Uneven illumination two-dimensional code image recognition algorithm research

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***Abstract*—Aiming at the problem that complex and changeable field light environment will affect the feature recognition of two-dimensional code image, the Niblack algorithm based on block is improved according to the characteristics of two-dimensional code image. A fusion two valued algorithm is proposed, which is based on the improved block Niblack and Otsu. First of all, the threshold of each block is respectively calculated by the Niblack and the Otsu algorithm on account of the improved block analysis. Then, the final threshold is obtained by weighted sum of two thresholds, and the image is segmented. Experiments show that this method can not only overcome the effects of uneven illumination, but also have the characteristics of strong anti-noise ability and fast processing speed.**

Keywords—two-dimensional code; Otsu algorithm; Niblack algorithm; Fusion algorithm

I. INTRODUCTION

With the continuous development of two-dimensional code (TDC for short) technology, TDC has been widely used in many fields. TDC is not only rich in information, large storage capacity, but also fault-tolerant ability. In addition, it has a strong confidentiality, safe and reliable[1]. The form of recognition of TDC is mainly two forms of laser and image. Because of the limitation of laser equipment, its utilization rate is much smaller than that of image. Then in the form of image to identify TDC, the first step is to TDC image processing, which is also the key to the successful identification of TDC[2-4]. However, the TDC image captured by the camera is easily affected by the complex environment such as illumination anomaly, which leads to the lower quality of TDC images, for instance, uneven illumination, blurred boundaries and artifacts. Undoubtedly, this brings great trouble to the subsequent steps of the TDC recognition, and the decoding failure or decoding is impossible to reduce the recognition accuracy of the TDC. Therefore, how to deal with these low quality TDC images has become one of the key problems in the fast recognition of TDC.

Many experts at home and abroad have put forward their own views on how to quickly and efficiently deal with uneven illumination of TDC image. Such as, an improved correction algorithm based on background gray estimation is proposed in document [5], but the computation time is too long due to the increase of computation. An adaptive method is proposed in document [6], which uses the histogram to determine whether the illumination is uniform, and then uses the B spline to fit the histogram and the adaptive threshold method for two values, that increases the complexity of the algorithm. In document [7], a correction algorithm based on improved local background gray estimation is proposed, which improves the correction part of uneven illumination images, but reduces the efficiency of the algorithm. In document [8], homomorphic filter is improved and then Otsu algorithm is used to process it. In literature [9], an improved two valued algorithm based on background gray is proposed, which needs to calculate the difference of each pixel, and needs to set threshold artificially, the calculation is larger. Therefore, the Niblack algorithm based on fast analysis is improved according to the feature of TDC image. A fusion two valued processing algorithm[10] that is based on improved block Niblack algorithm[11] and Otsu algorithm[12] is proposed. Experiments show that this method has better processing effect under uneven illumination.

II. ALGORITHM PRINCIPLE

A. Traditional Niblack algorithm

Niblack algorithm [13] is a two valued dynamic threshold algorithm based on local feature of gray image, whose threshold $T(x,y)$ can be described as:

$$T(x,y) = m(x,y) + \alpha \times s(x,y) \tag{1}$$

In(1), $m(x,y)$ and $s(x,y)$ respectively represent the gray mean and standard variance of all pixel points of the center point (x,y) in the neighborhood range $r \times r$, α is the correction factor, which means that the pixels in the offset range belong to the same pixel.

Compared with the global threshold method, Niblack algorithm can be affected by complex environment such as uneven illumination, and has strong adaptability.But the Niblack method will produce some pseudo noise for the image details on exaggerated background regions identified as the goal, and the amount of calculation is large when long.

B. Improved block Niblack algorithm

To a great extent, the Niblack algorithm based on block solves some problems brought about by the traditional Niblack algorithm itself, for example. It is easy to cause the computation of the algorithm is large when longer due to the $r \times r$ template based image domain, if all of the $r \times r$ neighborhood is background, then the pixel will definitely be part of the target,

which produces pseudo noise. But these problems have not been completely solved. When the algorithm is applied to the two valued of TDC, there are still some noise and time-consuming problems. There is no doubt that the processing time is too long will directly affect the speed of TDC recognition. This cannot guarantee the timeliness of TDC recognition.

