Design and Implementation of an Android-Based Intelligent Parking Reservation Management System

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Abstract: With urban traffic congestion and parking issues becoming increasingly severe, the emergence of smart parking systems offers a solution. This research designs and implements an Android-based intelligent parking reservation management system. It aims to provide convenient and efficient parking services by combining mobile technology with intelligent management. The system includes core functions such as user management, parking facility information retrieval, parking space reservation, and driving navigation, catering to diverse needs in urban parking scenarios. Through rigorous system testing, this solution demonstrates excellent performance in user experience, functionality, and efficiency. The Android-based parking reservation management system proposed in this study offers an innovative solution to address urban parking challenges. It paves the way for new possibilities in smart city transportation management.

Keywords: Parking Reservation; Intelligent Parking; Parking Facility; Navigation

1. Introduction

As urbanization accelerates and the prevalence of automobiles increases, the challenges associated with urban parking have become increasingly pronounced[1]. The contradiction between the growing number of vehicles and insufficient parking resources poses a pressing issue that demands resolution in urban traffic management. In this context, the introduction of smart parking systems emerges as a key strategy to alleviate traffic congestion and enhance parking efficiency.

Currently, scholars have conducted extensive research on intelligent parking frameworks and related applications. Representative solutions include the vision-based parking management system proposed by Lin et al. [2] the SPS architecture based on ultrasonic detectors proposed by Kianpisheh et al. [3] the parking navigation payment system based on infrared sensors and RFID technology proposed by Agrawal et al. [4] and the intelligent parking system based on wireless sensor networks proposed by Chinrungrueng et al.[5] For instance, Thangam et al. [6] proposed an online reservation intelligent parking solution based on infrared sensors and facial recognition. The evolution of smartphone technology provides new possibilities for intelligent urban transportation management. Kabir et al. [7] leveraging Web 4.0 and Internet of Things (IoT) technologies, address parking challenges by designing and implementing an automated parking allocation system. This system incorporates features such as automatic parking allocation, location monitoring, parking management, real-time invoice creation, and payment functionalities. Additionally, Peyal et al. [8] connect photoresistors to a mobile application for data transmission and develop a smart parking allocation system based on IoT technology, aiming to minimize road traffic congestion and better balance the time resources of passengers and drivers. Alkhuraiji et al. [9] focus on facilitating advance parking reservations for university staff, designing and developing an Android-based smart parking mobile application. Test results indicate effective management of available parking spaces, with plans for expansion to other regions and venues. In order to reduce traffic congestion during the parking space search process, Lin et al. [10] conduct a literature review on Mobile Crowdsourcing Parking (MCP) applications, analyzing identified issues and unresolved problems in existing systems. The study offers a comprehensive review from an interdisciplinary perspective. Kate et al. [11] propose an Android prototype for the vehicle

parking system S-park. In this work, proximity sensors placed at parking locations periodically send signals to the server, which are then received by drivers seeking parking spaces.

In conclusion, an Android-based intelligent parking reservation management system holds great potential for urban traffic management. This paper delves into the design, implementation, and application of such a system. Through a detailed analysis of key functionalities including user management, parking facility information retrieval, parking space reservation, driving navigation, and parking records, the aim is to reveal the system's contribution to solving urban parking challenges. A comprehensive assessment of the system's design principles and practical effectiveness will provide valuable insights for the future development of smart parking systems.

2. Analysis of Market Demand

In recent years, the number of automobiles in China has experienced rapid growth. According to data from the National Bureau of Statistics (as shown in Figure 1), as of the end of 2022, the total number of registered vehicles in China reached approximately 311.84 million, and it is expected to continue growing at a rate of 20 million vehicles per year. However, the number of parking spaces has failed to keep up with the pace of automobile growth. By the end of 2022, the total number of parking spaces in China was only 168.85 million, resulting in a shortfall of approximately 142 million parking spaces. The research and implementation of parking lot management systems in China started relatively late, leading to widespread issues of "difficulties in finding parking and difficult parking" in many domestic cities. With the future scarcity of land resources, this problem is expected to become more severe. Consequently, the demand for parking management systems is projected to increase annually. In the long term, traditional parking lots are insufficient to meet the growing demand for parking, and the future demand for parking spaces is expected to remain tight. With the rapid development of the internet and the continuous improvement of smart terminal technology, traditional parking lot management systems are unable to meet market demands. Intelligent parking management systems, incorporating IoT technology and utilizing user smart terminals, offer a short construction cycle, low costs, and the ability to rapidly meet market demands. Therefore, they have vast prospects for development.

