Design and Implementation of an Autonomous Parking Controller Using a Fuzzy controller and AHP for Car-Like Mobile Robot

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Abstract

This paper designs and implements an automatic parking system for car-like robot. The car-like robot uses Arduino micro control unit as the core for system integration and data computation. It controls peripheral hardware of the car body, including DC motor and driver module, servo motor, ultrasonic range sensor, and Bluetooth module. The image processing often fails in an outdoor setting due to lighting and weather. Therefore, this study used an ultrasonic range sensor to detect environments, and design a fuzzy controller with Analytic Hierarchy Process (AHP). The purpose was to reduce the time of correcting parking position in the parking space, thus accelerating the parking effectively. In terms of user-side, as the traditional remote controller is too heavy, this study designed the Android control interface connected to the car-like robot via Bluetooth transmission module. The external interference can be reduced, so it is convenient and portable. Finally, the controller proposed in this paper is validated by the simulation results. The experimental results proved the feasibility of the proposed automatic parking system for car-like robot.

Keywords: car-like robot, fuzzy theory, Analytic Hierarchy Process, automatic parking system, Android.

1. Introduction

Under economic development, various construction projects are taking place. In order to shorten the gap between urban and rural areas, more roads need to be built, which will result in heavier traffic. More and more people use vehicles as the main means of transport, so the rate of traffic accidents increase. The reversing radar, driving recorder and electronic brake force distribution system are developed to guarantee the safety of vehicles when the driver is driving. However, the driving experience or unexpected situations in the driving process sometimes result in traffic accidents as the drivers fail to respond instantly. Therefore, the unmanned or artificial intelligence (AI) supporting system, such as thunderbolt car in TV play, is developed. A practical application is the smart vehicle. When a vehicle is in motion, the main point is to avoid colliding with other vehicles or objects. Therefore, there are multiple methods for obstacle avoidance, such as artificial potential field approach [1], which uses attraction and repulsive forces to create destination and obstacle, and calculates the vector among target, obstacle and destination. In addition, fuzzy theory [2], the fuzzy membership function and rule list are established according to the specifications of hardware, so that the robot or vehicle can evade obstacles smoothly in motion. The extension theory proposed by this laboratory [3], which stipulates the extension matter-element and calculates the correlation function for good evaluation, has effective obstacle avoidance strategy. The issue of parking is a topical subject in the research on smart vehicles, such as fuzzy neural network controller simulated automatic roadside parking [4], or Bezier Curve based fuzzy controller and proportional-integral-derivative (PID) controller simulated automatic roadside parking [5]. The sensors used in the research on actual simulation of automatic parking, such as infrared sensor [6], ultrasonic sensor [7] and Light Detection And Ranging (LIDAR), can detect the environment around the vehicle, and search for the parking space. Different methods, such as fuzzy theory, are used to finish parking. In addition, the parking grid is detected by using visual image processing [8-10], which detects the characteristic of parking grid lines, and calculates the size of parking space to check whether it is a parking grid or not. The parking control is then implemented to finish parking action, or the visual image is combined with projection source [11] to convert the detected light source into a depth map, identify the parking grid position, and complete the parking action. However, the automatic parking by image processing is influenced by the light environment, so that the parking grid lines are incomplete or indistinct, reducing the accuracy of detection result.

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The obstacle avoidance is often used for running detection in an open area. The obstacle information receiving is divided into two items, laser or ultrasonic detection, and image detection of cameras. The data fed back by laser or ultrasonic detection are analyzed by algorithms to determine the dynamics of vehicles or robots. The ambient information of the vehicle is obtained from the images captured by camera or video lens by preprocessing, feature extraction, detection and segmentation and algorithm processing, so as to warn the driver or to change the vehicle's dynamics. For example, the lane departure warning [12-13] is mostly implemented by using image recognition to detect the road lines on expressways or freeways. The front pedestrian detection during driving [14-15], front vehicle collision warning [16] and vehicle rear blind spot detection [17] are derived from the driving safety and road user's safety.

The Analytic Hierarchy Process (AHP) was proposed by Prof. Thomas L. Saaty of University of Pittsburgh in 1971. It is mainly applied to deciding uncertain conditions and to the problems with multiple evaluation criteria. Its main purpose is to systemize complex and difficult problems, and to take out the bottommost elements to hierarchize the whole problem, and the opinions of decision makers or experts and scholars are considered. This part is compared with basic elements of different layers. The eigenvalues of various hierarchies are obtained from the eigenvector and evaluated comprehensively to provide the decision maker with a better option.

2. Hardware and System Architecture

The overall system architecture of car-like robot is divided into hardware architecture and software architecture. The software architecture is the operating bridge integrating the hardware architecture with user side. The overall architecture of car-like robot of this paper is shown in Figure 1. Its dimensions are shown in Table 1. Figure 2 shows the hardware architecture of this car-like robot. The user-side smart phone with Android operating system is connected to the micro control unit through the special vehicle control application program developed in this paper and Bluetooth transmission, and the micro control unit controls the DC motor driver module and servo motor according to the user's command.

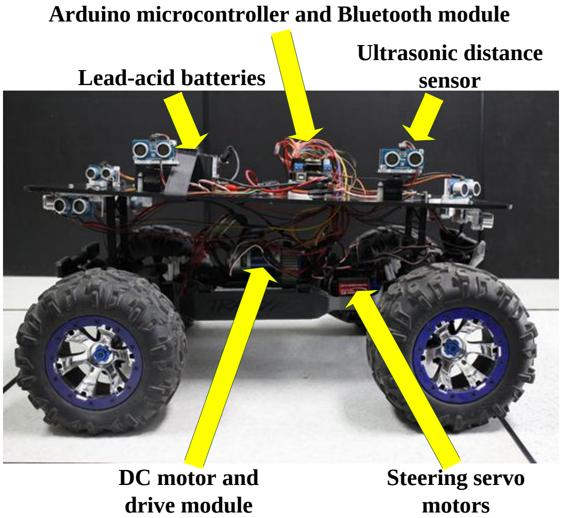


Figure 1: The car-like mobile robot

Table 1: Car-like mobile robot's specification

Project	Specification
Dimensions (length*width*height)	60*45*35 Centimeter
Weight	7 Kilogram

