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Research of license plate recognition and location based on SUSAN corner detection

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ABSTRACT

Recognition technology of license plates is one of the important research subject in the field of intelligent traffic. It relates to computer vision, digital imaging processing and pattern recognition and has extensive real application background. Based on license plate location method of SUSAN corner detection, the paper proposes a location method of license plates aiming at The method firstly uses mathematical morphology for initial location on license plate area. Then, the method uses SUSAN corner detection method to detect the corner of candidate regions. Lastly, the method uses the achieved angular point figure for accurate location by using clustering method. The experiment proves that when the angle of inclination of license plates is great and even is vertical, the method not only has ideal segmentation effect, but also has rapid segmentation speed, which helps real-time location of license plates.

KEYWORDS

License plate location; Gray image; Slant correction; Corner detection; SUSAN.

INTRODUCTION

With the increase of privately-owned vehicles, the traffic demand is increasing. The construction speed of the existing transport infrastructure is slower than that of motor vehicles and other vehicles. Traditional artificial management ways can't satisfy the demands of real work. Traffic accidents caused by breaking rules and regulations are growing in frequency, and urban congestion makes conveying efficiency low, which seriously influences the development of urban economy and people's life. It has become an urgent demand of management departments to implement automation vehicle identification in road and bridge toll, intersection traffic and parking toll. Therefore, in order to solve the problems, while continuing to accelerate the construction of transport infrastructure, we should make full use of satellite navigation, video surveillance and computer scheduling management to develop intelligent transportation system to improve the transportation efficiency, guarantee the safety of the traffic, ease traffic congestion and realize the automatic management.

The development of computer hardware and software technology, image processing technology, computer intelligence technology and intelligent traffic system not only solves the problems of computer vision and image processing technology of the previous road traffic surveillance, and overcomes the limitation of memory capacity and computing speed, but also improves the processing speed and accuracy, and satisfies the real-time, safety and reliability of real system.

License plate recognizing system consists of license plate location, character segmentation and character recognition[1-10]. License plate location is the basis of character segmentation and character recognition. It not only plays a critical role in the performance of the system, but also determines the recognizing speed and accuracy of the system. Therefore, license plate location is one of the most important technologies in license plate recognizing system.

As vehicle images are acquired outside, the image background is complicated and noise jamming is severe, license plate location technology is the research focus in license plate field. License plate recognizing system refers to computer vision, digital image processing and pattern recognition. The study on it not only promotes the development of the relevant fields, but also is an important application of computer vision, digital image processing and pattern recognition to intelligent traffic filed. License plate recognizing system can automatically acquire vehicle images and collect vehicle information to realize intelligent management, which greatly improves the operation efficiency of traffic management, saves manpower and resources, and makes traffic management scientific, regulated and intelligent. Therefore, studying license plate location which is the primary problem of license plate recognition not only has great theoretic importance, but also has important practical significance.

SUSAN EDGE DETECTION AND CORNER DETECTION ALGORITHM

SUSAN edge detection principle

SUSAN judges the edge point and corner point according to the distribution of the brightness value in local area with a point as the center. As shown in Figure 1, a finish machined round plate moves on the image. If the difference between the gray level of pixels in the template and the gray level of pixels in the center of the template is less than the threshold t, the point and the center of the template has the same gray level. The area composed by the pixels satisfying the requirements is called USAN. We can see from Figure 1 that when the finish machined round plate is completely in the background or foreground, the area of USAN zone is the largest such as e in Figure 1. When the template moves to the target edge, USAN zone reduces gradually such as c and d in Figure 1. When the template center is on the edge, USAN zone is the smallest such as b in Figure 1. When the template center is on the corner point, USAN zone is the smallest such as a in Figure 1. Therefore, USAN value of pixels can be compared with the given threshold. If USAN value of the pixel is less than the threshold, the point is an edge point. Concrete edge detection steps are as follows.

