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Research on Grassland Demarcation Line Extraction Based on Improved Least Squares Method

Yin Yalin[1, a,*], Hu Lianjun[2,b] and Song Hong[3,c]

[1]*School of Automation and Information Engineering, Sichuan University of Science and Technology. Yibin City, Sichuan Province, China;*

[2]*School of Mechanical Engineering, Sichuan University of Science and Technology. Yibin City, Sichuan Province, China;*

[3]*Sichuan University of Science and Technology. Yibin City, Sichuan Province, China;*

a.562546435@qq.com, b.hlj28288@sina.com, c.sh8887878@sina.com

**corresponding author*

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Abstract: The rapid development of mobile robots has made intelligent mowing robots widely concerned. The dividing line between grassland and non-grass is an important reference for robots to carry out mowing navigation.Aiming at this problem, this paper proposes a grassland boundary line extraction algorithm based on improved least squares method based on image segmentation binary image.Firstly, the corner point in the image is detected by the Shi-Tomasi algorithm, and the approximate range of the grass boundary line is obtained. Then, the modified corner point is fitted by the improved least squares method, and finally the boundary line between the grassland and the non-grass is obtained. Finally, three straight line fitting methods were compared by experiments. The results show that the improved least squares method has the best effect and the fastest running speed.

1. Introduction

With the increase of urban greening area, the intelligent mowing robot integrating mobile robot and service robot is a hot spot of current research. Among them, the most far-reaching impact on intelligent mowing robots is the formulation of path planning algorithms, and the collection and analysis of surrounding environment is the basis of path planning. At present, most mowing robots on the market implement automatic mowing in the area by pre-laying cables. In response to this problem, this paper analyzes the grassland environment with obvious boundary features and extracts the boundary between grassland and grassland. Provide theoretical support for the path planning of intelligent mowing robots.

Extracting the grassland boundary line actually uses the line segment to represent the grassland boundary. Considering that the field of vision of the intelligent mowing robot is limited, the speed in the mowing work is not too fast, and the curve with a certain arc can also be represented by a straight line. On the basis of image segmentation, this paper selects the straight line fitting method to extract the grass boundary. Commonly used straight line fitting methods include Hough transform and least squares. Hough transform is susceptible to noise and small short lines, and is not suitable for the case where the edge of the grass is sparse.

Considering a comprehensive consideration, this paper proposes a straight line fitting method combining the Shi-Tomasi corner detection algorithm and the improved least squares method. The corner points in the image are detected first by the corner detection, and then the improved least squares method is used. By fitting a line, this algorithm can improve the fitting accuracy and avoid the influence of noise points on the least squares fitting straight line.

2. Shi-Tomasi algorithm

At present, researchers have proposed a variety of corner detection algorithms, including Moravec operator, Harris operator, Shi-Tomasi operator and FAST operator. Among them, the Harris corner detection algorithm is not sensitive to image rotation and is not sensitive to illumination changes and noise. The Shi-Tomasi algorithm is improved on the basis of the Harris algorithm. Relatively speaking, the Shi-Tomasi algorithm is adaptive. Better ability.

2.1 Harris algorithm

The definition of a corner point means that the local neighborhood of a point has different boundaries in two different areas. It can also be considered that the corner point is the intersection of two edges. These points are different from other points in that they have some mathematical features. , such as local maximum or minimum gray scale. The Harris algorithm is the most typical of the corner detection algorithm. Its principle is to use a window to move on the image, and to determine whether the window changes in various directions and the degree of change.