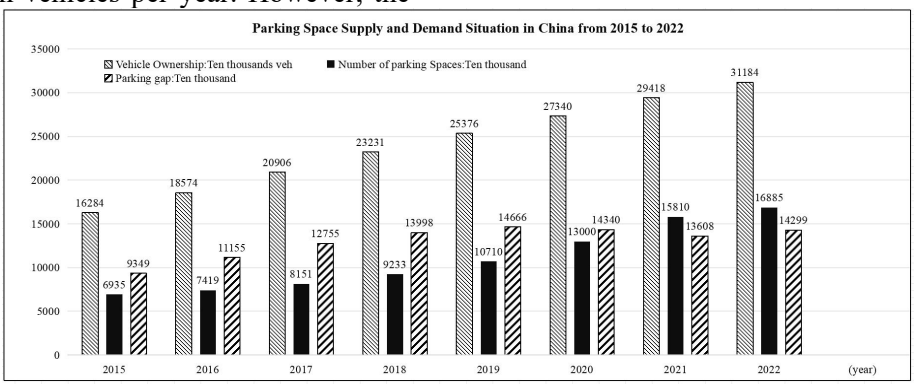


Figure 1. Parking Supply and Demand Situation in China

3. System Architecture of Intelligent Parking Management System

Based on the analysis of system requirements and the design of key functionalities, the system is structured into three layers: the User Service Layer, Data Storage Layer, and Intelligent Control Layer[12].

(1) User Service Layer:

The first layer is the User Service Layer, which provides a user-friendly mobile application enabling users to reserve and manage parking spaces. It facilitates real-time display of parking information, including available, reserved spaces, and users' parking history. It supports functions such as initiating parking requests and accessing navigation services. The interface is designed to be intuitive, allowing users to interact conveniently and efficiently with the system.

(2) Data Storage Layer:

The second layer is the Data Storage Layer, responsible for storing user information, including personal details and parking history

records. It maintains real-time status information of parking spaces, ensuring accurate presentation of their utilization on the frontend. The layer provides data persistence support, ensuring system reliability and stability.

(3) Intelligent Control Layer:

The third layer is the Intelligent Control Layer, primarily composed of monitoring, sensors, and other hardware devices. These devices can sense vehicle information, capturing real-time dynamics within the parking facility. Through these hardware devices, information such as the location and status of vehicles is sensed and transformed into data, which is then transmitted to the upper-layer system data endpoint for processing and analysis.

4. Intelligent Parking Management System User Interface

Author names and affiliations are to be centered beneath the title and printed in Times New Roman 11-point, non-boldface type. (See example below)

4.1 Introduction to the Main Functions of the System

This system is primarily designed to provide convenient parking services for Android users. Users are allowed to log in to the system to access detailed information about parking facilities, such as garage names, addresses, prices, and specific details about parking spaces. Users can utilize the system to reserve parking spaces, thereby facilitating the parking process. The system incorporates the following key functionalities:

(1) User Management Module:

User Login Management: Existing users can directly log in by entering their account credentials, while new users need to register before logging in.

User Information Management: This includes viewing and modifying personal information, changing passwords, and adding or removing personal vehicles.

(2) Querying Parking Garage Information:

Viewing parking garage information, including details about parking spaces such as names, geographic locations, capacities, and prices.

Checking the status of parking spaces, which is crucial for determining the current status of spaces in a specific garage (occupied, reserved, or available), providing convenience for reservation.

(3) Parking Space Reservation:

The primary purpose is to offer convenience to users, saving time spent searching for parking spaces. After a successful reservation, a series of reservation details is generated.

Users must be logged in to select the desired parking space, indicate the vehicle they intend to park, and choose the preferred time slot from the list of available spaces.

(4) Driving Navigation:

Navigation functionality is provided to users with reserved parking spaces, ensuring a quick and efficient route to the parking location. This is achieved by invoking map navigation interfaces to guide users from their current location to the designated parking space.

(5) Parking Records:

Viewing completed parking record orders.

