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Research on Path Planning of Automatic Parking System

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Abstract. A non-parallel initial state path planning algorithm for the automatic parking system is presented in this paper. Automatic parking system is a hot research point in intelligent vehicle application fields, and the trajectory generation is one of its key technologies. In the actual process of parking, the initial state of vehicle is always non-parallel to the parking place, so this situation should be researched to serve automatic parking system better. According to the analysis of vehicle kinematics model and the parking process, the trajectory can be considered as the combination of some sections of tangent arc. In this article, the trajectory is composed of several period of circular arc and it is improved by combining with the actual circumstance, then a strong adaptable parking trajectory for the automatic parking system is designed. The simulation analysis is done to verify the geometry trajectory, and the method is used on our intelligent vehicle to check out the feasibility. Compared with traditional trajectory generation method, experimental results show the adaptability and success rates of the method designed in this paper is much more better, which the parking success rates is about 90%.

Introduction

In modern society, the car ownership is on the rise. On one hand, the quality of our life is improved. On the other hand, it is more difficult to park a car in modern cities. For driving beginners, parking a car in a narrow place is so hard. So the research of the automatic parking system is necessary and have broad market prospect.

The research of automatic parking related area is developed rapidly in recent years. As one of its key technology, trajectory generation is a hot research area. The related research work has been carried out in some countries. Such as nonholonomic constraint path planning problem of parking system is studied by Mukherjee [1], the continuous control problem of automatic parking is studied by Paromtchik [2]. In environmental perception, trajectory generation and part, the automatic parking technology is still not perfect.

In this paper, to research the trajectory generation of automatic parking system better, the author focus on the practical application. On the basis of previous studies [3][4][5][6], a strong adaptability of trajectory generation method is designed. According to comparing with the traditional method, the new method shows the better results.

Kinematics model analysis

In order to generate the trajectory better, the vehicle parking process should be analyzed firstly. The vehicle reverse process is a low-speed driving process. So the Vehicle kinematics model can be set as follow.

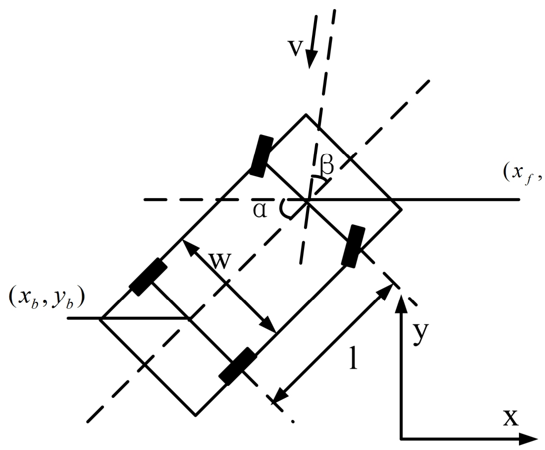


Fig. 1 Vehicle kinematics model

Where,(x_b,y_b) is the rear axle center coordinates.(x_f,y_f) is the former axle center coordinates. V is the former axle center speed. L is the vehicle wheelbase. W is the rear wheelbase. α is the inclined angle between vehicle body direction and X axis. β is the inclined angle between vehicle body direction and front wheel direction.

In general, the parking speed is low (<5Km/h), Which can be assumed that the wheel don't have lateral sliding. So the equations can be got as follows.

$$y' \cdot \cos\alpha - x' \cdot \sin\alpha = 0\,. \tag{1}$$

$$\begin{cases} x_b = x_f - l \cdot \cos\alpha \\ y_b = y_f - l \cdot \sin\alpha \end{cases}. \tag{2}$$

Based on (1) and (2), the speed relationship can be got as Eq. 3.

$$x_f' \cdot \sin\alpha - y_f' \cdot \cos\alpha + \alpha' \cdot l = 0\,. \tag{3}$$

According to the analysis of kinematics model, we can see that the parking trajectory is a standard circular arc. That is the parking process can be considered as a circular motion composed by periods of circular arcs.