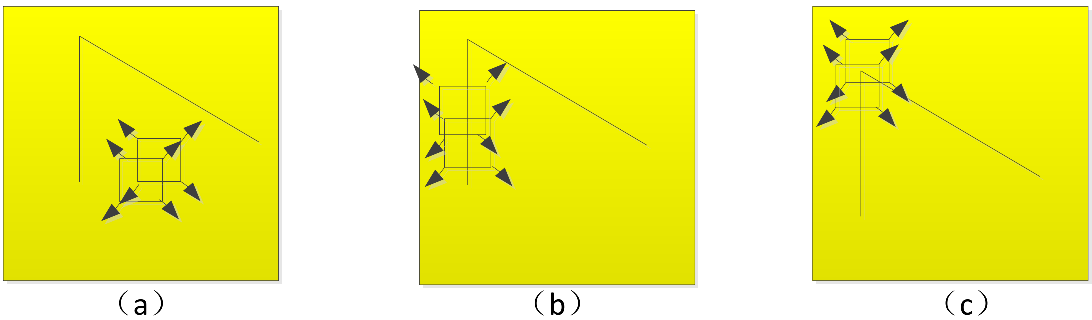


Figure 1: Harris corner detection schematic.

Suppose there is a pixel to be processed and W is a rectangular window centered on the pixel. After the window moves in (u, v) units in any direction, the gray scale is converted to $E(u, v)$.

$$E(u,v) = \sum_{x,y} w(x, y)[I(x, y) - I(x+u, y+v)]^2 \tag{1}$$

Among them $w(x, y)$ is the Gaussian kernel function. In addition, Taylor expansion can be known:

$$I(x+u, y+v) = I(x, y) + I_x u + I_y v + o(u^2 + v^2) \tag{2}$$

Bring formula (2) into (1) to get:

$$E(u,v) = \sum_{x,y} w(x, y)[I_x u + I_y v]^2 = \sum_{x,y} w(x, y)[u, v]\begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}\begin{bmatrix} u \\ v \end{bmatrix} \tag{3}$$

$$M = \sum_{x,y} w(x, y)\begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} = \begin{bmatrix} A & C \\ C & B \end{bmatrix} \tag{4}$$

The matrix M is called an autocorrelation matrix.That is to say, the eigenvalue of the matrix reflects the curvature of the autocorrelation function.When the two eigenvalues are relatively small, it indicates a flat area; one of the two eigenvalues is larger when the value is smaller, and the edge is represented; in the end, when both are large, they are corner points. However, this method does not directly solve the size of the feature value, but uses a function R to determine the characteristics of the pixel by solving the value of R.

$$R = (\lambda_1 \lambda_2) - k(\lambda_1 + \lambda_2)^2 = |M| - k \cdot tr^2(M) \tag{5}$$

When the absolute value of R is small, it indicates a flat area; When R is a negative number, it is a boundary; when R is a positive angle, it is a corner point. Where $|\cdot|$ is the determinant of the matrix, tr is the trace of the matrix, and the value of k is 0.04~0.06.

In summary, the Harris algorithm detects the corner points by the following steps:

(1) Find the Gaussian partial derivative of the image I through the image I;

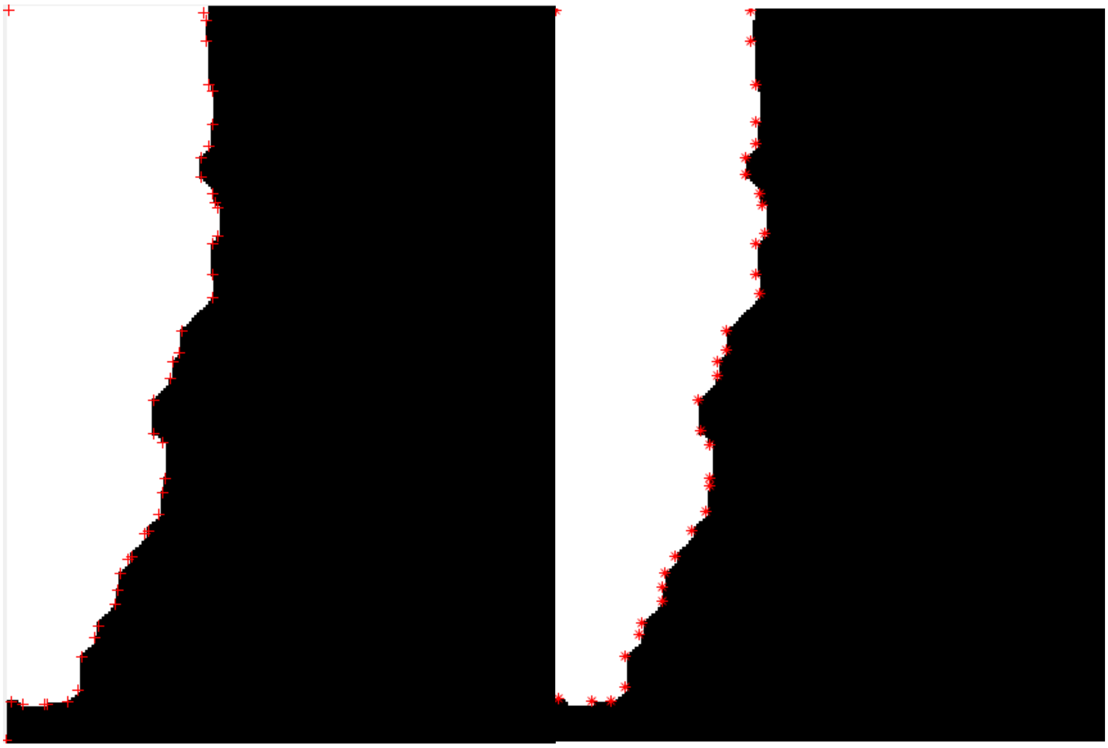
(2) Then processing the target pixel points to construct a correlation matrix M;