① SUSAN principle uses finish machined round plate, the objective for which is to make the detection isotropic. In practice, the digitization of images makes it difficult to realize real finish machined round plate. The templates with 37 pixels and traditional 3 3 templates are generally used. In fact, SUSAN measurement operator can provide edge detection accuracy which is independent of the size of the template. In other words, the calculation of the smallest USAN zone area is a corresponding concept, and has nothing to do with the template size. The template is placed in each point of the image. Except for the center, the gray value of each point and core points of the template are compared by using the following comparison functions.

$$c\left(\vec{r},\vec{r_0}\right)=\begin{cases}1 & \text{if } \left|I\left(\vec{r}\right)-I\left(\vec{r_0}\right)\right|\le t\\ 0 & \text{if } \left|I\left(\vec{r}\right)-I\left(\vec{r_0}\right)\right|> t\end{cases} \tag{1}$$

In the formula, $I\left(\vec{r_0}\right)$ and $I\left(\vec{r}\right)$ are the gray value of the center point of the template and that of the points of the template except for the center point. t is brightness difference threshold. And it represents the minimal contrast of the detected characteristics, is the maximum tolerance of the noises which can be ignored, and determines the feature extraction. The smaller t is, the more the characteristics, and the greater t is, the fewer the characteristics. So different t should be used for the images with different contrasts and noises. We can see that in light images, the target and the background are mainly differentiated by the edge. The value of t should be taken between 6 and 16, and $c\left(\vec{r},\vec{r_0}\right)$ is the comparison value. In order to achieve more accurate detection, more stable and more effective similarity comparison functions are used, as follows.

$$c\left(\vec{r},\vec{r_0}\right)=e^{-\left(\frac{I\left(\vec{r}\right)-I\left(\vec{r_0}\right)}{t}\right)^6} \tag{2}$$

The theory and experiment prove that the index takes 6, the reason for which is that the probability of misjudgment is the minimal.

The size of USAN region is figured out by using formula 3.

$$n\left(\vec{r_0}\right)=\sum_{\vec{r}}c\left(\vec{r},\vec{r_0}\right) \tag{3}$$

The value of $n\left(\vec{r_0}\right)$ is the numerical value of pixels in USAN, and it represents the area of USAN.

Formula 4 can figure out the initial edge response.

$$R\left(\vec{r_0}\right)=\begin{cases}g-n\left(\vec{r_0}\right) & \text{if } n\left(\vec{r_0}\right)<g\\ 0 & \text{otherwise}\end{cases} \tag{4}$$

In the formula, $R\left(\vec{r_0}\right)$ is the initial edge response. g is the threshold of the geometry, and determines the maximum of USAN region of edge points, which means that if USAN value of pixels in the image is less than g, the point is considered to be edge point. When g is too great, the pixels near the edge point can be extracted out as the edge. When g is too small, some edge points may not be detected. As the template is not round, g takes nmax/2. The experiment proves that when g is 3nmax/4, the edge points can be detected out, and nmax means the maximum of USAN region. It needs to eliminate redundant pixels to achieve the accuracy of single pixel.

The position of the local maximum value of the initial response which is vertical to the local edge is taken as the edge point, refined and smoothed. The local direction of the edge can be determined by one of the following methods. And the type of the edge is used to choose the method. The ideal ladder edge is called inter-pixel edge. When the boundary is not sharp-pointed, the edge is called intra-pixel edge. For inter-pixel edge, the vector of the template center pointing to USAN centroid is figured out, and the local edge direction is the direction which is vertical to to the vector. For intra-pixel edge, the direction of the edge is achieved by calculating the longest symmetry axis of USAN. And the following summations are used for estimation.

$$\overline{(x-x_0)^2}\left(\vec{r_0}\right)=\sum_{\vec{r}}(x-x_0)^2\,c\left(\vec{r},\vec{r_0}\right) \tag{5}$$

$$\overline{(y-y_0)^2}\left(\vec{r_0}\right)=\sum_{\vec{r}}(y-y_0)^2\,c\left(\vec{r},\vec{r_0}\right) \tag{6}$$

$$\overline{(x-x_0)(y-y_0)}\left(\vec{r_0}\right)=\sum_{\vec{r}}(x-x_0)(y-y_0)\,c\left(\vec{r},\vec{r_0}\right) \tag{7}$$

The proportion of $\overline{(y-y_0)^2}$ and $\overline{(x-x_0)^2}$ determines the direction of the edge.

