An Automatic Parking Strategy Optimization Based on Open-drive and BIM

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Abstract

Aiming at the problem of path planning from vehicles entering the environment to discovering vacant parking spaces in large indoor environments such as parking buildings and underground garages, this paper proposes an automatic parking strategy optimization method based on OpenDRIVE+BIM. The optimal parking space selection method is proposed, and the fusion algorithm of the improved A* algorithm and DWA algorithm is used for path planning. The fusion algorithm is superior to the traversal algorithm in terms of search time, path length, turning angle, trajectory length and time consumption, and reduce the time and energy consumption problems in the process of traversing parking spaces.

Keyword

OpenDRIVE, BIM, Automatic parking, Path planning

1. Introduction

With the rapid increase of urban population and the improvement of living standard, the number of cars has increased dramatically. The rapid growth of urban car ownership not only increases the burden of urban traffic, but also aggravates the problem of insufficient parking space. The extra driving distance in the parking process increases energy consumption, aggravates parking difficulties, and thus increases the probability of minor accidents, such as friction and collision [1-2]. According to a survey and analysis of parking accidents conducted by the University of Michigan Transportation Research Institute, about 10,000 of the 12 million traffic accidents are caused by entering or leaving a parking lot. In fact, the actual number of accidents far exceeds the number of traffic reports.

Figure 1 (a) Parking scene identification and (b) parking trajectory planning

At present, intelligent vehicle is the main development trend of the automobile industry, and also the research focus of Oems and research institutions at home and abroad. As a key component of intelligent vehicle technology, automatic parking technology has become a hot topic in current research. The future automatic parking technology can safely and quickly complete parking operation, effectively improve driving comfort, and greatly reduce the probability of accidents during parking.

At present, the degree of automation of automatic parking technology is relatively low, as shown in Figure 1. The research direction mainly focuses on intelligent identification of parking scene and parking trajectory optimization, etc., while there is little research on path planning during autonomous

ICCEIC2022@3rd International Conference on Computer Engineering and Intelligent Control
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movement of vehicles after entering the parking lot area. With the increase of urban traffic burden and the rise of underground garages and parking buildings, GNSS technology, which is relied on by traditional vehicle navigation, has weak signals in large indoor environments and cannot provide sufficient information for autonomous vehicle movement. In addition, the lack of navigation map information leads to the need to constantly apply ultrasonic sensors or visual sensors to detect parking space information in the early stage of the parking process, which increases parking time and energy consumption. BIM(Building Information Modeling) is a digital and intelligent building information model [3-4], which contains all the information of a building and plays an indispensable role in such concepts as "smart city" and "smart transportation". OpenDRIVE describes the static road traffic network required for driving simulation applications and provides descriptions of standard interchange formats. In terms of path planning, common global path planning algorithms include node-based A* algorithm and D* algorithm [5], model-based artificial potential field method [6], etc. Bayili[7] proposed an A* algorithm with damage, which took damage as a feasibility criterion and considered its collision risk to obtain a safer path. Park[8] took potential risks as safety indicators and introduced risk costs into the search function of A* algorithm. Isikdag[9] proposed a navigation method through high-level semantic and geometric information in intelligent building model, which provided more abundant information for indoor navigation.

For automatic parking scenario, because of the lack of large-scale indoor environment map information, vehicles enter into the underground garage to find the right car consumes more energy and time in the process of problem, this paper proposes a automatic parking scenarios strategy based on BIM OpenDRIVE + optimization method, calculated based on BIM information extraction and information architecture, The OpenDRIVE information is extracted to obtain the road network information, and the two kinds of information are matched, and the dynamic environment information is fused to construct the navigation map. The improved A* algorithm and the improved DWA fusion algorithm are used for path planning, and the optimal parking space judgment method is given, so as to reduce the time and energy consumption.

2. Navigation map construction based on OpenDRIVE and BIM

2.1. Static scene navigation map construction

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Currently, the SLAM(Simultaneous Localization and Mapping) method is mainly used for map construction in unknown environments, but this method requires vehicles to perform complete inspection in unknown environments and the equipped sensors to obtain complete map information. Applying this method to the automatic parking scenario will undoubtedly increase the consumption of time and energy cost in the path planning process. BIM contains all building information [10], and OpenDrive contains static traffic network information, as shown in FIG. 2. In this paper, BIM information is extracted according to IFC(Industry Foundation Classes) standards. According to OpenDRIVE's standard exchange format, road network and parking space information are extracted, and the static navigation map is obtained after registration.

