Plant Protection Robot Row-type Guidance Technique

Based on Laser Radar

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Abstract. The research objective was to achieve local path planning of plant protection robot in row-type plants like vineyard. To acquire the robot pose (yaw angle and lateral offset) in row-type plants, laser radar was used as a single sensor to detect the row-type plants information, fitted row boundary line and center line. With
the aid of MATLAB simulation, algorithm feasibility was gotten verified. The results show the lateral offset error is in mm level and yaw angle is in minute level. The distance error calibration experiment was also implemented by means of a wall, and the result shows the maximum error is 16.6mm. Both of them meet demands for row-type guidance technique.

Introduction

Plant protection robots have the potential to dramatically transform row-type tree production by automating key operations such as mowing, spraying and harvesting. From a robotics perspective, all these applications can be enabled with a relatively simple yet challenging capability: determination of position and orientation [1-2]. Using the method of machine vision has certain limitation in row-type guidance such as light conditions and atmospheric effects [3]. Laser radar technology does not suffer from the effects of ambient lighting conditions and thus can be more reliable in an agricultural environment [4].

Pawin and Jongmin put forward the method of correcting lateral offset when running in a row of lead correction. Experimental results show that when the speed is 0.36m/s, the minimum error is 0.21m [5-6]. Professor Jin-lin Xue took the agricultural robot as research platform based on LMS291-05 laser radar sensor. And then the path information was obtained by the control system. Least square method was used to gotten platform pose (lateral offset and yaw angle) in the row [7].

The objective of this research is to put laser radar as row identified sensor and acquire the row-type environment information. And data processing such as encoding, decoding, filtering, coordinate transformation, boundary fitting, navigation center line extraction are also necessary and finally obtained the pose (yaw angle and lateral offset) of the plant protection robot in row-type.

Data acquisition and processing

The plant protection robot control system diagram is shown in Figure 1, which includes the data processing, mobile platform and motion control.
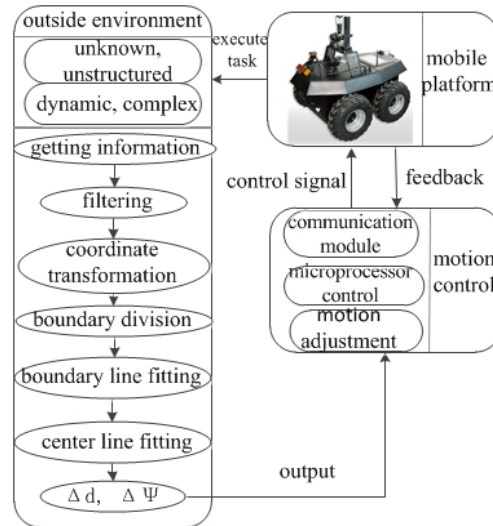
Figure 1.The whole control system diagram

Data collecting

The laser radar model used in this research is URG-04LX-01, which is a two dimensional sensor, using USB transport protocol to transfer data, detecting distances between -30°-210° angle ranges and the angle resolution is about 0.38°.

Coordinate transformation and boundary division

In order to facilitate the acquiring of the row boundary line and center line, it is necessary to transform polar coordinate system into Cartesian coordinates system. Conversion formula is as follows:

$$\begin{cases} x = r\cos a \\ y = r\sin a \end{cases} \tag{1}$$

Where ρ is the polar distance, which can be gotten from laser radar, α is also given by laser radar,

(x, y) is coordinates value.

Divide the row-type into two sides depending on the angle ranges, one side:-30°~60°, and another side: 120°~210°.

Row boundary line fitting

The least square method is used to fit the point cloud data of laser radar. The formulas are as follows:

$$\begin{cases} y1 = k1 * x1 + b1 \\ y2 = k2 * x2 + b2 \end{cases} \tag{2}$$

Where k1,k2 are two row boundary line slopes, b1,b2 are row boundary line intercepts, (x1,y1) is the coordinate value of one side border, (x2,y2) is the coordinate value of the other side border.

Center line fitting

The center line of the row should be fitted according to the linear equation of boundary, which

calculation formula is as follows:

1) Acquiring the slope of the row center line k3:

$$k3 = (k1 + k2)/2 \qquad (3)$$

Where k3 is slope of the center line, $k1, k2$ is given in equation (2).

2) Parallel judgment of boundary lines:

(1) If the two boundary lines are parallel $(k1 = k2)$:

$$b3 = (b1 + b2)/2 \qquad (4)$$

Where b3 is the intercept of row center line, $b1, b2$ are given in equation (2).