We can determine the type of the edge according to the following method. If the area of USAN is less than the diameter of the template, the edge is intra-pixel edge. If the area of USAN is greater than the threshold, we can firstly use inter-pixel edge to calculate the direction of the edge. If the distance between the template center and the centroid is less than a pixel, the edge is still intra-pixel edge.

SUSAN corner detection principles

The first two steps of corner detection and edge detection are the same, but the value of g in the second step is not the same. As g not only determines the sharp degree of the achieved corner points, but also determines the amount of the characteristics which are extracted from the response matrix of USAN area. The smaller g is, the sharper the achieved angle points. So the value of g is generally nmax/2. For the achieved initial edge response, false angular points are eliminated by finding the centroid and neighboring nodes of USAN. And the maximum limit is used to determine the angular point.

From the above description about SUSAN edge detection algorithm, we can see that the algorithm can be used for edge detection of images being polluted by the noise. For independent gaussian noise with identical distribution, only the noise is less than the brightness difference threshold t of USAN function can ignore the noise. For isolated noise with local mutation, although the gray level of the noise is similar to that of the nuclear, only the value of local USAN is less than the threshold has no influence on edge detection. Traditional edge detection operators are very sensitive to the noise. In addition, the algorithm is flexible. Different thresholds t can be setted according to different situations to detect the edges of the images with different contrasts.

Figure 1: SUSAN corner detection

LOCATION PROCESS BASED ON SUSAN CORNER DETECTION

The above chapter introduces the basic principles of SUSAN edge detection and corner detection. This chapter mainly introduces license plate location method based on SUSAN corner detection, and the location process is shown in Figure 2. In fact, location process includes initial location and accurate location. The initial location includes preprocess, SUSAN edge detection, mathematical morphology operation and connected area calculation license plate segmentation. And accurate location includes SUSAN corner detection and accurate license plate segmentation. To make the paper systematic, the detailed process figure is shown as follows.

License plate image preprocess and SUSAN edge detection

The collected license plate images are preprocessed, and the process is as follows.

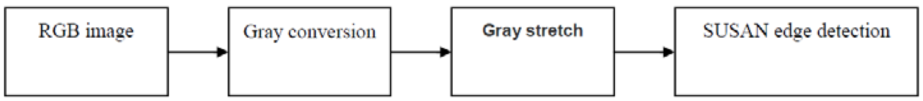

Figure 2: Preprocessing flow chart

Gray conversion uses the formula 3-2. The color image is converted into gray image, and the gray image is shown in Figure 3. Gray stretch uses the formula 3-6, and the image after gray stretch is shown in Figure 4. And the image after SUSAN edge detection is shown in Figure 5. In the experiment, the brightness different threshold t of a large number of license plate images is taken as 15. We can see from the image of SUSAN edge detection that SUSAN edge detection algorithm is not sensitive to the local noise, and the noise immunity is great. After edge detection, the edges achieved by centroid criterion and edge criterion are thinner. The traditional edge detection operators in the chapter 3.5 are compared, from which we can see that the edge image achieved by SUSAN edge detection algorithm is very ideal, and doesn’t need binarization, which saves processing time. At the same time, we see that the detection errors in each direction are very stable, which means that SUSAN edge detection is not sensitive to the direction. So we use SUSAN algorithm to process edge detection of images.