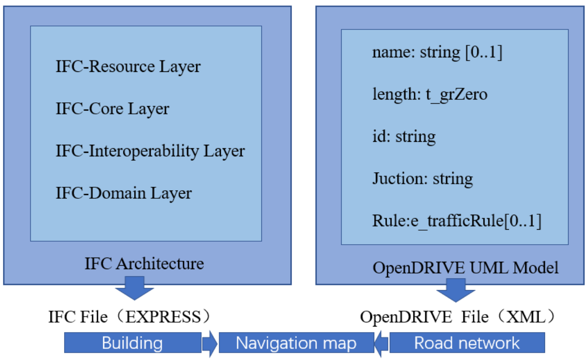

Figure 2 OpenDRIVE+BIM information extraction

An underground garage is taken as the experimental prototype for information extraction. The simulation scene of the underground garage is shown in Figure 3. Information extraction is carried out on OpenDRIVE+BIM in this scene, and the navigation map of the static scene is shown in Figure 4.

Figure 3 Underground garage simulation scene

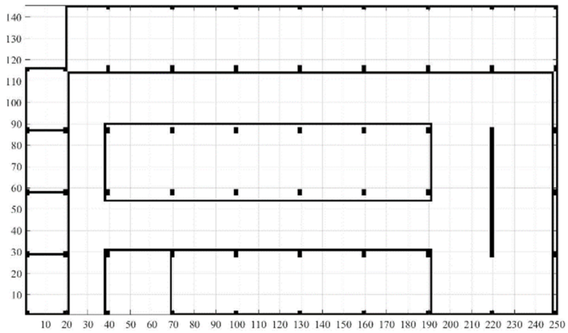

Figure 4 Static scene navigation map

2.2. Dynamic scene information fusion

At present, GNSS(Global Navigation Satellite System) technology is widely used in vehicular positioning, which has high accuracy and reliability in open outdoor environment. Due to the influence of signal power and signal penetration, this method is not suitable for large indoor parking lot environment. Commonly used indoor positioning methods include SLAM based on dead calculation principle, WiFi, Ultra Wide Band (UWB), ultrasonic and other positioning technologies based on signpost method. Among them, UWB technology has the characteristics of high accuracy and strong anti-interference ability. Therefore, this paper chooses UWB positioning technology as the way to obtain dynamic scene information. Dynamic vehicle location information and parking space information are used to supplement static scene information, and the information interaction between vehicles and underground garage environment is completed. The optimal path is obtained through the optimal parking space selection method and path planning method. The flow chart of the automatic parking strategy optimization method is shown in Figure 5.

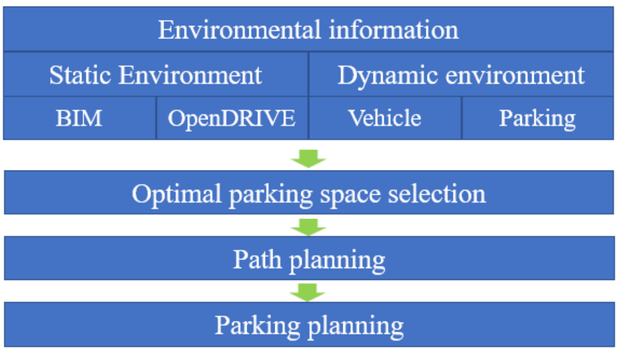

Figure 5 Automatic parking strategy optimization method

3. Optimization of path planning algorithm

3.1. Optimal parking space selection method

After the navigation map is obtained by fusing the dynamic and static environment information, it is necessary to select the vacant parking space that is closest to the current vehicle position and has the least time and energy to move from the current position to the parking target point. Therefore, this paper proposes an optimal parking space selection method based on Manhattan distance. As shown in FIG. 6, the Manhattan distance from the starting point to the end point of the vehicle is denoted as:

$$M_n = |s_x - g_x| + |s_y - g_y| \qquad (1)$$

In Formula 1, $(s_x, s_y)$is the center coordinate of the starting point grid of the vehicle, and $(g_x, g_y)$is the center coordinate of the terminal grid corresponding to different empty parking Spaces.

