Intelligent Vehicle Auxiliary Handling System Based on the Internet of Things Technology

Chenxiao Wu[1]*, Jue Wang[2], Han Sui[2], Jingru Li[2], Zihang Wang[3]

[1]School of Civil Engineering and Transportation, Northeast Forestry University, Harbin 150040, China
[2]Aulin College, Northeast Forestry University, Harbin 150040, China
[3]College of Computer and Control Engineering, Northeast Forestry University, Harbin 150040, China

*Corresponding author: Chenxiao Wu, 13253293902@163.com

Abstract: This paper proposes an intelligent vehicle auxiliary handling system based on Internet of Things (IoT) technology, featuring an innovative holding mechanism design that adjusts to the length and width of various vehicles. The system combines precise positioning using satellite tracking technology, intelligent recognition via OpenCV, and the interconnectivity of IoT. This intelligent vehicle auxiliary handling system can independently identify vehicle positions and plan optimal handling paths, eliminating the traditional reliance on manual operation. It offers efficient and accurate handling, setting a new trend in the handling industry. Additionally, the system integrates seamlessly with parking lot management systems, providing real-time updates on vehicle locations and statuses. This allows managers to monitor the parking lot operations clearly and efficiently. This intelligent coordination greatly enhances overall work efficiency and streamlines parking management. Overall, the innovative design of the intelligent vehicle auxiliary handling system represents a significant breakthrough in both function and performance, gaining user favor with its smooth operation. Looking ahead, continued technological advancements and the expansion of application fields will bring even more vitality and intelligence to societal development.

Keywords: Vehicle handling; Intelligent network; OpenCV; Image recognition

1. Project background

In modern cities, parking and moving cars have always been challenging, especially in areas with limited space or high parking density, causing significant inconvenience to people's lives (**Figure 1**).

To address this issue, an intelligent car porter has been developed. Beyond solving parking difficulties, the intelligent car porter also has a fire evacuation function. As urbanization progresses, the design and application of underground garages have become more complex. Given that underground garages are enclosed spaces, designing for fire prevention and safe evacuation is particularly challenging. In the event of a fire, these spaces can easily become hazardous, leading to significant losses and casualties. Traditional fire prevention and safety studies in buildings typically conduct fire and evacuation simulations independently, determining safe

evacuation conditions based on the necessary and available evacuation time for pedestrians. However, this approach does not account for the impact of fire spread on pedestrian evacuation or the interaction between pedestrian and vehicle evacuations in an underground garage, complicating fire evacuation simulations [1]. In emergencies, such as fires, traditional car porters can obstruct evacuation routes, hindering the safe evacuation of people. To address this, the intelligent car porter uses a single-chip controller to enable automatic movement, creating clear paths for fire evacuation and ensuring the safety of personnel.

In urban parking management, poor parking behavior often leads to traffic congestion, safety risks, and wasted parking resources (**Figure 2**). Traditional law enforcement methods, which typically rely on traffic police patrols or personnel monitoring for illegal stops, are inefficient and costly. To address this issue, the intelligent car porter project introduces an automatic satellite tracking function. This function enables the automatic processing and notification of non-standard parking behavior through image recognition and intelligent network connectivity.

Figure 1. Improper parking

Figure 2. Improper disposal of old cars

On January 1, 2020, a major fire accident occurred in Chongqing Municipality, China. The fire, which rapidly spread from the second floor to the 30th floor, was extremely intense and in critical condition. It took more than 100 firefighters to bring the fire under control, and it was finally extinguished within four hours. Fortunately, no one was injured. However, due to traffic congestion, fire vehicles could not arrive at the scene promptly (**Figure 3**), allowing the fire to spread further and complicating the firefighting efforts (**Figure 4**). This incident underscores the importance of strengthening urban fire safety management and improving fire emergency response capabilities to protect people's lives and property.