Figure 3: Gray conversion

Figure 4: After gray stretch

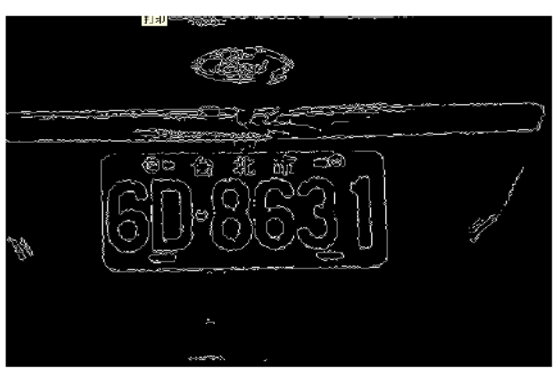

Figure 5: SUSAN edge detection

Using morphology to process license plate images

The license plate images after preprocess and SUSAN edge detection receives morphology operation. From the chapter 4.2, we can see that the opening operation which corrodes firstly and then inflates not only can segment the objects which have small interval, but also can plays the role of smoothing the boundary of larger objects. The closing operation which inflates firstly and then corrodes can fill the small holes of the objects, connect the neighboring objects and smooth the boundary of the objects. Therefore, in order to accurately locate license plate and eliminate the other non-license plate area, we use the opening operation and closing operation of morphology to process license plate images.

From the edge image of Figure 5, we can see that the pixel texture of license plate in the horizontal direction is more abundant than that in the vertical direction. So in the opening operation, the expansion texture in the horizontal direction is greater than that in the vertical direction. In the experiment, 10 and 3 are taken, and the corrosion takes omnidirectional corrosion. We can see from (a) in Figure 6 that after closing operation, the neighboring characters of license plate area are connected to be a connected area. But there are some non-character regions connecting license plate region or composing similar license plate area. In order to reduce some small independent regions and ensure that there is no cross structure between connected domains, the opening operation is needed after closing operation. The result of the opening operation is shown in (b) of Figure 6. After the opening operation, the areas like license plate and some non-license plate areas are retained. As inflation operation expands license plate area, the achieved license plate region includes a little other information besides frame, so accurate location is still needed to eliminate non-license plate region.

(a)Closing operation **(b)Firstly closing operation and then**

Figure 6: Firstly opening operation and then closing operation of license

The order of using morphology opening operation and closing operation needs to be noticed. If the opening operation is firstly used, we can get distinct effect, the license plate area can be divided into many parts, and even form tiny segments, as shown in Figure 7(a). The license plate area in the figure can't be connected, and we can't see which figure is license plate and which figure is non-license plate area. If the closing operation continues to be made for license plate images, they can't connect license plate area, as shown in (b) of Figure 7, the reason for which is that the opening operation eliminates too much character information, which makes the subsequent closing operation can't connect the left information. It likes that we firstly corrode the characters to make the distance between them great. When we inflate them, the expanded characters can't connect together.

(a) Opening operation **(b) Firstly opening operation and then closing**

Figure 7: Firstly opening operation and then closing operation of license plate images

Using connected domain calculation for preliminary determination on candidate region of license plate

We can see from 6(b) that the region including license plates integrate, and the other non-license plate areas may integrate, which means that a license plate image includes many target objects. If the objects which we are interested in are separated from the background, we must determine the connected region and make the mark of connected domain. Therefore, after receiving mathematical morphology operation, the achieved candidate license plate area needs to make connected domain operation.

(a) Neighborhood

The point set{（x+p, y+q）;((p, q) is a meaningful integer)}corresponding to the pixel （x, y）is called the neighborhood of pixel （x, y）. The fourth and eighth neighborhood is often used to process discrete images, and are marked as:

$$F_4(x,y)=\{f(x+1,y), f(x,y+1), f(x-1,y), f(x,y-1)\}$$

$$\begin{aligned}F_8(x,y)=\{&f(x-1,y-1), f(x-1,y), f(x-1,y+1), f(x,y-1),\\ &f(x,y+1), f(x+1,y-1), f(x+1,y), f(x+1,y+1)\}\end{aligned}$$

(b) Connection

There is pixel $f(x,y)=f(x+i,y+j)$, i and j exist in image region R, the adjacent points in $f(x,y)$ and $f(x+i,y+j)$ path have 4-oint connected domain or 8-point connected domain, and the point $f(x,y)$ connects with $f(x+i,y+j)$.

