Research on parking lot management system based on parking space navigation technology

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***Abstract*—The number of vehicles has increased dramatically, with the continuous expansion of vehicle production scale. This paper designs and implements a parking lot management system, which solves the problems of parking difficulty and complex vehicle management. Compared with the previous system, the administrator can check the parking space and vehicle information at any time, which greatly reduces the workload. The driver can not only check the parking information of the nearby parking lot, but also book the parking space by selecting key words. At the same time, this paper analyzes the complexity of different path guidance algorithms, considering the different real-time requirements of the map in the parking lot and off-site path guidance, and finally uses Dijkstra algorithm based on heap optimization and Floyd algorithm to realize the parking space navigation, which greatly reduces the time for the driver to find the parking space.**

Keywords—parking lot management system, book the parking space, route guidance module, Dijkstra algorithm based on heap optimization, Floyd algorithm

I. INTRODUCTION

The scale of automobile production continues to expand, with the rapid increase of the number of automobiles. Finding a parking space has become a big problem for most people to go out. Most drivers search for parking spaces based on experience or luck. They often find that there is no extra parking space, or spend a lot of time looking for several parking spaces, which greatly wastes the driver's time and energy. And looking for a parking space will lead to the driver 's inattention and speed decline, leading to traffic congestion and frequent traffic accidents. In addition, the large increase of vehicles makes the work of parking lot managers more and more complex, and managers need to spend a lot of energy to manage parking spaces and vehicles in and out constantly.

This paper, according to the software development steps, that is, demand analysis, outline design, detailed design, coding, testing and maintenance, designs and implements a parking lot management system to meet the needs of drivers and parking lot managers, which solves the problems of parking difficulties and complex vehicle management. At present, drivers in most parking lots can't book the parking space online, or even if they can book the parking space, they can't know the environmental information around the parking space, which causes drivers to spend a lot of time looking for the straight ladder or rolling ladder to leave the parking lot. And the current parking lot route guidance is not very good to meet the needs of drivers to find parking space. Therefore, this paper designs a parking space module and path guidance module to solve the above problems. The user can select the target parking space according to the parking space status and surrounding environment information. At the same time, this paper analyzes Dijkstra algorithm, Floyd algorithm and ant colony algorithm, decides to use Floyd algorithm in the parking lot, and Dijkstra algorithm based on heap optimization in the parking lot to guide the driver to reach the target parking space, which solves the parking problem well and meets the driver's demand for parking space.

II. RELATED WORK

In the past, many scholars have proposed different solutions to solve the problems of parking difficulty and complex vehicle management tasks. The intelligent parking system of parking lot based on the Internet of things can guide users to the nearest available parking space by effectively managing the parking lot. [1]. The intelligent anonymous parking management system adopts the improved spatial selection algorithm to determine the parking mode with the lowest parking cost [2]. The driver can use the parking lot management system to check the parking availability and directly arrive at the site, reducing the time for the driver to find the parking [3]. The automatic robot parking system integrates a complete set of path planning, elevator scheduling and resource allocation algorithms to reduce customer waiting time and maximize space utilization [4]. RFID parking management system introduces automation into parking management system and adopts passive UHF RFID technology to improve the effectiveness of parking management system [5]. Other scholars have designed a parking lot management system which can display the driver's time and location through the best path considering the road conditions in the traffic network [6]. Abu Dhabi indoor parking management system intelligent mobile application helps reduce the time wasted in finding parking spaces and improve the efficiency of the parking system [7]. The residential parking management information release system realizes the display and record of the electronic parking information by using the single chip microcomputer technology, and effectively solves the parking problems around the residential area by using the residential parking space [8]. Intelligent parking system can provide services for parking space search and allocation through mobile applications. [9]. The intelligent parking system based on the Internet plus is combined with the WeChat parking platform to provide users with real-time parking information and road guidance [10].

III. METHODOLOGY

A. Overall Design

The overall goal of parking lot management system is to shorten the search time of driver for parking information, reduce the workload of management personnel, realize the systematization and automation of parking lot management. The design structure of the system is shown in Figure 1.