Figure 3. Vehicles blocking the fire escape

Figure 4. Photo of the fire

This system, aligning with modernization and intelligence trends, offers innovative solutions for future urban management and emergency response efforts. The specific implementation process involves sensor monitoring by the MCU, which triggers fire signals and plans optimal evacuation paths. The microcontroller then autonomously controls the vehicle handling device to navigate the planned path, avoiding obstacles and ensuring clear fire escape routes, all while continuously monitoring the environment and adjusting paths as needed to handle new emergencies. Through this process, the intelligent vehicle auxiliary handling system autonomously vacates fire passages during emergencies, ensuring safe personnel evacuation and adding a safety guarantee to urban parking management.

2. Functions

2.1. Parking area correction

The vehicle carrier autonomously follows preset routes to patrol parking areas, utilizing a built-in navigation system and sensors for accurate and efficient movement within complex environments. Real-time HD cameras capture vehicle images, which are then identified using a deep learning algorithm trained on extensive data to accurately determine vehicle position, posture, and parking compliance. If a vehicle is improperly parked, the system further analyzes its type and size. Upon identification of a misaligned vehicle, the carrier plans an optimal movement path using its built-in sensors and algorithms. Utilizing its robotic arm, the porter securely lifts and moves the vehicle to a designated parking space, ensuring smooth relocation. Throughout the process, the porter extracts the vehicle's license plate number through image recognition technology, comparing it with pre-stored owner registration information to obtain contact details. Notifications are then sent to owners via SMS or app push, informing them of the relocation and prompting payment, including specific amounts, methods, and deadlines. This function significantly enhances parking area order and standardization, as the vehicle carriers can detect and address improperly parked vehicles in real time, thereby preventing disruptions to other vehicles and reducing the likelihood of scratches and disputes. Moreover, it improves parking management efficiency and intelligence by automating patrol and recognition tasks, eliminating the need for manual intervention, and streamlining payment processes through real-time owner notification and payment reminders.

2.2. Firefighting tasks for dredging vehicles

In a fire emergency, firefighters can connect to the Raspberry Pi via Bluetooth to control the smart vehicle-assisted processing system. The wireless connection is simple, quick, and responsive, giving firefighters valuable time for rescue. Firefighters can use mobile devices such as mobile phones or tablets to remotely monitor and control vehicle carriers, accurately guide them to designated locations, and effectively carry vehicles that prevent fire from entering. The intelligent vehicle auxiliary processing system has good identification and positioning function, and can accurately identify the vehicles occupying the fire channel, and plan the optimal processing path. At the same time, the system has high stability and reliability and can maintain a stable operation state even in a complex and changeable environment. Through the fire evacuation function of the intelligent vehicle auxiliary processing system, it can effectively solve the problem of occupying the fire ladder, and improve the benefit of the fire ladder

3. Working scheme

In 2010, the Xiamen People's Hall parking lot introduced the "Momo" parking system, leveraging IoT

