TELKOMNIKA, Vol. 11, No. 12, December 2013, pp. 7324~7330
e-ISSN: 2087-278X

Simulate Study of Automatic Parking System

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Abstract

The development of the automotive technology is toward to the intelligent direction, that automatic parking system is one of the aspects. This paper has been working on research of the path planning and control method of the automatic parking system. The vehicle's kinematic model is established at the condition that the vehicle is in a low speed reversing movement. Through studying the vehicle's kinematic model and analyzing the parking process, the foundation is finished for the research of the path planning and control method about the automotive parking system. In this paper, the particle swarm optimization algorithm is used to the path planning. Through analysing fuzzy control knowledge, use a fuzzy method to control the process of the parking. The simulate results of parking process was gotten in the environment of MATLAB7.0 software.

Keywords: *automatic parking system, path planning*

1. Introduction

The development of the automotive industry has passed 100 years, now automotive technology has developed toward to the intelligent direction, which take some convenience to the human driving life, it is also conform to the trend of the development of the future cars. Automatic parking system [1-3] is one aspect of the intelligent for the vehicles. Researching on automatic parking system can reduce the operational burden of drivers and can improve the driving safety. In this paper, the vehicle's kinematic model was gotten through establishing and analyzing the process of the parking. In view of the two aspects of the automatic parking system (One is path planning, which is a advance feasible path that considered the environment constraints and automobile's kinematic condition. The other is the control method), research on the automatic parking system. we make the particle swarm optimization algorithm used to the path planning. Through analysing fuzzy control knowledge, use a fuzzy method to control the process of the parking. The simulate results of parking process was gotten in the environment of MATLAB7.0 software.

2. Parking Path Analysis

2.1. Vehicle Kinematic Model

In the process of the parking, the traveling speed of the vehicle is generally low, so it is not necessary to consider the role of the lateral acceleration and the slippage between the wheels and ground. We can establish a vehicle's kinematic model [4, 5] as shown in Figure 1. In Figure 1, vehicle is simplified into a rigid body, *a*,*b*,*c*,*d* respectively represent the contact point of four wheel of the vehicle and the ground; *f*,*r* respectively represent the midpoint of the front and rear axle; *g* represents the center point of the vehicle; φ represents the front-wheel steering angle of the vehicle; θ is the angle between the center axis of the vehicle and the horizontal direction, which is named body direction angle.

From the kinematic model of the vehicle, the following equation is gotten:

$$x_r^2 + \left(y_r - l\cot\varphi\right)^2 = \left(l\cot\varphi\right)^2 \quad (1)$$

Received March 13, 2013; Revised July 28, 2013; Accepted August 15, 2013

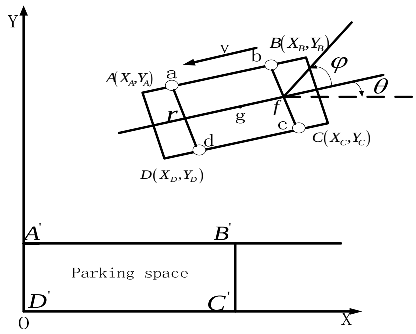


Figure 1. The Kinematic Model of the Vehicle

Here, *l* stands for the distance of the vehicle from front axis to rear axis. From the equation, it can be seen that the vehicle's trajectory has nothing with the reverse speed at any time when ignore the vehicle's wheel sideslip condition; that is, as long as the vehicle in the case of a certain low reverse speed, the same steering wheel angle fixed to the driver, the vehicle's trajectory would be no change. The speed of vehicle in the reversing process only has influence on the distance in a fixed time, do not have influence on the vehicle's driving route.