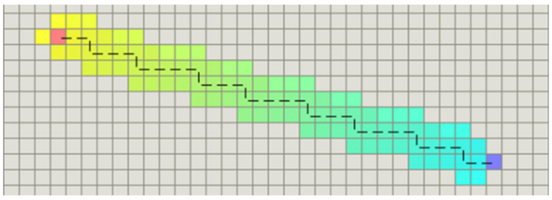

Figure 6 Manhattan distance diagram

The Manhattan distance corresponding to all empty parking Spaces in the garage is compared. When$M_n = M_{min}$, the second parking space is considered as the optimal parking space.

3.2. A* algorithm search strategy optimization method

A* algorithm takes the established navigation map as input, adopts the heuristic search method, introduces the cost function to reduce the search range of path nodes and improve the search efficiency, so as to carry out global path planning. The cost function of A* algorithm is defined as:

$$F(n) = G(n) + H(n) \qquad (2)$$

In Equation 2, n represents the current node, F(n) is the cost function of the current node n, G(n) is the actual surrogate value of the vehicle from the initial node to node n, and H(n) is the surrogate value of the vehicle from the current node n to the endpoint, namely the heuristic function of A* algorithm. In this paper, the A* algorithm is improved according to the application environment, and the improved algorithm is used for global path planning, so as to verify the rationality of the selected optimal parking space.

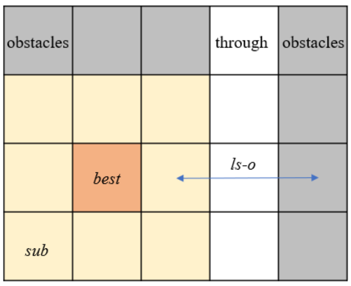

Figure 7 Improved A* algorithm optimization method

The path searched by the original A* algorithm is close to obstacles and has many redundant nodes. In this paper, the search conditions of the algorithm are improved for the security of the global path, as shown in FIG. 7. Assume that the node with the smallest *F* in openlist during a search is *best*. In the subsequent node *subs* of *best*, assume that the distance between node *sub* center and obstacle grid center is $l_{s\text{-}o}$, and σ is the safety factor.If $l_{s\_o} < \sigma w_r + s$, the node sub is not considered as the search object.

Figure 8 Redundant node judgment method

As shown in FIG. 8, the A* algorithm is improved according to the judgment method of redundant nodes. The node in the path is set as, and the direction of the node is. If:

(1) n_i and n_{i-1} are adjacent nodes, and $\boldsymbol{n}_i = \boldsymbol{n}_{i-1}$,then n_i is the redundancy turning point.

(2) $n_i$and n_{i-1} are adjacent nodes, and $\boldsymbol{n}_i \neq \boldsymbol{n}_{i-1}$,if the line connecting n_{i+1} and n_{i-1} can pass through, n_i is a redundant turning point.

3.3. DWA algorithm optimization method

In terms of local path planning, the evaluation function of the original DWA algorithm is:

$$G(\boldsymbol{v},\boldsymbol{w}) = \varepsilon(\alpha \cdot heading(\boldsymbol{v},\boldsymbol{w}) + \beta \cdot dist(\boldsymbol{v},\boldsymbol{w}) + \gamma \cdot velocity(\boldsymbol{v},\boldsymbol{w})) \qquad (3)$$

In Equation 3, *heading*(**v**,**w**) direction Angle evaluation function; *dist*(**v**,**w**) represents the nearest distance between the vehicle and the obstacle on the current trajectory; *velocity*(**v**,**w**) is the magnitude of the current simulation velocity.ε is a smooth function;α, β, γ is the weighting coefficient.

By Equation 3, you can see that the original DWA algorithm only considered and the distance between the obstacles, not considering the influence of the width of the vehicle itself in the narrow space, applied to the underground garage scene may cause safety problems, therefore, this paper improved the original DWA algorithm to increase safety coefficient judgment judgment conditions, and the obstacles contour edge extensions, The algorithm can meet the needs of narrow space application.

