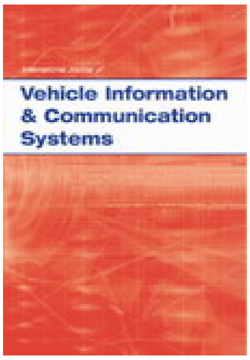

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The application of BIM-based architectural space and omnidirectional vision in smart parking systems

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Abstract: At present, parking has become an important issue affecting urban traffic flow and residents' quality of life. A smart parking system based on building information modelling technology and comprehensive visual concepts has been proposed to address issues such as parking difficulties. The new system uses HybridA* algorithm and building information modelling technology to plan the path of vehicles, and then tracks the trajectory of vehicles through omnidirectional vision and predictive control algorithms to improve parking efficiency. The research results indicate that the error variation of path tracking is 0.1492 on the X-axis, 0.1318 on the Y-axis, and 4.1220 on the yaw angle. During the entire parking process, the changes in braking and yaw angle are relatively small. This indicates that the new intelligent parking system can improve parking efficiency and safety. This provides better guidance for the efficiency and safety research of parking systems.

Keywords: BIM technology; omnidirectional vision; predictive control algorithm; HybridA* algorithm; parking.

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1 Introduction

Building Information Modelling (BIM) is a digital modelling technology that integrates architectural design, construction and operational management. It can comprehensively model and analyse buildings (Shi et al., 2023). Through BIM technology, precise modelling and management of building space can be achieved, including information on building structure, layout, equipment, etc. Omnidirectional Vision Technology (OVT) is a technology that achieves all-round perception of the environment through multiple cameras or sensors (Yang et al., 2023). Through OVT, real-time information on vehicles and available parking spaces in the parking lot can be obtained, achieving intelligent monitoring and management of the parking lot. The continuous progress of technology has made the construction of smart cities an important goal of modern society. In smart cities, smart transportation systems are a crucial component. The Smart Parking System (SPS), as one of the important components, has received widespread attention and research (Amara, 2023). In addition, the omnidirectional vision system provides an effective technical support for intelligent parking systems by installing cameras that can capture environmental information 360° without dead angles. These systems, through real-time video monitoring, not only accurately guide drivers to idle parking spaces, but also monitor and manage the safety status of parking lots, greatly improving the user's parking experience and the safety of the venue. The continuous acceleration of urbanisation has gradually exposed urban transportation problems, and problems such as parking difficulties and traffic congestion have become a major hidden danger that restricts the sustainable development of cities. To address this issue, SPS has emerged, utilising modern technology to provide convenient and efficient parking solutions for urban residents. In addition, how to solve the safety issues of vehicles during parking and reduce vehicle collisions caused by buildings is also a current issue that needs to be considered. Based on this, to improve the parking efficiency and safety of parking, this study introduces the commonly used BIM technology in architecture for the first time, and simulates the construction of parking spaces in parking lots. By simulating and optimising it, the collision of vehicles was reduced, and the trajectory during the parking process was tracked comprehensively using the OVT concept (Shimi et al., 2022). Wong et al. (2023) proposed a vision based deep learning method for the application of automatic parking systems in the field of parking space detection. The research results indicate that methods such as object detection, image segmentation, regression and graph neural networks can effectively address the challenges posed by different shapes, colours, functions, lighting and obstacles, providing strong support for the development of automatic parking systems (Wong et al., 2023). Zahid proposed an IoT vacant parking space detection system based on low-cost passive UHF RFID tags to address the challenge of drivers manually searching for parking spaces in crowded parking lots. The system detects the presence of vehicles by analysing the strength of backscattered signals from tags. The research results indicate that the reduction of Received Signal Strength Index (RSSI) can effectively indicate the presence of vehicles, significantly improving the efficiency and accuracy of parking space detection (Zahid et al., 2023). Building Information Modelling, BIM technology has demonstrated its strong potential in the fields of architecture and urban planning. BIM provides a three-dimensional digital way to represent the physical and functional characteristics of buildings and infrastructure, enabling architects and engineers to efficiently plan space and resources during the design phase. In the application of intelligent parking systems, BIM can help designers optimise the layout of parking spaces, predict the operational effectiveness of systems and achieve optimal utilisation of parking facilities. The innovations of the study are (1) Improvement of the parking system using HybridA* algorithm to enhance the parking efficiency and spatial planning capability of the parking system. (2) Planning and tracking the path of the parking system using BIM technology to improve the spatial planning capability and parking safety of the parking system.

This research is divided into four parts, firstly, Section 1 introduce the domestic and international research on this direction, analyse the current problems and achievements in this direction. Secondly, Section 2 is a planning study of the environment and path of parking by using BIM technology and HybridA* algorithm. Section 3 is to test the system, simulation and real car, to verify the feasibility of the constructed system. Section 4 is to summarise the whole current article and the future direction.

2 Literature review

Parking system, as a commonly used intelligent system, has brought convenience to people's travel. In this field, many experts and scholars have put forward their own views on other issues such as the Intelligence of Parking System (IPS). Uzun and Cakir (2022) found in their research that BIM technology can be applied not only in construction but also in the AEC industry. This study designed new process development trends for the use of BIM tools through some case studies. BIM technology could provide helpful designs for some industries related to architecture. Liang and Yu (2021) found that traditional BIM technology can plan and model some building information, which is quite useful for studying information and data related to buildings. The use of BIM technology for the design and optimisation of building information and housing was an important guarantee measure for ensuring the construction and use of houses. Mojarad et al. (2022) believed that the use of new transportation electrification is an important method to solve the problem of car pollution, and the establishment of intelligent parking systems can improve usage efficiency. Therefore, a two-stage algorithm was used to optimise the parking system and build a new parking system. The usage and installation costs of the new system could be minimised through this algorithm. Gu et al. (2021) found that using a new micro model can improve parking efficiency, so they constructed a new micro simulation model. The new model considered the capacity issue of parking on the roadside and off the road, and used a new parking search algorithm to track parking status and obtain new parking data. This model could improve parking efficiency and reduce traffic congestion caused by limited capacity.

