Automatic Parking Guidance System Based on Ultraviolet Communication

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Abstract. In view of the existing parking guidance system in the process of vehicle guide dynamic programming efficiency is not high, poor compatibility in different parking environment, thus give negative influence large parking guidance system reliability problems, compatible with a variety of parking environment was designed based on the "blind" technology of ultraviolet communication parking guidance system, adopts the path planning algorithm in the preprocessing module, promote efficiency of dynamic programming, using the "blind" ultraviolet communication technology on the environment compatibility strong, less susceptible to environmental characteristics, improve the compatibility of the parking guidance system. Experiments show that the system can effectively reduce the dynamic path planning time, ensure the effective communication distance of single node of 4 m in a variety of parking environments, and meet the basic requirements of parking guidance system.

Keywords: Ultraviolet communication · Piloted parking · Solar blind

1 Introduction

Due to the continuous improvement of residents' economic strength in recent years, China has become the largest automobile market in the world, with the sales volume of over 28.88 million vehicles in 2017. With the continuous surge of the number of vehicles, the scale of the parking lot is increasing, and the environment is increasingly diversified. How to park vehicles orderly and efficiently in the parking lot has become a hot issue for managers and drivers [1]. At present, the commonly used parking assistance system usually marks whether the parking space is guided passively by the different colors of the lights above the parking space. When the parking area is too large and there are too many vehicles, it is difficult for the driver to directly find the available parking space through visual inspection. Existing active guidance system research of popular technology is to use visible light communication guide [2], but when parking in the underground space, cannot ensure that normally on visible light and outdoor light background noise is serious, at the same time, the path planning algorithm of active guidance system is used more A* algorithm or ant colony algorithm, the algorithm for dynamic heavy planning efficiency is low, when parking inside information change, can't fast response, which would influence the efficiency of the guidance system of [3].

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In order to solve the parking guidance system, poor adaptability of heavy dynamic planning efficiency is low, this paper puts forward a "solar blind" [4–6] ultraviolet communication technology of automatic parking guidance system, with the aid of D*-lite [7, 8] algorithm for dynamic heavy planning excellent adaptability to enhance the guidance system efficiency, using the "solar blind" minimal ultraviolet communication technology background light noise disturbance and itself does not have the function of lighting, not affected by the characteristics of other functional disturbance [9–11], improve the compatibility and reliability of the guidance system. The experimental results show that the parking guidance system based on sunblind UV communication technology is feasible, which effectively improves the efficiency of the guidance system and enhances the adaptability in different environments, providing a feasible idea for the application of sunblind UV communication technology.

2 System Overview

The system is mainly composed of real-time information collection module, path planning module and ultraviolet communication module. Figure 1 is a schematic diagram of the automatic parking guidance system.

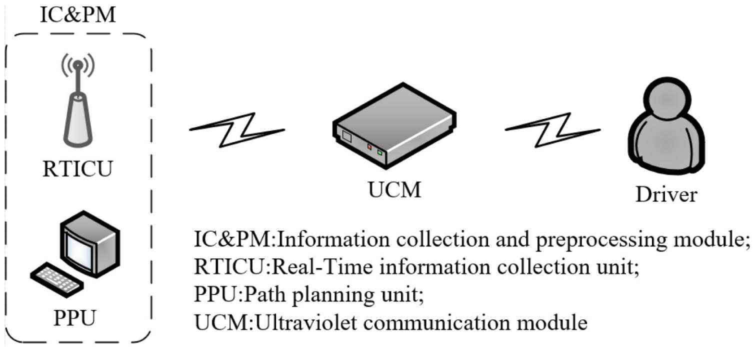

Fig. 1. Schematic diagram of the automatic parking guidance system

The real-time information collection module is responsible for collecting parking space information in the parking lot and transmitting it to the path planning module. The path planning module USES the D*-lite algorithm to plan the vehicle's travel path. Meanwhile, the path information is transmitted to the driver via the ultraviolet light communication module through the wireless channel to complete the automatic parking guidance.