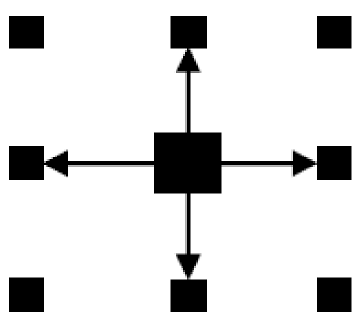

Figure 8: 4-point connected domain

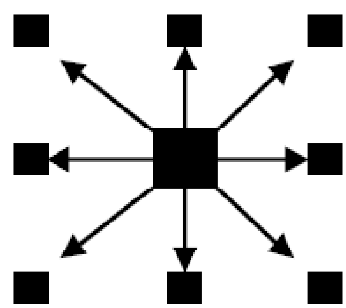

Figure 9: 8-point connected domain

(c) Connected components

The interconnected 0- pixel set or 255- pixel set in binary image are called connected components. 0- pixel surrounded by 255- pixel is called the hole. When 255- pixel connected component has no hole, it is called simply connected component, and when it has connected components of one or more holes, it is called multiple connected components.

(d) Mark

The segmented one-frame image may have multiple connected components. Every non-connected component corresponds to one target image area. Allocating labels to target image areas is called mark.

We can see from Figure 6 that the license plate image consists of only two gray levels, 0 and 25, after mathematical morphology operation. The background is represented by 0, and the candidate area is represented by 255. The candidate area of each connected domain is marked, and the background keeps invariant. The paper uses 8 connection judgment algorithm.

After calculating connected areas, we can get the length and width of the connected domain. As the length and width of the license plate are fixed values (between 1 and 3.5), the proportion of the length and width of the license plate can be used to wipe out a part of non-license plate candidate area, and the result is shown in Figure 10. We can see that there is a false license plate area with abundant edge characteristics except for real license plate. Next, we use corner detection to get rid of the false license plate.

Figure 10: License plate candidate

Corner detection and accurate location on license plate area

After the above calculation, we can get one or more candidate regions including license plate area. After making SUSAN corner detection on the candidate areas, the angular points of candidate areas including license plates are near the license plates. But there are few angular points and there is no candidate area of license plate outside the boundary of license plate area, and the angular points are dispersed and appear on any point of candidate regions randomly, as shown in Figure 11. And we can eliminate non-license plate candidate area and accurately locate the license plate. The concrete process of locating license plate is as follows.

Using the formula to calculate the mean coordinate of all white pixels of candidate area

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad x_i \text{ is the abscissa of all white pixels} \tag{8}$$

n is the number of all white pixels in candidate area.

Calculating the density p of white pixels in candidate area

$$p = \frac{n}{width \times height} \tag{9}$$

(3) All lines above the line which $\bar{x}$ is on are averagely divided into m small regions. The density p1 of white pixels in each small region is calculated. If $p_1 \geq \frac{p}{2}$, it indicates that the small region

belongs to license plate area, or it reaches the upper boundary of the license plate. X value is preserved, and the line represented by it is used as the upper boundary of license plate area, top.

(4) The above methods are used to find the bottom, left and right boundary of the license plate.