Intelligent car systems not only help with parking efficiency and safety, but also have advantages in other aspects. Guo and Gong (2022) found in their research on new energy vehicles that using solar powered parking lots can achieve integrated design of parking and charging. Therefore, to calculate the arrival and departure time of the car, a new intelligent car control system was constructed using new deep reinforcement learning and fuzzy algorithms. The new system could enhance system efficiency, and improve system load and matching. Said et al. (2021) found that finding a free parking lot is relatively difficult at present. Therefore, to better manage daily life, a parking reservation system based on the Internet of Things has been designed, which realises the payment of parking fees for vehicles and other issues. This system could reduce traffic congestion and save time. Gao et al. (2021a) believed that the use of intelligent autonomous driving technology is crucial for driving safety, so a new complex scene generation testing system based on genetic algorithm was constructed. This system could generate more complex scenes and improve testing efficiency to a certain extent, and could also be applied to collision detection in IPS. Gao et al. (2021b) found that parking problems have caused serious traffic congestion, and therefore proposed an intelligent parking system based on intelligent guidance algorithms. The new algorithm could make decisions based on information such as parking locations and select the optimal design route. The use of a new algorithm system could reduce the time spent searching for parking spaces and reduce traffic congestion.

In summary, parking has become a relatively important traffic problem at present, and the parking of vehicles and the search for parking spaces are all important issues that need to be addressed. Therefore, it is necessary to optimise the parking system. This paper on IPS will incorporate new BIM technology and OVT concepts to build a new IPS to address current parking difficulties and other issues.

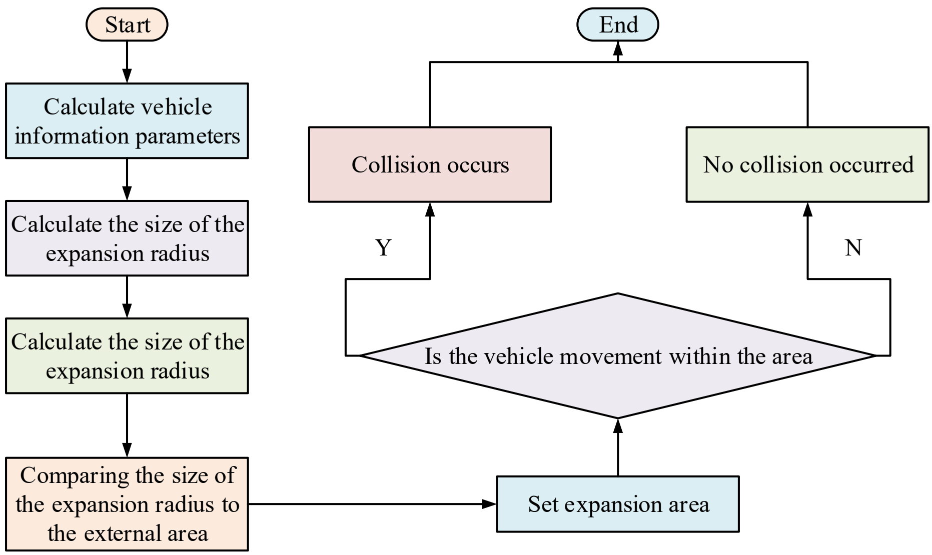
3 Building space analysis and trajectory tracking simulation model for SPS

This section focuses on modelling the methods used in the study, and improving the efficiency of the parking system and the ability of road tracking planning by improving the HybridA* algorithm. Secondly, BIM technology is used to analyse the parking buildings in the parking space to reduce the probability of collision in the parking process, so as to improve the safety of the system operation process.

3.1 Parking path planning and building space design based on improved HybridA algorithm and BIM*

In complex vehicle driving environments, the path of the vehicle can affect the speed of the car during parking, thereby affecting driving efficiency. Meanwhile, buildings in complex paths can also affect the speed of vehicles during parking. Therefore, building environmental building models is crucial in system research. The HybridA* algorithm can constrain the motion of different forms of cars. It mainly designs the path and step size of the car's motion model, and sets nodes at any position in the algorithm grid (Fang et al., 2022). Owing to the fact that the HybridA* algorithm can expand the connection nodes through continuous retrieval of spatial nodes, the node path generated by the algorithm is a curve that can be used for path tracking planning. The judgment of the motion status of cars and the detection of collision results in the system mainly rely on collision detection algorithms for data analysis. The collision detection process is Figure 1.