Path generation based on non-parallel initial state unequal radius method

Based on the analysis of the kinematics model, the trajectory is constituted by several sections of equal tangent arcs. The traditional way of trajectory generation is minimum radius method. In the method, the trajectory is composed of two arcs, and both of them are vehicle minimum radius. In this method, the initial state of the vehicle body must be parallel to the parking space. And the parking range exist some limitations.

In the non-parallel initial state method, problems can be solved. As shown in Fig. 2, the vehicle rear axle center coordinates represent the entire vehicle trajectory. And the each vehicle coordinate position can be calculated through the vehicle geometry size and the current steering angle θ. The initial position of the vehicle is S_0 and target position is S_d. The parking trajectory is composed of arc S_0N, arc NC and arc CS_d, and the radius is unequal.

Given the actual process of parking, the initial state of the vehicle is always non-parallel to the obstacle. It is always right skewed or left skewed.

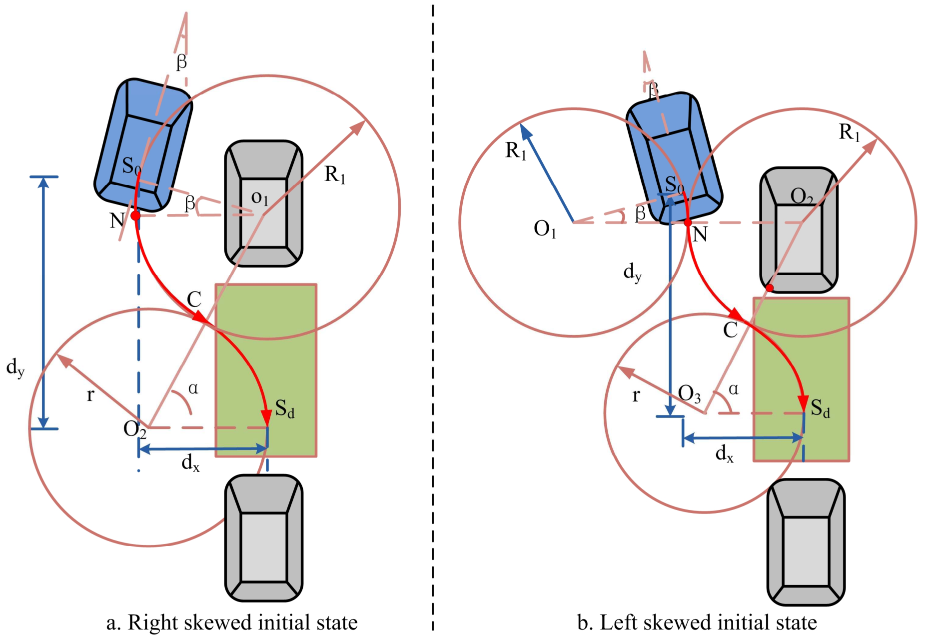


Fig. 2 Non-parallel parking reference trajectory

In the right skewed condition, turn left with center point O_1 and a radius of R_1 firstly. As the rear axle center point come to the point N, turn right with center point O_1 and a radius of R_1. Then keep parking as the vehicle come to the point C. Finally, turn left with center point O_2 and a radius of r until reach to the point S_d. Based on the geometrical relationship and parking process analysis, the relationship between circle O_1 and circle O_2 can be expressed by Eq. 4.

$$\begin{cases} d_x = x_0 = (R_1 + R_{\min}) \cdot (1-\cos\alpha) - R_1 \cdot (1-\cos\beta) \\ d_y = y_0 = (R_1 + R_{\min}) \cdot \sin\alpha + R_1 \cdot \sin\beta \end{cases} . \tag{4}$$

The d_x is the horizontal distance of the parking and d_y is the vertical distance, they can be got by ultrasonic detector. The β is initial attitude angle of the vehicle. Then the α and R_1 can be got.

In the above, the trajectory equations in the right skewed initial state can be got as Eq. 5.

