An Efficient Bar Code Image Recognition Algorithm for Sorting System

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Abstract: In the sorting system of the production line, the object movement, fixed angle of view, light intensity and other reasons lead to obscure blurred images. It results in bar code recognition rate being low and real time being poor. Aiming at the above problems, a progressive bar code compressed recognition algorithm is proposed. First, assuming that the source image is not tilted, use the direct recognition method to quickly identify the compressed source image. Failure indicates that the compression ratio is improper or the image is skewed. Then, the source image is enhanced to identify the source image directly. Finally, the inclination of the compressed image is detected by the barcode region recognition method and the source image is corrected to locate the barcode information in the barcode region recognition image. The results of multitype image experiments show that the proposed method is improved by 5+ times computational efficiency compared with the former methods, and can recognize fuzzy images better.

Keywords: Bar code recognition, Hough transformation, binarization, image processing.

1 Introduction

Bar code is a graphic recognizer [Hu (2011)] that arranges several black bars and white spaces of different widths according to certain coding rules to express a group of information. With the rapid development of science and technology, bar code technology is becoming more and more mature, and it has applications in all areas of commodity circulation. Barcode carries various information of commodities, which is the basic technology of supply chain management and one of the important means of management modernization [Liu (2013); Zhang (2000)]. The accurate recognition of bar code will greatly accelerate the circulation of goods and enhance the competitiveness of enterprises.

Currently, image bar code recognition mainly adopts software programming technology and hardware technology [Fan and Guo (2003); Zheng (2012)]. Compared with the hardware recognition system, the recognition scheme based on software programming technology has the advantages of non-contact, high efficiency and low cost [Wu (2016)],

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Received: 10 February 2020; Accepted: 01 May 2020.

with greater development potential. There are two main ways of working: recognition using coding principles and the toolkits. The toolkit mainly includes ZBar [Brown (2011)] and ZXing [Srowen (2019)], both of which can be used for bar codes in various formats, and ZBar was based on C language, decoding high efficiency. There are mainly two algorithms: direct recognition method [Xie (2008)] and bar code region recognition method [Shao, Yao and Hu (2007)] for bar code recognition. The direct recognition method is simple, but the recognition rate is low and it is not suitable for slanting image while the bar code region recognition method is relatively high, but the calculation is large and the recognition process is time-consuming [Lambing and Berry (2006)].

In order to solve the above problems, a new bar code recognition process is proposed: 1) image blurring: object motion and light intensity may cause blurring in the captured image, which may affect the positioning and segmentation of bar code in the image. Image enhancement should be carried out before recognition; 2) image tilt: generally speaking, the shooting Angle is fixed, and the image is inclined to a certain extent, which should be corrected before recognition; 3) recognition time: high-precision images increase the computational load, resulting in a longer recognition process.

2 Related work

According to the research findings in recent years, many scholars have conducted fruitful research on the application of image processing method to recognize bar codes, and achieved great results. The focus of the study is to solve the common problems in the process of image bar code recognition. For example, low resolution and a lot of noise due to insufficient light; Angle tilt and nonrigid deformation result in the change of width of the same bar code unit; Device jitter caused image bar code fuzzy.

Youssef et al. [Youssef and Salem (2007)] proposed an intelligent barcode detection and recognition system based on fast hierarchical Hough transformation. The back propagation neural network (BPNN) is selected as a powerful tool to perform the recognition process. DCGAN is used to generate sample that is difficult to collect and proposed an efficient design method of generating model. Fang et al. [Fang, Zhang, Sheng et al. (2018)] combine DCGAN with CNN for the second time. Use DCGAN to generate samples and training in image recognition model, which based by CNN. This method can enhance the classification model and effectively improve the accuracy of image recognition. Liu et al. [Liu, Yang and Liu (2008)] described an image processing system based on movement, which can binarized, locate, segment and decode the two-dimensional code.