Figure 1 Collision detection algorithm detection process (see online version for colours)



In Figure 1, collision detection requires the calculation of vehicle parameters. The most primitive radius can be represented by the set of overlapping ranges of vehicles. Secondly, increasing the calculation frequency within the radius can reduce the size of the expansion radius and improve the accuracy of collision detection. The area where the obstacle is located is expanded outward by the size of the radius, and the expanded area forms the overall motion area of the car. This area is marked as occupied and vehicles are not allowed to pass through. There are two states to judge in this area. If one is within the area, it is judged as a collision, and if it is not within the area, it is judged as no collision. The HybridA* algorithm stores information about different state nodes of the car during parking path planning, such as Continuous Motion States (CMS) and Intermittent Motion States (IMS). CMS includes data information such as the location of the car. CMS information is generally used to ensure that the predicted route by the algorithm is a complete smooth route. (x, y) represents the position of the front and rear wheels of the vehicle at the centre. θ represents the yaw angle of the car, and IMS is obtained by discretising the CMS. The conversion formula is equation (1) (Prongnuch and Sitjongsataporn, 2022).

$$\breve{x} = \frac{x - O_x}{\sigma} \tag{1}$$

In equation (1), $\breve{x}$ represents the horizontal coordinate of the IMS. O_x represents the horizontal axis of the starting position of the data origin in the detection algorithm. σ represents the edge length of the expansion range in the detection algorithm. Equation (2) represents vertical transformation.

$$\breve{y} = \frac{y - O_y}{\sigma} \tag{2}$$

In equation (2), $\breve{y}$ represents the vertical coordinates of the IMS. O_y represents the vertical coordinate of the starting position of the data origin in the detection algorithm. Equation (3) represents the conversion of yaw angle.

$$\breve{\theta} = \frac{\theta}{\sigma_\theta} \tag{3}$$

In equation (3), $\breve{\theta}$ represents the lateral angle of the car in an intermittent state. σ_θ represents the discretised yaw angle. The node step size expansion of the HybridA* algorithm needs to meet several conditions. Firstly, during a single expansion, it must cross the expansion radius range of the detection algorithm, as shown in equation (4).

$$l > \sqrt{2}\sigma \tag{4}$$

In equation (4), l represents the length of expansion per unit step. The curvature size of the expansion step will be limited by the rotation angle of the car, and the conditions met are shown in equation (5) (Alharbi et al., 2021).

$$-\delta_{\max} \le \delta \le \delta_{\max} \tag{5}$$

In equation (5), $\delta_{\max}$ represents the maximum steering angle of the car. The amount of change in the steering angle of a car is the current discrete integer of the yaw angle, represented as equation (6).

$$\Delta\delta = k\sigma_\theta, k \in Z \tag{6}$$

In equation (6), $\Delta\delta$ represents the change in steering angle. k, Z represents real numbers. σ_θ represents the discretised yaw angle. Owing to the fact that the planning of a car path is composed of multiple nodes, the optimal node is replaced by a cost function in the search of the path, and its basic formula is equation (7).

$$f(n) = \lambda_n g(n) + h(n) + c_n \tag{7}$$

In equation (7), n represents the current node. $g(n)$ represents the cost function from the initial node to the current node. The cost formula accumulated through continuous accumulation is equation (8).

$$g(n) = \sum_{i=1}^{n} l_i \tag{8}$$

In equation (8), l represents the length of expansion per unit step. In equation (9), λ_n represents the penalty value of the node during expansion, and the expression of its penalty coefficient is equation (9).

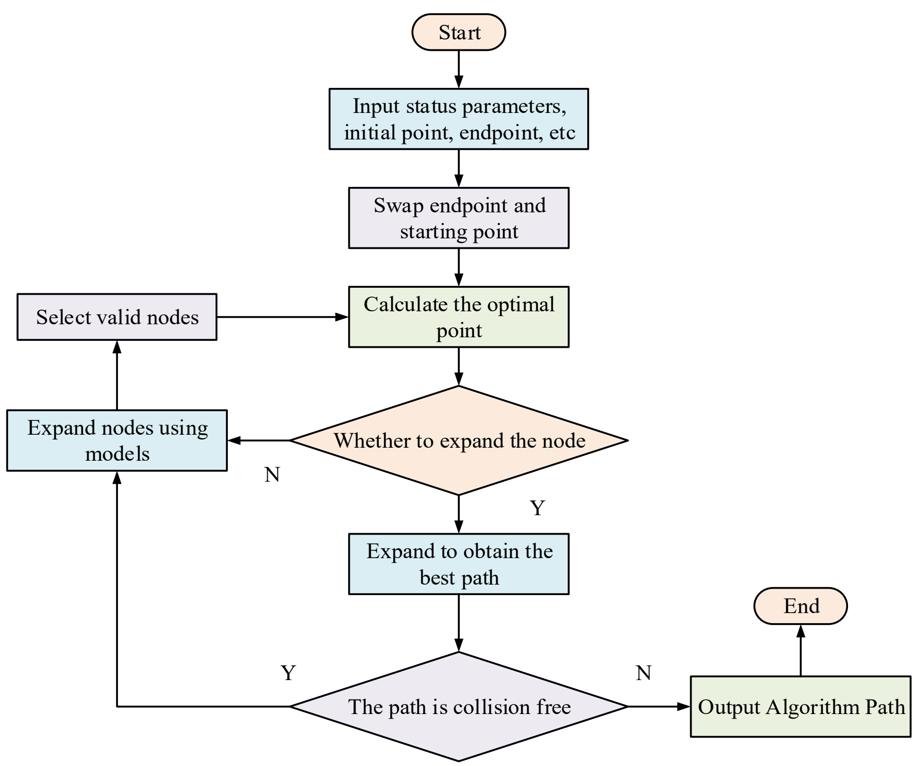
$$\lambda(n) = \begin{cases} c_{forward} \\ c_{reverse} \end{cases} \tag{9}$$

In equation (9), $c_{forward}$ represents that the expansion step size is forward expansion. $c_{reverse}$ indicates that the expansion step size is backward expansion. In equation (7), c_n represents the size of the penalty coefficient when the expansion direction changes. The change in c_n value can control the frequency of node expansion angle changes, and its calculation formula is equation (10).