In order to solve the time-consuming problem of the algorithm, the improved block Niblack algorithm is proposed in this paper. Because the TDC is to record the data information by arranging the black and white square on the two-dimensional plane, some pixels can be selected to operate when the TDC image is two valued. According to the characteristics of TDC image feature, the sampling points of the pixel gray value of the image are reduced, so as to reduce the time required for the algorithm. If the length and width of the image are a and b, the length and width of the image are equal to λ, the length and width of each block are $h=\frac{a}{\lambda}$ and $v=\frac{b}{\lambda}$. If its value is decimal, the maximum integer less than h and v is selected. It is assumed that $m(x,y)$ is the gray mean of block, the standard variance of $s(x,y)$ is block, $g(i,j)$ is the gray value of each pixel in block, and $b(i,j)$ is the two results of every pixel in block, the implementation of this method is as follows:

(1)According to the size of the image to calculate the value of λ to block the image, in each block, the horizontal ordinate coordinates i and j values are multiples of k pixels are selected, and its gray mean $m(x,y)$ is calculated:

$$m(x,y)=\frac{1}{h'\times v'}\sum_{i=(v\times(x-1)+1)}^{v\times x}\sum_{j=(h\times(y-1)+1)}^{h\times y}g(i,j) \tag{2}$$

In the upper expression, (x,y) represents the coordinates of blocks after image block, and the values of horizontal and vertical coordinates are all from 1 to λ, among them, the number of pixels selected in horizontal and vertical coordinates are $h'=\frac{h}{k}$ and $v'=\frac{v}{k}$. If h' and v' are decimals, the maximum integer less than their value is obtained.

(2)In each block, the horizontal ordinate coordinates i and j values are multiples of k pixels are selected, and its standard deviation $s(x,y)$:

$$s(x,y)=\sqrt{\frac{1}{h'\times v'}\sum_{i=(v\times(x-1)+1)}^{v\times x}\sum_{j=(h\times(y-1)+1)}^{h\times y}(g(i,j)-m(x,y))^2} \tag{3}$$

(3)The threshold $T(x,y)$ of the block is calculated:

$$T(x,y)=m(x,y)+\alpha\times s(x,y) \tag{4}$$

In the formula, the α is the correction factor.

(4)By using the threshold $T(x,y)$ of blocks, the blocks are processed by two values of the image one by one:

$$b(i,j)=\begin{cases}0 & ;g(i,j)\le T(x,y)\\ 255 & ;g(i,j)>T(x,y)\end{cases} \tag{5}$$

In the formula, $g(i,j)$ is the gray value of all pixels in the current block,so its horizontal and vertical coordinates are $v\times(x-1)+1\le i\le v\times x$, $h\times(y-1)+1\le j\le h\times y$.

In order to study the effectiveness of the algorithm, a TDC image with uneven illumination was fabricated in the laboratory and tested in MATLAB. The result is shown in figure 1. Figure 1a is a code image with uneven illumination, figure 1 b-j is the processing result of improved block Niblack algorithm when k is 1-9 respectively. Table I is the processing time required for different K values.

Fig.1 processing results of different K values ofimproved block Niblack algorithm

TABLE I SPEED COMPARISON OF IMPROVED BLOCK NIBLACK ALGORITHM AT DIFFERENT K VALUES

k	1	2	3	4
Time	2.79s	0.92s	0.54s	0.42s

k	5	6	7	8	9
Time	0.35s	0.32s	0.30s	0.27s	0.27s

It selects all pixels to operate, so it takes the longest time. With the increase of the K value, the distance between the selected pixels is also increased, so that the number of pixels is greatly reduced, and the time required for the algorithm is greatly shortened. When the K increases to 5, the reduction time of the algorithm becomes smaller and tends to be stable. It can be seen from the graph 1b-i that with the increase of K, the algorithm does not change the processing effect of TDC image with uneven illumination, and the processing effect becomes worse until K is 9 (As shown in Figure 1j, red marked area). Therefore, when k takes the appropriate value, it can not only ensure the algorithm to TDC two value effect, but also to a great extent, improve the efficiency of the algorithm.

III. TWO VALUED FUSION ALGORITHM

In dealing with uneven illumination of TDC images,improved block Niblack algorithm has a great improvement in processing speed, but there are still a lot of noise. In order to eliminate these noises, Otsu algorithm is introduced based on the improved block Niblack algorithm. An improved block Niblack algorithm combined with the Otsu method is proposed. Its specific steps are as follows：

(1)The threshold T_1 of each block is calculated by using improved block Niblack algorithm:

(2)The threshold T_2 of the block is calculated by the Otsu algorithm:

(3)The threshold T_1 of the improved block Niblack algorithm is weighted with the threshold T_2 of Otsu, and the threshold T of the block is obtained:

$$T = \delta T_1 + (1-\delta) T_2 \tag{6}$$

In the formula, δ is the weighted coefficient, and its value satisfies $0 < \delta < 1$, after the uneven illumination of TDC processing experiment, we can get the best effect when $\delta = 0.8$.

