Implementation of Auto Parking System Based on Ultrasonic Sensors

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Abstract

In this study, an ultrasound sensor that was put on a smart wheeled mobile robot (SWMR) was used to detect parking space environment, simulate drivers' parking strategy, and complete roadside parking and reverse parking. In order to achieve automatic parking, the functions of the system included searching for suitable parking space, detecting adjacent obstacles, planning the parking path, producing pulse width modulation (PWM) signals to drive servo motors, and completing steering control to achieve roadside parking. Once the ultrasonic sensors detect enough parking space, the SWMR can automatically control the servomotors of two wheels to turn around, go straight, move backward and stop, until the car is placed well in the target parking space. According to the experimental results, this study indeed can effectively simulate the actual parking situations, shorten parking safety spacing, and complete automatic parking.

Keywords: Wheeled mobile robot, Ultrasonic sensor, Automatic parking, Servo motor, PWM signal

1 Introduction

Volkswagen Company introduced the automatic parking technology [1-2] into its concept car integrated research Volkswagen (IRVW) in 1992. Besides, IRVW can realize automatic parking, and drivers can operate automatically, and complete the whole parking program. However, Volkswagen did not put this equipment into mass production of cars. Moreover, BMW also published a remote parking system, which enabled drivers to stop the car in the parking space by using a control panel and remote control after driving to the desired parking area and walking out of the car, but the system did not come into the market in the end. Toyota began to provide the choice equipment of automatic parking, namely, Intelligent Parking Assist System for the Japanese version of the hybrid vehicle Prius in 2003. In addition, such hybrid vehicles [3-5] should be the first volume production vehicle with the function of automatic parking in the car markets. For safety, the Prius automatic parking assistance system is only responsible for turning the steering wheel, and drivers must step on the accelerator and brake pedal to control the speed.

Parking assist system [6-7] technology has become increasingly mature, and many best-selling vehicles regard automatic parking as their standard configuration. For example, park assist pilot (PAP) system developed by Volvo can lead drivers to find parking spaces by combining with smart image sensor technology, detect nearby obstacles, plan multi-steering paths, and control electric auxiliary steering. As long as "One Touch" on the remote control [8] module was switched on, the car will be able to automatically control steering, transmission, and brake until it is well settled in the parking space. At present, there are many related literatures about the researches on automatic parking of vehicles and wheeled robot. Many scholars have studied and explored this kind of problem. Ultrasonic sensors and CCD cameras are the two research mainstreams. As for the researches on the infrared or ultrasound, literature [9] detects scanning parking spaces based on infrared range, and achieves smart parking control and path following control on the basis of the fuzzy controller. Jiang et al. [10-11] scan the roadside parking space area with an ultrasonic sensor so as to locate the starting point and the end point of the parking path, and plan a path without collision parking with two connected circular arcs. Literature [12] identifies the parking space position and the attitude of the wheeled robot [13] by putting the ultrasound sensor [14] on a rotating mechanism.

The main purposes of this paper is to use software 3ds Max for modeling the design of body components of a car, and then print the car body structure of a

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wheeled robot with Kingssel 3D list machine, and finally install left and right wheel servo motors and front, rear, and right ultrasound sensors. The ultrasound sensors will conduct parking space environment detection, simulate drivers' parking strategy, and complete roadside parking and reverse parking. Finally, the experimental results show the feasibility and practicability of the ultrasound automatic parking strategy and algorithm proposed in this paper.

2 System Architecture

The wheeled robot constructed in this paper includes four rigid bodies, namely, one platform, left and right fixed wheels, and a front free wheel (for support). In addition, the left and right fixed wheels are driven by two sets of servo machines and are used to control the wheeled robot to move forward, backward, turn left, and turn right. The ontology mechanism drawn through AutoCad and system block diagram are listed in the right and left side of Figure 1. One ultrasonic sensor was installed in the front, rear, and right side of the robot. Three SRF05 ultrasounds produced by Devantech Company were employed as distance measurement devices to detect the location and size of the parking space, and get the corresponding relationship between the wheeled robot and parking space. Besides, Timer1 was used to produce two sets of PWM drive signals; the PWM signal produced by PB1 (OC1A) drove the left wheel servo machine, and the PWM signal generated by PB2 (OC1B) drove the right wheel servo machine.