Fan et al. [Fan, Jiang and Liu (2008)] proposed a bar code positioning method based on gradient and morphological mathematics, which could accurately detect bar codes from complex backgrounds. Zhang et al. [Zhang, Yin, Yang et al. (2017)] presented a blind detection approach for seam carved image with low scaling ratio (LSR). Wang et al. [Wang, Jiang, Luo et al. (2019)] proposed a novel deep residual dense network, which not only ensure good training stability and successfully converge but also has less computing cost and higher reconstruction efficiency. In Dense-MobileNet models, convolution layers with the same size of input feature maps in MobileNet models are taken as dense blocks, and dense connections are carried out within the dense blocks [Wang, Li, Zou et al. (2020)]. Rocholl et al. [Rocholl, Klenk and Heidemann (2010)] introduced a new method for decoding linear barcodes from blurred camera images. Wu et al. [Wu, Liu and Lou (2019)] proposed a new method called soft SPM (sSPM) to reduce feature ambiguity. Zhang et al. [Zhang, Wang, Han et al. (2006)] proposed a real time barcode positioning method through joint analysis of texture and shape. Fang et al. [Fang, Wu, Luo et al. (2006)] proposed a fast and robust noise code 39 barcode recognition method. Based on the characteristics of PDF417 barcode image, two methods are proposed to improve the recognition ability of barcode and reduce the bit error rate [Zhang, Bao and Pu (2012)].

Zhang et al. [Zhang, Ma and Mao (2011)] analyzed the structure of 2d barcode and its development status at home and abroad. A two-dimensional barcode recognition system based on image processing is proposed. Fang et al. [Fang, Chang, Chu et al. (2012)] proposed a new method of using digital cameras to recognize bar codes, in which both the “bar code” and “code” parts are recognizable. It is integrated with the database to further improve the recognition rate. Nejad et al. [Nejad and Shir (2019)] proposed a new learning approach based on the Salp Swarm Algorithm and implemented and evaluated it on learning algorithm Decision Tree, K-Nearest Neighbors and Naive Bayes. Han et al. [Han, Teng, Yang et al. (2010)] proposed a new 2d barcode image binarization method. Kim et al. [Kim and Lee (2016)] proposed a new segmentation and normalization method to improve its recognition rate and accuracy. Xia et al. [Xia and Ding (2010)] introduced a bar code image acquisition system based on contact image sensor to realize dynamic adjustable image resolution.

Liu et al. [Liu and Yang (2003)] proposed a two-dimensional barcode recognition algorithm based on Fourier transform. Liu et al. [Liu and Yang (2004)] published peak detection methods for dealing with severe noise. Li et al. [Li, Zhu, Zhu et al. (2019)] adopted machine learning method to train for the construction of a bridge between the Rényi discord and the geometric discord. Wachenfeld et al. [Wachenfeld, Terlunen and Jiang (2008)] proposed an algorithm that USES camera phones to recognize one-dimensional bar codes. Gallo et al. [Gallo and Manduchi (2009)] proposed a new bar code reading method, which does not need to binarization the image and USES a deformable bar code digital model in the maximum likelihood setting. Yahyanejad et al. [Yahyanejad and Ström (2010)] designed a blind deconvolution algorithm to remove translation motion in blurred bar code images.

3 Algorithm

3.1 The bar code region location algorithm

3.1.1 Image enhancement

A large number of experimental results show that the Laplacian operator can process the blurred image well. Laplace operator is a second order differential operator, a continuous binary function $f(x, y)$, whose Laplace operation is defined as:

$$\nabla f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \tag{1}$$

For digital images, the Laplace operator can be simplified as follows:

$$g(i,j) = 5f(i,j) - f(i+1,j) - f(i-1,j) - f(i,j+1) - f(i,j-1) \tag{2}$$

The above formula can also be expressed as convolution:

$$g(i,j) = \sum_{r=-k}^{k} \sum_{s=-l}^{l} f(i-r, j-s)H(r,s) \tag{3}$$

Among them, $i, j = 0,1,2 \dots \dots, N-1; k = 1, l = 1$

$H(r, s)$ is as follows:

$$H = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix} \tag{4}$$

3.1.2 Hough transformation

Hough transform is one of the basic methods to recognize geometric shapes from images. The curve detection problem in the original image is transformed into the peak value problem in the parameter space. The point-line duality principle is shown in Fig. 1. The standard Hough transformation is shown in Eq. (5), where (x, y) represents a point in the Cartesian coordinate system, (ρ, θ) represents a parameter in the Hough transformation parameter space, and the points of common lines in the image space intersect at a point in the parameter space.

$$\rho = xcos\theta + y \sin\theta, \rho \geq 0, 0 \leq \theta \leq 2\pi \tag{5}$$

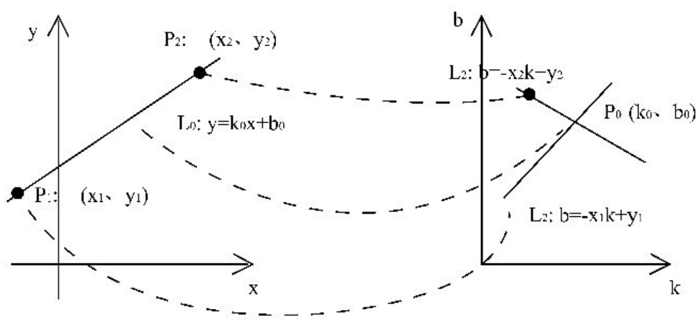

Figure 1: Point-line duality

3.1.3 Tilt correction

For the tilted image, the source image srcG was first corrected to obtain the target image dstG. The detection of image tilt is the key to correction, and the detection of tilt is realized by Hough transform. The process of correction algorithm is as follows:

Step 1: compress the source diagram srcG to get the compressed diagram to reduce the calculation amount;

Step 2: extend compressed image srcC for DFT transform optimum size to speed up DFT transformation;

Step 3: fuse the real and imaginary mat of a single channel into a multichannel mat to store the transformation results;

Step 4: perform DFT transformation and split the result into real part and imaginary part;

Step 5: the source graph is binarized and Hough transformation is performed;

Step 6: get the tilt Angle correction source map srcG to get the target map dstG.

3.1.4 Binarization

By binary processing of gray image, the contour of the target of interest can be highlighted. In order to obtain the ideal binary image, the improved OTSU algorithm is adopted in this paper. OTSU algorithm is simple and fast, but the background target is not clearly differentiated and the gray level is discontinuous bar code image, the threshold is easy to fall into the local optimal, cannot converge to the global optimal. The improved OTSU calculation method in this paper is as follows: firstly, the optimal threshold of each discontinuous part of the image is calculated, and the maximum inter-class variance is calculated at this time. Then, the local maximum interclass variance is compared, and the threshold corresponding to the largest interclass variance is found, namely the global optimal threshold. The steps of binarization algorithm in this paper are as follows:

Step 1: calculate the histogram of the image;

Step 2: calculate the grayscale $L, min(image) < L < max(image)$ with the number of grayscale levels of 0, where $min(image)$ and $max(image)$ are the minimum and maximum grayscale values, stored in array $a[m]$;

Step 3: initial variable: initial optimal target value $g = 0$;Initial optimal threshold $T = min(image)$;Initial loop variable $I \ = min(image)$;

Step 4: cyclic calculation of target value g_0 and judgment:

$$If(g_0 > g)\{g = g_0, T = i + 1\} \tag{6}$$

Step 5: store g in the one-dimensional array sum;

Step 6: turn to Step 4 when $i = a[j](j = 1,2,3, \dots \dots, m)$; Stop when $i \geq a[m]$;

Step 7: find out the largest term in sum and calculate the corresponding threshold T.

After verification, T is the optimal threshold of the image.