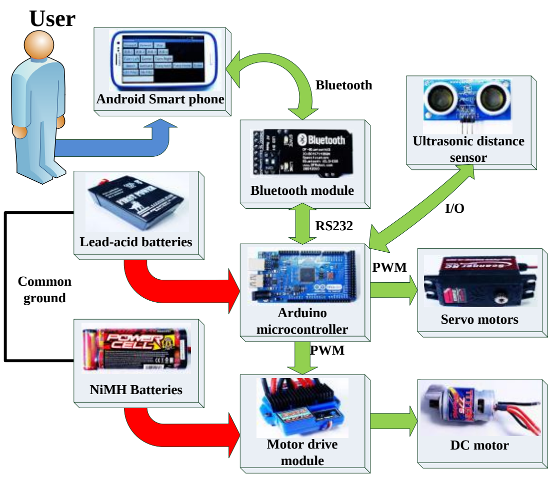


Figure 2: The robot system of the hardware link

3. Design of Fuzzy Controller for Automatic Parking

This section discusses the design of the automatic parking system. The data obtained by the car-like robot in motion are derived from the ultrasonic range sensor, so the location of the sensor is crucial. The obtained data are imported into the automatic parking system, and then the automatic parking system controls the vehicle's dynamic state.

First, the actual parking situation is simulated. When the vehicle runs to a fixed point, the user issues the automatic stopping instruction, so the peripheral parking information is searched. Whether there is the parking space for reversing the car into a garage or roadside parking is identified according to the information obtained by the ultrasonic range sensor. The sensed state is fed back to the user side, and the automatic parking behavior pattern is executed. Figure 3 shows the flow chart of this automatic parking system.

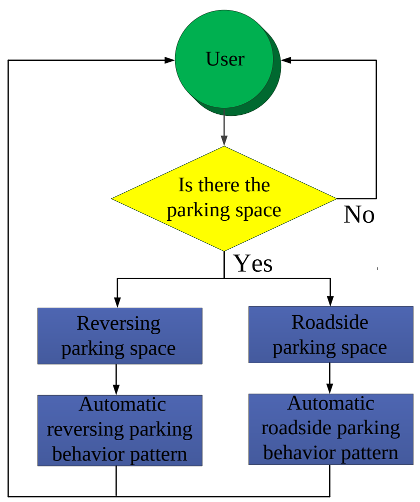


Figure 3: The flow chart of the proposed Automatic parking system

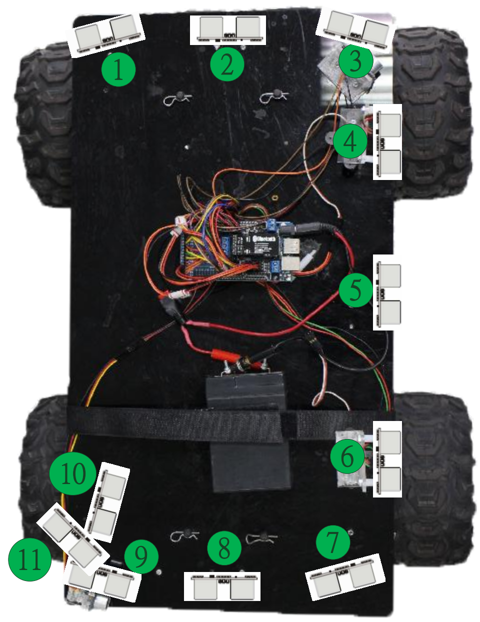


Figure 4: A configuration of an Omni directional mobile robot

3.1 Layout of Ultrasonic Range Sensors

The layout of ultrasonic range sensors is shown in Figure 4. There are 11 ultrasonic range sensors. As the sensing range of each sensor is limited, in order to enlarge and reduce the dead angles the ultrasonic range sensors cannot detect, multiple sensors are used. No. 4 and No. 6 are the input of fuzzy controller, and No. 8 is the input of AHP. The other ultrasonic sensors detect the vehicle movement and distance and obstacles of parking space.

3.2 Parking Space Detection

This study sets two types of parking space, the parking space for roadside parking, and the parking space for reversing the car into a garage. As the vehicles run on the right lane in Taiwan, the parking detection is mostly on the right side in this paper. The size of parking space is set from 1.5 to 2 times of the length and width of the car-like robot. Figure 5 shows the schematic diagram of roadside parking space detection. Whether the space is enough for the car-like robot to park is judged according to the information fed back from the ultrasonic range sensors. The roadside parking space is set as:

$$1.7 \times L \le U3dis \le 2.4 \times L \tag{1}$$

$$1.5 \times W \le \begin{Bmatrix} U4dis \\ U5dis \\ U6dis \end{Bmatrix} \le 2 \times W \tag{2}$$

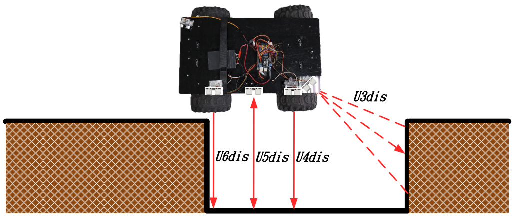


Figure 5: Roadside parking space detection schematic diagram

In Eqs. (1-2), L is the length of car-like robot, W is the width of car-like robot, *U3dis*, *U4dis*; *U5dis* and *U6dis* are the distance values detected by the ultrasonic range sensors; *U4dis*, *U5dis* and *U6dis* must meet the condition of Eq. (2) simultaneously, guaranteeing this space is not the spacing between obstacles. Figures 6 and 7 show the reversing parking space detection. The reversing parking space is set by Eqs. (3-4). *U4dis*, *U5dis* and *U6dis* must meet the condition of Eq. (4) simultaneously, guaranteeing this space is the reversing parking space.