The best measurement range of liDAR detection is set to d_{max}, the field of view is set to $[\phi_{min}, \phi_{max}]$ and the scanning Angle corresponding to the vehicle heading is set to ϕ_{car}.

The measurement Angle of liDAR is:

$$\phi_i = \phi_{min} + (i-1)\Delta\phi \qquad (4)$$

In Equation 4, ϕ_{min} is the minimum FOV Angle corresponding to the LIDAR, and $\Delta\phi$ is the angular resolution.

According to the contour of the vehicle, edge expansion is carried out on the contour of the obstacle, where the calculation formula of the expansion Angle is:

$$\theta_j = arctan(r_{\mathrm{car}}/d_j) \qquad (5)$$

In Equation 5, r_{car} is the expansion parameter of vehicle contour, and d_j is the distance of obstacle edge.

As shown in FIG. 9, the passable interval of the vehicle is set to $[\phi_{j\_1} + \theta_j, \phi_{j\_2} - \theta_j]$, the midpoint of this interval is set to ϕ_{mid}, and the Angle corresponding to the velocity trajectory is set to ϕ_{i_o}. Then, the Angle evaluation function within this interval is:

$$angle(v,w,\phi_{i\_o}) = \begin{cases} \frac{1}{\phi_{mid}-(\phi_{j_1}+\theta_j)} \cdot \phi_{i_o} - \frac{\phi_{j_1}+\theta_j}{\phi_{mid}-(\phi_{j_1}+\theta_j)}, \\ \phi_{i\_o} \in [\phi_{j\_1} + \theta_j, \phi_{mid}] \\ \frac{1}{\phi_{mid}-(\phi_{j_2}-\theta_j)} \cdot \phi_{i_o} + \frac{\phi_{j_1}-\theta_j}{\phi_{mid}-(\phi_{j_2}-\theta_j)}, \\ \phi_{i\_o} \in [\phi_{mid}, \phi_{j\_2} - \theta_j] \end{cases} \qquad (6)$$

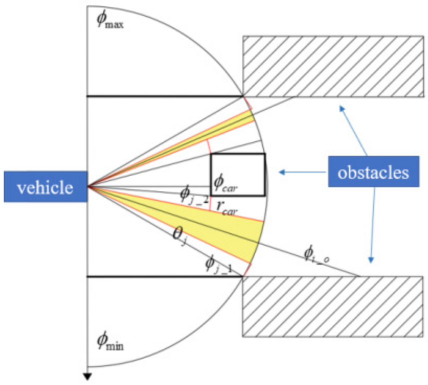

Figure 9 Diagram of improved DWA algorithm

Therefore, the evaluation function of the improved DWA algorithm is:

$$G(v,w) = \varepsilon(\alpha \cdot heading(v,w) + \beta \cdot dist(v,w) + \gamma \cdot velocity(v,w) + \omega \cdot angle(v,w,\phi_{i\_o})) \quad (7)$$

In Equation 7, $\alpha, \beta, \gamma, \omega$ is the weighted coefficient of the improved evaluation function.

3.4. Fusion method of improved A* algorithm and improved DWA algorithm

The improved A* algorithm is used for global path planning, and the DWA algorithm is used for local path planning. The fusion method of the two algorithms is given in this paper, as shown in Figure 10.

After the judgment and deletion of redundant nodes, the global path obtained by the improved A* algorithm is composed of key nodes, starting point and ending point, namely $path = \{S, P_1, P_2, \ldots, P_i, D\}$. The starting point S and P_1 nodes in *path* are set as the starting point and ending point of the improved DWA algorithm. If the distance between the vehicle and the node is less than the critical value $R_1 \leq R_{\sigma\_1}$, the vehicle is judged to have reached P_1 node, and the end point of the improved DWA method is switched to P_2. After several switches, it is finally switched to D and $R_i \leq R_{\sigma\_i}$, which is considered as the end of navigation.

