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Research on Geometric Positioning Algorithm of License Plate in Multidimensional Parameter Space

[1] Yinhua Huan, [2] Shiqi Zhao

[1] Department of Automobile Engineering, Huaian College of Information Technology, 223003, China
[2] School of Mechanical Engineering, Nanjing University of Science & Technology, 210004, China
[1] Tel.: 13912089093
[1] E-mail: ahua_09@126.com

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Abstract: Considering features of vehicle license plate location method which commonly used, in order to search a consistent location for reference images with license plates feature in multidimensional parameter space, a new algorithm of geometric location is proposed. Geometric location algorithm main include model training and real time search. Which not only adapt the gray-scale linearity and the gray non-linear changes, but also support changes of scale and angle. Compared with the mainstream locating software, numerical results shows under the same test conditions that the position deviation of geometric positioning algorithm is less than 0.5 pixel. Without taking into account the multidimensional parameter space, Geometric positioning algorithm position deviation is less than 1.0 pixel and angle deviation is less than 1.0 degree taking into account the multidimensional parameter space. This algorithm is robust, simple, practical and is better than the traditional method. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Vehicle license geometric location, Multidimensional parameter space, Model training, Real time Search, Positioning algorithm.

1. Introduction

License plate location is the key step in the license plate recognition. With the rapid development of intelligent transportation, the locating speed and precision is demanded higher and higher. Visual identification and localization algorithm is the key technology of license plate recognition. Adopt advanced technology for vision detection and location to identify license plate which can achieve fast intelligent identification [1].

In recent years, some researchers investigated the positioning method of license plate mainly including some traditional algorithms [2-4]. The localization algorithms are mainly the template matching method [5-7] and least square algorithm etc [8, 9]. Those are sensitive to the scale, rotation and signal strength of the target region of interest. There are also some new unconventional methods. Fractal is applied to the license plate image positioning [10]. Neural network is applied to realize license plate image positioning. Most of the literature takes the license plate image positioning method and the image matching processing into consideration [5, 11]. The studies and reports are not many for how to analyze location problem on shape characteristics of the license plate image.

In this article, a new geometric location algorithm of the license plate was developed. The method can not only adapt to the gray linear change and gray nonlinear variation, and support the scale and angle change. The location algorithm is simple, practical and strong robust, which is better than the traditional regional location and edge positioning methods.

2. Localization Algorithm

The overall frame of geometric positioning for license plate is shown in Fig. 1. Geometric location is made up of model training and real-time search.

2.1. Model Training

Model training includes the following steps: 1) Granularity choice; User Set or automatic select granularity parameters. 2) License plate boundary point detection; Detect license plate point image edge information, the input is training images, the output is boundary point list. 3) Boundary point connection; Connect the adjacent boundary point in the same direction. 4) Chain objects generation; According to the boundary point connection properties to create a chain. 5) Line object generation; Segment the chain objects into the multiple low curvature line object. 6) Detection point spacing and quantity calculation; According to the total length of line to segment the detection point spacing and quantity. 7) Probe points list generation; depending on amount and spacing of the probe points to create probe point list. 8) Pattern contrast calculation; Calculate the contrast of license plate point mode image. AS shown in Fig. 2, the task of the geometric positioning model training part is: extracted edge information from the training image mode, select a number of boundary points to constitute geometric description of the model. Training images shown in Fig. 2(a), The geometric description of the training mode shown in Fig. 2(b).