The design of this system requires the effective communication within 4 m of a single ultraviolet LED node. By increasing the power and number of ultraviolet LED, the effective communication distance can be increased. If nodal network is adopted, large areas can be effectively covered and large areas of indoor and outdoor parking can be guided automatically.

For the biological security of the ultraviolet communication system, the “solar blind” ultraviolet light with a wavelength of 265 nm belongs to the photochemical ultraviolet range. According to IEC/EN 62471, when the emission limit is less than 0.003 W/m^2, ultraviolet light will not have a negative impact on human body. In this paper, the modulation method of ultraviolet light signal USES 4-PPM modulation, only 1/4 of the time of light emission per unit time. In the process of parking, drivers are all inside the vehicle, and the ultraviolet light irradiation during parking will not harm human body.

3 Information Collection and Preprocessing Module

3.1 Real-Time Information Collection Unit

Parking information real-time monitoring by geomagnetic parking sensor module, compared to the traditional optical and ultrasonic parking sensors, magnetic parking sensor technology better adaptability, photosensitive parking sensor is difficult to play a role in the above the surface of the parking lot, the use of ultrasonic sensor in the reversing radar makes the ultrasonic parking sensors are susceptible to interference.

The working principle of geomagnetic parking sensor is that the vehicle’s iron wheel hub, engine, transmission shaft, frame and other components have disturbance effect on the geomagnetic field. The geomagnetic parking space sensor detects whether the geomagnetic field is disturbed, so as to judge whether there are vehicles parked in the parking space, and thus judge the usage of the parking space.

3.2 Path Planning Unit

D*-lite algorithm is based on the ideas of A* algorithm [12] and Dynamic SWSF-FP [13] algorithm. It is more efficient than other algorithms to search the optimal path for starting point (real-time position of vehicle) changes while ending point (parking space) is fixed.

The D*-lite algorithm requires 2D planar cell modeling for parking lots, where each cell is a cell with environmental information. The driver and the vehicle are located in the center of the cell, abstracted as a point in the center of the cell, which is also the basic unit of operation and movement. Figure 2 shows the two-dimensional plane cell model of the parking lot, in which gray shadow is the obstacle cell and white is the free cell.

A* algorithm introduces the heuristic function on the basis of Dijkstra algorithm, and the most critical one in A* algorithm is the evaluation function [12]:

$$f(v) = g(v) + h(v) \tag{1}$$

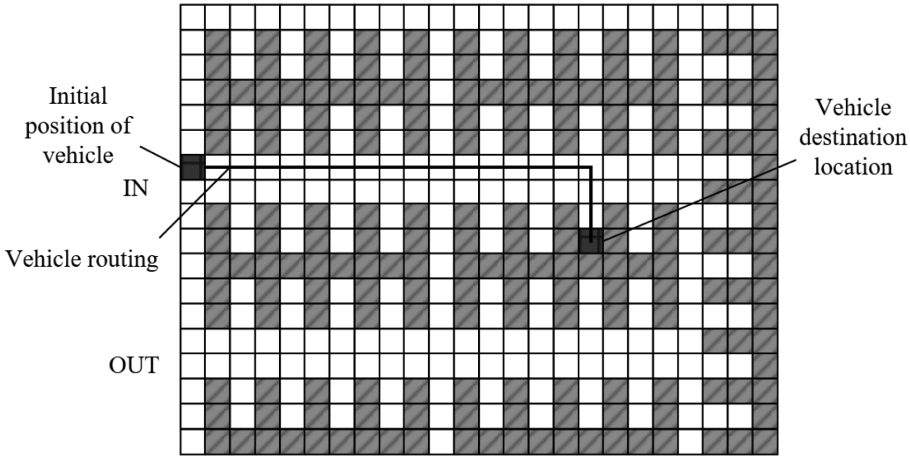

Fig. 2. Parking lot 2D planar cell model

Formula (1) $f(v)$ is the evaluation function of A* algorithm. Since the direction of D*-lite algorithm is to search from the end point to the starting point, $g(v)$ is the actual path cost from the destination cell to the current vehicle location cell v, and $h(v)$ represents the estimated path cost from the current vehicle location cell v to the vehicle destination location cell.