$$1.7 \times L \leq U3dis \leq 2.4 \times L \tag{3}$$

$$1.4 \times L \leq \begin{Bmatrix} U4dis \\ U5dis \\ U6dis \end{Bmatrix} \leq 1.8 \times L \tag{4}$$

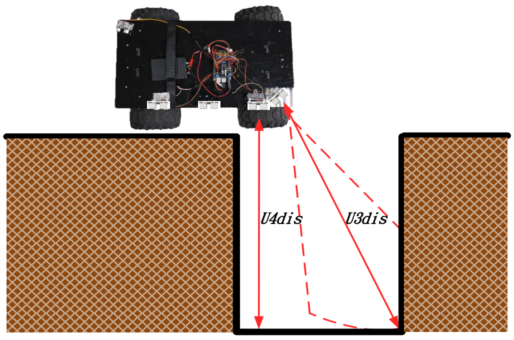


Figure 6: Reversing parking space detection Schematic diagram

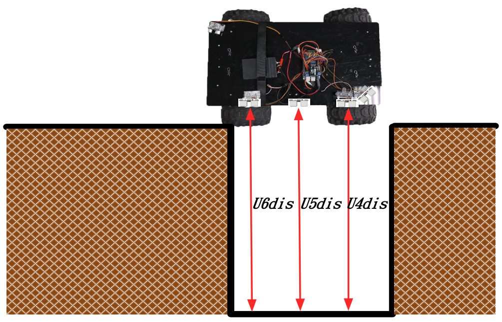


Figure 7: Reversing parking space detection Schematic diagram

3.3 Design of Fuzzy Controller for Reversal of Car-like Robot

The speed of roadside parking system and reversing system is set as the minimum speed of car-like robot. The controller is in charge of steering control of car-like robot, and the input of fuzzy controller is the data received by the designated ultrasonic range sensor.

$$C_m = U6dis \tag{5}$$

$$C_t = U6dis - U4dis \tag{6}$$

U4dis and *U6dis* are the distance values fed back and converted into cm by the ultrasonic range sensors.

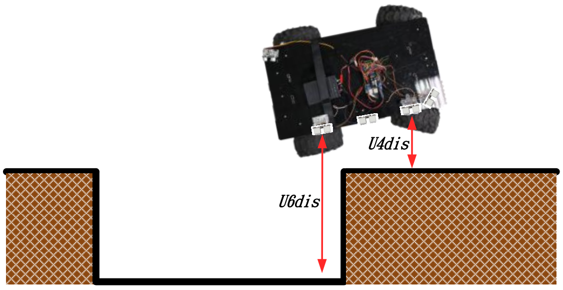


Figure 8: Roadside parking ultrasonic distance sensor detection schematic diagram

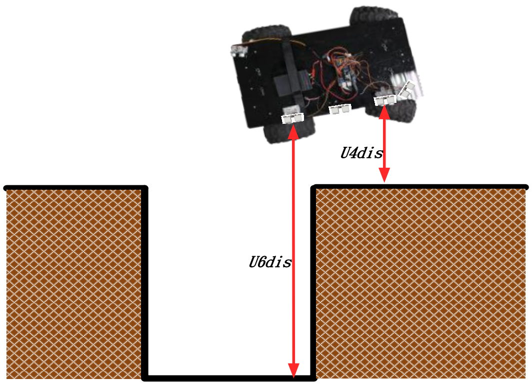


Figure 9: Reversing parking ultrasonic distance sensor detection schematic diagram

C_m and C_t are the input variables of a fuzzy controller, representing the distance between the rear end of car-like robot and the wall surface, and the steering state of car-like robot in relation to the horizontal wall surface respectively during reversing in roadside parking. The larger the C_m value is, the farther the car-like robot is from the wall surface of roadside parking space. When the C_t value is positive, meaning that the rear end moves away from the wall surface or parking space gradually as the car-like robot runs. The output of fuzzy controller controls the front wheel steering angle θ of car-like robot, when the controller output value is negative, the steering angle θ of car-like robot turns clockwise; the larger the output value is, the larger is the steering angle.

In fuzzy adjustment, this paper uses triangular membership function which is convenient for calculation as fuzzy membership function. Table 2 shows the meaning of fuzzy interval in the input/output of fuzzy controller. Five triangular membership functions are used to represent the range of inputs C_m and C_t and output θ. Figures 10-15 show the membership function range of input variables and output variables.

Table 2: Fuzzy interval significance.

C_m	C_t	θ
NB (Negative Big)	NB (Negative Big)	NB (Negative Big)
NS (Negative Small)	NS (Negative Small)	NS (Negative Small)
Z(Zero)	Z(Zero)	Z(Zero)
PS (Positive Small)	PS (Positive Small)	PS (Positive Small)
PB (Positive Big)	PB (Positive Big)	PB (Positive Big)