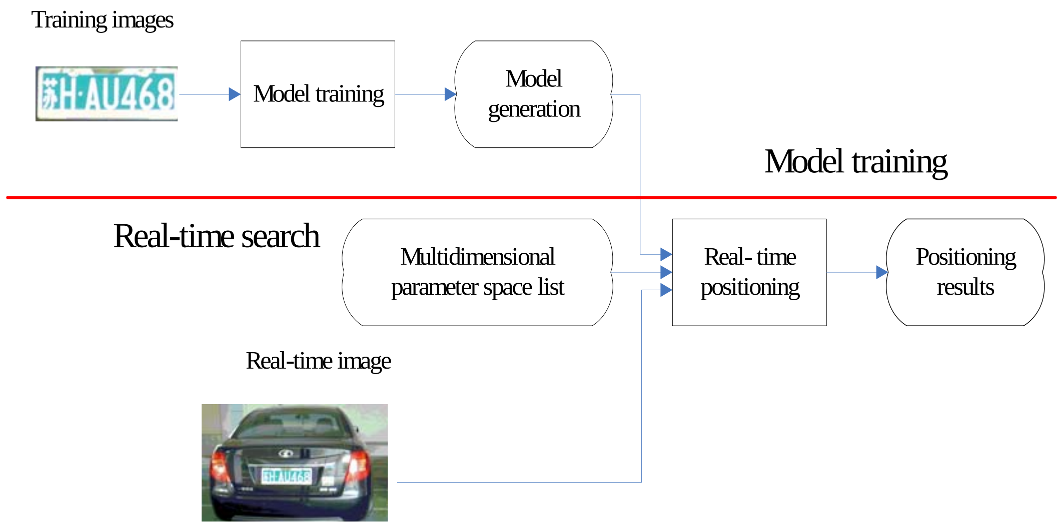

Fig. 1. Framework of geometric positioning.

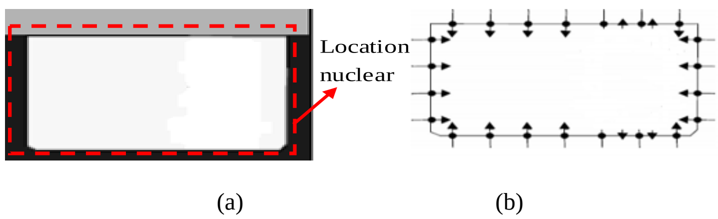

Fig. 2. Geometric positioning mode training.

2.2. Real-time Search

Geometric positioning real-time search is mainly composed of the search space and real-time positioning strategy. The basic idea of real-time positioning strategy is: gradually reduce the step length, orientate many times to get the final localization results.

The search space is more parameters, including two translational and four non-translational parameters. Two translational parameters is X direction and Y direction translation parameters X and Y, Four non- translational parameters is zoom parameters LogX and LogY, scaling and rotation parameter LogS. Multidimensional parameter transformation is to obtain the corresponding coordinates in the real-time image of the model probe points by multi-dimensional transformation. Probe point list of multidimensional parameter transformation is organized in the form of an array. Offset is offset position of the probe points converted into real-time image. The gradient direction is gradient direction converted into real-time image later.

Assuming that matrix C is the transformation matrix of non-translational parameters. Vector t denotes the translational parameters. Vector L indicates probe point position in training mode. Vector L' indicates probe point offset in the real-time image. F_x is the column address deviation and F_y is the row address deviation in real-time image. Probe point offset of multidimensional parameter space transformation F calculation such as formula (1):

$$L' = CL + t,\ x = round(L_x),\ y = round(L_y),\ F = xF_x + yF_y \tag{1}$$

Assumes that the gradient direction of probe points in the training mode is α, the gradient direction of multidimensional parameter space transformation α' is shown in formula (2):

$$\alpha' = \arctan\left(\frac{|\det(C)|}{\det(C)}\begin{pmatrix}0 & 1\\ -1 & 0\end{pmatrix}C\begin{pmatrix}0 & -1\\ 1 & 0\end{pmatrix}\begin{pmatrix}\cos(\alpha)\\ \sin(\alpha)\end{pmatrix}\right) = \begin{cases}\arctan\left(\begin{pmatrix}C_{22} & -C_{21}\\ -C_{12} & C_{21}\end{pmatrix}\begin{pmatrix}\cos(\alpha)\\ \sin(\alpha)\end{pmatrix}\right)\cdots\det(C) < 0\\ \arctan\left(\begin{pmatrix}-C_{22} & C_{21}\\ C_{12} & -C_{21}\end{pmatrix}\begin{pmatrix}\cos\alpha)\\ \sin(\alpha)\end{pmatrix}\right)\cdots\det(C) > 0\end{cases} \tag{2}$$

Direction scores used to evaluate the difference degree between detection point direction after space transform and the corresponding gradient direction in real-time image. Amplitude scores used to evaluate edge strength of real-time image. Localization algorithm evaluation matching scores are defined as follows: F_i – probe point i address offset of transformation in the license plate image. d_i – probe point i gradient direction of transformation in the license plate image. λ_i – probe point i weight of transformation in the license plate image. $M(a)$ – gradient amplitude of offset address a in license plate real-time image. $D(a)$ – gradient direction of offset address a in license plate real-time image. $f_{dir}()$ – gradient direction evaluation function. $f_{mag}()$ – gradient amplitude evaluation function. $M(a+F_i)$ – gradient amplitude of probe point i in corresponding real-time image. $D(a+F_i)$ – gradient direction of probe point i in corresponding real-time image. $D(a+F_i)-d_i$ – gradient direction difference of probe point i.