$$c_n = \begin{cases} 0 \\ c_{direction} \end{cases} \tag{10}$$

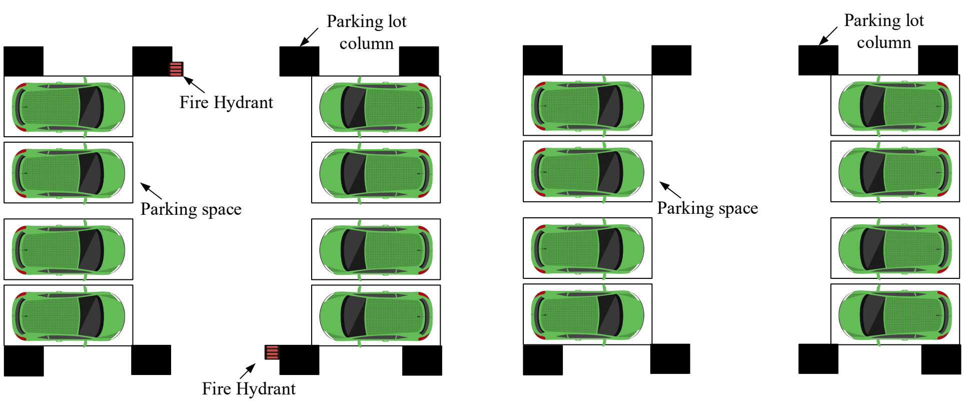
In equation (10), $c_n = 0$ represents that the direction of the expansion step remains unchanged. $c_n = c_{direction}$ indicates a change in the direction of the expansion step. $h(n)$ represents the heuristic function in the expansion step size. $c_{direction}$ represents the proxy value from the node to the target. The heuristic function can guide the expansion direction, and the algorithm's expansion direction is towards the target direction, improving the algorithm's computational speed. The conventional HybridA* algorithm generates a large number of useless nodes during expansion, which increases the computational complexity of the algorithm and reduces its efficiency. Therefore, the conventional algorithm operation chooses the reverse expansion method, which involves swapping the initial point and endpoint to expand the algorithm from the internal examination, reducing the number of nodes and improving the efficiency of the algorithm. The improved algorithm process is Figure 2.

Figure 2 Reverse expansion HybridA* algorithm process (see online version for colours)



In Figure 2, the algorithm first inputs the initial and intermediate values during operation, and then exchanges the target points. By calculating the optimal state of the nodes, it determines whether to expand the step size of the nodes. If expansion is performed, the distribution expansion obtains its optimal path. If expansion is not performed, the model is used to expand the nodes. Simultaneously detecting collision states, selecting useful nodes and then calculating the optimal node. At this point, to determine whether the calculated path is in a collision state. If it is in a collision state, continue to expand the node step size and calculate the optimal point. If it is not in a collision state, output the current path. In the parking system, some building spaces can affect the efficiency of parking, including fire hydrants, adequacy of parking space, and pillars next to the parking lot. Therefore, when parking vehicles, it is necessary to consider whether the space size is reasonable. The BIM model can obtain location information such as fire hydrants and drainage channels around parking lots and parking spaces, providing a visual analysis environment for parking systems. The data construction of BIM models enables visual analysis of parking space. Figure 3 shows the parking lot data information graph constructed by the BIM model.

Figure 3 Comparison of optimisation before and after BIM parking lot (see online version for colours)



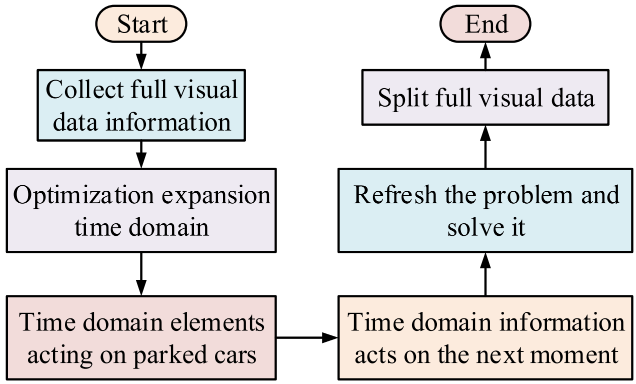
(a) Before optimizing the parking location (b) After optimizing the parking location

In Figure 3, when the car is parked, the position of the fire hydrant will affect the parking and reduce the use of space. After obtaining the situation data in the garage, the fire hydrant next to the parking space will be optimised, and the parking space will be improved, increasing the operating space for parking and improving parking efficiency.

3.2 IPS trajectory tracking based on OVT

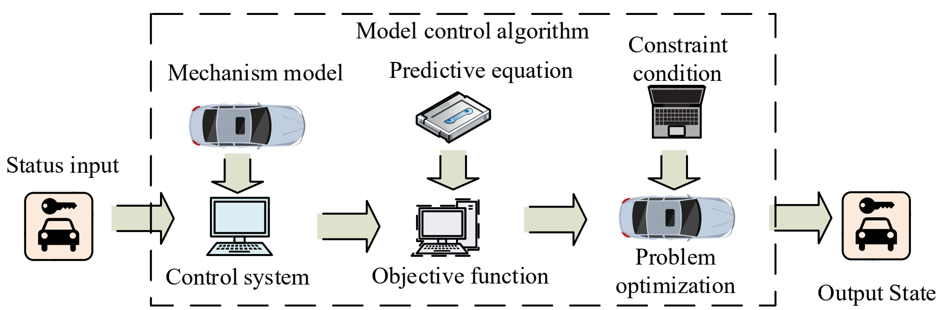
In IPS, vehicle tracking control can be calculated and analysed through system algorithms, and then automatically parked and tracked through visual analysis of comprehensive information data (Mudgal et al., 2023). The traditional car control algorithm controls the car system offline, while the Model Predictive Control (MPC) algorithm can solve car control optimisation problems online and update periodic data. Therefore, it is often applied in automotive control, and the specific process is Figure 4.