This paper selects the Euclidean distance. The formula (2) is the Euclidean distance calculation formula between point and point:

$$\rho = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{2}$$

The D*-lite algorithm introduces the concept of $rhs(v)$ in the LPA* algorithm, where $rhs(v)$ represents the minimum generation value of the current node v to the target node, equal to the cost value $g(v')$ of the parent node v of the current node v plus the edge generation value $c(v, v')$. When expanding the surrounding 8 adjacent cells, $g(v)$ will be recalculated to find the smallest surrogate value $g(v)$ in the extended cell, and the $g(v)$ value of the parent v' with v will get the minimum cost of the current point v to the target point. $rhs(v)$ is defined as shown in Eqs. (3) and (4).

$$h(v) = \begin{cases} 0 & ; \quad v = v_{start} \\ \sqrt{(x_{start} - x_v)^2 + (y_{start} - y_v)^2}; & otherwise \end{cases} \tag{3}$$

$$rhs(v) = \begin{cases} 0 & ; \quad v = v_{goal} \\ \min(g(v') + c(v, v')); & otherwise \end{cases} \tag{4}$$

Where $c(v, v')$ represents the edge generation value of the current node v to its parent node v'. The priority queue for storing the points to be expanded is denoted as U, and the nodes are sorted by U according to the k value, denoted as $k(v)$, and the node with the smallest k value is selected as the new extension base point. Equation (5) is a calculation formula of the k value.

$$k(v) = min(g(v), rhs(v)) + h(v) \tag{5}$$

The D*-lite algorithm initializes the $g(v)$ and $rhs(v)$ values of all cells to infinity, and then calculates the $g(v)$, $rhs(v)$, $h(v)$, and k values of the adjacent 8 cells according to formulas (2)–(5) from the target node. The value of $g(v)$ is greater than the value of $rhs(v)$. The value of $rhs(v)$ is assigned to $g(v)$, and then the candidate with the smallest value of K is selected as the next extended node, and the expansion process is repeated. When the new extended base point v and the initial node v_{start} are the same point, the planning is completed; From the current position, the cell with the least path cost is moved to form a driving path to the target point. When the environmental information changes, the k value of the cell is updated, and then the calculation searches for a new driving path. By using the D*-lite algorithm, the driver and the vehicle can be mapped out and the parking can be guided automatically.

The advantage of D*-lite over A* is that A* is A static path planning algorithm. When the environmental information changes, the planned path information will be invalid and must be re-planned. The D*-lite algorithm is a dynamic path planning algorithm that takes less time to plan a path using previously computed cell information when environmental information changes. In parking lots where parking information can change at any time, the D*-lite algorithm is obviously more applicable.

4 Ultraviolet Communication Module

In this paper, MCU is used as the core component of the solar blind ultraviolet communication system. Automatic parking guidance system based on real-time collected the information such as the parking lot vehicle location, the parking problem, the D*-lite path planning algorithms to calculate and get the path of the guide information by MCU modulated by ultraviolet light signals to the communication channel LED driver circuit to transfer, ultraviolet light signal is UVC sensor is converted to electrical signals, after amplification by amplifying circuit demodulation by MCU route guidance

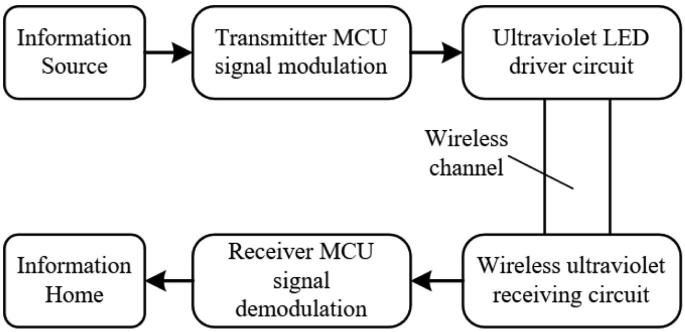

Fig. 3. Structure of ultraviolet communication module

information, finally passed to the vehicles and drivers. Figure 3 is the structure diagram of the ultraviolet communication module.