(6) Reservation Order Management:

Users can cancel current reservation orders and have control over arrival and departure times.

4.2 System Flow Design

(1) User Login Process: To ensure the security of the system and manage information, it is mandatory to have an account and proceed with login. Refer to Figure 2 for the detailed process.

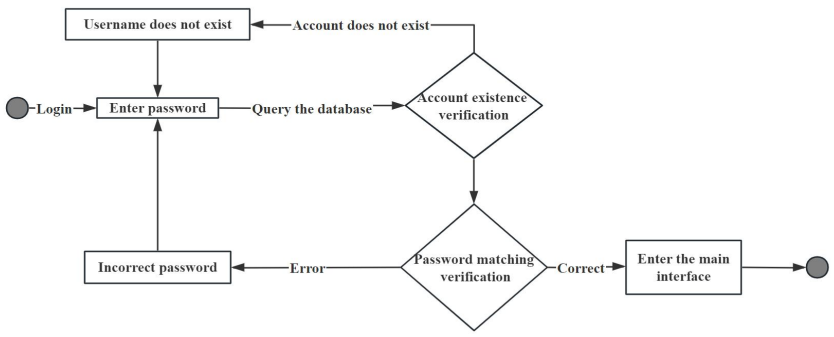


Figure 2. User Login Process

(2) After successful user login, they enter the main interface and click on the "Personal Information" page within the personal center. Clicking the "Modify Information" button takes the user to the information modification page. Subsequently, users fill in the desired information changes, click the "Modify" button, and upon completion, return to the personal center page. The password modification process is also within this information modification page. By clicking the "Change Password" button, users can input a new password for modification. If the password field is left empty, no changes will be made. The user data modification process is illustrated in Figure 3.

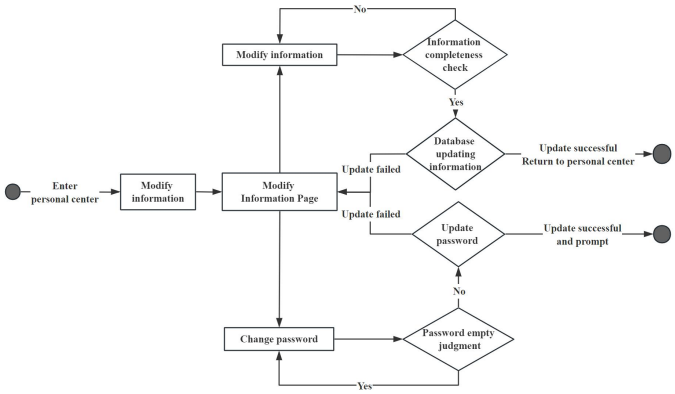


Figure 3. User Data Modification Process

(3) Upon logging into the system, users access the main interface, select parking garage information, and proceed to the list of parking garage details. By clicking, users can view the specific information about the desired parking garage and further inspect the details of parking spaces they intend to use. Refer to Figure 4 for the visual representation.

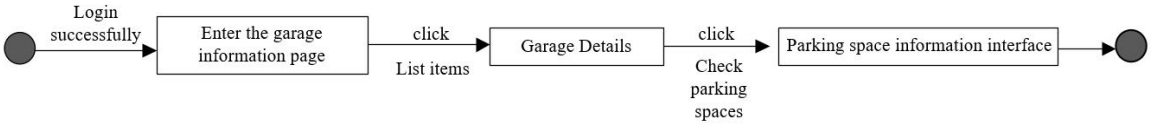


Figure 4. Parking Space Information Inquiry

(4) There are two methods for parking space reservation: the first method involves clicking into the quick reservation page after user login. Users can then select the parking space, vehicle, and desired time slot for quick reservation. After clicking "Quick Reserve," users enter the quick reservation process, where parking spaces are allocated by the system. The second method allows users to view detailed information about the parking facility after login. Users can check the status of parking spaces, choose an available space, and click "Reserve" to select the desired vehicle's license plate for a detailed reservation. The parking space reservation process is illustrated in Figure 5.