technology to provide real-time parking status information to drivers via a mobile client. The system utilizes vehicle location and license plate information to enable illegal parking detection, employing target detection and trajectory tracking algorithms to track vehicle locations and identify potential violations. Its main functions include automatic capture of illegally parked vehicles, automated handling of violations, remote monitoring and communication capabilities, as well as processing of illegal parking incidents and user notifications (**Figure 5**).
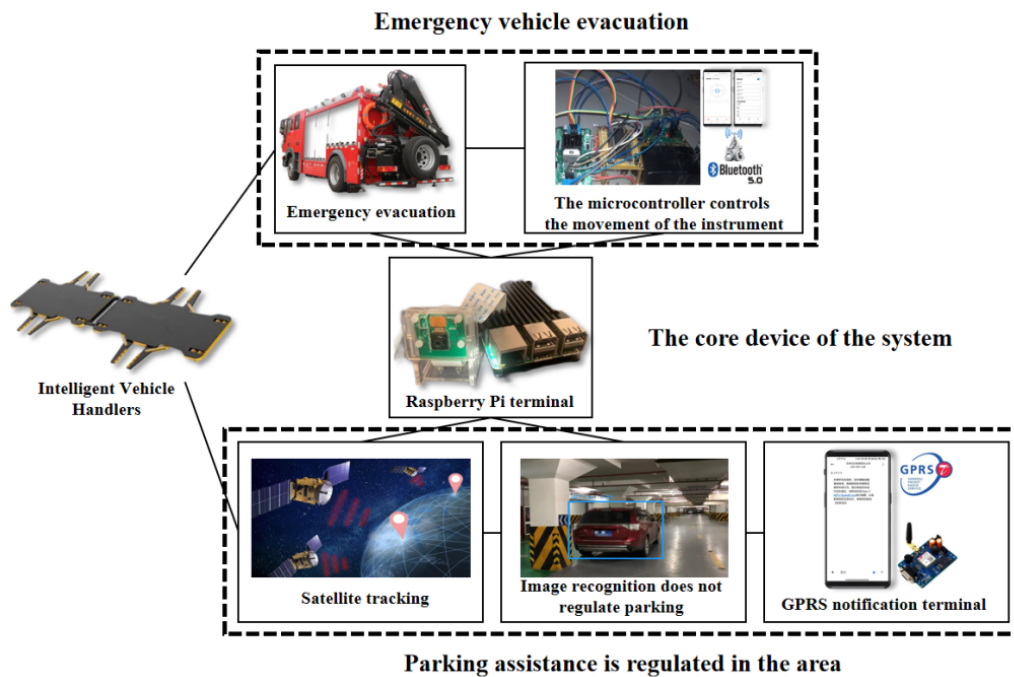
Figure 5. System overview process diagram

3.1. Automated capture of illegally parked vehicles

The automatic capture of illegally parked vehicles relies on three core technologies: image recognition, intelligent algorithm processing, and data transmission and processing. Deep learning models, such as convolutional neural networks (CNN), are employed to identify vehicles and license plate numbers. Cameras collect vehicle images, and image processing algorithms extract vehicle features and license plate information. To enhance the coverage of parking induction systems, integration with map navigation and real-time traffic applications is utilized, aligning with the concept of "car-road synergy." The system's information architecture design incorporates IoT technology to transmit camera images and processing data to cloud servers for further analysis [3]. Cloud-based data analysis is then conducted to identify illegal parking behavior. As technology evolves and application requirements change, continuous optimization and system upgrades are essential. This entails enhancing the accuracy and speed of image recognition algorithms, improving system processing capacity and stability, and implementing advanced IoT technology and data transmission methods for enhanced efficiency and security. Additional violation processing measures and feedback mechanisms are also integrated to enhance user satisfaction and system practicality. Collaboration with relevant departments is crucial to promote system optimization and upgrades. Through ongoing improvement and innovation, systems for automatically capturing illegally parked vehicles will better serve urban management and social development needs.

The intelligent vehicle auxiliary handling system incorporates an automatic capture function for illegal

parking vehicles, utilizing multiple dimensions including image recognition technology, intelligent algorithm processing, and data transmission and processing to achieve accurate identification and efficient processing of illegal parking behavior. At the core of this function lies image recognition technology, which leverages HD cameras to capture vehicle images in the parking lot, providing crucial information for subsequent analysis and processing. During the image recognition process, deep learning models, particularly convolutional neural networks (CNN), play a pivotal role, enabling the system to accurately identify vehicles and their license plate numbers due to their exceptional feature extraction and classification capabilities. Through continuous training and optimization of the CNN model, the system can enhance the recognition accuracy of vehicles and license plates, ensuring the precise capture of illegal parking behavior.