2.2. Parking Process Analysis

By analyzing the vehicle's kinematic model, some regularity can be found, that is, in the constraint condition of the kinematic model, the vehicle's reverse trajectory is a standard arc, the process of parking can be regarded as a combination of several tangent arcs, where the straight running portion can be seen as the infinite radius of the arc. At a point, the direction angle of vehicle body can indicate the deviation angle, when know the coordinates of a point, the state of each point can be deduced according to the geometric shape of the body and the body angle. The state variable can be represent as (x, y, θ) for the vehicle at a point. The process of parking can be regarded as the expression from the initial state (x0, y0, θ0) to the destination state (xd, yd, θd). We need to solve the problem that find a suitable state as the initial state under the condition known (parking space has been given, the ultimate deviation angle of the vehicle should be zero). Through realizing and analysing real driving experience, we know that in the process of parking, the most simple path is the 'S' type of track [6, 7] which is composed by two tangent arc. The 'S' type of track is shown in Figure 2. In Figure 2, the initial position of the vehicle is S0 (x0, y0, θ0) and the destination point is Sd (xd, yd, θd). When the vehicle run at the point S0, play the steering wheel to the right, the vehicle run with the minimum radius by taking the point O1 as the circle center; When run to the point C, play the steering wheel to the reverse, the vehicle run with the minimum radius by taken the point O2 as the circle center. Finally, the vehicle reverse into the target space, the process of parking is completed.

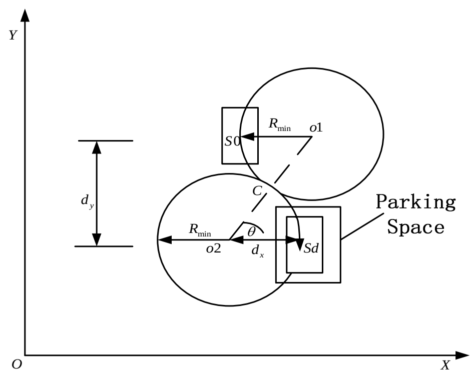


Figure 2. 'S' Type of Track

3. Path Planning of Particle Swarm Optimization
3.1. Particle Swarm Optimization

Particle swarm optimization (PSO) was first introduced in 1995 by American psychologist Kennedy and electrical engineer Eberhart put together. PSO is simulation of the birds foraging, fish swimming and other animal groups, between each individual collaboration social behavior [8]. PSO has strong universality, simple principle, easy realization, group search, retain local individual and global population optimal information, cooperative search, and it can use the individual local information and global population information to guide the search and other features. The literatures [9, 10] used particle swarm optimization to the mobile robot path planning and achieved certain results.

Particle swarm optimization takes each individual as a flight particle which has no quality and volume with a certain speed in the *M* dimensional search space. The evolution equation for the speed and position of the particle swarm optimization is shown in below formula:

$$\begin{cases} v_j(t+1) = \omega v_j(t) + c_1 r_1 (p_j(t) - x_j(t)) + c_2 r_2 (p_g(t) - x_j(t)) \\ x_j(t+1) = v_j(t+1) + x_j(t) \end{cases} \quad (2)$$

In the formula,

$v_j(t+1)$ represents the speed of the particle j in the generation t.

ω represents the inertia weight.

c_1 represents the cognitive coefficient.

r_1, r_2 represent the random numbers which obey the uniform distribution.

$p_j(t)$ represents the individual best position of particle j.

$x_j(t)$ represents the position of particle in the generation t.

c_2 represents the social coefficient.

$p_g(t)$ represents optimal location of the population history.

3.2. The Model of Path Planning based On PSO

In this paper, the path planning based on swarm optimization algorithm is mainly aimed at that the vehicle around obstacles find the best parking position in the process of parking. The path planning is from point O to point S0 shown in Figure 3.