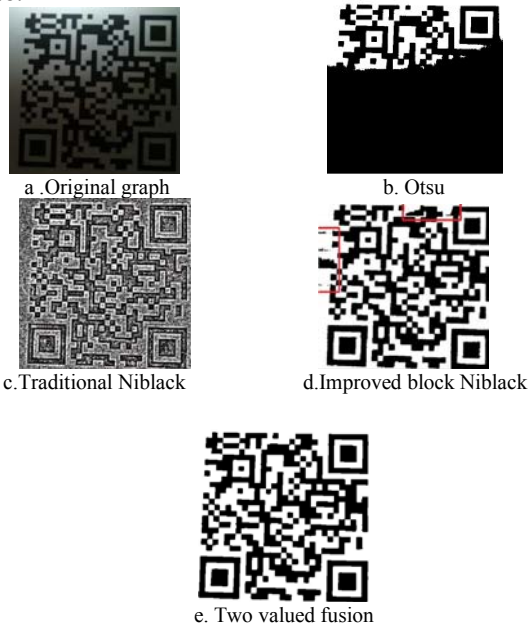
(4)By using the formula (6) in the threshold T , block is one by one binarization processing:

$$b(i,j) = \begin{cases} 0 & ; g(i,j) \le T(x,y) \\ 255 ; & g(i,j) > T(x,y) \end{cases} \tag{7}$$

The algorithm combines the improved block Niblack algorithm with the Otsu algorithm, which effectively reduces the influence of the change of illumination intensity, and improves the ability of resisting noise. Especially, the improved block Niblack algorithm can make the algorithm faster.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

In order to test the proposed algorithm on the treatment effect of uneven illumination of the TDC image, the use of mobile phone and the lights in the laboratory with uneven illumination TDC image, a resolution of 432 × 421 were collected. The computer used in the experiment is Lenovo G410, and the experimental program is written and run in Matlab 2013a environment.The algorithm that is respectively Otsu algorithm, traditional Niblack algorithm, improved block Niblack algorithm and the two valued fusion algorithm is used to process the collected TDC image, their respective processing results are shown in figure 2. Among the results correction factor of the traditional Niblack algorithm is α =0.08, k=8 in improved block Niblack algorithm, the factor of two valued fusion algorithm δ =0.8.



a .Original graph b. Otsu

c.Traditional Niblack d.Improved block Niblack

e. Two valued fusion

Figure 2 The result of two valued code

Because Otsu is a global threshold algorithm, which has poor resistance to uneven illumination, the Otsu algorithm of 2b is poor, and the target in the lower half of TDC image is very serious. In figure 2c, the results of the traditional Niblack algorithm show that the algorithm overcomes the influence of uneven illumination, but it generates a lot of pseudo noise because it pays too much attention to the details of the image, which makes the efficiency of the algorithm low and the calculation time is too long, so that it cannot meet the requirements of accuracy and timeliness of TDC recognition. In figure 2d, The improved block Niblack algorithm is better than the classical Niblack algorithm of graph 2c, which eliminates a lot of spurious noise, but there is still some noise in the red labeled region of the graph 2d. Compared with other algorithms, the two valued fusion algorithm has the best effect in figure 2e, which has a strong ability of pit noise, and can quickly and effectively extract the TDC image target information.

TABLE II TIME COMPARISON OF ALGORITHM

Algorithm	Time
Otsu algorithm	0.025s
Traditional Niblack algorithm	73.78s
Improved block Niblack algorithm	0.27s
Two valued fusion algorithm	0.29s

After repeated tests on TDC images, table II is the average time that is calculated by Otsu algorithm, traditional Niblack algorithm, improved block Niblack algorithm and the two valued fusion algorithm. You can see from table II that the improved block Niblack algorithm greatly reduces the running time of the traditional Niblack algorithm.The two valued fusion algorithm has little difference with the running time of the improved block Niblack algorithm, but it is much less than the traditional Niblack algorithm.

V. CONCLUSION

For the special application environment of TDC, in order to meet the requirements of the accuracy and real time of the mobile portable TDC reader, it is of great practical value to solve the problem of poor quality of two-dimensional code processing caused by uneven illumination. In this paper, the advantages and disadvantages of the traditional Niblack algorithm Then, the Niblack algorithm based on block is improved according to the characteristics of TDC image, and on the basis of this, a fusion algorithm which are Improved block Niblack algorithm and Otsu algorithm is proposed. The experimental results show that this algorithm has a great advantage in considering the processing effect and time by comparing with the traditional algorithm.

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