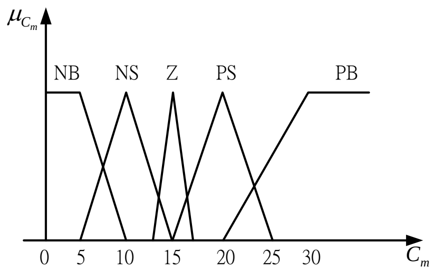


Figure 10: Roadside parking input variable C_m membership functions

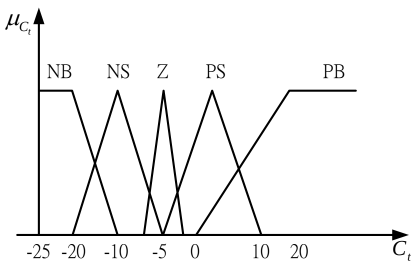


Figure 11: Roadside parking input variable C_t membership functions

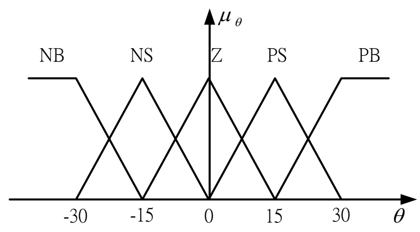


Figure 12: Roadside parking output variable θ membership functions

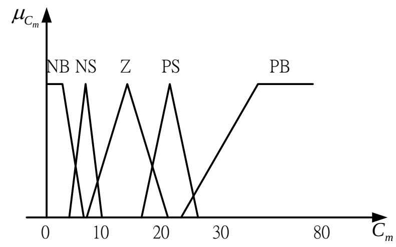


Figure 13: Reversing parking input variable C_m membership functions

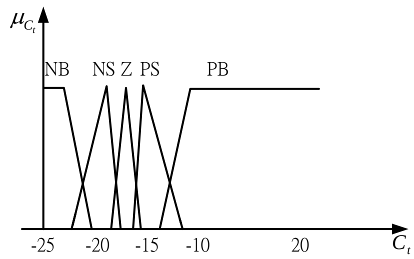


Figure 14: Reversing parking input variable C_t membership functions

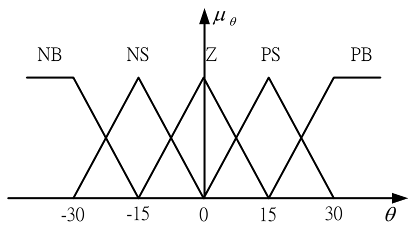


Figure 15: Reversing parking output variable θ membership functions.

Table 3: Reversal fuzzy controller rule table for Car like mobile robot

C_t \ C_m (θ)	NB	NS	Z	PS	PB
NB	PB	PB	PS	PS	Z
NS	PB	PS	PS	Z	NS
Z	PS	PS	Z	NS	NS
PS	PS	Z	NS	NS	NB
PB	Z	NS	NS	NB	NB

According to the defined membership function of inputs C_m and C_t, the If-Then inference sentence of rule base of $5 \times 5 = 25$ clauses of reversal fuzzy controller can be set as follows:

R^i :IF C_m is A_1^i AND C_t is A_j^i , THEN θ is a^i, i=1,…,25。

Where R^i is the label of the i-th fuzzy if-then rule, A_j^i={NB, NS, Z, PS, PB } are antecedent fuzzy, a^i is the grade of certainty of the fuzzy if-then rule R^i.
The above inference sentence is changed to the rule list of fuzzy controller, as shown in Table 3.

4. Analytic Hierarchy Process

AHP [18-19] can determine the magnitude and coverage of membership function of fuzzy controller in the automatic parking system. When the automatic parking command is issued, the parking space and ambient environment of car-like robot may differ. When the car-like robot has entered the parking space, the data fed back from the ultrasonic range sensors are different when the parking space is being corrected. Therefore, the membership function of fuzzy controller should be adjusted, so that the car-like robot can complete the task of automatic parking correctly and rapidly.

For deciding the optimal membership function, the right ultrasonic range sensors No. 4 and 6 and the rear ultrasonic range sensor No. 8 of car-like robot are used as three main influencing factors. There are three optional membership function schemes. The hierarchical structure of decision is drawn according to this condition, as shown in Figure 16, and the ultrasonic number position is shown in Figure 4.

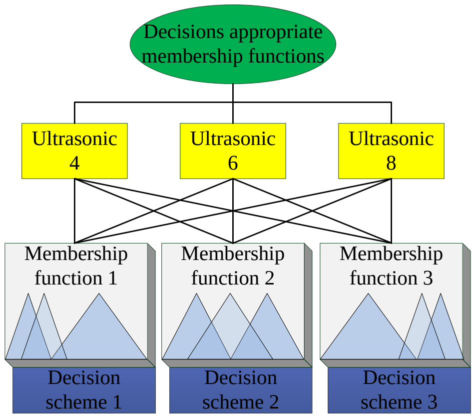


Figure 16: The hierarchical structure diagram

The three input influencing factors are converted into pairwise comparison matrix of the second ply, as shown in Eq. (7). The weights are obtained from the pairwise comparison matrix by using Average of Normalized Columns, as shown in Eq. (8). Whether there is consistency or not is checked. Therefore, Eq. (12) is used to obtain the consistency ratio C.R. If the degree of consistency is acceptable, i.e. $C.R. \leq 0.1$. The C.I. in Eq. (12) is consistency index, as shown in Eq. (9). When calculating the C.I. value, the eigenvalue λ is shown in Eq. (10), and the consistency vector v_i is shown as Eq. (11). The R.I. is random index value, as shown in Table 4. There are three influencing factors in this study, so the order number of R.I. is three, i.e. $R.I. = 0.58$. For the selection scheme of the third ply, the weights are calculated in the aforesaid way. Eq. (13) is the pairwise comparison matrix of influencing factors of the second ply. Eqs. (14) and (15) are the pairwise comparison matrix of the third ply. Mb_1 and Mb_2 are the decision-making scheme pairwise comparison matrix under ultrasonic No. 4 and No. 6. Mb_3 is the decision-making scheme pairwise comparison matrix under ultrasonic No. 8. When the weights of schemes of the third ply are calculated, the weights of influencing factors of the second ply are weighted and evaluated comprehensively. Finally, the evaluation vector values of three selection schemes are obtained, the highest value will be the preferred scheme.