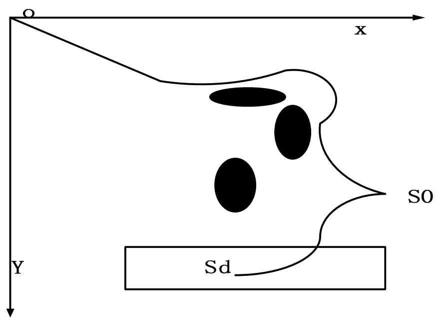


Figure 3. Path Planning Figure

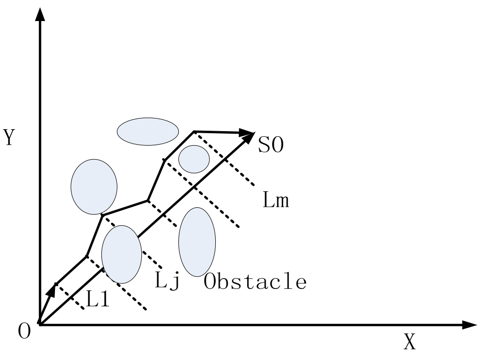


Figure 4.The Model of Path Planning

A model for the path is established and shown in Figure 4, in which, point O in the coordinate system is the start point, point S0 is the best parking position. Take the line segments between the two points into m+1 equal parts, do the vertical line in each diversion point, get m parallel lines. These points of intersection between the straight and path L compose the destination point sequence $(L1, L2, \cdots, Lm)$, the entire length of the path can be expressed as:

$$S_L = \sum_{j=0}^{m} S_{L_j L_{j+1}} \tag{3}$$

The formula can be trasformed into the following equation:

$$S_L = \sum_{j=0}^{m} \sqrt{\left(S_{OS_0} \big/ m+1 \right)^2 + \left(x_j - x_{j+1} \right)^2} \tag{4}$$

This problem can be transformed to optimize the S_L, ensure the connection lines $L_j L_{j+1}\ (j = 0,1,\cdots,m)$ to avoid obstacles, and make the S_L obtain the minimum.

3.3. Algorithm Realization

1. Load the map with the obstacles, then set the starting point and the termination point.
2. Make the lineOS$_0$ into $m+1$ equal division, then make verticals at each equal diversion point, get m parallel straight lines.
3. Initialize the speed and position of the particle.
4. According to the formula 2, update the speed and position.
5. Seek the fitness of every particle from the formula 4.
6. Turn to step 4, iterate until reache the maximum number of iteration.

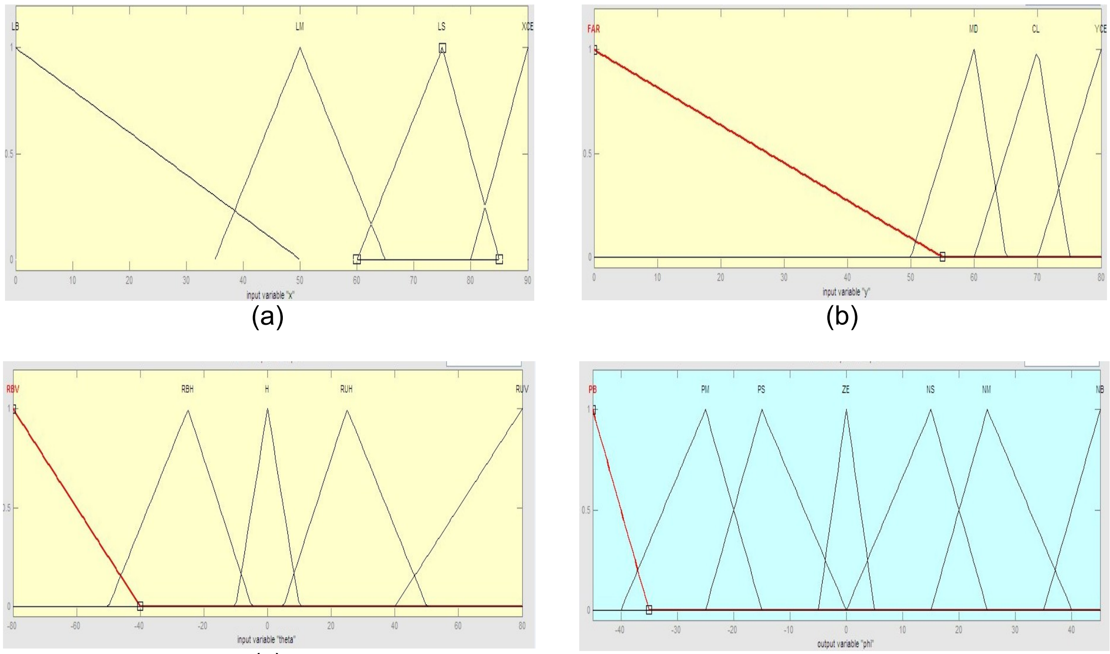
4. Fuzzy Control of Automatic Parking System