4.1 Ultraviolet Light Signal PPM Modulation

Compared with the traditional open critical control (OOK) mode, pulse position modulation (PPM) has smaller average power requirements of light radiation and stronger anti-interference ability [14]. The essence of pulse position modulation (PPM) is to control the relative position of each pulse in the transmitted pulse sequence. An n bit data are $M = (m_1, m_2, \cdots, m_n)$, and the time slot position is I, then the mapping relation of PPM modulation is as follows:

$$I = m_1 + 2m_2 + \cdots + (2n-1)m_n, m \in \{0, 1, 2, \cdots, 2n-1\} \tag{6}$$

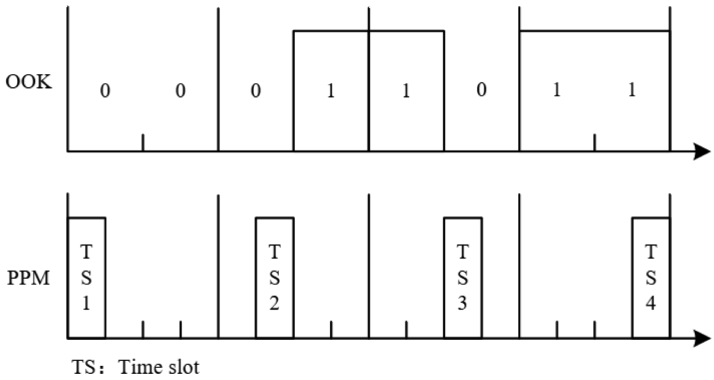

Fig. 4. PPM modulation and OOK modulation mapping comparison chart

Text is composed of 2-bit binary data, corresponding to 4-PPM modulation as an example. It coding mapping relationship and OOK comparison is shown in Fig. 4. In this paper, 4-PPM modulation is used for ultraviolet signal modulation to enhance the anti-interference ability and stability of the communication system in the communication channel.

4.2 Ultraviolet LED Driver Circuit

There are two ways of signal modulation: analog modulation and digital modulation. Compared with traditional analog modulation, digital modulation has better reliability, better anti-interference ability and longer transmission distance, so this paper chooses digital modulation for signal modulation.

The ultra-violet LED drive circuit first USES a high-precision operational amplifier to form a voltage comparator, so as to solve the “trailing” phenomenon when a single triode drives the LED and the triode is switched on and off. Capacitor C2 improves the switching rate of the drive circuit, thus improving the high-frequency performance of the drive circuit [15]. R4 is the bias resistor and R5 is the variable resistor used to regulate the current through the UV-LED. Digital modulation circuit is the use of coded signal INPUT from the INPUT end, control transistor Q1 on and off, so as to control the UV-LED on and off, so as to achieve the modulation of optical signals. Figure 5 is a schematic diagram of ultraviolet LED drive circuit.