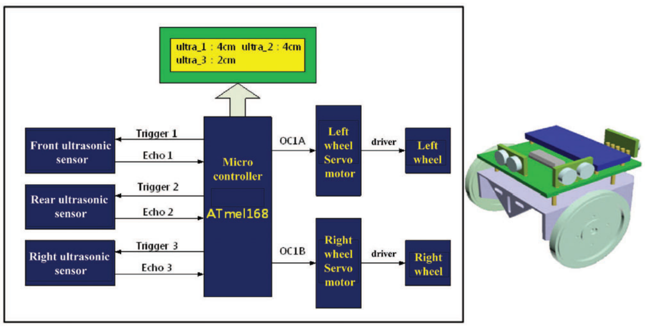

Figure 1. System block diagram

2.1 Design of 3ds Max Car Body

3ds Max, as a powerful 3D modeling, animation, and color rendering software, is widely applied in the field of visual effects, interior design, character animation, and game development. Its functions include base modeling, curve modeling, polygon modeling, model modification, setting texture mapping, lighting setting, photography, animation, and color rendering. The whole car body model components of the SWMR are made by 3ds Max 2009 modeling. Figure 2 shows the assembly diagram of the SWMR, and Figure 3 shows the SWMR model after assembly.

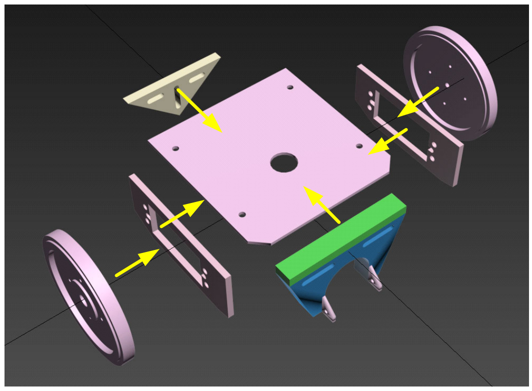

Figure 2. Assembly and dismantling diagram of SWMR car body components

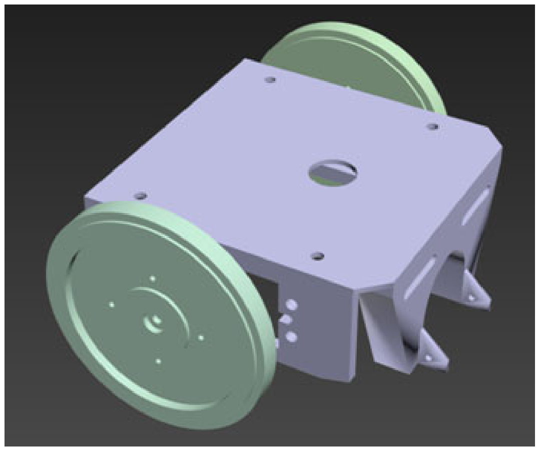

Figure 3. Picture of SWMR after the completion of assembly

2.2 Continuous Rotation Type Servo Motor

The continuous rotation servo machine has low volume, light weight, large torque, and high power saving, and its main structure includes external casing, control circuit boards, DC motor, reduction gear, and position sensor, as shown in Figure 4. Because the servo machine has an internal feedback control circuit, users can achieve a good positioning effect even if they use open loop control. In addition, the control signals of continuous rotation servo machines are pulse width modulation (PWM) signals, and there is a variable resistance inside, being the calibration device for the servo machine.

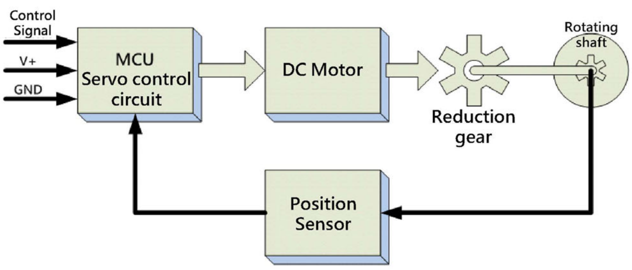

Figure 4. Servo mechanism system block diagram

3 SWMR Auto Parking Algorithm

The SWMR automatic parking algorithm proposed in this paper was based on the experience of people's actual driving. This algorithm detected parking space environment information through ultrasound sensor, searched for a sufficiently large parking space, designed roadside parking, reverse parking, and vertical parking control algorithm, and controlled the wheeled robot to achieve automatic parking. First, the parking interval width was calculated to judge whether there was enough parking space. Second, the roadside parking, reverse parking, and vertical parking algorithms were put forward and were implanted within the embedded microcontroller controller so as to cooperate with ultrasound sensors to detect the parking state and complete the automatic parking.