Intelligent algorithm processing forms the cornerstone of this function. Upon acquiring the vehicle image, the system employs image processing algorithms to preprocess the image, including denoising and enhancement, with the goal of enhancing image quality. Following this, through techniques such as edge detection and morphological analysis, the system can extract key features of the vehicle information, such as vehicle contours and license plate positions, providing a robust foundation for subsequent illegal parking judgment. Furthermore, the system utilizes intelligent classification algorithms to meticulously classify vehicles, accurately distinguishing between legally parked vehicles and those parked illegally.

In the domain of data transmission and processing, IoT technology plays a pivotal role in facilitating this function. The system utilizes IoT technology to transmit captured images and processed data from the camera to the cloud server for further analysis. Within the cloud environment, the system employs big data analysis and machine learning algorithms to conduct in-depth mining of the received data, thereby accurately identifying instances of illegal parking behavior (**Figure 6**). Simultaneously, the system is capable of real-time push notifications of illegal parking information to the parking lot management system or relevant law enforcement departments, ensuring timely and effective resolution of issues.
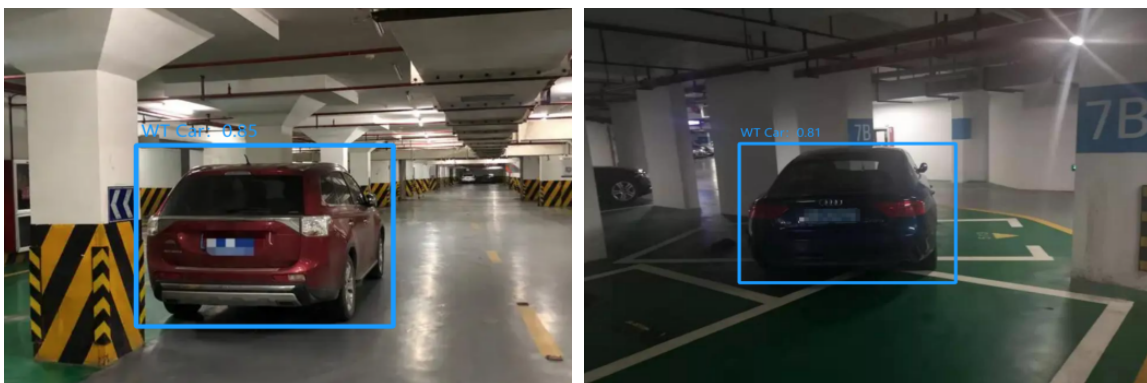

Figure 6. Schematic diagram of identifying illegally parked vehicles

3.2. Automatic handling of illegally parked vehicles

To achieve the locking and position adjustment of the vehicle, a robust clamp mechanism and adjustment device must be designed. The clamp mechanism can utilize hydraulic clamping or a sturdy clamping structure to ensure secure locking of the vehicle in place. The adjustment device can incorporate either an electric or hydraulic system to enable precise adjustment and movement of the vehicle's position. Additionally, a remote control system should be established, allowing operators to remotely monitor and control the porter's movement and operation via an intelligent terminal (**Figure 7**). This control system must possess real-time performance and stability to ensure the accuracy and safety of remote operations. Safety measures, such as emergency stop buttons and anti-theft devices, should be equipped to guarantee the safety and reliability of the operation