Figure 4 Model predictive control algorithm flow (see online version for colours)



In Figure 4, the control algorithm collects environmental data information of cars at different times, unfolds and optimises the time domain in finite space, and solves it to achieve control over the time domain. It then applies some time-domain elements to the cars that need to be parked, and applies the sampled data obtained at different times to the next time, refreshing the problem and solving it. At the same time, the data information from full vision is split and optimised for full vision analysis to achieve control of vehicle parking trajectory. The use of model MPC can achieve lateral and longitudinal control of the car, as well as real-time information acquisition of the parking environment, achieving tracking control of OVT. Figure 5 shows the control logic flow of the algorithm.

Figure 5 Algorithm control logic flow (see online version for colours)



In Figure 5, after inputting the environmental data information of the car's state, the control algorithm can control the parking system through the data information. It incorporates the mechanism model of the car, solves the function through predicted equations, and adds constraints for parking system trajectory tracking to optimise the data problem. Finally, the data was subjected to action decomposition to achieve control design analysis of the vehicle (Haghifam et al., 2021). The size of the objective function in the control algorithm can ensure that the vehicle can quickly and smoothly track the path during parking. At the same time, the surrounding environment of cars under OVT can also achieve good information analysis. But for the calculation of the objective function, it is necessary to predict the vehicle control data through the system. The output in the future time is the state error at the future moment, which can be represented by the current state error data. However, the state error at that moment does not require indirect representation processing, so a new state function formula is constructed as shown in equation (11) (Gai et al., 2023).

$$\xi(k) = \begin{bmatrix} \widehat{x}(k) \\ \widehat{u}(k-1) \end{bmatrix} \tag{11}$$

In equation (11), $\widehat{x}$ represents the current state vector of the vehicle. $\widehat{u}$ represents the input vector of the control algorithm. k represents the serial number of discrete time. $\xi(k)$ represents the new total vector of states. By judging equation (11), a new control system formula (12) can be obtained.

$$\begin{cases} \xi(k+1) = A_2(t)\xi(k) + B_2(t)\Delta\widehat{u}(k) \\ \eta(k) = C_2(t)\xi(k) \end{cases} \tag{12}$$

In equation (12), A_2 represents the size of the matrix in the system. B_2 represents the matrix of system input. C_2 represents the matrix size of the system output. η represents the size of the identity matrix in stage *m*. At this point, the objective function is transformed into equation (13) (Mojarad et al., 2022).

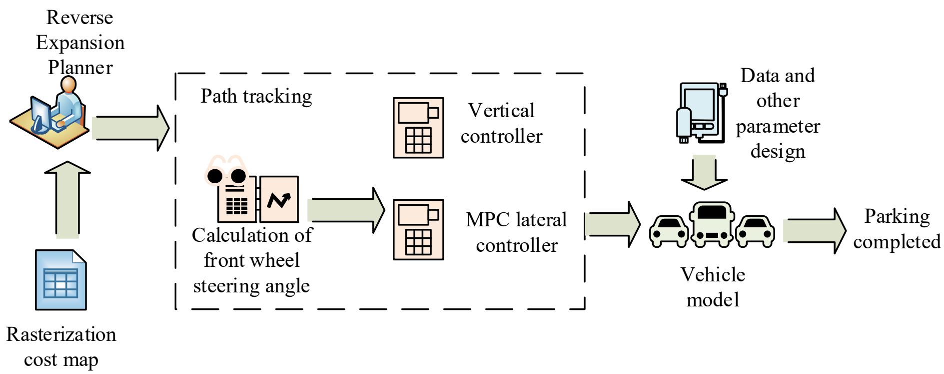
$$J\left(\xi(k), \Delta\widehat{U}(k)\right) = \sum_{i=1}^{H_p} \left\| \hat{\eta}\left(k+i \middle| k\right) - \eta_{ref}\left(k+i \middle| k\right) \right\|_{Q2}^{2} + \sum_{i=1}^{H_{C-1}} \left\| \Delta\widehat{u}\left(k+i \middle| k\right) \right\|_{R2}^{2} \tag{13}$$

In equation (13), $\Delta\widehat{U}$ represents the optimised vector, mainly composed of the control vectors of the system. $\hat{\eta}\left(k+i \middle| k\right)$ represents the value of the predicted output vector at time $k+i$. η_{ref} represents the output vector referenced by the system. If the time state error and time domain control error of the current system are obtained, then the output of the system can be obtained and the complete prediction objective function is equation (14).

$$J\left(\widehat{x}(k), \widehat{u}(k)\right) = \sum_{j=1}^{H} \widehat{x}^T\left(k+j \middle| k\right) Q_1 \widehat{X}\left(k+j\right) + \widehat{u}^T\left(k+j-1\right) R_1 \widehat{u}\left(k+j-1\right) \tag{14}$$

In equation (14), the formula parameters are the same as in the above equation, where H represents the time domain size of the system discretisation in the time system. $Q_1 \setminus R_1$ represents weight matrices of different sizes (Zan, 2022). In IPS, parking conditions not only require observation and analysis of the surrounding environment to avoid damage to vehicles or other vehicles, but also require tracking of the system’s operating path. In order to conduct software simulation of the parking system and verify the feasibility of its control algorithm, model simulation was conducted on each working model and building environment. Figure 6 is a flowchart of simulation model control.