4.1. Fuzzy Control Theory

Fuzzy control theory [11-13] is an important branch of intelligent control, which is built on the basis of the rules of linguistic variables and fuzzy reasoning. L. A. Zadeh who is an American people, proposed the fuzzy set theory in 1965. E. H. Mamdani in UK, applied the fuzzy control theory to the control of the steam engine in 1974, is the first human that used the fuzzy control theory to the field of industry. The fuzzy control theory has achieved further development, with the development of computer technology, fuzzy control theory is also applied to more fields.

4.2. Fuzzy Control Realization

According to the analysis of the kinematic model of vehicle, vehicle parking process can be known at a low speed. In this process, the trajectory of parking has nothing with the speed of vehicle, the reverse speed of vehicle only has a influence on the running distance within a fixed time, and don't have influence on its route. The trajectory of the vehicle can be represented by (x, y, θ). The control amount of vehicle's trajectory change can be regard as (x, y, θ), the direct output is φ. Select x, y, θ as the input variables amount of the fuzzy control and φ is an output variable amount. Setting the number of the fuzzy set for x is 4, the language variable is represented as LB LM LS XCE; The number of fuzzy set for y is 4, the language variable is represented as FAR MD CL YCE; The number of fuzzy set for θ is 5, the language variable is represented as RBV RBH H RUH RUV; The number of fuzzy set for φ is 7, the language variable is represented as PB PM PS ZE NS NM NB. The fuzzy membership function is very important for the design of fuzzy control, the shape of membership function is related to the designers' required characteristics and experience. The general common shapes of membership function have triangular and trapezoidal, this paper used the triangular membership function, the membership function of the variable is shown in Figure 5.



(a) (b) (c) (d)

Figure 5. The Membership Function of the Variable

In the Figure 5, Figure (a) is the membership function of the variable x; Figure (b) is the membership function of the variable y; Figure (c) is the membership function of the variable θ; Figure (d) is the membership function of the variable φ.

In design of fuzzy control, the rule base is a very important part, because all the state must be operated accordance with the rules that we defined. This paper produced a total of 60 rules shown in Table 1 to Table 4.