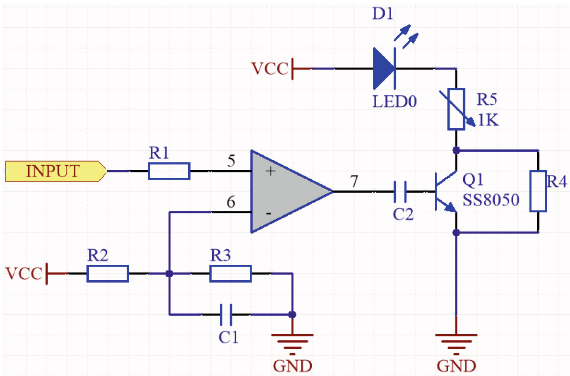

Fig. 5. Ultraviolet LED driver circuit principle that block diagram

4.3 Wireless Ultraviolet Receiving Circuit

The vehicle-mounted receiving terminal is composed of UVC ultraviolet sensor and preamplifier circuit, and the signal demodulation is completed by MCU. The UVC sensor [4, 5] converts optical signals into photoelectric signals, which are amplified by the preamplifier circuit into voltage signals that can be processed by MCU, and then demodulated by MCU. The navigation information of vehicle path after demodulation is finally transmitted to the driver through screen display. Thus, the basic function of the vehicle-mounted wireless ultraviolet receiving module in the automatic parking guidance system is realized. Figure 6 is a schematic diagram of the ultraviolet receiving circuit.

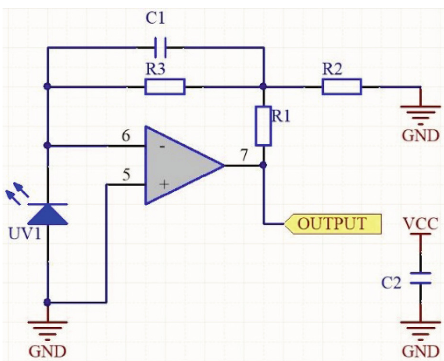

Fig. 6. Principle diagram of wireless ultraviolet receiving circuit

Among them, UV1 is the UVC sensor, R1, R2 and R3 are the feedback resistors, MCP6241 is selected as the operational amplifier, C1 is used to reduce the input noise, and C2 is used to stabilize the power supply. Formula (7) is the gain formula of the amplifier module.

$$A = R_3\left(1 + \frac{R_1}{R_2}\right) \tag{7}$$

Adjust the appropriate resistance of R_1, R_2, and R_3 to meet the needs of the actual circuit.

5 Analysis and Discussion

Figure 7 is the detail diagram of the ultraviolet LED driving end and wireless ultraviolet receiving end of the parking automatic navigation system based on ultraviolet communication. Figure 8 is the overall physical experiment model of the system.