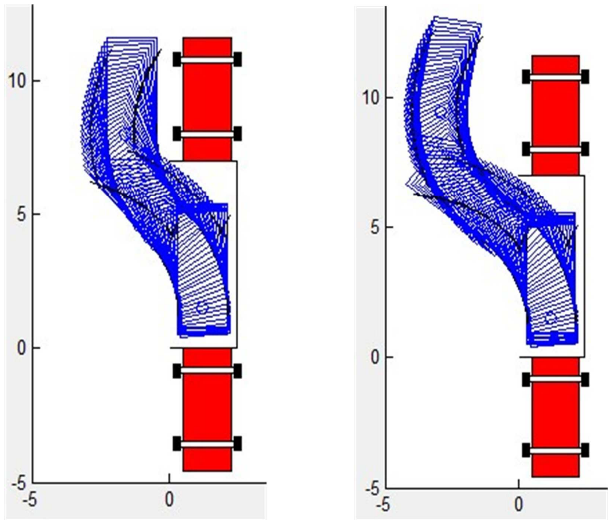
$$\begin{cases} (x - R_{\min})^2 + y^2 = R_{\min}{}^2 ; (0 < x < x_c) \\ [x - R_{\min} + (R_{\min} + R_1) \cdot \cos\alpha]^2 + y^2 = R_1{}^2 ; (x_c < x < x_0) \end{cases} . \tag{5}$$

In the actual parking process, the common initial state of the vehicle is left skewed (See in Fig. 2). The process is familiar with the right skewed state. According to the Fig. 3, the trajectory equations in the left skewed initial state can be got as Eq. 6:

$$\begin{cases} (x - R_{\min})^2 + y^2 = R_{\min}^2 ; (0 < x < x_c) \\ [x - R_{\min} + (R_{\min} + R_1) \cdot \cos\alpha]^2 + [y - (R_{\min} + R_1) \cdot \sin\alpha]^2 = R_1^2 ; (x_c < x < x_n) \\ [x - R_{\min} + (R_{\min} + R_1) \cdot \cos\alpha - 2R_1]^2 + [y - (R_{\min} + R_1) \cdot \sin\alpha]^2 = R_1^2 ; (x_n < x < x_0) \end{cases} . \tag{6}$$

Simulation

Build simulation environment in the MATLAB. The algorithm is verified by simulation experiment. Make the comparison to the minimum radius method, which is the traditional trajectory generation method. The parameters are set as follows. The vehicle length and width are 4.6 m and 1.8m, the parking space length and width are 7 m and 2.5 m. And the initial deflection angle is set from 0°to 30°.



a b

Fig. 3 The simulation results of the two methods

The simulation results of the two methods are shown in the Fig. 3. In the Fig. 3, a is the result of minimum radius method, b is the result of the non-parallel initial state unequal radius method.

Both of the two methods are verified in the intelligent vehicle platform. The experiment results show that in the non-parallel initial state unequal radius method, the parking is more accurate. And its success rate is high than the minimum radius method. Its success rate can reach to the 90% while the minimum radius method is 70%.

Experimental results

Both of the two methods are verified in the intelligent vehicle platform.