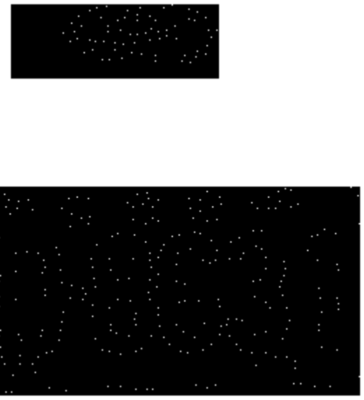

Figure 11: Corner detection of candidate

Figure 12: Accurate location on license plate

After getting the bottom, left and right boundary of the license plate, we use the proportion of width and length of the license plate to remove the false license plate. And we can get the located license plate, as shown in Figure 12. From the figure, we can see that the clustering algorithm after using corner detection can effectively remove false license plate area, and we finally get the real license plate.

The above chapter has introduced that the algorithm is also suitable for inclined license plate images. The following is a testing result of inclined license plates, as shown in Figures from 13 to 20. It indicates that the method can accurately locate the inclined license plate images.

Figure 13: Original image of license plate

Figure 14: Gray conversion

Figure 15: Gray stretch

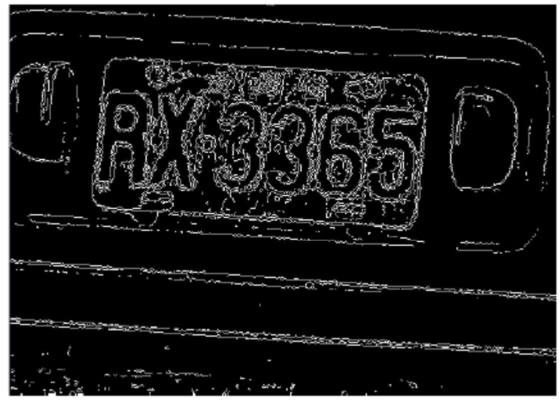

Figure 16: SUSAN edge detection

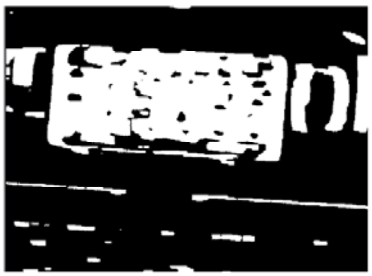

Figure 17: Morphology algorithm

Figure 18: Candidate area of license plate

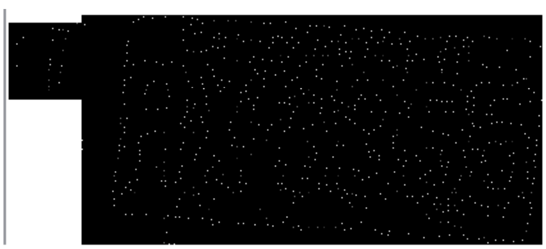

Figure 19: Corner detection of candidate area

Figure 20: Accurately locating license plate

CONCLUSION

The character stroke of license plates has abundant angular points which distribute densely and regularly, for which the paper proposes license plate location method based on corner detection. In the process of location, as the texture of license plates in horizontal direction is abundant compared with that in vertical direction, the operators of inflation and corrosion of morphology take different values. The dilation operator in horizontal direction is greater than that in vertical direction, and corrosion operator uses omnidirectional corrosion. For initial location, we use the edge of graying image to detect the morphology of the image and get the connected domain. Then, we use the clustering algorithm after corner detection to remove false license plate and get the license image with accurate location. The algorithm has no too many thresholds which are setted artificially, and can be applied widely. And the localization rate is improved.

License plate location method based on SUSAN corner detection is a license plate location method for the characteristic that the character stroke of license plates has abundant angular points which distribute densely and regularly. In the process of localization, the algorithm uses SUSAN operator for edge detection, uses mathematical morphology to make initial location on edge images of license plates, and uses SUSAN operator to make corner detection on the achieved candidate areas.

Then, the corner density is used to accurately locate the license plate. When the inclination of license plate is greater and the vertical and horizontal direction incline, the method not only has ideal segment effect and rapid segment velocity, but also helps real-time recognition of license plates.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article.

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