Takes into account the gradient amplitude of the probe point, the difference and weight of gradient direction, the normalized matching scores and noise suppression, license plate matching scores is defined as in formula (3):

$$S = \frac{\sum_i \lambda_i f_{mag}\left(M\left(a+F_i\right)\right) f_{dir}\left(\left|D\left(a+F_i\right)-d_i\right|\right)}{\frac{1}{\pi}\int_0^{\pi} f_{dir}\theta d_\theta \sum_i \lambda_i} \tag{3}$$

3. Real-time Positioning

License plate real-time positioning include: determine the name scaling factor of dimensional parameters, the tag particle degree of the real-time image, calculate gradient amplitude and gradient direction, determine the change of parameters scope and step length, reduce the step length, locate many times, output positioning results.

In order to determine the change of multidimensional parameters and step length, definition is shown as following: p_i – The i[th] probe point. (x_i, y_i) – The ith probe point coordinates. α_i – The ith probe point gradient direction. V_i – The ith probe point corresponding unit vector of gradient direction. λ_i – The weight of the ith probe point. N – non-fixed multidimensional parameter number. C – The multidimensional parameters matrix corresponding to the step length. S_f – The multidimensional parameters length factor corresponding step.

Define the projection node $c(c_x, c_y)$. That it is minimum distance square sum point to probe point tangent contour. Through the outline of the ith probe point tangent can be expressed as: $x\cos\alpha_i = y\sin\alpha_i - r_i = 0$. Projection center $c(c_x, c_y)$ meet the formula: $F(c_x, c_y) = \sum_i (c_x\cos\alpha_i + c_y\sin\alpha_i - r_i)^2 \to \min$, also can be expressed as the formula (4):

$$\begin{cases}\dfrac{\partial F}{\partial c_y} = \sum_i 2\sin\alpha_i\left(c_x\cos\alpha_i + c_y\sin\alpha_i - r_i\right) = 0\\ \dfrac{\partial F}{\partial c_y} = \sum_i 2\sin\alpha_i\left(c_x\cos\alpha_i + c_y\sin\alpha_i - r_i\right) = 0\end{cases} \tag{4}$$

Formula (5) can be obtained from formula (4):

$$\begin{cases}c_x = \dfrac{\sum_i r_i\cos\alpha_i\sum_i\sin^2\alpha_i - \sum_i r_i\sin\alpha_i\sum_i\sin\alpha_i\cos\alpha_i}{\sum_i\cos^2\alpha_i\sum_i\sin^2\alpha_i - \left(\sum_i\sin\alpha_i\cos\alpha_i\right)^2}\\ c_y = \dfrac{\sum_i r_i\sin\alpha_i\sum_i\cos^2\alpha_i - \sum_i r_i\cos\alpha_i\sum_i\sin\alpha_i\cos\alpha_i}{\sum_i\cos^2\alpha_i\sum_i\sin^2\alpha_i - \left(\sum_i\sin\alpha_i\cos\alpha_i\right)^2}\end{cases} \tag{5}$$

Define the parameter S as formula (6), Dimensional parameters of the step length is defined as the formula (7).

$$s=\sqrt{\frac{\sum_i \lambda_i \bullet [(V_i \bullet (p_i - c))]^2}{\sum_i \lambda_i^{\ 2}}} \tag{6}$$

$$MSS=\frac{S_f \bullet \min\left(\frac{1.5\sqrt{\sum_i \lambda_i^{2}}}{\sqrt{\sum_i \lambda_i \bullet [V_i \bullet (p_i - c)]^2}},2\right)}{\sqrt{N}} \tag{7}$$

In license plate real-time search phase, geometric positioning algorithm is different from the regional location and edge localization algorithm only in translation parameter space to search, but in the multidimensional parameter space to search. Evaluate the similarity between the evaluation results and training mode to output the highest similarity scores for the final positioning result. As shown in Fig. 3, the overall strategy for license plate geometry localization algorithm in real-time search stage is: search in real-time image once, and then based on the results of positioning reduce the search step length, locate and search twice again, get the final accurate positioning results.