3.1.5 Corrosion expansion

Expanded $X \oplus B$ is the set of sums of all vectors, the two operands of vector addition come from X and B respectively, and take any possible combination.

$$X \oplus B = \{p \in \varepsilon^2, p = x + b, x \in X, b \in B\} \tag{7}$$

Corrosion uses vector subtraction on set elements to merge two sets. Corrosion algorithm is the dual operation of expansion algorithm, and the formula is expressed as follows:

$$X \ominus B = \{p \in \varepsilon^2, p + b \in X, \forall b \in B\} \tag{8}$$

The relationship between corrosion and expansion can be described as follows:

$$\left(X \ominus B\right)^C = X^C \oplus B^T \tag{9}$$

where B^T is the transpose of B with respect to the reference point. According to this equation, expansion operation can be used to realize corrosion operation.

3.1.6 Location bar code region

After correction of the original image, it is necessary to locate the rectangular area of the barcode from the target image dstG and identify the rectangular area. In this paper, the identification processing process includes the following steps:

Step 1: filtering and noise reduction: Gaussian smoothing filtering is carried out on the target image to suppress the noise that obeys normal distribution;

Step 2: horizontal and vertical gradient difference: Sobel operator is used to obtain the gradient difference of gray image;

Step 3: mean filtering: eliminate high-frequency noise;

Step 4: binarization: binarization is carried out according to the threshold to prepare for the closed operation;

Step 5: closed operation: fill the gap of barcode;

Step 6: corrosion: remove outliers in the background;

Step 7: expansion: fill the gap caused by corrosion;

Step 8: regional positioning: locate the rectangular boundary of the barcode region.

The bar code region recognition method has a high recognition rate, but its calculation process is complicated with long lasting time. The algorithm firstly compresses the source image in large proportion, detects the tilt of the thumbnail image and corrects the source image. Then according to the target map positioning rectangular area, using a small proportion of compression diagram to complete the bar code region interception, speed up the operation, shown as Fig. 2.

Algorithm 1 Location bar code area Algorithm

Input: Gray image,$srcG$;

Output: Bar code information or error message;

Compress $srcG$ to get $srcR$;
Test the inclination of $srcG$;
Correct $srcG$ to get $dstG$;
Locate rectangle imagePart in $dstG$;
Identify imagePart;
if Bar code can be identified **then**
    return Barcode information
else
    return Error message
end if

Figure 2: Location bar code region algorithm

3.2 The recognition algorithm

The recognition algorithm in this paper can be divided into the following four Steps: 1) scale down the source image and recognize the thumbnail image according to the algorithm. Recognize success to Step 4, failure to perform Step 2; 2) enhance the source diagram, highlight the details of the source diagram, and recognize the enhancement diagram according to algorithm 1. Go to Step 4 successfully, fail to execute Step 3; 3) compress the original image in a large proportion, detect the tilt Angle of the thumbnail according to algorithm 2, use the tilt Angle correction source image, locate the rectangular area and detect the barcode. Success to Step 4, failure to show error message to Step 4;4) display the recognition information, and the algorithm ends. The recognition algorithm is shown in Fig. 3:

```
Algorithm 2 The Recognition Algorithm
Grayscale the image;
Compress image;
Enhance image;
if Bar code is recognized then
    return Barcode information
else
    Locate and return the original image to recognize
    if Bar code is recognized then
        return Barcode information
    else
        return Error message
```

Figure 3: The recognition algorithm

4 Experiment and result analysis

In order to test the performance of the improved recognition algorithm after the process, direct recognition method [Xie (2008)], bar code region recognition method [Shao, Yao and Hu (2007)] and this paper recognition method are respectively used to test the public data set and different types of images. The recognition rate and recognition time are analyzed in detail. The paper divides the benchmark into two groups, one is special case group with slope and curve degree images, the other is normal case group. All the images are chosen from Google Image randomly.