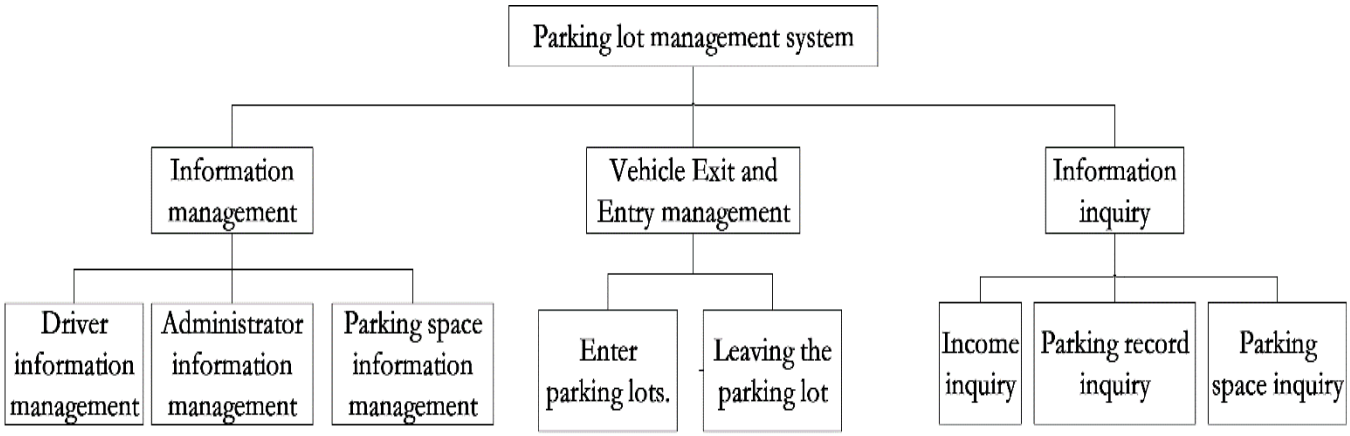

Fig.1. Parking lot management system design structure. It is mainly divided into three modules: information management, vehicle access management and information query.

As shown in Figure 1, the parking lot management system is mainly divided into three modules: information management, vehicle access management and information query. The functions of each module are as follows:

- Information management module: the main function is to add, delete and modify user information and parking information. It mainly includes driver information management module, administrator information management module and parking information management module. For driver and administrator information management module, driver can register or modify personal information, while administrator can not only modify personal information, but also modify driver's personal information. For the parking space information management module, the driver can indirectly change the parking space information by booking the parking space and paying online fees. The administrator can directly add, delete or modify the parking space information.
- Vehicle entry and exit management: the system will obtain the current time and store it as the starting parking time when the vehicle enters the parking lot. And the system will guide the driver to the target parking space. The system will calculate the driver's payment amount and return it to the driver when the vehicle leaves the parking lot.
- Information query: it mainly realizes the query of basic information. It mainly includes parking plot information query, past parking record query, parking revenue query. When the user clicks the corresponding module system, the query results will be displayed in the form of appropriate bar chart, sector chart and other charts. Users can also export some query results to excel tables.

B. Detailed Design

This paper uses the principle of top-down, step-by-step refinement and gradual improvement to program and debug. Users use mobile phones or computers, enter login information into the system, and perform various operations according to the needs. This paper introduces the design of reservation module and path navigation module in detail.

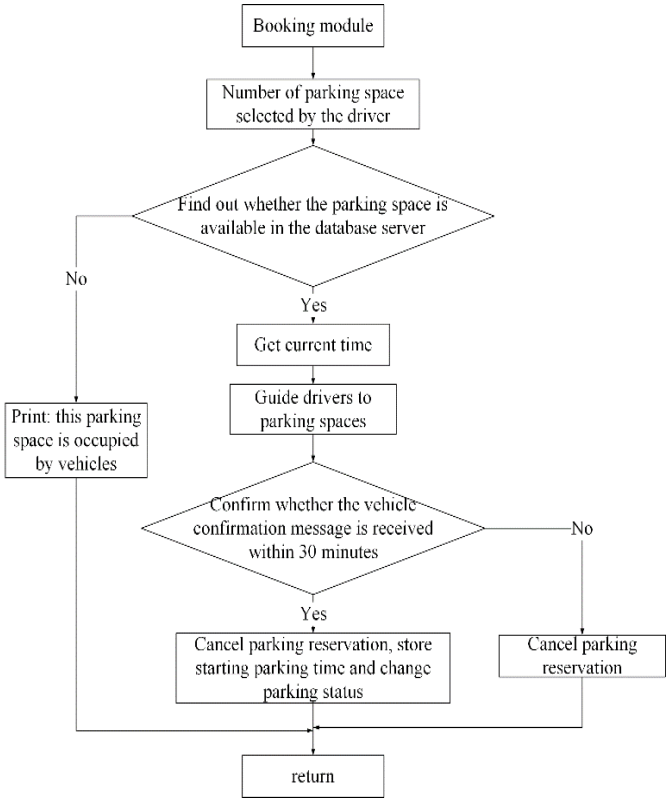

Fig. 2. Flow chart of parking spaces reservation algorithm

Booking module. The driver can select the target parking space by selecting key words, which include the parking space status, parking space number and the surrounding environment information of the parking space, such as whether there are vertical ladders or rolling ladders around. The system first obtains the parking space information and the time when the driver booked the parking space when the driver booked the parking space. Then enter the database server to check whether the parking space is available. If available, parking space information, driver information, and booking time are stored in the session container. In addition,