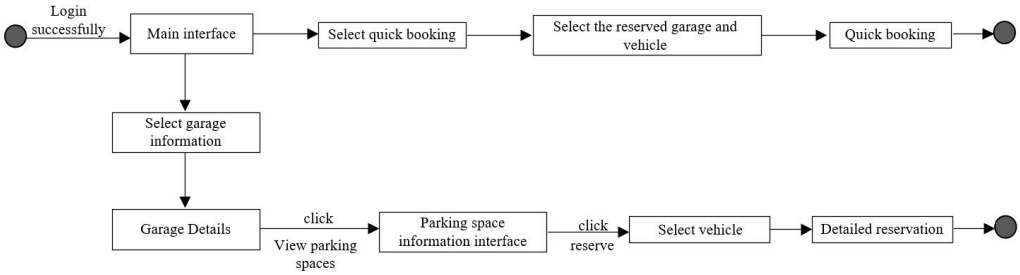


Figure 5. Parking Space Reservation

5. System Data Implementation

The core components of the system include the backend data center, server-side, real-time location information service platform, and the client-side. In the entire system, data collection and transmission are crucial. To achieve this goal, advanced parking sensors are installed on each parking space. These sensors use wireless transmission mechanisms to send real-time information, including the status of parking spaces, to the backend system, which is then

delivered in real-time to users' mobile client terminals. When a vehicle completes parking, the parking sensor immediately sends information about the occupied space to the backend.

5.1 Detection Module

(1) Parking Sensors: RFID devices are installed above each parking space, and RFID readers identify whether a space is occupied. These sensor nodes wirelessly transmit real-time information about parking spaces to the backend data center, providing immediate feedback on the status of these spaces to user terminals[13].

(2) Network: Reliable wireless network connections, such as Wi-Fi or 5G signals, are introduced to ensure real-time communication between the parking lot and the backend server. Through network connectivity, the system can monitor and collect data promptly, providing users with real-time parking information.

(3) LED Indicators: LED indicators are configured for each parking space, enabling quick identification of vacant and occupied spaces and providing clear parking guidance to users.

(4) Surveillance System: A surveillance system is implemented to ensure the security of the parking lot. Cameras are installed at entrances and exits to monitor vehicle movements. The system automatically controls gate opening and closing and maintains a count of the number of vehicles in the garage.

5.2 System Data Implementation Process

Users send parking information to the server using mobile internet technology for data transmission. The system then receives the data from users and passes it to the sensing end for retrieval. After retrieval at the sensing end, the system performs AI calculations to quickly allocate parking spaces and detect the availability of remaining spaces. The system data implementation process is illustrated in Figure 6.

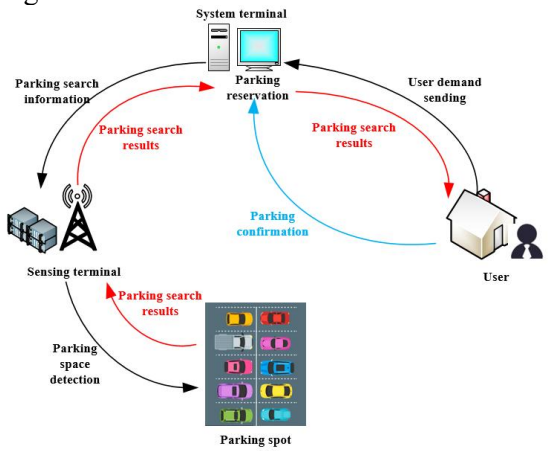


Figure 6. System Data Execution Process

5.3 Database Logical Structure Design

The essential databases within the system are organized into various tables, as shown in Tables 1-4:

Table 1. User Information Table

Table Name	loggedinuser			
Describe	User Information Table			
Field Name	Chinese Name	Type	Constraints	Remarks
userid	User ID	Varchar (16)	Not null	Primary Key
name	User Name	Varchar (16)	Not null	
password	Password	Varchar (16)	Not null	
gender	Gender	Char (1)		'M' for male, 'F' for female
phone_number	Phone Number	Int		
personal_id	Personal ID	Int		

Table 2. Vehicle Information

Table Name	Car			
Describe	Vehicle Information Table			
Field Name	Chinese Name	Type	Constraints	Remarks
car_id	User Name	Varchar (10)	Not null	Primary Key
car_name	The vehicles' respective owners are listed in the table.	Varchar (16)	Not null	
car_type	Brand and model of the vehicle	Varchar (16)		