$$a_{ij} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{i1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} \frac{W_1}{W_1} & \frac{W_1}{W_2} & \cdots & \frac{W_1}{W_n} \\ \frac{W_2}{W_1} & \frac{W_2}{W_2} & \cdots & \frac{W_2}{W_n} \\ \vdots & \vdots & & \vdots \\ \frac{W_n}{W_1} & \frac{W_n}{W_2} & \cdots & \frac{W_n}{W_n} \end{bmatrix} \quad (7)$$

$$W_i' = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \qquad i, j = 1,2,......,n \quad (8)$$

$$C.I. = \frac{\lambda - n}{n-1} \tag{9}$$

$$\lambda = \frac{\sum_{i=1}^{n} v_i}{n} \qquad i = 1,2,......,n \tag{10}$$

$$v_i = \frac{\sum_{j=1}^{n} w_j a_{ij}}{w_i} \qquad i, j = 1,2,......,n \tag{11}$$

$$C.R. = \frac{C.I.}{R.I.} \tag{12}$$

$$L_2 = \begin{bmatrix} 1 & \frac{U6dis}{U4dis} & \frac{U6dis}{U8dis} \\ \frac{U4dis}{U6dis} & 1 & \frac{U4dis}{U8dis} \\ \frac{U8dis}{U6dis} & \frac{U8dis}{U4dis} & 1 \end{bmatrix} \tag{13}$$

$$Mb_1 = Mb_2 = \begin{bmatrix} 1 & 5 & 7 \\ \frac{1}{5} & 1 & 3 \\ \frac{1}{7} & \frac{1}{3} & 1 \end{bmatrix} \tag{14}$$

$$Mb_3 = \begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{3} \\ 2 & 1 & \frac{1}{4} \\ 3 & 4 & 1 \end{bmatrix} \tag{15}$$

L_2: Pairwise comparison matrix of influencing factors of the second ply.

U4dis、*U6dis* 、*U8dis*: Distance values detected by No. 4, 6, 8 ultrasonic range sensors

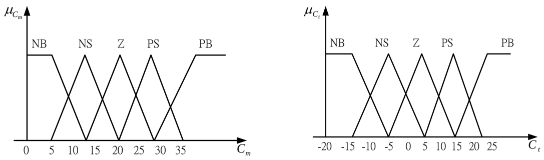
Mb_1 、Mb_2 Mb_3: Third ply of scheme selection.

Table 4: Random index value

Order	1	2	3	4	5	6
R.I.	0.00	0.00	0.58	0.90	1.12	1.24

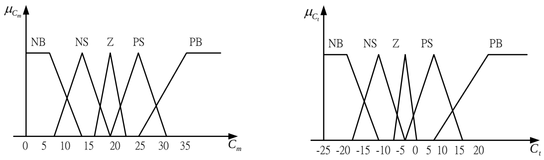
The main design concept of pairwise comparison matrix of the second ply is that No. 8 ultrasonic range sensor is more important than No. 4 and No. 6, and No. 6 ultrasonic range sensor is more important than No. 4. Therefore, the ratios in the matrix are designed as follows, if the numerical values of No. 4, 6 and 8 ultrasonic range sensors are 20, 30 and 40, respectively. The importance of No. 8 to No. 6 ultrasonic range sensor is 4/3 in the pairwise comparison matrix. The importance of No. 8 to No. 4 is 2, and the importance of No. 6 to No. 4 is 3/2.

The three selection schemes of the third ply in AHP represent three different fuzzy membership functions respectively. The car-like robot can select appropriate fuzzy membership function via AHP decision making in different parking states by changing the fuzzy membership function. Automatic parking is implemented by fuzzy controller. The three input variable membership functions of fuzzy controller for roadside parking are shown in Figures 17-19. And the three input variable membership functions of fuzzy controller for reversing parking are shown in Figures 20-22. The membership function of output θ is identical with the original setting.



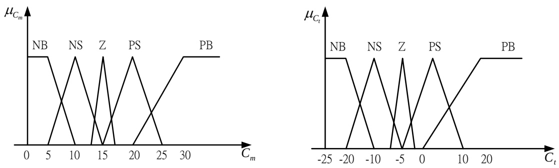
(a) (b)

Figure 17: The input variable membership functions of fuzzy controller for roadside parking (scheme one): (a) input variables C_m; (b) input variable C_t



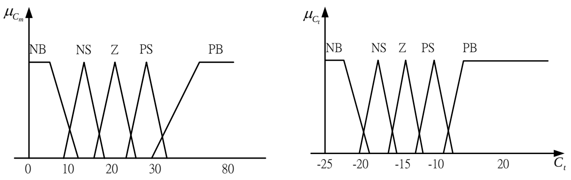
(a) (b)

Figure 18: The input variable membership functions of fuzzy controller for roadside parking (scheme two): (a) input variables C_m; (b) input variable C_t



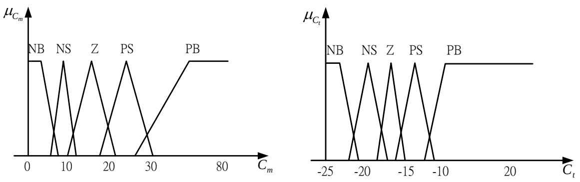
(a) (b)

Figure 19: The input variable membership functions of fuzzy controller for roadside parking (scheme three): (a) input variables C_m; (b) input variable C_t



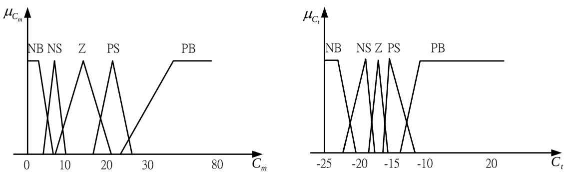
(a) (b)

Figure 20: The input variable membership functions of fuzzy controller for reversing parking (scheme one): (a) input variables C_m; (b) input variable C_t



(a) (b)

Figure 21: The input variable membership functions of fuzzy controller for reversing parking (scheme two): (a) input variables C_m; (b) input variable C_t



(a) (b)

Figure 22: The input variable membership functions of fuzzy controller for reversing parking (scheme three): (a) input variables C_m; (b) input variable C_t

5. Experiment and Simulation Results

In the simulation of this automatic parking system, first, the user issues the command of automatic parking, if the car-like robot has found the parking space, it keeps running until it reaches the position to start reversal. At this point, the ambient environment data detected by ultrasonic range sensors are fed back, and then the membership function of fuzzy controller is adjusted by AHP before running backward. The fuzzy controller for automatic parking changes the running direction of vehicle, so the automatic parking is finished until the vehicle is adjusted to proper position. If the roadside parking space is found, the automatic parking system flow is shown in Figure 23.