the driver's booking request will be automatically cancelled if the driver fails to reach the parking space within 30 minutes. If the driver arrives, the time when the driver arrives at the parking lot will be recorded as the start stop time for calculating the driver's payment. If the parking space is not available, the driver will be prompted: "parking space is not available, please select again". The specific algorithm flow is shown in Figure 2.

Path navigation module. Dijkstra algorithm, Floyd algorithm and ant colony algorithm are common path navigation algorithms in parking lot system.

1) Dijkstra algorithm.

Dijkstra algorithm is a typical single source shortest path algorithm, which is used to calculate the shortest path from one node to all other nodes. The main feature is that the time complexity is $O(n^2)$. But the same algorithm uses different data structures, and the time complexity is different, so this paper adopts Dijkstra algorithm based on heap optimization. Dijkstra algorithm takes the nodes connected with the shortest path as the temporary mark points in the search process. Each cycle searches the node with the shortest path from the source point as the permanent marker node from the temporary marker node, until the target node is found or all nodes become permanent marker nodes to end the algorithm. The temporary tag nodes are stored in the unordered table in the classic Dijkstra. Every time you search the shortest node in the temporary tag node, you have to traverse all the temporary tag nodes, which undoubtedly takes a lot of time. Therefore, this paper uses binary heap to store temporary labeled nodes, and the minimum value taken out of the heap is the node to be searched, so the complexity of the whole algorithm is $O(m + n\log C)$. Where m is the number of nodes in the flow network, n is the number of edges, and C is a constant.

2) Floyd algorithm.

Floyd algorithm, also known as interpolation method, is an algorithm that uses the idea of dynamic programming to find the shortest path between multiple source points in a given weighted graph. The time complexity is $O(n^3)$. The specific idea of the algorithm is as follows:

a) Dist stores the path, and the final state represents the shortest path of the point. Among them, the distance between two points that are not directly connected is infinite.

b) Traverse each node and add it to the graph in turn. Also test if any path length has been changed when adding each point. The specific method of exploration is to traverse every point in the graph, and judge whether the distance of each point pair changes with the minimum distance due to the added points. If it changes, change the distance between the two points.

c) Repeat the above until the final insertion is completed.

3) Ant colony algorithm.

Ant colony algorithm is a kind of bionic algorithm, which simulates the behavior process of finding the shortest path when ants are searching for food. It combines greedy algorithm, parallel computing, distributed computing and other algorithms. The main steps are as follows:

a) Enter a matrix of 0 and 1 to represent the map. Where 0 indicates that it can pass, and 1 indicates that it is an obstacle.

b) Input the initial pheromone matrix, select the initial point and the end point, and set various parameters.

c) Select the next node that can be reached from the initial point. calculate the probability of going to each node according to the pheromone of each node, and use the roulette algorithm to select the next initial point.

d) Update path and path length.

e) Repeat (3) (4) until the ant reaches the destination or has no way to go.

f) Repeat (3) (4) (5) until the iteration of a generation of M ants ends.

g) Update pheromone matrix. The update method is shown in the following formula:

$$\tau_{ij}(t+1) = (1-\rho) * \tau_{ij}(t) + \Delta\tau_{ij}$$

$$\Delta\tau_{ij}(t) = \begin{cases} \dfrac{Q}{L_k(t)} & \text{if ant k passes through i, j} \\ 0 & \text{if ant k doesn't pass through i, j} \end{cases}$$

Where τ_{ij} is the concentration of pheromone on the dialyzing arc(i,j). ρ is the Volatilization Coefficient of pheromone. Q increases the intensity of pheromones. $L_k(t)$ is the path length

h) Repeat (3) - (7) until the iteration of N generation ant is over.

For the above three algorithms, Dijkstra algorithm based on heap optimization obtains the shortest path through finite step iterative operation. Although the time complexity is reduced, it is inefficient and time-consuming, which is not suitable for real-time calculation of large-scale road network. Moreover, the path guidance in the parking lot is only from the entrance to the parking lot, and the starting and ending points are fixed, so Floyd algorithm is not suitable for the path planning in the parking lot. Ant colony algorithm has a strong ability to search for the optimal solution, but the convergence speed is slow, easy to fall into stagnation, cannot guarantee to get the optimal solution. Therefore, this paper uses Floyd algorithm to guide the path outside the parking lot, and Dijkstra algorithm to guide the path inside the parking lot. The specific flow chart is shown in Figure 3.