(2) If the two boundary lines are parallel. The intersection point coordinates of two boundary lines ((x', y')) should be solved first of all.

$$b3' = y' - x' * k3 \qquad (5)$$

Where $k3$ is the slope of row center line, $b3'$ is the intercept of row center line, (x', y') is the intersection point coordinates of two boundary lines.

In summary, the linear equation for the center line of the row is as follows:

$$y3 = k3 * x3 + b3 \qquad (6)$$

Where $(x3, y3)$ are coordinates of the center line, $k3, b3$ are given in equation (3) and (4).

In conclusion, we can get the yaw angle:

$$\Delta y = \arctan(k3) \qquad (7)$$

and the lateral offset:

$$\Delta d = \frac{|b3|}{\sqrt{k3^2 + 1}} \qquad (8)$$

Result analysis

Simulation test analysis

The row-type information was collected by the laser radar, which includes distances and angles information and can express in figure 2(a). Fitting boundary line and center line are as follows in Figure 2(b).
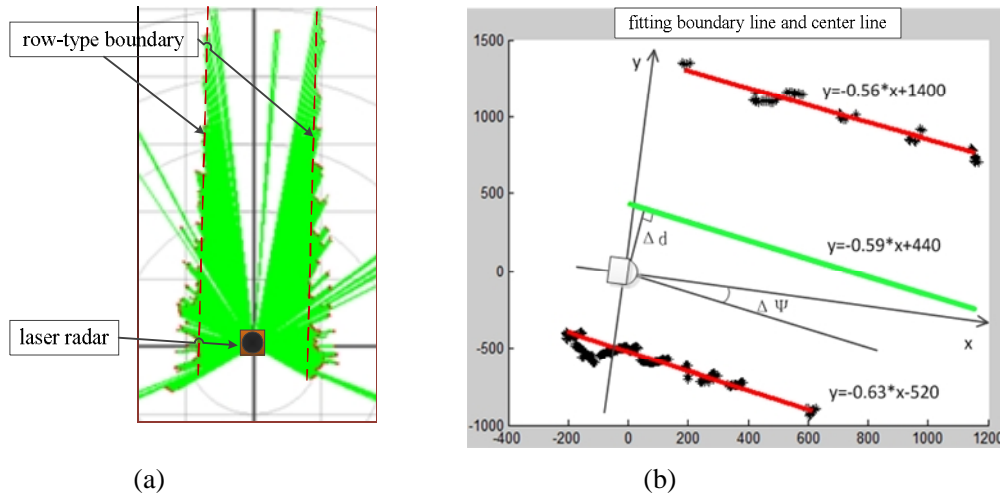
(a)   (b)

Figure 2(a). Schematic diagram of laser radar acquisition row environmental information

Figure 2(b). Fitting boundary line and center line

In order to verify the feasibility of the above algorithm, MATLAB should be used to simulate the information collected by the laser radar. In accordance with the above algorithm programming , and the results shown in Figure 2(b).

The linear fitting results are as follows:

$$\Delta y = \arctan(k3) = \arctan(-0.59) = -30.54° \tag{9}$$

$$\Delta d = \frac{|b3|}{\sqrt{k3^2 + 1}} = \frac{|440|}{\sqrt{(-0.59)^2 + 1}} = 378.95(mm) \tag{10}$$

According to the analysis of Figure2 (a) and (b), the results show that the error of lateral offset is in mm level and yaw angle is in minute level, which meet the requirements of the row line recognition accuracy, and can be used as the row recognition algorithm.

Laser radar ranging error calibration experiment

In order to further verify the reliability and feasibility of the algorithm, the wall is considered as a line standard. Keep the wall and the laser radar parallel, changing the distance between the laser radar and the wall. The measurement and data processing summary is in Table 1.

Table1. Measurement and processing data summary

actual measurement data	Processing data	difference
245	243.7	1.3
267	269.9	-2.9
330	333.8	-3.8
370	375.9	-5.9
483	494.4	-11.4
500	516.6	-16.6
525	518.2	6.8
560	572.8	-12.8
567	560.8	6.2
616	614.9	1.1
627	616.0	11.0
640	654.0	-14.0
685	683.4	1.6
741	736.1	4.9
787	786.0	1.0

Table1. shows that the maximum error is 16.6mm, which can meet the plant protection robot

positioning demands.

Conclusions

By means of laser radar for data collection, Data processing includes encoding, decoding, filtering, coordinate transformation, boundary extraction, row centerline extraction process, acquiring the yaw angle and lateral offset. By means of MATLAB simulation, calibration experiment and field test, it is proved that the algorithm is reasonable and practical.

Acknowledgement

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