Figure 6 Simulation model control process (see online version for colours)



The simulation model in Figure 6 uses the BIM model to obtain building spatial data, and then uses the HybridA* algorithm to plan the parking path. To input the planned path into path tracking control, use MPC control algorithm to control the steering angle, lateral angle and longitudinal direction of the car, and build the control and parking model of the car. Setting the speed and other parameters of the car to achieve data control during the parking process, thereby achieving intelligent parking of the entire system.

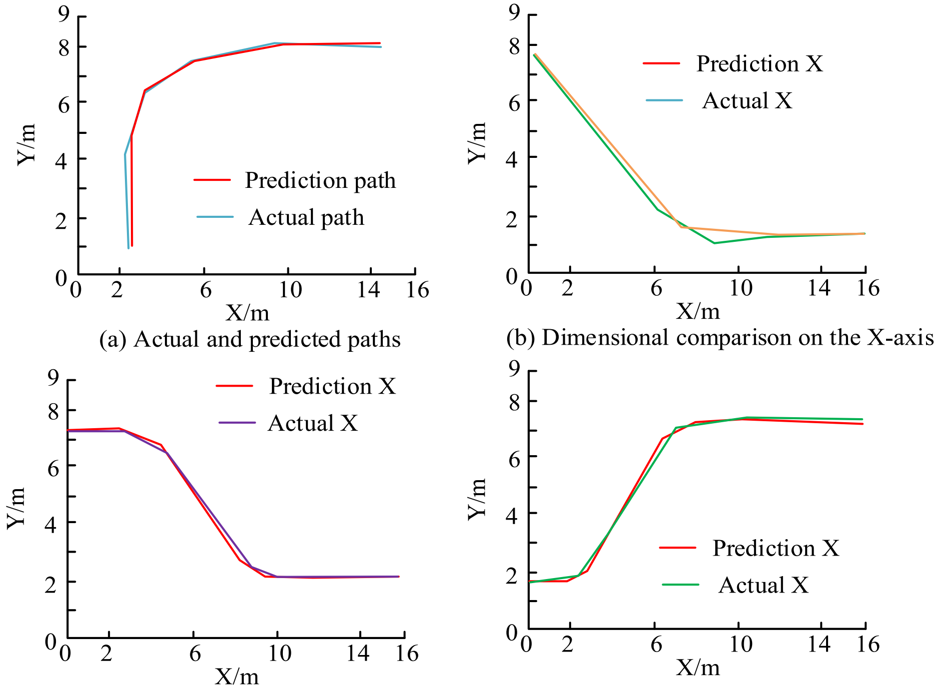
4 Data analysis of IPS simulation model

This section focuses on the data analysis of the system operation effect and model performance of the parking system, firstly, the practical application effect of the model is analysed to test the actual operation effect of the system in the operation process. Secondly, the performance of the algorithm of the system is analysed to compare the operation effect of different methods in order to explore the effectiveness of the current research method.

This study used MATLAB as a simulation software for automobiles. The hardware is P720, and the processor is Intel Xeon@2.4Ghz. The RAM is 16GB. The length and width of the garage selection are the standard garage length and width, respectively. The underground garage and ground parking space in a shopping mall is selected as the testing scenarios for parking. Reverse parking is the current way for vehicles to park. The simulated test results are shown in Figure 7.

In Figure 7, the actual curve of the vehicle test and the changes in the test curve are basically the same, but there are slight differences in some distance and parameter values. The maximum variation error of its path tracking error on the *X*-axis is 0.1492, on the *Y*-axis is 0.1318 and the error variation of the yaw angle is 4.1220. In the simulation experiment of using algorithms for parking, the IPS of the car can predict the real situation with a small error range. After conducting model experiments, normal vehicle brands are not limited to being selected as real vehicle testing research for reverse parking. Figure 8 shows the indicator chart of actual vehicle testing data.

Figure 7 Comparison of real test and actual results of the model (see online version for colours)



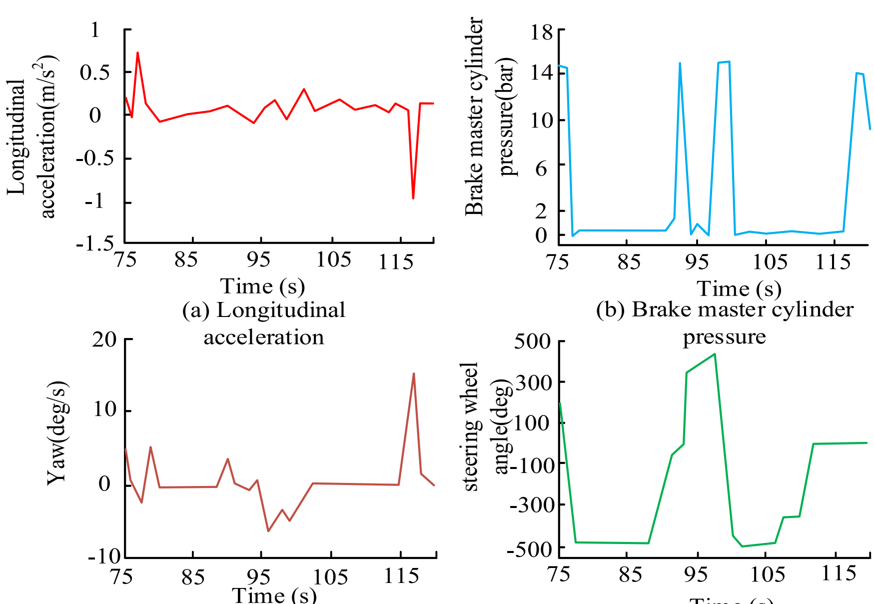
(a) Actual and predicted paths

(b) Dimensional comparison on the X-axis

(c) Dimensional comparison on the Y-axis

(d) Dimensional comparison of yaw angle

Figure 8 Vehicle parameter changes during reverse storage testing (see online version for colours)



