Interpolation Methods

C. *Image geometric correction*

The image geometric distortion will emerge because of the shooting angle, image rotation and other issues. QR code geometric distortion will bring great recognition errors and reduce the recognition rate. In general, the QR code image distortion is linear distortion. As a result, QR codes can be used to correct for the characteristics of being a square. Distortion correction algorithm is as follows.

1) Obtain images of the four vertices of QR codes. Due to the rotation process the external noise information has been ruled out, so we can scan QR code image line by line, from the eight directions of the QR code region (up, down, left, right, upper left, lower left, upper right, lower right) in a straight line to scan the QR code until two or more intersection between the line and black block. After the scan at eight directions, we will get 16 points at least; the point appeared in both directions is the vertex. When these steps are completed, there are three or more vertices. Based on the distance between vertices and the center of position detection patterns, 3 shortest vertices can be obtained and there are the vertexes.

2) Determine the fourth vertex. The reference [10] proposed algorithm that hollows out internal points of the bar code, get the edge information, with over a known point Hough transform to detect the fourth vertex of QR code. This paper presents a new detection algorithm. According to the known relationship among the location of three vertexes, we can determine the orientation of the fourth vertex in the QR code (upper left, lower left, upper right, lower right). Then the location of the adjacent two lines to the resulting the fourth vertex can be known. Scanning along the center coordinates of position detection patterns until the intersection between black line and the QR code module. The slope of the two boundary lines can be calculated. Then the point at which these two straight lines intersect is the fourth vertex, just as shown in fig. 5.

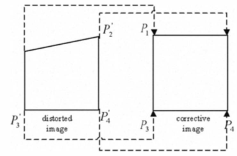

Fig. 5. Calculate the Fourth Vertex   Fig. 6. Control point transformation

3) As shown in fig. 6, P_1, P_2, P_3, P_4 are the four vertexes of the QR code image without distortion, P_1', P_2', P_3', P_4' are the four vertexes of the QR code for the actual image. Use $f(x, y)$ as the gray value at coordinate (x, y) in corrected image, use $f(x', y')$ as the gray value at coordinate (x', y') in uncorrected image. Suppose the coordinate of $P_i (1 \le i \le 4)$ is (x_i, y_i), suppose the coordinate of $P_i' (1 \le i \le 4)$ is (x_i', y_i').

Then there exists the following relationship:

$$\begin{cases} x_i = a x_i' + b y_i' + c x_i' y_i' + d \ (1 \le i \le 4) \\ y_i = m x_i' + n y_i' + p x_i' y_i' + q \ (1 \le i \le 4) \end{cases}$$

By Jacobi iteration method can solve the 8 parameters a, b, c, d, m, n, p, q in above equations, and then it realizes the calibration transformation from the general quadrilateral to a square.

When the point (x', y') transforms into point (x, y) via geometric distortion correction, bilinear interpolation can be used to determine gray value $f(x, y)$.Suppose the four adjacent coordinates of (x', y') are (x_0', y_0'), (x_0', y_1'), (x_1', y_0'), (x_1', y_1') and the corresponding gray values are $f(x_0', y_0')$, $f(x_0', y_1')$, $f(x_1', y_0')$, $f(x_1', y_1')$.Then the bilinear interpolation formula is:

$$f(x, y) = \left[f(x_1', y_0') - f(x_0', y_0') \right] \times (x' - x_0') + \left[f(x_0', y_1') - f(x_0', y_0') \right] \times (y' - y_0') + \left[f(x_1', y_1') + f(x_0', y_0') - f(x_0', y_1') - f(x_1', y_0') \right] \times (x' - x_0') \times (y' - y_0') + f(x_0', y_0')$$

D. *Image Normalization*

The QR code image which is almost on regular can be obtained by geometric transformation. Then it needs to be normalized. The research in reference [14] proposed a method that the QR code is divided into models based on Sobel edge detection and deblurred based on Fourier transform, and all bit-stream data correspond to the code are obtained in the end, which can be decoded. While in this paper, the strategy is as follows.

Firstly, make sure the version number of the QR code based on the decoding algorithm given in the national standard and symbol structures of QR code itself. Secondly, divide equally the QR image into $n \times n$ small grids according the version number, re-sample the center of each grid as the sampling point and get the normalized QR code symbol. In this process, since the computer step length is integer, the cumulative error must produce more or less. By using of averaging method, some modules that are supposed to be within the grid shift, leading to errors in QR codes dividing. Therefore, it is better to make a full-scale expansion to the image before grid-dividing based on the principle of image scaling so that it minimize the error which is generated when cutting image. While the new gray values generated in amplifying procedure can be solved using bilinear interpolation. Thirdly, decode the standard QR code symbol according the National Standard Method of Quick Response Code after image re-sampling.

III. EXPERIMENT RESULTS

During the experiment, the 100 sample pictures, all 320 *240 pixels were collected by shooting in different direction using the ordinary camera for chat. Images include the following situations. Different versions of bar code, from version 1 to version 7; Bar illumination conditions are different, respectively, in the general light, strong light and weak light, In non-uniform lighting conditions, 10 uneven illumination images were shoot; Geometric distortion, which shot out of a square than the standard two-dimensional code; the tilt angle exists in the image; some images are surrounded by the noise information.