(3) Calculating a response function R of the target pixel;

(4) Threshold processing is performed on the response function R, and a point larger than the threshold T and being a local maximum value can be used as a corner point.

2.2 Shi-Tomasi algorithm

The Shi-Tomasi corner detection algorithm is improved on the basis of the Harris algorithm. The Harris algorithm is easy to repeat detection when detecting corner points, and the detected corner points are not uniform enough, and the Shi-Tomasi algorithm avoids feature aggregation to a certain extent. The phenomenon of clusters is shown in Figure (2).



(a) Harris algorithm (b) Shi-Tomasi algorithm

Figure 2: Comparison of two corner detection algorithms.

Table 1: Comparison of two algorithm corner detection effects.

	Harris	Shi-Tomasi
Number of corner points	42	35
Run time (ms)	3.58	1.02

The detection principle of the Harris algorithm is to use a response function R, subtract its trace from the value of the matrix M determinant, and then compare this value with a given threshold T to determine whether it is a corner point. The essence of the Shi-Tomasi algorithm is to directly compare the eigenvalues of the matrix M with a predetermined threshold. If the smaller of the two eigenvalues is greater than the minimum threshold, the point can be considered a strong corner.

$$R = \min(\lambda_1 \lambda_2) \tag{6}$$

3. Improved least squares method

The principle of fitting the straight line by the classical least square method is to give a given point and find its approximate function curve. Suppose you want to fit a set of data in a straight line. The fitted linear equation is $y = ax + b$, The sum of squared errors is:

$$E = \sum_{i=1}^{n} (ax_i + b - y_i)^2 \tag{7}$$

The ultimate goal of the algorithm is to minimize the value of E, which can be achieved by biasing the linear parameters:

$$\frac{\partial E}{\partial a} = 0 \ , \ \frac{\partial E}{\partial b} = 0 \tag{8}$$

When the amount of data to be fitted is small, it is feasible to directly solve the two first-order partial derivatives to find the values of a and b, but when the number of data points is relatively large, the calculation amount of the method will increase. The speed of the straight line will also decrease. In order to improve the speed of straight line fitting, this paper introduces the average value and changes the a and b values.

$$E = \sum_{i=1}^{n} \Delta d_i^{\ 2} = \sum_{i=1}^{n} (y_i - a - bx_i)^2 \tag{9}$$

$$\frac{\partial E}{\partial a} = -2\left(\sum_{i=1}^{n} y_i - na - b\sum_{i=1}^{n} x_i\right) \tag{10}$$

$$\frac{\partial E}{\partial b} = -2\left(\sum_{i=1}^{n} x_i y_i - a\sum_{i=1}^{n} x_i - b\sum_{i=1}^{n} x_i^2\right) \tag{11}$$