For the experimental results of this study, this section uses the controller designed by fuzzy theory and AHP introduced in previous chapters and peripheral hardware facilities of vehicle to implement automatic roadside parking of car-like robot.

This study uses Arduino micro control unit and car-like robot platform, as well as ultrasonic range sensors in automatic parking system. When the user issues the instruction of automatic parking via Android application program to transfer it via Bluetooth to the micro control unit, the car-like robot begins to search for the parking space. The search results include roadside parking space and no parking space. If a parking space is found, the automatic parking controller designed by fuzzy-AHP corresponding to the parking space implements automatic parking. If there is no parking space found, the user can issue another command to let the car-like robot move forward to search for an appropriate parking space.

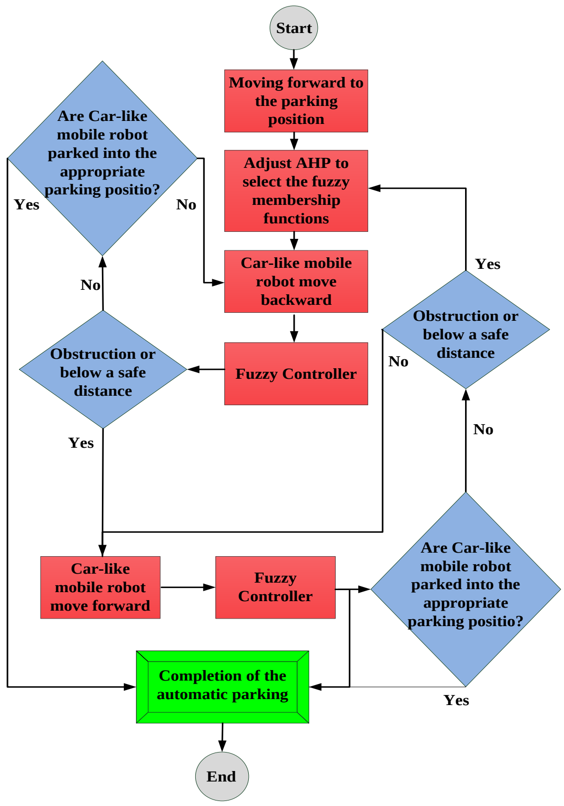


Figure 23: The automatic parking system flow

5.1 User-side Android Control Interface of Car-like Robot

The car-like robot of this study communicates with the application program of Android system via Bluetooth transmission module. The application program designed in this study is applicable to current smart phone or tablet PC above Android 4.0, as shown in Figure 24. The travel mode, automatic parking and micromotion in the automatic parking system of car-like robot can be controlled at the user side, such as the detection of parking space, roadside parking and parking stall adjustment. The state is displayed in the bottommost window of control interface.

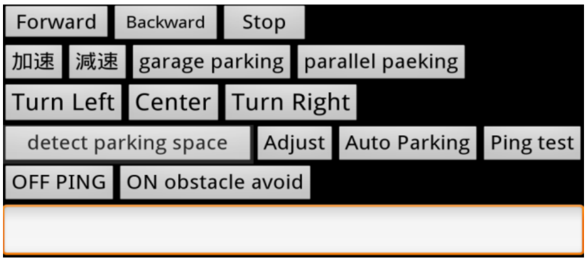


Figure 24: User-side control interface of car-like robot

5.2 Automatic Parking Controller Simulation Results

As this car-like robot is in relative testing environment, the exact physical coordinates are unknown, so the Matlab software is used for simulation, so as to validate the accuracy of the controller designed in this paper. The simulation result of automatic roadside parking controller is shown in Figure 25. The simulation result of automatic reversing parking controller is shown in Figure 27. Figures 26 and 28 show the fuzzy controller without AHP. It is obvious that the fuzzy controller with AHP is better than the simple fuzzy controller.

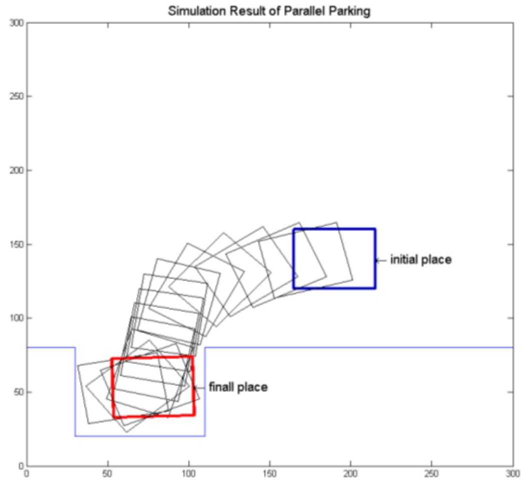


Figure 25: The simulation result of automatic roadside parking controller

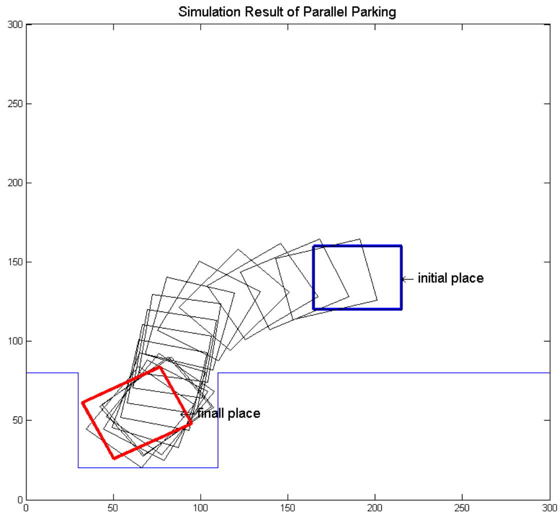


Figure 26: The simulation result of automatic roadside parking controller (without AHP)