3.1 Calculation of the Parking Width

The basic strategy was to make the wheeled robot go straight ahead in the driveway, and search for enough space for roadside parking with the right side ultrasound sensor, as the parking space shown in Figure 5. When the ultrasonic distance measurement result was $d_1 < n$, it showed other cars parked by the road, and the wheeled robot would continue to advance, where n was the threshold. When the distance measuring results were greater than the threshold ($d_2 > n$), it suggested the ultrasound could directly hit the metope of the road shoulder; there was no car at the roadside, it began to calculate parking width and judge whether there was enough space for parking. One counter was set up in the program. When the counter result was $c_1 < m$, it showed the parking space was too narrow and was suitable for parking; then, the wheeled robot would continue to advance, where m was another threshold. In addition, when the counter result was greater than the threshold ($c_2 > m$), it showed that a wide parking space was needed; and then, the roadside parking algorithm began. Figure 6 shows the flowchart of the calculation for the parking interval width. The module program of the right side ultrasonic sensor in the program was read, and the value was read to be *ult3* cm, showing the module could get the distance between the right side of the car and barrier, was stored in the ult3 temporary register, being equivalent of the distance between d_1 and d_2 in Figure 5. Second, mr_forward_0 was the module driving SWMR to go straight.

3.2 Roadside Parking Algorithm

Once the wheeled robot detected a large enough parking space and regarded it as one parking space target, it began to execute the roadside parking algorithm. In the first stage, the car moved backward slowly, and read the information of the right side