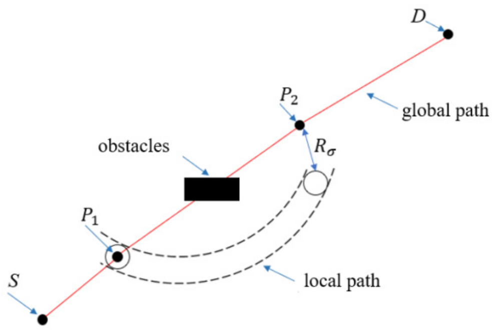

Figure 10 Combination method of improved A* algorithm and improved DWA algorithm

The position of the test vehicle entering the underground garage is shown in FIG. 11. Taking this position as the starting point, the location information of the free parking space is returned by the UWB positioning chip, and the free parking space in the underground garage is selected according to the selection method of the optimal parking space. According to the Manhattan distance from each free parking space to the starting point, M_1=182, M_2=164, M_3=158, respectively. Therefore, M_3 is selected as the optimal parking space.

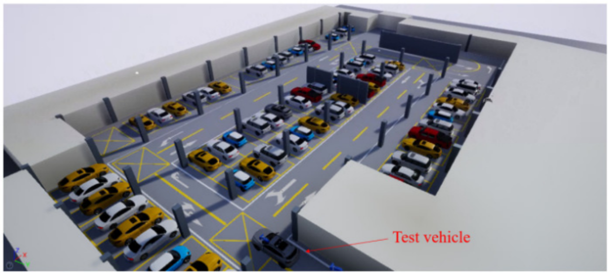

Figure 11 Test vehicle into underground garage position

Table 1 Comparison of global path planning algorithms

	T / s	*S* / m	*A* / (°)
Original A* algorithm	36.5	52.4	90
Improved A* algorithm	3.31	47.4	90
Traversal path	17.2	101.4	270

After the optimal parking space is obtained, the improved A* algorithm is applied for global path planning, and the obtained path is shown in FIG. 12.

As shown in Table 1, this paper compares the global path obtained by the original A* algorithm, the improved A* algorithm and the ordinary traversal path from three aspects: search time T, path length S and turning Angle A. The improved A* algorithm is superior to the other two algorithms in three aspects.

The local paths obtained by the improved DWA algorithm and the ordinary traversal algorithm are shown in Figure 13, and the length and time of the trajectories of the two algorithms are shown in Table 2.

Figure 12 Improve the path obtained by A* algorithm

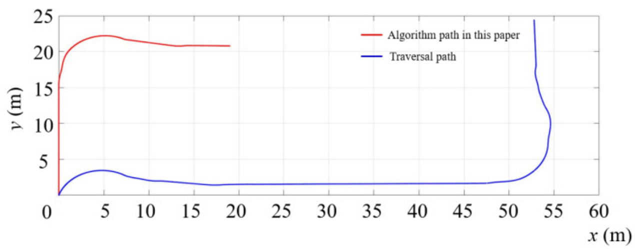

Figure 13 Comparison of algorithm path and traversal path in this paper

Table 2 Length and time of vehicle track

	S / m	*T* / s
Improved DWA algorithm	36.45	25.72
Traversal path	86.74	50.64

4. Conclusion

This paper proposes an automatic parking strategy optimization method based on OpenDRIVE+BIM, which is used to solve the problem of path planning from the beginning to the vacant parking space in large indoor environments such as underground garages and parking buildings. The road network information is obtained based on the OpenDRIVE file, the building information is obtained based on the BIM file, and the dynamic environment information is obtained using UWB. The optimal parking space judgment method is given, and the A* algorithm is improved for global path planning, and the DWA algorithm is improved for local obstacle avoidance. The path length of the improved A* algorithm is reduced by 9.5% compared with the original A* algorithm. Compared with the traversal path, the path length of the improved A* algorithm is reduced by 53.2%, and the turning Angle is reduced by 66.7%. Compared with the traversal algorithm, the trajectory length of the local path obtained by the improved DWA algorithm is reduced by 57.9% and the time is reduced by 49.2%. Therefore, the OpenDRIVE+BIM based automatic parking strategy optimization method proposed in this paper can effectively reduce the time and energy consumption of autonomous vehicles in the process of finding free parking Spaces in large indoor parking environments.

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