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \ , \ \ \bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \ , \ \ \overline{x^2} = \frac{1}{n}\sum_{i=1}^{n} x_i^2 \ , \ \ \overline{xy} = \frac{1}{n}\sum_{i=1}^{n} x_i y_i \tag{12}$$

$$a = \bar{y} - b\bar{x} \quad b = \frac{\bar{x}\bar{y} - \overline{xy}}{[(\bar{x})^2 - \overline{x^2}]} \tag{13}$$

Suppose there is a set of data (163 186), (134 126), (150 172), (123 125), (141 148), which are respectively fitted by the least squares method before and after the improvement, and the fitting time before the improvement is improved. It is 1.56s, and the time for the improved algorithm to fit the line is only 0.85s, which is 45.5% faster than the original time.

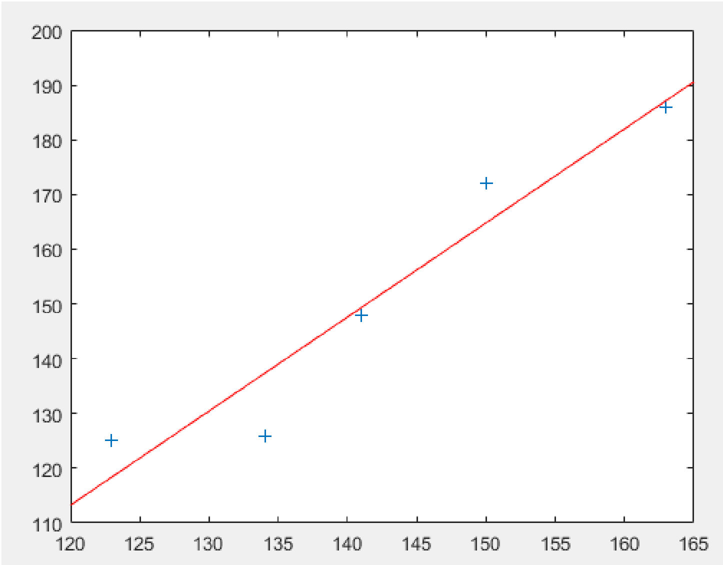
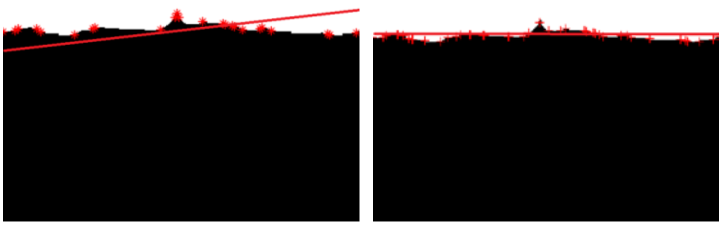


Figure 3: Least squares fitting straight line

4. Analysis of experimental results

Three different algorithms were used in the experiment, namely least squares method, Harris algorithm and improved least squares method, Shi-Tomasi algorithm and improved least squares method. The results are shown in (a)(b)(c) respectively.



(a) (b) (c)

Figure 4: Comparison of straight line fitting effects of three algorithms.

Table 2: Comparison of experimental results.

method	Slope	intercept	operation hours
Least squares	0.5364	31	3.65s
Harris+Least squares	0.2566	24	1.96s
Shi-Tomasi+Least squares	0.0954	2	1.15s

Combining the straight line fitting effect comparison chart of Figure 4 with the data in Table 1, it is not difficult to find that the straight line fitting algorithm used in this paper is superior to the other two methods in both the fitting accuracy and the running time of the algorithm.

5. Conclusion

In this paper, a method of extracting grassland boundary line based on Shi-Tomasi algorithm and least square method is proposed. Firstly, the corner point in the grassland segmentation binary map is detected by Shi-Tomasi algorithm, and then the detected angle is fitted by least squares method. Point to get the dividing line of the grass border. The algorithm solves the problem that the least squares method fits the line directly to the noise to some extent. Finally, the experimental simulation proves that the method not only has a good straight line fitting effect, but also improves the running speed when extracting the boundary line between grassland and non-grass.

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