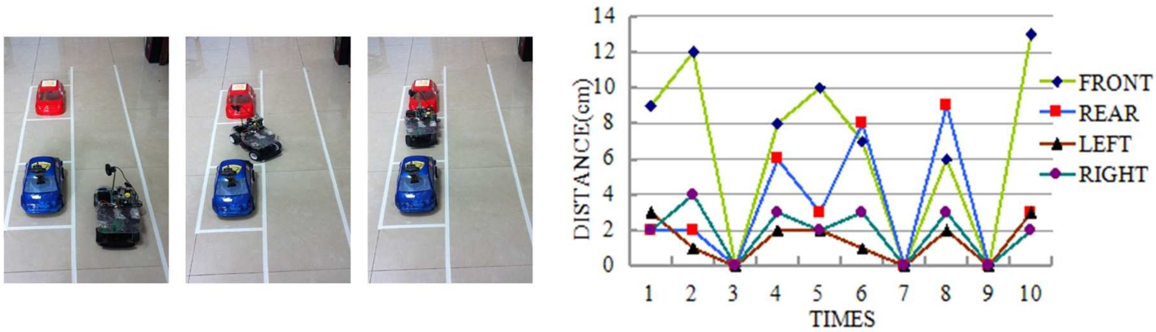


Fig. 4 Minimum radius method parking experiment and results

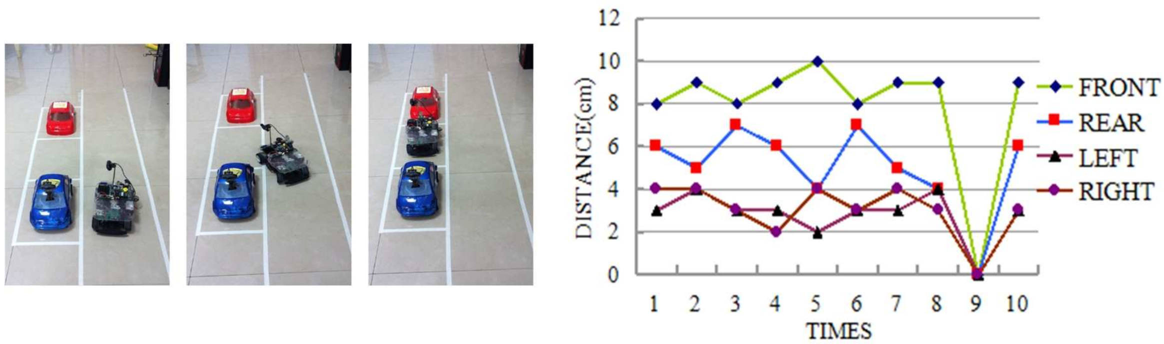
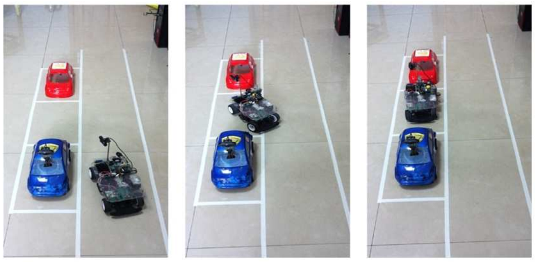


Fig. 5 Right skewed initial state unequal radius method parking experiment and results



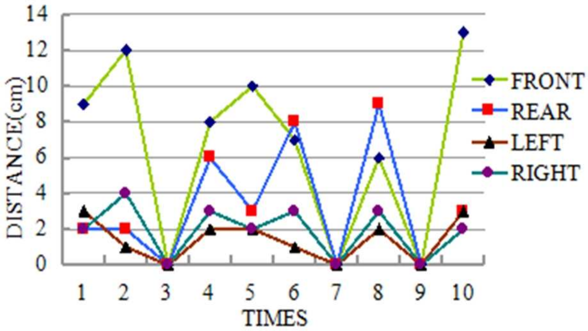


Fig. 6 Left skewed initial state unequal radius method parking experiment and results

The experiment results show that in the non-parallel initial state unequal radius method, the parking is more accurate. And its success rate is high than the minimum radius method. Its success rate can reach to the 90% while the minimum radius method is 70%. We measure the distance between the vehicle and parking boundary. The results are shown in the following figures.

Conclusion

This paper discussed a new trajectory generation method for automatic parking system. Firstly, establishing kinematics model to analyze the vehicle parking process, an algorithm for trajectory generation based upon the kinematics model is presented. Then comparing the two kinds of methods, we attest our new method has more advantages. And the failure rate is only equal or lesser than 10%.

The main reason for the failure is some inaccuracy existed in the distance detection. Finally, the experiments based on our intelligent vehicle platform are done to verify the new method, and the results are encouraging.

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