Table 1. Fuzzy Control Rules when y is FAR

	LB	LM	LS	XCE
RBV	PB	PB	PB	X
RBH	PM	PB	PB	X
H	ZE	PB	PM	X
RUH	NS	PB	PM	X
RUV	NM	ZE	ZE	X

Table 2. Fuzzy Control Rules when y is MD

	LB	LM	LS	XCE
RBV	PB	PB	PB	X
RBH	PS	PB	PB	X
H	ZE	PM	PM	X
RUH	NM	PM	PS	X
RUV	NB	ZE	ZE	X

Table 3. Fuzzy Control Rules when y is CL

	LB	LM	LS	XCE
RBV	X	PB	PB	PB
RBH	X	PB	PB	PB
		M	M	E
UH		S	S	S
UV		E	E	M

Table 4. Fuzzy Control Rules when y is YCE

	LB	LM	LS	XCE
RBV	X	PB	PB	PB
RBH	X	PB	PB	PB
H	X	ZE	ZE	ZE
RUH	X	NB	NS	NB
RUV	X	NB	NM	NB

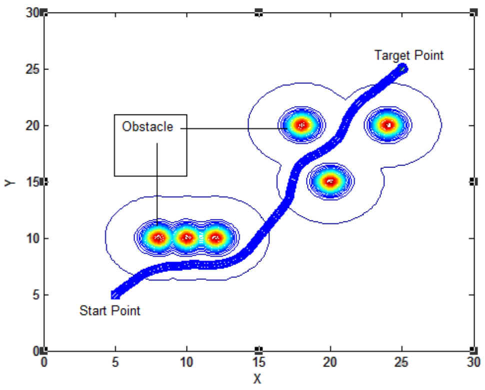


Figure 6. A Path Planning

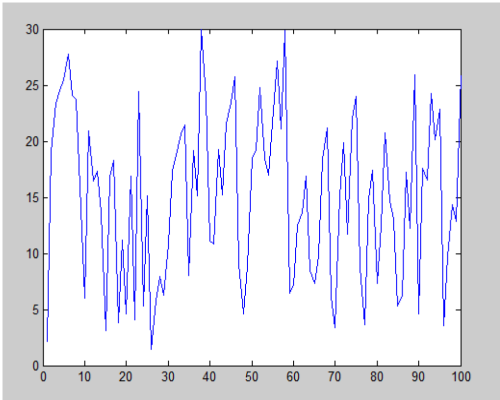


Figure 7. The Optimal Value

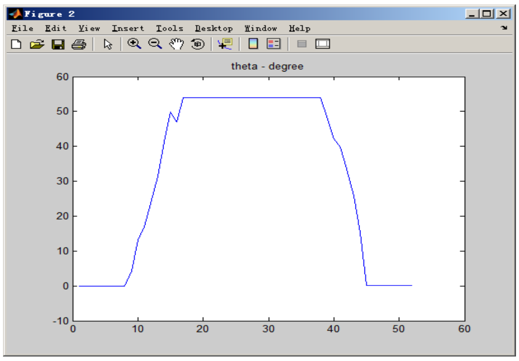


Figure 8. The Change Curve of θ

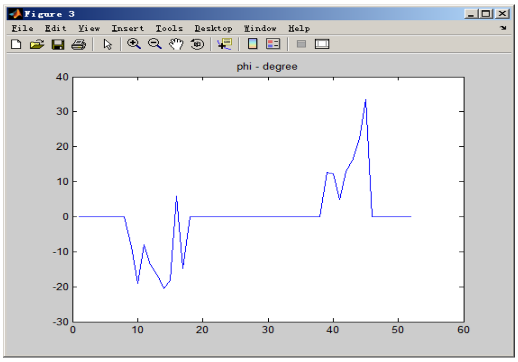


Figure 9. The Change Curve of φ

The first row in the table is the language variables of the input variable x; the first rank in the table is the language variables of the input variable θ; X is not output (it does not generate rule); the rest output of the language variables is the variable φ.

5. Simulation Analysis

Through simulation in MATLAB software, we obtain the path planning shown in Figure 6, the optimal value of the particle swarm after 100 iterations is shown in Figure 7.

Through analysing the figure 6, it can be seen that the path planning can be achieved; from Figure 7, it can be seen that the particle swarm optimization is convergence.

Through simulation of fuzzy control by MATLAB software, the change curve of the angle θ and φ shown in Figure 8 and Figure 9 are gotten.

It can be seen from Figure 8 and Figure 9 that the vehicle is able to achieve the process of parking, the body and the steering wheel are able to return back.

6. Conclusion

This paper aims to study the automatic parking system. To the path planning and control method of the automatic parking system, used the particle swarm optimization algorithm and fuzzy control. Through simulation by MATLAB, this paper put the path planning and control method can achieve. There are some conclusions as following:

1. Established the kinematic model of the vehicle and analyze the process of parking; these study have great significance on the real design and operation.

2. Particle Swarm optimization algorithm has the characteristics that calculation is simple, convergence is fast, can realize the parallel search, don't have the local advantages points; these characteristics are very useful to the path planning.

3. Fuzzy control do not need to establish a precise mathematical model using is simple; to multivariable interference and complicated control behavior, it has strong adaptive ability.

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