4. Experimental Results and Discussion

Use license plate image as shown in Fig. 4 to test the relative accuracy of geometric positioning. Geometric positioning range is from minus 15 degrees to 15 degrees, the particle size is 2.2. The experimental results are shown in Table 1. Deviation is less than 0.5 pixel and the angular deviation less than 0.5 degrees. Low signal to noise ratio image, low contrast image, partial bright image, darker images, fuzzy degraded image, part of the cover image of Fig. 4 are used to test the robustness. The experimental results are shown in Table 2. Data shows that the robustness is better.

Evaluate the efficiency of this position used license plate image shown in Fig. 4. The granularity is 2.5, rotational degree of freedom for -15~15 degrees, accept the score is 0.70; Experimental platform is PIV1.7 CPU, 1 G memory, VC6 development environment, the results as shown in Table 3.

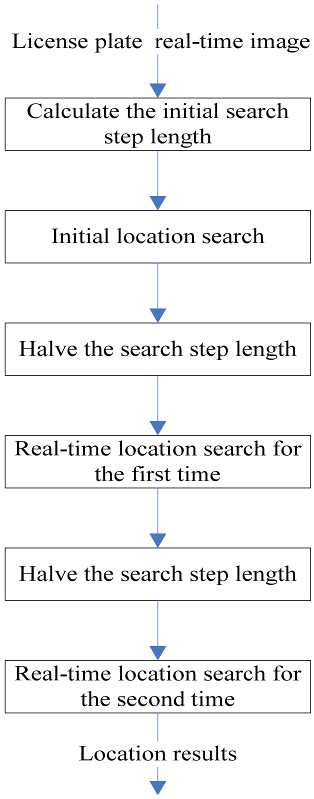

Fig. 3. License plate positioning flowchart.

Pattern 1

Pattern 2

Pattern 3

Pattern 4

Pattern 5

Pattern 6

Fig. 4. Test images and results.

Table 1. Accuracy test data sheet.

License Plate Image Test	Geometric Positioning		Standard Value		Relative Error	
	Coordinates	Angle	Coordinates	Angle	Coordinates	Angle
1	(181.82,137.54)	3.89	(181.53,137.04)	3.65	(0.29,0.50)	0.24
2	(369.00,170.31)	4.05	(369.05,169.76)	3.79	(-0.05,0.55)	0.26
3	(543.96,177.75)	4.36	(543.59,177.49)	4.75	(0.37,0.24)	-0.39
4	(165.47,330.95)	4.22	(165.78,330.56)	3.88	(-0.03,0.39)	0.34
5	(353.43,337.13)	4.04	(353.50,336.53)	3.72	(-0.07,0.60)	0.32
6	(501.74,378.87)	3.94	(500.92,378.58)	3.44	(0.18,0.29)	0.40

Table 2. Robustness experimental data sheet.

License Plate Image Test	Geometric Positioning		Standard Value		Relative Error	
	Coordinates	Angle	Coordinates	Angle	Coordinates	Angle
Training image	(269.96,190.19)	0.02	(269.99,189.99)	0.46	(-0.03,0.20)	-0.44
Low SNR image	(269.99,190.32)	0.11	(270.02,190.07)	0.41	(-0.03,0.25)	-0.30
Low contrast image	(269.96,190.23)	0.06	(269.98,189.97)	0.43	(-0.02,0.26)	-0.37
Partial bright image	(269.96,190.19)	0.10	(270.00,189.99)	0.38	(-0.04,0.20)	-0.28
Darker image	(50.04,50.07)	0.19	(50.17,49.76)	0.62	(-0.13,0.31)	-0.43
Fuzzy degraded images	(269.89,190.01)	1.17	(269.96,190.18)	0.90	(-0.07,0.17)	0.27
Some shade image	(269.94,190.18)	0.38	(269.99,190.00)	0.15	(-0.05,0.18)	0.23

Table 3. Efficiency test data sheet.

Geometric Positioning Algorithm			
Training	1.56		
Real-time positioning	Preprocessing	Filter	8.53
		Interpolation	2.24
		Edge detection	5.25
		Total	14.02
	Positioning	Initial position	12.92
		Second position	3.22
		Third position	4.89
	Total, ms		35.49

5. Conclusion

Geometric positioning algorithm of license plate is proposed in this paper. The accuracy, robustness and efficiency of the algorithm have been verified by the experiment. The results of numerical experiments showed that this method can effectively complete the recognition of license plate, satisfy the requirement of intelligent transportation visual real-time positioning.

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