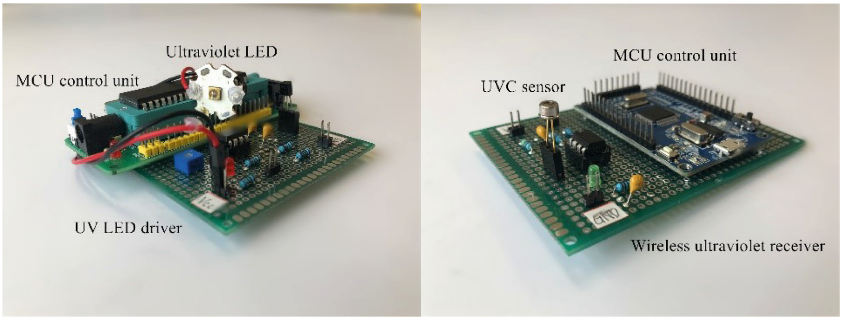

Fig. 7. Ultraviolet LED driver and wireless ultraviolet receiver

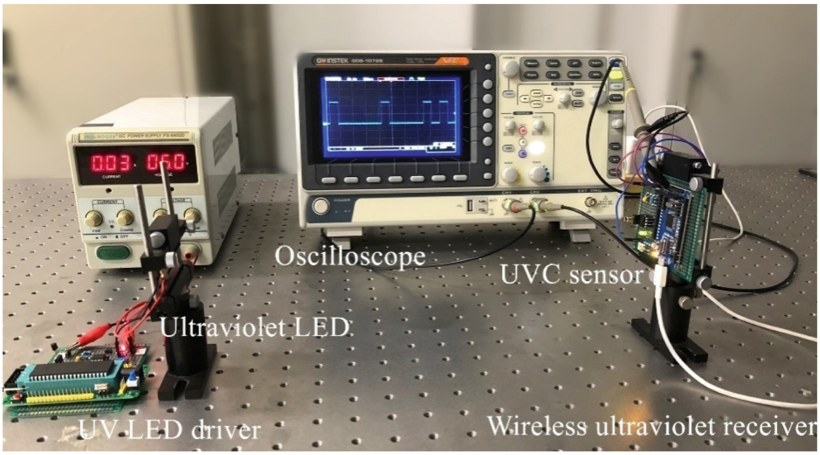

Fig. 8. Physical experiment model

This system adopts the UV-LED light source and UVC sensor's field of view Angle of 60°, the NLOS not look straight communication link model, send and receive of elevation Angle less than 90°. A single node is composed of multiple UV-LED, and each UV-LED is responsible for communication within a certain sector area. During the experiment, the Angle of the drive end and the receiver end bracket was adjusted to simulate the NLOS mode.

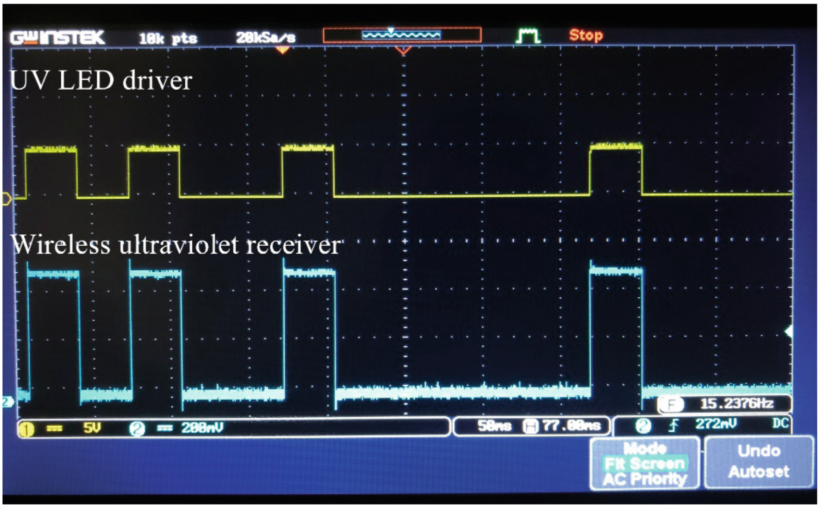

Fig. 9. Experimental waveform

The parking navigation information is modulated by MCU and sent through the ultraviolet LED2 drive circuit. The UVC sensor at the wireless ultraviolet receiver is responsible for receiving. After being processed by the amplification circuit, the information is demodulated by MCU and transmitted to the vehicle and driver. Figure 9 shows the waveform displayed on the oscilloscope by the ultraviolet LED driver and the wireless ultraviolet receiver.

Experiments have shown that UV-LED driver side and ultraviolet wireless receiver are 4 m, high level of UV-LED drive on the amplitude of 5 V, wireless receiver of ultraviolet high level after receiving signal amplified by amplifying circuit amplitude is 400 mV, transmitting and receiving signal waveform are basically the same, still can guarantee that the system within 4 m has the good communication performance, can meet the demand of communication.

6 Conclusion

This article in view of the existing parking guidance system in poor compatibility and high efficiency is not high question, designed a set of "solar blind" technology of ultraviolet communication based automatic parking guidance system, the D*-lite algorithm improve the efficiency of path planning, the use of "solar blind" ultraviolet communication technologies to promote the compatibility of the parking guidance system, attempt to provide a kind of technology of ultraviolet communication application direction in daily life. The system can still be optimized and the modulation mode can be changed to increase the transmission reliability and stability of the UV communication system.

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