This experiment is carried on in the windows XP system, using visual C++ programming to process image, and both image encoding and decoding adopts the method proposed in QR[S] national standards. The results are as follows. (1) Under the normal light and bright light, using OTSU method, genetic algorithm to process can obtain good results, but image under uneven light will cause part of the shadow that would not be recognized after processing, take adaptive threshold instead. The recognition rate is 90%.Average time used in OTSU is 0.005500s while genetic algorithm used in threshold is 0.02044s; Bimodal histogram method can only be recognized when there are two obvious peaks on the picture, the recognition rate was 80%, the spent time is 0.004540s;Niblack method takes 0.164254s when window size is 5.Adaptive threshold method can identify most of the non-uniform image, but the algorithm processing speed is much slower than OTSU, the average time is 0.22361s; (2) the lower the version is, the more simple images are, binary images are more clear and the result is better. (3) In the same programming environment used for the time to determine the rotation angle. As opposed to 0.104890s in general Hough transform and 0.002622s in hollowing algorithm, the time used in algorithm in this paper time 0.000427s, shortened by 245 times and 6.14 times.

IV. CONCLUSION

This paper discusses QR code recognition algorithm based on image processing, including image binarization, image tilt correction, image orientation, image geometry correction, image normalization, making the acquisition images be correctly identified through a series analysis and treatment. Main innovation of this paper is as follows.

(1) In the rotation process, the QR code symbol was extracted and the surrounding noise information can be effectively eliminated. (2) In terms of the geometric correction, not using Hough transform, but using the coordinates of known points to infer the fourth vertex of QR code, and this method reduces the time complexity. (3) In terms of image normalization, using the principle of image scaling to reduce the error caused by average means. The first step in identifying takes the first priority, image binarization method has a large impact on the bar code identification system, hence the issue how to select an appropriate algorithm to binarize is the focus of future research papers. With the further development in the of the industry, two-dimensional code recognition technology based on image processing image dedicated in reader reading applications will have broad application prospects, the article have a certain significance on the promotion and development of QR codes.

REFERENCES

[1] Y.Liu,M.Y.Liu,"Research on Data Encoding of Two-Dimensional QR Code Barcode",*Transactions of Beijing Institute of Technology*, Vol.25,No.4,pp.352-355, Apr.2005.

[2] H.Zhang,Q.W.Han,F.M.Yu,"Two Dimensional Bar Code in Medicine Trade Logistic Management System",*Journal of Chongqing University*, Vol.27,No.4,pp.122-125, Apr.2004.

[3] X.X.Huang,"Research on Restaurant Reservation System Based on Two Dimensional Bar Techology",*China Computer & Communication* , pp.61-62, Feb.2010.

[4] C.Y.Kang. "Study on System of Electronic Ticket on Two-dimensional Code",*Journal of Harbin University of Commerce (Natural Sciences Edition)*, Vol.25,No.2,pp.178-181,Apr.2009.

[5] Article Numbering Centre of China, *QR code Two-dimensional Bar Code Technology and Application*,Beijing,Standards Press of China,2002.pp.2-50.

[6] *Quick response code*, GB/T 18284- 2000,2001.

[7] TRIER,O.D.,JAIN,A.K.,"Goal-Directed Evaluation of Binarization Methods",*Pattern Analysis and Machine Intelligence,IEEE Transactions on PAMI*, Vol.17,No.12,pp.1191-1201,Dec.1995.

[8] R.Zhang,H.Zhu,T.Zhang,X.Shen,"A Pre-Processing Method on QR Code Two Dimensional Code Image",*Computer Science*, Vol.35,No.4 ,pp.146-148,2008.

[9] Q.L.Ai,L.C.Wang,S.X.Zong,"A Method of QR Code Image Pre-Processing Based on the Surface Fitting",*Journal of Hunan First Normal University*, Vol.9,No.4 ,pp.167-169,Aug.2009.

[10] M.Sun,L.S.Fu,X.T.Yang,S.H.Zhang,"Image Analysis Method for QR Code's Automatic Recognition",*Journal of University of Electronic Science and Technology of China*, Vol.38,No.6,pp.122-125,Nov.2009.

[11] D.Liu,X.Q.Gao,"Research on Algorithm of Processing and Identification of QR Barcode Image",*Inforamtion Technology*, Vol.28,No.1,pp.61-63,Jan.2004.

[12] L.S.Fu,M.Sun,S.Q.Han,L.Yang,"Research of Dot Matrix Two dimernional Bar Code Based on Morphological Iiroge Processing",*Packaging Engineering*, Vol.29,No.5,pp.49-51,May.2008.

[13] X.P.Hu,Q.Dong,Z.Q.Yu,"QR Code Recognition Based on Image Processing",*Aeronautical Computing Technique*, Vol.37,No.2,pp.99-102,Mar.2007.

[14] H.J.Liu,"Omnidirectional Recognition of Quick Response Code image",*Chinese Journal of Scientific Instrument*, Vol.27,No.4,pp.376-379,Apr.2006.

[15] H.W.Liu,Y.Yan,"Recognition and Decoding of QR Code",*Computer Engineering and Design*, Vol.26,No.6,pp.1560-1562,Jun.2005.

[16] W.T.Cai,Z.Liu,"Research on Two-dimensional Bar Code Positioning Approach Based on Convex Hull Algorithm",*Journal of Zhejiang University of Technology*, Vol.36,No.6,pp.669-672,Dec.2008.

[17] F.G.Yuan,J.C.Liu,"Research on Different Interpolation Methods of Digital Image Rotation",*Software Guide*,Vol.9,No.4,pp.187-189,Apr.2010.