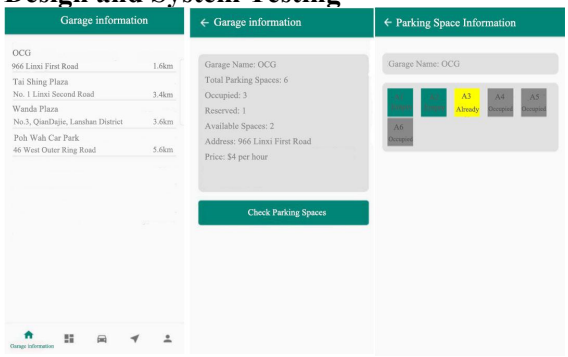
Table 3. Parking Garage Information

Table Name	Garage			
Describe	Parking garage information Table			
Field Name	Chinese Name	Type	Constraints	Remarks
garage_id	Parking lot number	Int	Not null	Primary Key
name	Parking lot name	Varchar (50)	Not null	
Content	Number of parking lots in the parking area	Int	Not null	
IsFilled	Number of parking spaces already occupied	Int	Not null	
IsOrder	Number of parking spaces already reserved	Int	Not null	
RemainingNumber	Remaining parking spaces in the parking lot	Int	Not null	
address	Address of the parking lot	Varchar (100)		
price	Unit price for parking	Money		

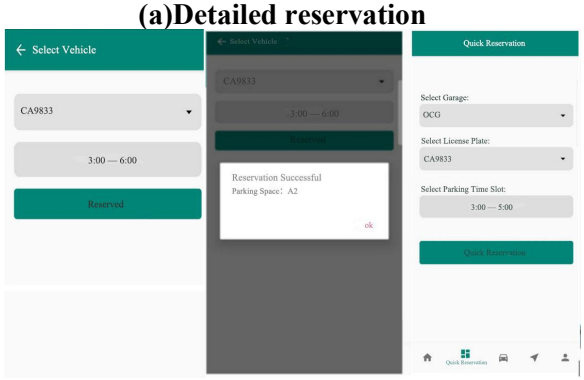
Table 4. Parking Space Information Table

Table Name	Parking Space			
Describe	Parking Space Information			
Field Name	Chinese Name	Type	Constraints	Remarks
parking_space_id	Number of parking space	Varchar (8)	Not null	Primary Key
garage_id	The parking space belongs to the garage	Int	Not null	FK (CarPortInfoTable)
Status	Current status of parking space	Char (1)	Not null	Free-0 occupy-1unknown-N Reserved-O

6. Intelligent Parking Management System Design and System Testing



(a)Detailed reservation



(b)Express booking

Figure 7. System Implementation Results

(1) System testing is a crucial phase in the software development lifecycle, aimed at verifying whether the entire system complies with specifications, functions properly, performs acceptably, and meets user expectations. We will conduct system testing on the Android-based parking reservation management system to ensure the stability, reliability, and consistency of its various functionalities and features. Through comprehensive test coverage, we aim to identify and address potential issues, ensuring that the system can deliver excellent performance and user experience in practical applications.

(2) The system implementation results are depicted in Figure 7.

(3) During the system development process, specific modules are typically tested to ensure stable operation. The main methods include testing each submodule to ensure the system is bug-free and flawless. Data tracking in the testing environment is conducted to ensure correct data status. Overall testing is then performed to verify if the system meets the initial requirements. System testing ensures

smooth operation of user-related functions. It guarantees a positive user experience. Additionally, it ensures the robustness of managing vehicle-related operations and providing reliable information regarding parking space availability and reservations to users. The process and results of system functional testing are detailed in Tables 5 and 6.

Table 5. Test Case Table

Test Case ID	Feature Name	Test Progress	Expected Result	Actual Result
1	User Registration	Enter complete information with *	Registration successful	Registration successful, display registration
		Some * information not filled in	Registration failed	Registration failed, incomplete information prompt
		Complete information, but passwords differ	Registration failed	Registration failed, prompt for password mismatch
2	User Login	Account: 1001 Password: test123	Login successful, access system and see corresponding information	Login successful, access the main interface, display personal account page.
		Account: 1000001 Password: abc	If login fails due to wrong password, the system will prompt password error	If login fails due to wrong password, system prompts password error
		Username: 32423 Password: xxx	Login unsuccessful, username does not exist	Login failed, prompt "Username does not exist"
3	View Personal	After successful login, go to the personal Information	View user personal information center	After successful login, click on personal center page, display correct personal information
4	Personal Information Modification	Go to the lower right user interface, click on personal information modification, go to the modification information page, enter the information to be modified	Modification successful	Modification of information successful, redirect to personal center page, show updated information.
5	Password Modification	Go to the modification page, click on password modification, enter new password, select password modification	Modification successful	Modification successful, dialog disappears
		Go to modification page, click on password select password modification	Modification failed	Modification failed, dialog disappears, prompt: Password cannot be empty