process. Multiple safety systems, including limit switches and collision detection, should also be integrated to prevent accidents. Stable and reliable energy supplies, such as batteries or renewable energy sources, should be chosen to ensure continuous porter operation. Furthermore, an intelligent energy-saving scheme should be designed to optimize energy utilization efficiency and extend the porter's operational lifespan.
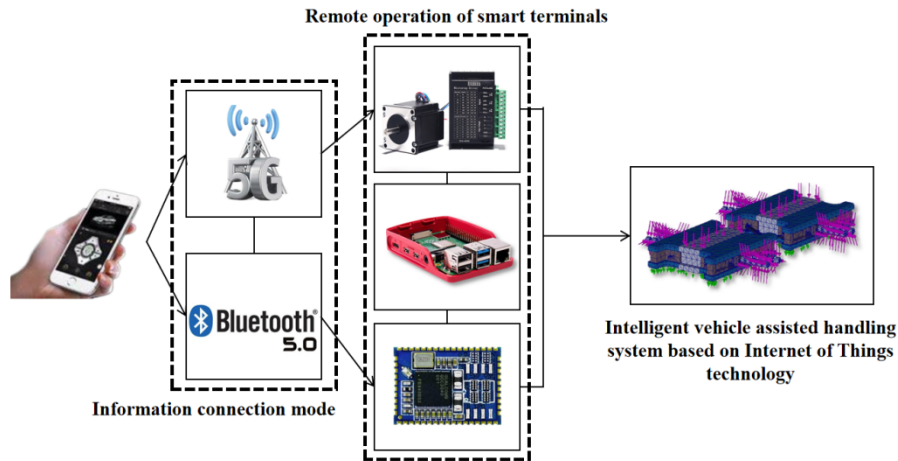
Figure 7. Schematic diagram of the process of automatically processing illegally parked vehicles

3.3. Remote monitoring and communication

By leveraging IoT technologies like 4G/5G networks or LoRaWAN, real-time communication and data transmission between the porter and the cloud server can be achieved, ensuring stability and security of communication and timely transmission and processing of remote monitoring data. A remote monitoring system can be established to enable real-time monitoring and remote operation of the porter. This system allows users to view the location, status, and working conditions of the porter through an intelligent terminal or a specialized monitoring platform.

3.3.1. Building the IoT communication network

Based on the working environment, communication requirements, and cost factors of the porter, the appropriate IoT communication technology can be selected. For scenarios requiring high-speed and high-bandwidth communication, such as urban areas with dense network coverage, 4G or 5G networks are suitable choices. On the other hand, for applications where long-range communication is needed, and where cost and power consumption are considerations, LoRaWAN can be a more suitable option. Once the appropriate IoT communication technology has been chosen, the corresponding communication module (e.g., 4G/5G communication module or LoRaWAN communication module) can be installed on the porter. These modules are responsible for transferring transport data to the cloud server in real time. To ensure that the communication module can correctly access the network and establish a communication connection with the cloud server, network parameters need to be configured for the communication module. This includes setting parameters such as Access Point Name (APN), IP address, port number, etc., to enable seamless and reliable communication between the porter and the cloud server.

3.3.2. Data transmission and processing mechanism

The sensors and camera modules on the porter continuously collect real-time information about its position, status, and working conditions. This data is then encrypted and transmitted in real time to the cloud server

via the IoT communication module. Upon receiving the data, the cloud server analyzes the real-time state information of the porter, performing tasks such as location positioning and state judgment. Simultaneously, the processing results are stored in a database for subsequent querying and analysis requirements. This process ensures that the porter's operational status is monitored and evaluated efficiently, facilitating effective management and decision-making.