4.1 Case analysis

4.1.1 The special case

The paper selects special images into the first group, including tilt, curvature, shadow, occlusion and so on. Among them, Case 1 (code-128.jpg) is a color image with the pixel point of 1920×1280 and the size of 1.07 MB. It has a certain degree of tilt, which needs to be corrected before recognition. Meanwhile, Case 2 (EAN-13-1.png) has shadow on the bar code and Case 3 (UPC-A-3.png) has curvature of the bar code, respectively.

4.1.2 The normal case

The normal images are placed in the second group. All of the images are normal merchandise color images with 600×600 pixel. All they have been chosen from Google Image randomly. Compared with the special case, the normal case's background color is lighter, bar code is relatively clear.

4.2 Experimental environment

The operating system used in the experiment is Ubuntu 18.04, CPU is Intel(R) Xeon(R) CPU E5-2609 v4 @ 1.70 GHz, GPU is Nvidia 1080ti, and matched with 8 GB of memory. While the experiment is going on, the CPU and memory are running at full speed.

4.3 Experimental result

The source image has a large tilt, so the direct identification method cannot identify bar code information from the source image. As the image code-128.jpg contains a large amount of information, the DFT transformation in the correction stage and the filtering, direction gradient, closed operation, corrosion, expansion and other operations in the positioning stage will take a lot of time, and the whole identification process will take a long time. Our method uses compressed image recognition method to make up for the shortcomings of direct identification method and bar code region identification method, and achieves a better identification effect.

4.3.1 The special case

Table 1: Algorithm contrast

	Case 1	Case 2	Case 3
Xie [Xie (2008)]	/	/	/
Shao et al. [Shao, Yao and Hu (2007)]	500	530	1513
Our Algorithm	421	436	405

It can be seen from the Tab. 1 that, in special cases, the direct recognition method [Xie (2008)] cannot make the correct identification, while the area recognition method [Shao, Yao and Hu (2007)] can make the identification, but the identification speed is very slow. Our algorithm improves the speed of identification, the recognition algorithm can keep fast in different situations, especially in the case that the bar code region is curved. The experimental results show that the new algorithm is more efficient than the algorithms in Xie [Xie (2008)] and Shao et al. [Shao, Yao and Hu (2007)].

4.3.1 The normal case

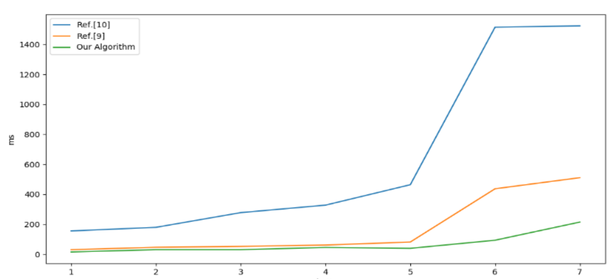

Figure 4: Time required for normal cases (ms)

In the normal images set, all three algorithms can recognize barcodes, but our algorithm is better and takes less time than the other two. The experimental results show that our method can recognize images and is 5+ times faster than the direct identification method and the bar code region identification method. Two other types of tilted bar code images are selected for the experiment. The test results show that the proposed method is also faster than the other two algorithms in the recognition of tilted bar code images.

5 Conclusion

This paper introduces two common bar code recognition schemes and two methods based on software programming technology. After discussing two bar code recognition algorithms based on Zbar, a progressive bar code compression recognition algorithm is proposed. The experimental results show that the proposed method is superior to the former in speed and rate. Bar code recognition can be completed in a short time to achieve a higher recognition rate based on the same benchmark. By using image processing technology to recognize bar code, the application of bar code is extended to the mobile phone with camera, etc., which still has a good recognition effect for the bar code image with poor quality.

Funding Statement: This work was supported by Scientific Research Starting Project of SWPU [Zheng, D., No. 0202002131604]; Major Science and Technology Project of Sichuan Province [Zheng, D., No. 8ZDZX0143]; Ministry of Education Collaborative Education Project of China [Zheng, D., No. 952]; Fundamental Research Project [Zheng, D., Nos. 549, 550].

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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