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Parking Planning with Genetic Algorithm for Multiple Autonomous Vehicles

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Abstract

The past decade has witnessed the rapid development of autonomous parking technology, since it has promising capacity to improve traffic efficiency and reduce the burden on drivers. However, it is prone to the trap of self-centeredness when each vehicle is automated parking in isolation. And it is easy to cause traffic congestion and even chaos when multiple autonomous vehicles require of parking into the same lot. In order to address the multiple vehicle parking problem, we propose a parking planning method with genetic algorithm. Firstly, an optimal mathematic model is established to describe the multiple autonomous vehicle parking problem. Secondly, a genetic algorithm is designed to solve the optimization problem. Thirdly, illustrative examples are developed to verify the parking planner. The performance of the present method indicates its competence in addressing parking multiple autonomous vehicles problem.

Introduction

Thanks to the rapid development of science and technology, including computer technology, chip technology, sensor technology and so on, the research of autonomous parking has made great achievements in recent decades[1,2,3,4,5].

In order to implement autonomous parking, lots of efforts have been paid into parking planning[6,7,8,9]. The geometric method is the most simple and practical implementation. Among the geometric curves, the arc[10], B spline[11] and clothoid[12] are most employed. Li[13] designs a single circular method that divides parking trajectory into three segments: a straight line, a circular arc, and another straight line. Wang et al[14] develop double circular trajectory to adapt to the change of the initiation parking pose. In order to make the joints of segments be continuous, Li et al[15] program double-constant-velocity parking trajectory. Kawabata et al[16] adopt Bezier curve to generate smooth trajectory. However, geometric methods are often only appropriate for specific parking scenarios. In order to unify parking planner, the sampling and search method has is concerned by worker unceasingly[17, 18]. Feng et all[19] combine model-based target tree and rapidly-exploring random tree (RRT), in order to accelerate the sampling process. Han et al[20] develop a unified parking planner for parallel, vertical and oblique slot based on RRT algorithm. But, since the core of RRT has a random seed, the planned path has randomness. In order to guarantee the planning efficiency and track quality, graph search method is widely used, such as A*[21] and hybrid A*[22]. Since the grid resolution is always difficult problem for graph search method[7, 8, 23], lots of machine learning method have been studied, such as artificial neural networks (ANN)[24], support vector machine (SVM)[25], General Radial Basis Function (GRBF)[26], and radial basis functions networks (RBFN)[27].

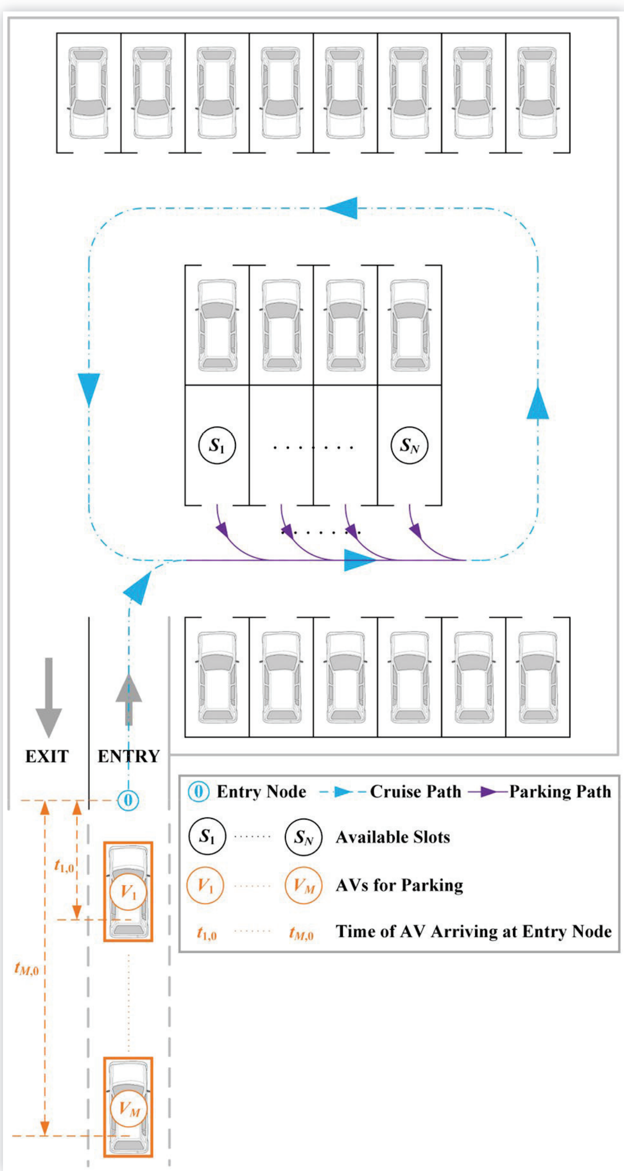
Although the parking planning algorithm of a single autonomous vehicle can be applied to real cars, however, there are two drawbacks impeding the existing parking planning algorithm directly applied to multiple autonomous vehicles. One of the drawbacks is the trap of self-centeredness when each vehicle is automated parking in isolation. And the other is traffic congestion and chaos since multiple autonomous vehicles requiring parking into the same lot. Therefore, we present a parking planning method to address those problems. Firstly, we establish an optimal mathematic model to describe the parking planning of multiple autonomous vehicles. Secondly, a genetic algorithm is developed to solving the built optimal problem. The remainder of the paper is structured as follows: In Sec. II, a description of problem for multiple autonomous vehicle parking planning. Illustrative Examples are discussion in Sec. III. Finally, Sec. IV provides the conclusion.