3.3.3. Construction of the remote monitoring system

The project aims to develop an intelligent terminal or a specialized monitoring platform to visually display the real-time status information of the porter. This monitoring platform retrieves real-time data from the cloud server and presents it on the interface, including the porter's position, speed, power level, and other state information, as well as its operational status and any fault alarms. Through this monitoring platform, administrators can achieve remote monitoring and control of the porter, enabling them to efficiently oversee its operations and address any issues that may arise in a timely manner (**Figure 8**).
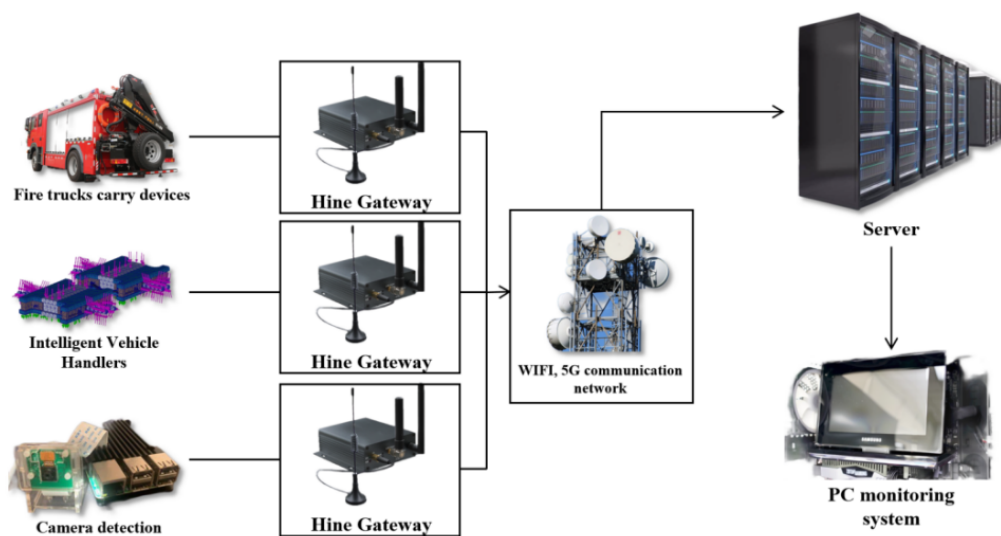

Figure 8. Schematic diagram of the remote monitoring and communication principle

3.4. Illegal parking processing and user notification

To facilitate convenient payment for illegal parking fees and ensure timely notification of violations, the system will integrate safe and reliable online payment systems supporting various methods such as Alipay, WeChat Payment, and credit cards [6]. Vehicle owners can use the online payment system to settle their illegal parking fines and unlock their transported vehicles. Additionally, a real-time notification system will be designed to push illegal parking information to relevant departments and vehicle owners in real-time. Upon detection of illegal parking behavior, the system will immediately push relevant information including vehicle type, license plate number, violation time, and location to management departments and users via GPRS. Simultaneously, the system will automatically capture images of the offending vehicles as evidence for subsequent processing. Upon receipt of violation information, management departments will promptly verify and take appropriate measures according to the situation, while the system will automatically update the status of offending vehicles for subsequent supervision and tracking. This real-time feedback and violation handling process are crucial steps to ensure the effectiveness of the system in enforcing parking regulations and maintaining order.