Table 6. Test Case Table

6	Vehicle Information Management	Go to the personal center, vehicle management page, click on add vehicle information, fill in the relevant information, click add vehicle information	Successful addition	Successful addition
		Go to the personal center, vehicle management page, click on add vehicle information, do not fill in information, click add vehicle information	Addition failed, information cannot be empty	Addition failed, prompt: Information cannot be empty
		Go to the personal center, vehicle management page, click on delete	Click on delete	Delete the corresponding vehicle, refresh the page, and prompt deletion successful
7	View Recharge Records	Go to the personal center, recharge records page	View recharge records information	Display recharge list information
8	View Garage Info	Go to the garage information page, click on a garage information	View garage details	Display detailed information of the clicked garage
9	View Parking Info	Go to the garage information page, click on a garage information	View parking information	Display parking information; show "Under construction" for garages without parking information
10	Detailed Reservation	In the parking information page, click on the reserve button, go to the vehicle selection page, select a vehicle, click reserve	Successfully reserve the selected parking space	Successfully reserve the selected parking space and return to the main garage information page
11	Quick Reservation	In the quick reservation page, select a garage, select a vehicle, click quick reserve	Successfully reserve and return to reserved parking space	Successfully reserve and prompt reservation successful
12	Driving Navigation	After successful reservation in quick reserve, choose navigation	Display route from current location to reserved garage	Display route from current location to the reserved garage

7. Discussion

(1) Result Interpretation

The results of the system testing indicate that the Android-based intelligent parking reservation management system has achieved satisfactory outcomes in various aspects. Firstly, the reliability and security of the user management module have been validated, allowing users to smoothly log in, register, and manage personal and vehicle information. Secondly, the parking garage information query feature demonstrates the system's ability to accurately retrieve and display real-time data, enabling users to conveniently check parking space statuses and prices. Functions such as parking space reservation, driving navigation, and parking record management also performed well in the testing, providing users with convenient and intelligent parking services.

(2) Challenges and Limitations

Despite the positive outcomes in multiple aspects, some potential challenges and limitations have been acknowledged. Firstly, further optimization of user experience is an ongoing process, especially refining and improving potential flaws in user management

and reservation processes. Secondly, system performance may be impacted under high loads, necessitating additional resource optimization, especially in scenarios with a substantial increase in user volume.

(3) Future Work

Based on the results and discussion of system testing, several recommendations for future work are proposed. Firstly, continuous optimization of user experience can be achieved through user feedback and behavioral analysis, refining the system's interface and process design. Secondly, performance optimization can be pursued by introducing advanced technologies and adopting more efficient algorithms. Additionally, integration with other intelligent transportation systems is a potential research direction to achieve comprehensive urban traffic intelligence.

In summary, while the system has achieved significant successes in many aspects, there are still numerous areas for further exploration and refinement. Future work will focus on user experience, performance optimization, and the integration of the system with other intelligent urban solutions, aiming to drive continuous evolution and improvement of the Android-based intelligent parking reservation management system in practical applications.

8. Summary

The main contribution of this research lies in the design and implementation of a comprehensive and user-friendly Android-based intelligent parking reservation management system. Users can efficiently manage their vehicles, access real-time parking information, make intelligent parking reservations, use convenient driving navigation, and view detailed parking records through this system. By leveraging the openness of the Android platform, the system successfully integrates these functionalities, providing users with an all-in-one parking solution. Based on the results of system testing and discussion, it can be concluded that the system performs exceptionally well in various aspects. The functionalities of user management, parking garage information query, and parking space reservation have all been validated, enhancing user experience and service convenience. Furthermore, the system demonstrates good performance, delivering fast and reliable parking services to users. Through continuous improvement and innovation, it is believed that this system will make significant contributions in addressing urban parking challenges and elevating the level of traffic management in the future.

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