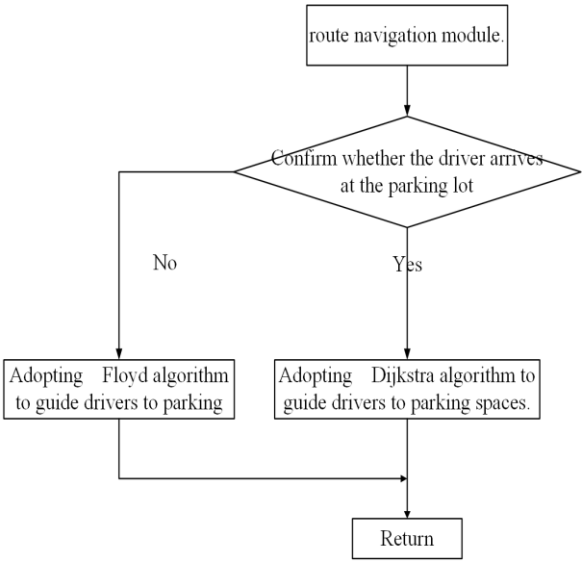

Fig. 3. Flow chart of route guidance algorithm

IV. Tests And Results

Software testing is an important part of program development. The errors in the program are found by testing, so as to measure the quality of the system. The test method used in this paper is black box test.

Black box test is also called function test, which tests whether each function can be used normally. In testing, the program is considered a black box that cannot be opened. Without considering the internal structure and characteristics of the program, the program is tested in the program interface. It only checks whether the function of the program is used normally according to the requirements, whether the program can receive the input data correctly and generate the correct output information. Black box testing focuses on the external structure of the program, without considering the internal logic structure. It mainly tests software interface and software function.

After testing, the functions of the parking lot management system are all realized. When the user enters the account number and password and selects the corresponding role, he can successfully enter the corresponding interface, and then click on different modules to achieve different functions. The home page is shown in Figure 4

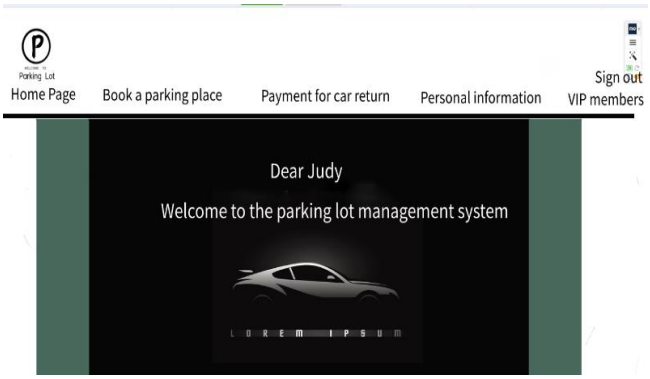

Fig. 4. Home page, It includes reservation, online payment, personal information, VIP membership and other modules

In addition, the system well realizes the online booking and route guidance functions. Driver can choose suitable target parking space according to their own needs. The specific results are shown in Figure 5. When the parking space is not available, the system prompts that the parking space is not available for booking. When the parking space is available, the system guides the driver to the target parking space, and the specific results are shown in the figure 6.

Fig. 5. The interface diagram of driver's reserved parking space. Driver specifies the parking space status and surrounding environment to select the target parking space. Red means the parking space is not selectable, blue means the parking space is selectable.

Fig. 6. Guide map of parking space route. The dashed box indicates the target parking space.

V. Conclusion

This paper designs and implements a parking lot management system, which solves the problems of parking difficulties and complex management tasks caused by the rapid growth of the number of vehicles. Drivers can use the system to book and pay for parking spaces, and managers use the system to manage vehicles and parking spaces. Compared with the previous parking lot management system, the system adopts the online booking module and the parking space path guidance module. For the online booking module, the driver can select different keywords to select the target parking space, and the reservation information will be automatically cancelled if the driver does not arrive at the parking space at the specified time. For the parking space path guidance module, this paper analyzes the Dijkstra algorithm based on heap optimization, Floyd algorithm and Ant colony algorithm. Considering the different real-time requirements of the map inside and outside the parking lot, Floyd algorithm is adopted in the parking lot, Dijkstra algorithm based on heap optimization is adopted in the parking lot, which greatly reduces the time for the driver to find the parking space.

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