Problem Description and Algorithm

Fig. 1 is the schematic diagram of parking problem for multiple autonomous vehicles. There are five assumptions: firstly, all vehicles are of the same size; secondly, all lots have the same size and are vertical type; thirdly, all vehicles in the parking lot cruise or park at a constant speed; fourthly, the vehicle can be parked in once operation ignoring all kinds of disturbances; fifthly, information about vehicles and parking lots is shared in real time by V2X facilities, and parking planning is done by the parking lot's central controller.

The available slots as marked as $s_1, \ldots, s_N$. All autonomous vehicles requiring parking could only enter parking lot from the entry. For parking lots with only one entry, only one vehicle may enter the parking lot from the entry at any one time. Since no more than one car being allowed to park in a single slot at any one time, there is a definite relationship that,

FIGURE 1 Schematic diagram of parking planning for multiple AVs.



$$\sum_{m=1}^{M} x_{n,m} \le 1 \tag{1}$$

where $x_{n,m} \in \{0, 1\}$ is binary integer variable. if the autonomous vehicle m parks into slot n, $x_{n,m} = 1$, otherwise $x_{n,m} = 0$.

As each vehicle allowed into the parking lot being assigned an available slot, therefore,

$$\sum_{n=1}^{N} x_{n,m} = 1, M \le N \tag{2}$$

$$\sum_{n=1}^{N}\sum_{m=1}^{M} x_{n,m} = M, M \le N \tag{3}$$

The time that the car m waits for the car m–1 (in front) to finish parking is marked as the blocking time b_m, which could be calculated by,

$$\begin{cases} b_m = 0, \Delta t_m = 0 & m = 1 \\ b_m = -\mathrm{sgn}\left(\min\left(0, \left(\left(\sum_{n=1}^{N}\left(n \cdot x_{n-1,m}\right) - \sum_{n=1}^{N}\left(n \cdot x_{n,m}\right)\right) \cdot \left(\dfrac{W_s}{v_p} - t_s\right)\right)\right)\right) \cdot \Delta t_m, & m > 1 \\ \Delta t_m = \max\left(0, t_{m-1,0} + t_s + t_p + b_{m-1} - t_{m,0}\right), & m > 1 \end{cases} \tag{4}$$

where sgn(.) is sign function, $t_{m,0} \ge 0$ is time of autonomous vehicle m arriving to entry node, $t_s > 0$ is safe time-distance between vehicle and vehicle in the front, $t_p > 0$ is the parking time of vehicle, W_s is the width of slot and v_p is parking speed.

As depicted in Fig. 2, the purpose of the safe time-distance $t_s > 0$ is to avoid a collision between the vehicle m (in the back) and the vehicle m–1 (in the front), of which value could be set refer to Xiong et al work[28].

As illustrated in Fig. 3 the parking path consists of three segments: a straight line going forward, a quarter arc turning left or right and a straight line going backward. Then the parking time could be calculated by follows,

$$t_p = \frac{W_s + (2+\pi)R + L_s + 2L_{RC}}{2v_p} \tag{5}$$

where $R > 0$ is turn radius, $L_s > 0$ is length of slot and $L_{RC} > 0$ is distance between the vehicle's mass center and the vehicle's rear axle.

In order to reduce the risk of traffic congestion, the cost function of parking planning is defined as follows,

$$\min\left(J = \sum_{m=1}^{M} b_m\right) \tag{6}$$

Finally, the problem of parking planning for multiple autonomous vehicles is modeled as the following optimization formulation by fusing the Eq.(1) ~ Eq.(6),

TABLE 3 Slot Allocation and Results

FCFS method		Our method	
AVs in Slots	***J/s***	***AVs in Slots***	***J/s***
(1, 2, 3, 4)	0.74	(2, 3, 1, 4) (2, 4, 1, 3) (3, 2, 4, 1) (4, 2, 3, 1) (2, 3, 4, 1) (2, 4, 3, 1)	0

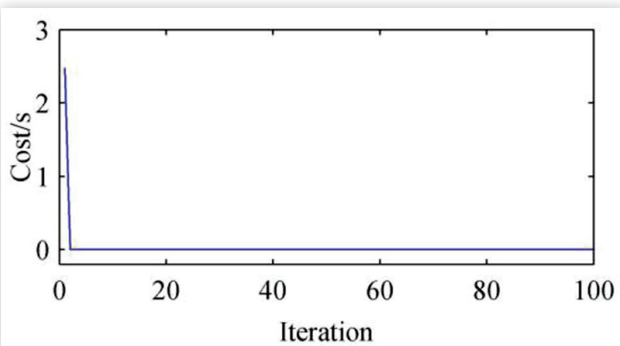
TABLE 4 Time of Autonomous Vehicle Arriving Entry Node

Parameters	$t_{1,0}$	$t_{2,0}$	$t_{3,0}$	$t_{4,0}$
Value/s	11	20	72	80

TABLE 5 Slot Allocation and Results

FCFS method		Our method	
AVs in Slots	***J/s***	***AVs in Slots***	***J/s***
(1, 2, 3, 4)	2.48	(4, 2, 3, 1) (2, 4, 1, 3)	0

FIGURE 7 Cost results.



Conclusions

We propose a parking planning method with genetic algorithm for multiple autonomous vehicles taking two problems into account. One of the problems is to avoid the trap of self-centeredness when each vehicle is automated parking in isolation. The other problem is to avoid traffic congestion and chaos due to multiple autonomous vehicles require of parking into the same lot. In order to address the problems, an optimal mathematic model is built to describe the problems firstly. And, secondly, a generic algorithm is applied to solve the problems. By comparing with the first-coming-first-serve (FCFS) planning method, the results illustrate that our method has competence in addressing parking multiple autonomous vehicles problem.

The further work will focus on real vehicle implementation and testing. Dynamic scenarios that multiple vehicles parks in and out. It may worth processing the uncertainty of sensors.

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