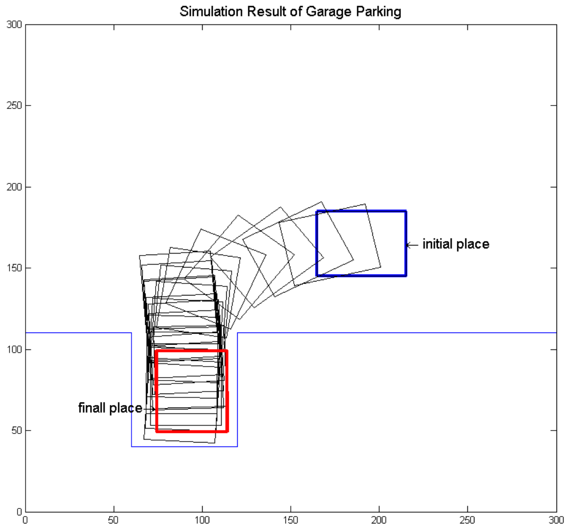


Figure 27: The simulation result of automatic reversing parking controller

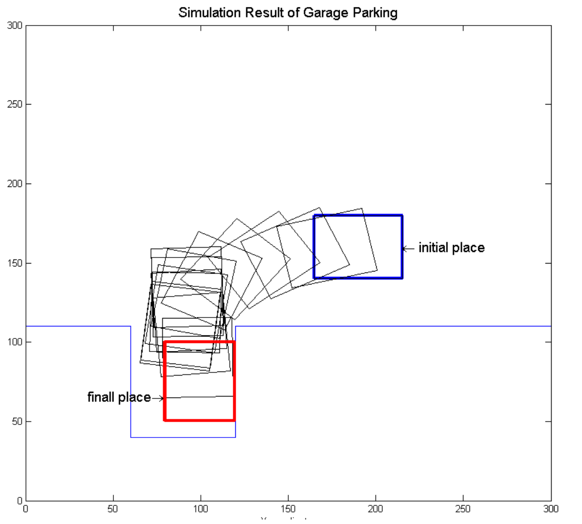


Figure 28: The simulation result of automatic reversing parking controller (without AHP)

5.3 Experimental Results of Automatic Parking System for Car-like Robot

The experimental site for automatic parking of car-like robot is shown in Figure 29. The car-like robot is parked in the parking space successfully by issuing the instruction of automatic parking, detecting the environment, corresponding to the found parking space controller, and the adjustment of AHP. Figure 30 shows the experiment on automatic roadside parking system of car-like robot. Figure 31 shows the experiment on automatic reversing parking system of car-like robot.

Figure 29: The experimental site for automatic parking of car-like robot

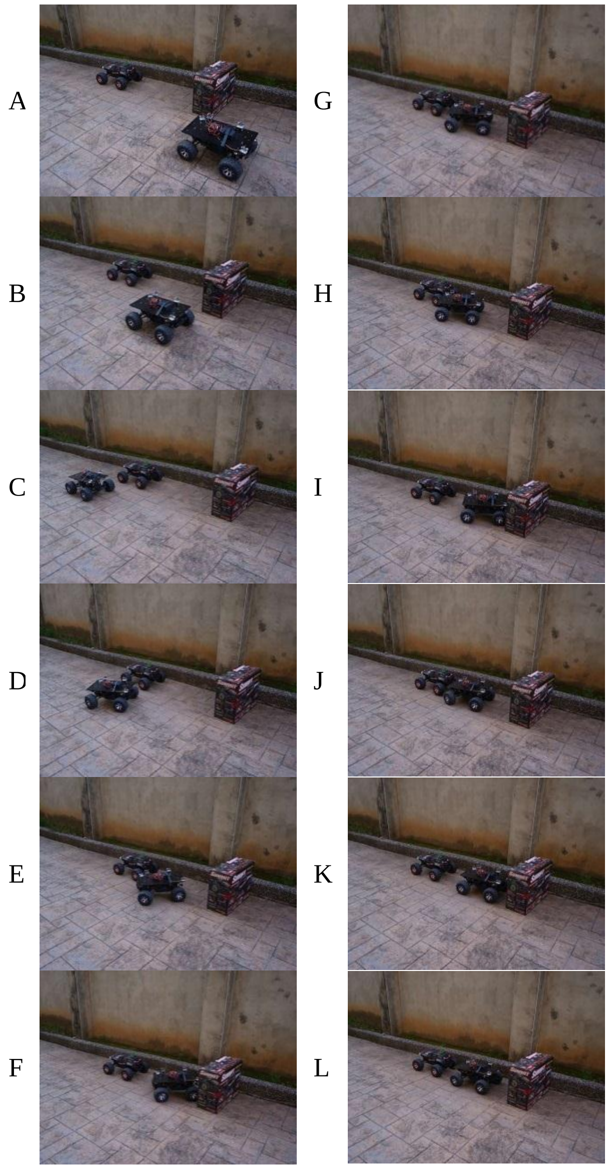


Figure 30: The experiment on automatic roadside parking system of car-like robot

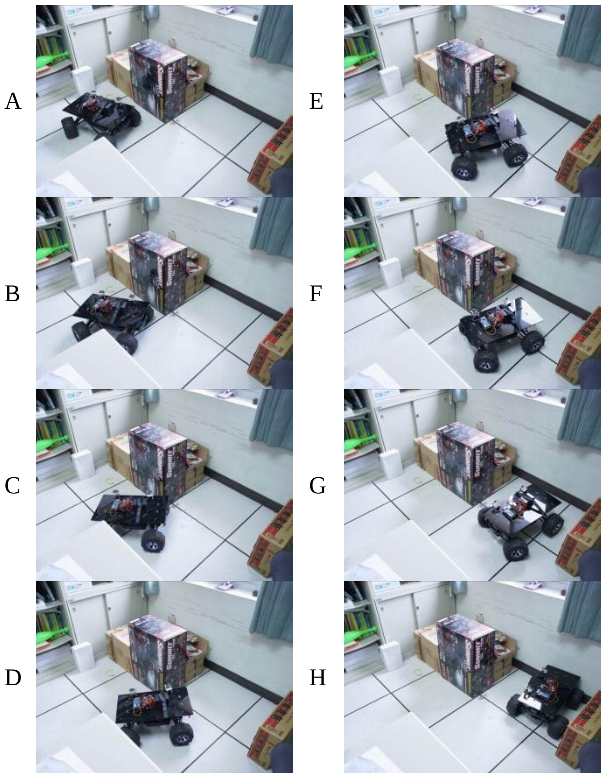


Figure 31: The experiment on automatic reversing parking system of car-like robot