(a) Longitudinal acceleration

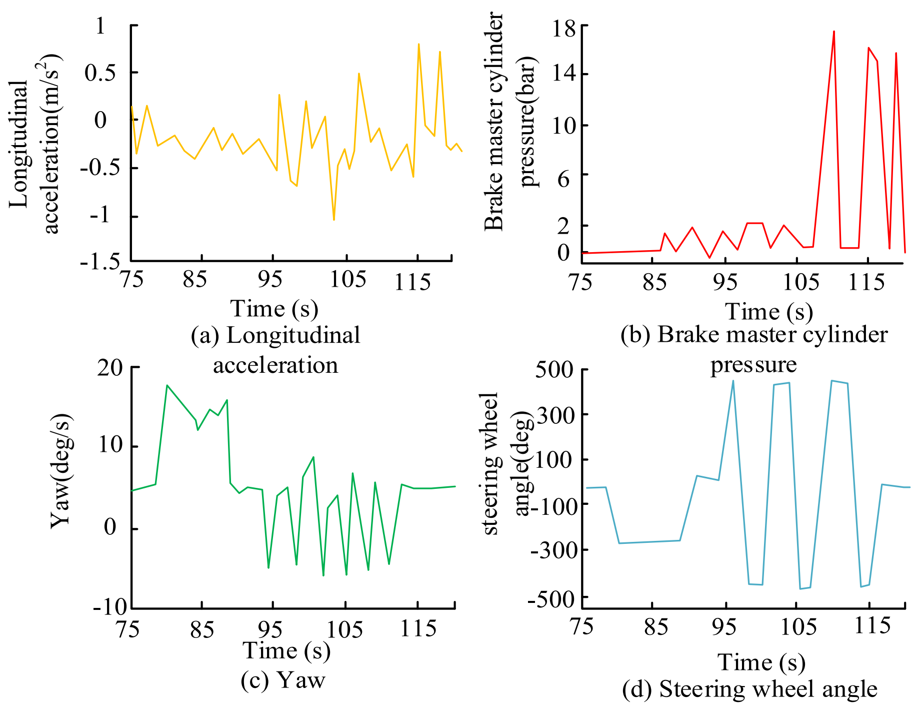
(b) Brake master cylinder pressure

(c) Yaw

(d) Steering wheel angle

In Figure 8, when the actual vehicle is parked in reverse, the total parking time of the vehicle is 120 seconds. During the entire process, there were three instances of vehicle braking, including steering and stopping completion. The cylinder pressure of the vehicle is maintained within 12 bar. The velocity change of its yaw angle is relatively small. The speed changes between 95–100s and 115–120s, which may be due to the change in yaw rate during the braking process of the vehicle as it moves. But its range of variation is relatively small, maintaining within the range of 7 deg/s, which may be due to the vehicle only rotating in place and not making relatively large directional changes. In addition, the rotation of the steering wheel can also change with the braking of the vehicle. Therefore, the driving path of reverse parking in the parking system can be perfectly tracked and replicated, but there will be significant changes in longitudinal acceleration in the initial and termination states. After performing the reverse parking operation, the vehicle was subjected to a side parking test and the performance chart of the actual vehicle test was obtained as shown in Figure 9.

Figure 9 Changes in vehicle parameters during side parking test (see online version for colours)

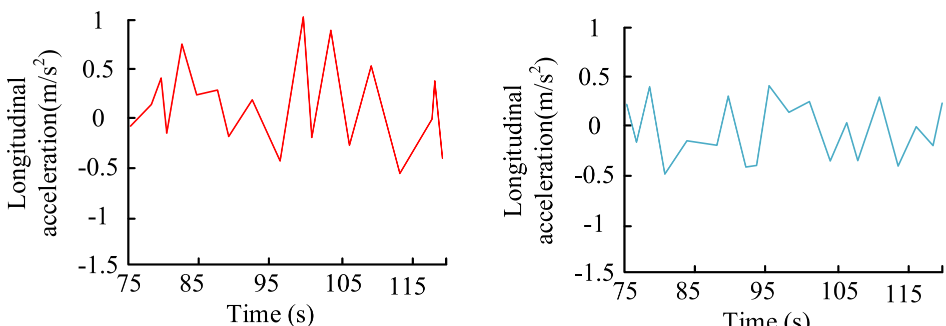


In Figure 9, the vehicle generated a total of 10 brakes during the lateral parking test. Among them, 9 were brake rotations during the parking process of the vehicle, and one was the completed braking during parking. The total parking time is consistent with the reverse time. However, it can be inferred from the changes in acceleration both horizontally and longitudinally that the vehicle has experienced multiple braking situations in the middle, which may have been caused by avoiding some obstacles. The pressure variation range of the car brake cylinder is within 18 bar, which may be due to the frequent occurrence of braking during this period. The range of lateral angular velocity variation throughout the entire process remains within the 3 deg/s range, which may be caused by the car turning in place during turning and parking.

4.2 Analysis of IPS algorithm performance test results

To test the feasibility of BIM technology in the parking system, this study compared the changes in vehicle lateral and longitudinal speeds during the entire parking process between a car parking model that applied BIM technology and a car parking model that did not apply BIM technology. Figure 10 shows the relevant acceleration comparison results.