4. Innovation advantages

The automatic satellite tracking function and illegal parking processing system have revolutionized parking management, making it more intelligent and efficient, and reducing the reliance on manual enforcement. This results in significant improvements in parking management efficiency (**Figure 9**). The automated system reduces the need for human resources, eliminating the requirement for a large number of traffic police or patrol personnel to monitor and address parking violations, thereby saving on labor costs. Timely handling of illegal parking incidents effectively reduces traffic congestion, enhances road traffic efficiency, and improves urban traffic conditions. The automatic satellite tracking function further enhances vehicle safety by enabling the tracking of stolen vehicles or responding to emergencies. Owners receive real-time notifications of illegal parking through their smartphones and can easily unlock their vehicles using the online payment system, thereby enhancing user experience and satisfaction. Overall, the system offers substantial benefits in improving parking management efficiency, reducing labor costs, enhancing traffic flow, and improving safety, with significant potential for broader adoption. Looking ahead, leveraging research findings from scholars like Zhou J, this paper proposes a future development direction for the system. This includes the Simulation Theory Interface for the Parking User Management System and the Simulation Theory Interface for the Parking Lot Management System, providing a framework for the envisioned plan.
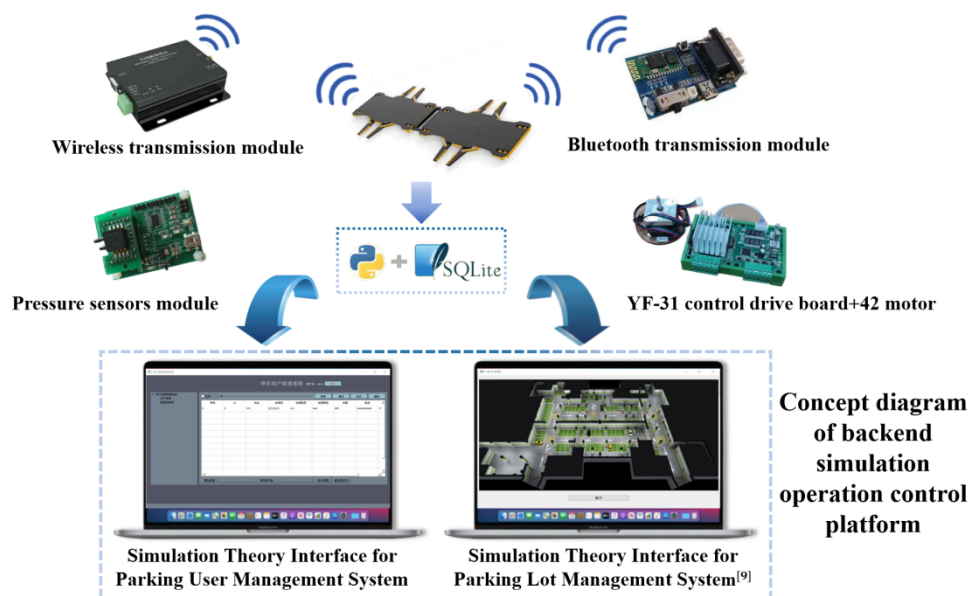
Figure 9. Concept diagram of backend simulation operation control platform

5. Conclusion

With the rapid urbanization in China and the continuous rise in car ownership, the issue of parking supply and demand has become increasingly severe, posing a significant challenge to urban management. Traditional parking management methods are struggling to keep pace with modern society's needs, prompting the adoption of intelligent and automated parking management systems as effective solutions. This paper introduces the Intelligent Vehicle Auxiliary Handling System, which integrates advanced technologies such as image recognition, intelligent algorithm processing, and the Internet of Things to achieve automatic capture, handling, remote monitoring, and processing of vehicles. It also offers solutions for addressing abandoned or scrapped vehicles, enhancing public safety. Furthermore, it presents a novel approach to urban parking management,

improving efficiency, reducing labor costs, and enhancing overall urban traffic conditions by optimizing road and parking lot availability. Moreover, the system elevates the parking experience and satisfaction for vehicle owners. Looking ahead, continuous optimization and upgrades will further empower the system to play an even greater role in urban management and social development.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Han C, 2023, Study on the Coupling Model of Underground Garage Fire and Mixed Flow Evacuation of People and Cars, dissertation, Chang'an University.

[2] Sun W, Feng H, 2023, Research on the Design and Implementation of the Intelligent Parking System. Special Purpose Vehicle, 2023(10): 75–77.

[3] Zhang Q, 2016, Research on the Application of Intelligent Urban Parking Lot Management System, dissertation, Nanjing University of Posts and Telecommunications.

[4] Zhang J, Wang C, Hu J, et al., 2023, Design and Application of Lateral Handling Device for Mechanical Three-Dimensional Parking Garage. Electromechanical Engineering Technology, 52(05): 35–39 + 149.

[5] Cui Z, 2022, Research on Vehicle Access Path and Scheduling Optimization of Plane Mobile Stereo Garage, dissertation, Chongqing Jiaotong University.

[6] Liu S, 2022, Research on the Management System and Scheduling Strategy for AGV Type Stereo Garage, dissertation, Chongqing University of Technology.

[7] Lu L, 2021, Study on Moving Axle Clip Vehicle Carrier, dissertation, Zhejiang University of Science and Technology.

[8] Yuan W, 2021, Research and Development of Vehicle Handling Robot for Intelligent Stereo Garage, dissertation, Chongqing University of Technology.