5.4 Experimental Results of AHP

For the car-like robot in different environments, the AHP is used to adjust the membership function of fuzzy controller. The experimental and simulation results are shown in Figures 32 and 33. Figure 32 (a) shows the ready position for parking, (b) shows the relative position when the vehicle just moves inside the parking space and (c) shows the relative position of parking position adjusted in the parking space. In the three testing environments in Figure 32, the distance data detected by ultrasonic range sensors, the decision selection fed back from micro control unit matches the result of computer software, as shown in Figure 33, as well as meeting the conditions of *C.I.<0.1* and *C.R.<0.1*.

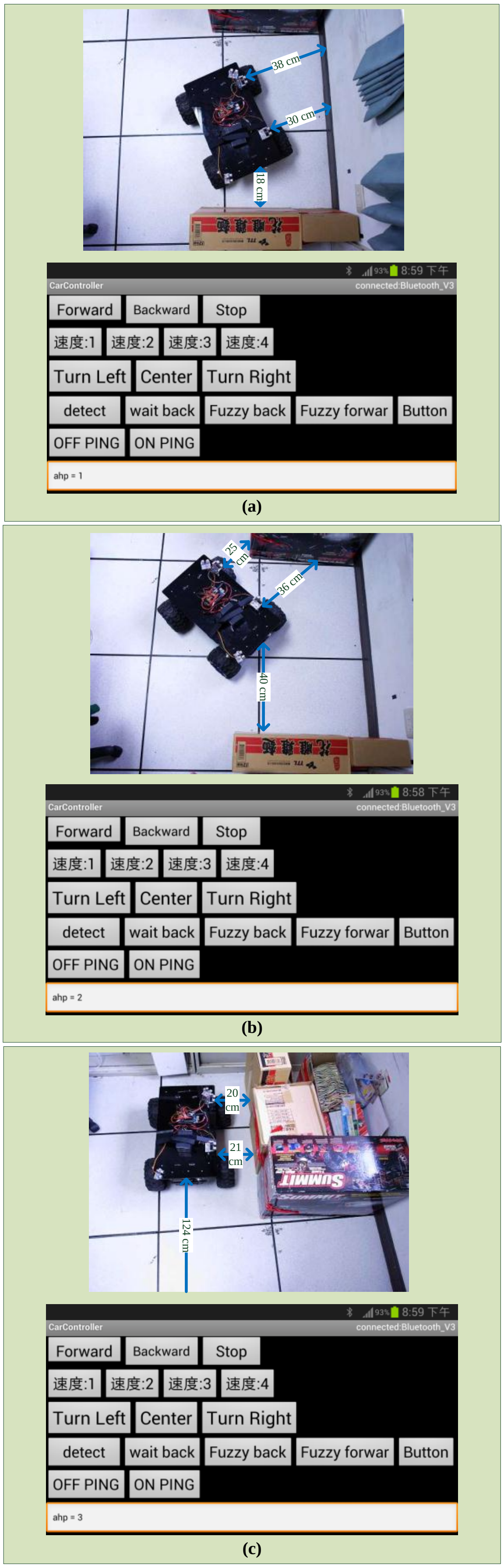


Figure 32: The experiment on AHP adjust the membership function.

Figure 33: AHP membership functions to adjust the calculation results

In the automatic parking system simulation and experiment, the simulation of computer software Matlab validates the accuracy of our controller. The judgment of car-like robot for the parking space in actual experiments and the fuzzy controller designed for roadside parking space can park the car-like robot in the parking space successfully. The fuzzy membership functions of the ready position for parking and the parking space for the car-like robot are adjusted by AHP, so that the fuzzy controller can adjust the car-like robot appropriately according to the environment.

6. Conclusion

This study installed ultrasonic range sensors around the car-like robot successfully, and used micro control unit, servo motor, Bluetooth transmission module and other hardware to complete the outdoor automatic roadside parking system. The system uses Android, in combination with smart phone or tablet PC. The users can use a portable device to control the car-like robot. According to the simulation results of computer software and the photos of consecutive actions taken in the actual car-like robot experiment, the proposed car-like robot can execute the user's command smoothly.

When the parking space is determined and the ready position for parking is reached, the vehicle moves towards the parking space, and the fuzzy controller changes the steering angle of car-like robot. The overall automatic parking system is completed until the car-like robot enters the parking space and reaches appropriate parking position. The membership functions of fuzzy controller for movement from the ready position for parking to the parking space and correcting parking position in the parking stall are different. General methods may design multiple fuzzy controllers in answer to the environmental change, using manual regulation, so the AHP is used. The membership function of fuzzy controller is adjusted autonomously according to the change in environmental factors. It is a major advantage of this automatic parking system. In addition, if the automatic parking is implemented by image processing, it fails to work normally as the outdoor environment is affected by light source. Therefore, this study only used ultrasonic range sensors for detection, which is not affected by light sources. The fuzzy controller and AHP are used to implement automatic parking.

This car-like robot is operated according to the control instruction issued by the user via smart phones or tablet PCs. Differing from general control modes using heavy computer or radio-frequency circuit which may have interference of the same frequency band, the Bluetooth of smart phone is matched with the Bluetooth device of car-like robot. As the Bluetooth transmission is one-to-one transmission, there will not be external interference other than range constraint. The users can install the car-like robot application program developed by this study in intelligent devices with Android system to control car-like robot, knowing the robot's state on the screen.

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