Figure 10 Comparison of vehicle longitudinal speed before and after optimisation (see online version for colours)

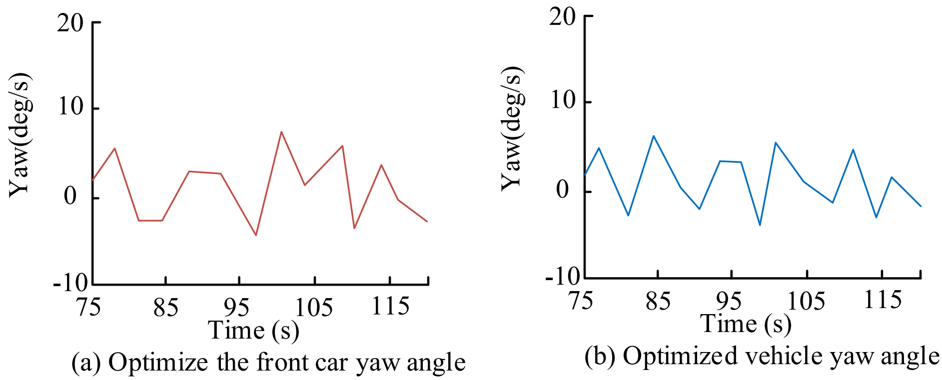


(a) Longitudinal acceleration before optimization

(b) Optimized longitudinal acceleration

In Figure 10, before optimising the model and parameters, the longitudinal acceleration of the car undergoes significant velocity changes during braking. Its range of variation ranges from –1 to 0.5m/s^2, and its speed variation curve is relatively large. After optimising the surrounding environment of car parking using BIM technology, the speed change value during car braking is relatively small, ranging from –0.5 to 0.5 m/s^2, which is reduced by 0.5 m/s^2 compared to the range before optimisation. At the same time, the variation of its velocity curve is relatively stable. Therefore, incorporating BIM technology into the parking system can reduce the speed changes that occur when the car brakes. As a result, it also reduces the time variation caused by the decrease in braking speed due to an increase in the entire process, improving the efficiency of longitudinal movement. Comparing the lateral velocity changes during the parking process of the car, the results are shown in Figure 11.

Figure 11 Changes in vehicle yaw angle before and after optimisation (see online version for colours)



In Figure 11, the lateral angular velocity before optimisation varies within a range of 5 deg/s during the braking process. The optimised range of angular velocity variation is between 4 deg/s, with a difference of 1 deg/s before and after optimisation. Among the changes in the curves of the two speeds simultaneously, the optimised curve is smoother with smaller changes, while the curve before optimisation has greater changes. Therefore, optimisation can achieve changes in lateral angular velocity, reduce time and improve efficiency. To test the performance of algorithms in the entire system, a comparison was made between the algorithms used in the system and some traditional trajectory tracking algorithms, as shown in Table 1. A comparison was made between PID control algorithm and Pure Pursuit Algorithm (PPA).

Table 1 Performance comparison of different algorithms

Algorithm	*Accuracy (%)*	*Average error (%)*	*Mean absolute error (%)*	*Root mean square error (%)*
PID	92.12	12.01	14.25	13.8
PPA	93.25	11.99	8.81	8.64
HybridA*	95.36	6.41	8.57	9.57
Improved HybridA*	96.24	6.3	7.95	9.12

When comparing the three algorithms in Table 1, it was found that the improved HybridA* algorithm significantly improved its performance. Its accuracy in tracking car parking paths is 4.12% higher than PID algorithm, 2.99% higher than PPA algorithm and 0.88% higher than HybridA* algorithm. Compared to the other three algorithms, the error value of the algorithm is lower. Therefore, using the improved algorithm model can improve the performance of the car in the parking system and steadily enhance its parking efficiency.

5 Conclusion

This study obtained a new parking system model through the study of car parking systems. By adding OVT to the driving trajectory of a car, its comprehensive trajectory data could be collected. At the same time, BIM technology has been introduced into the system to monitor the entire building environment and space of parking, allowing cars to avoid collisions during the parking process. Finally, the improved HybridA* algorithm was used to plan the path of the parking system, creating a faster and more convenient parking environment. Research has shown that during the path tracking experiment of the parking system, the error variation value of path tracking was 0.1492 on the *X*-axis, 0.1318 on the *Y*-axis and 4.1220 on the yaw angle. The total parking time for the vehicle during the reverse parking experiment was 120 seconds. There were three instances of vehicle braking during the entire process. The cylinder pressure of the vehicle was maintained within 12 bar. The range of change in yaw angle was small, only 7 deg/s. When conducting side parking experiments, the range of change in yaw angle was smaller, only 3deg/s and the entire vehicle braking occurred 10 times. The vehicle increased the number of braking times to avoid collisions. When comparing the performance of algorithms, the accuracy of the improved HybridA * algorithm was 4.12% higher than that of the PID algorithm, 2.99% higher than that of the PPA algorithm and 0.88% higher than that of the HybridA* algorithm. In summary, incorporating OVT and BIM technologies in the improvement research of parking systems can improve the parking efficiency and safety of the system. Although this study has achieved many results, there are still some problems. Firstly, the data and model scenarios used in this study belong to common scenarios, and more complex scenarios have not been experimented with. Therefore, further experiments will be conducted on more complex scenarios. Secondly, the vehicles used in this study cannot fully confirm their universality, and further experiments will be conducted on more different types of vehicles.

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