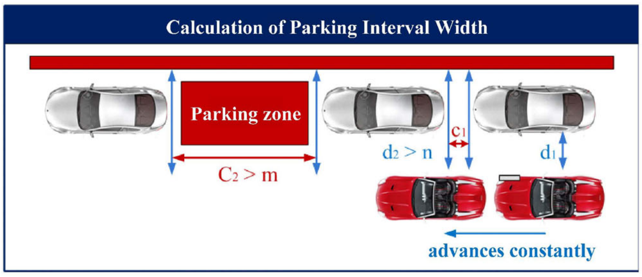

Figure 5. Calculation of parking interval width

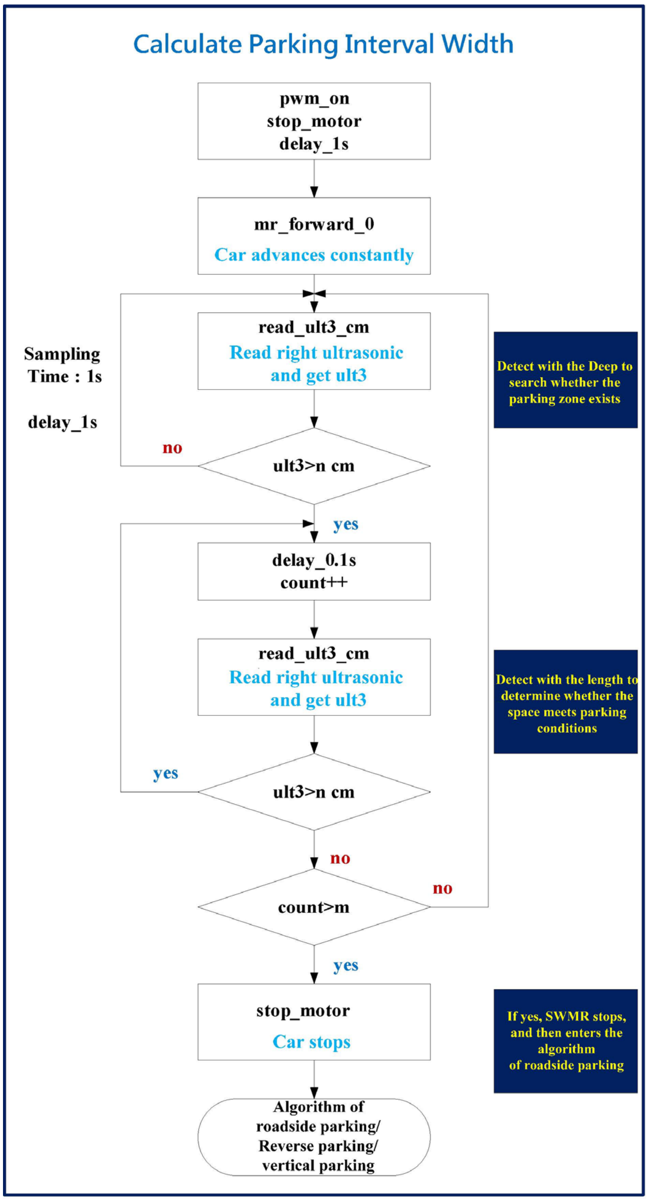

Figure 6. Flow chart of calculation of parking interval width

ultrasound sensor, which was the criteria to judge if the car should be stopped, and it stopped at the roadside. Its function was to make the car stop immediately once it detected the front edge of the parking space when the car moved backwards, or once it detected the front rear edge of the parking space when the car moved forward. The practice was as follows: the reading values of previous ultrasound (*ult3_LB*) and the ultrasound (*ult3_L*) were compared; because there was some error in each ultrasonic distance measurement, a threshold s was set in the program as the basis of the parking conditions. When the car moved backward, refer to Figure 7. A discussion was conducted for several intervals: in section (a), after ultrasound detected the distance of wall, although there was a little change, it must satisfy the condition of $|ult3\_L - ult3\_LB| < s$, and meet the requirements of case II/IV; flag must maintain the original state, and the car continued to retreat. In section (b), there was a car well settled by the side of the road; the previous ultrasound detected walls, whereas the ultrasound detected the roadside car; it must meet the condition of $ult3\_LB - ult3\_L \geq s$, and meet case III; flag was cleared to 0, and the car continued to retreat. The process in section (c) was similar to section (a): ultrasound detected the car parked at the roadside; It met the requirements of case II/IV; flag maintained the original state, and the car continued to retreat. Until section (d), there was a large enough parking space at roadside; the previous ultrasound detected the car parked at the roadside, and the ultrasound could not detect walls, it met the conditions of $ult3\_L - ult3\_LB \geq s$, and the case I; flag was set to be 1; the car stopped, and prepared for the next step. Chk_parking_space_A module was also applied to the state when the car advanced. Refer to the descriptions in Figure 8. A parking cell detection module (chk_parking _space_A) was planned on the roadside parking algorithm. Refer to the flowchart of Figure 9.

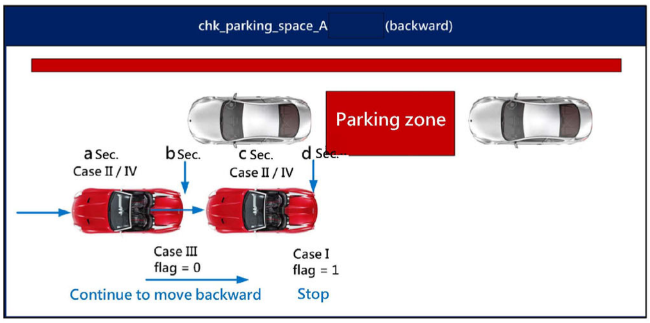

Figure 7. Schematic diagram of parking zone detection module A (Backward)

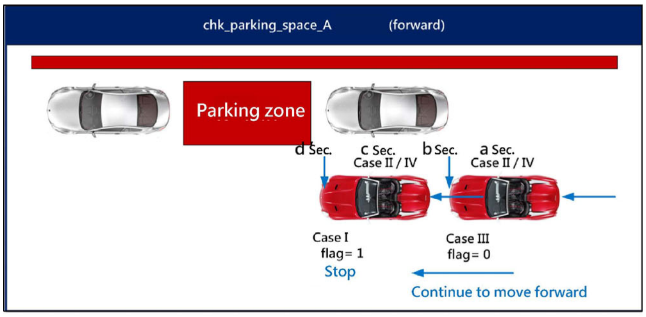

Figure 8. Schematic diagram of parking zone detection module A (Forward)

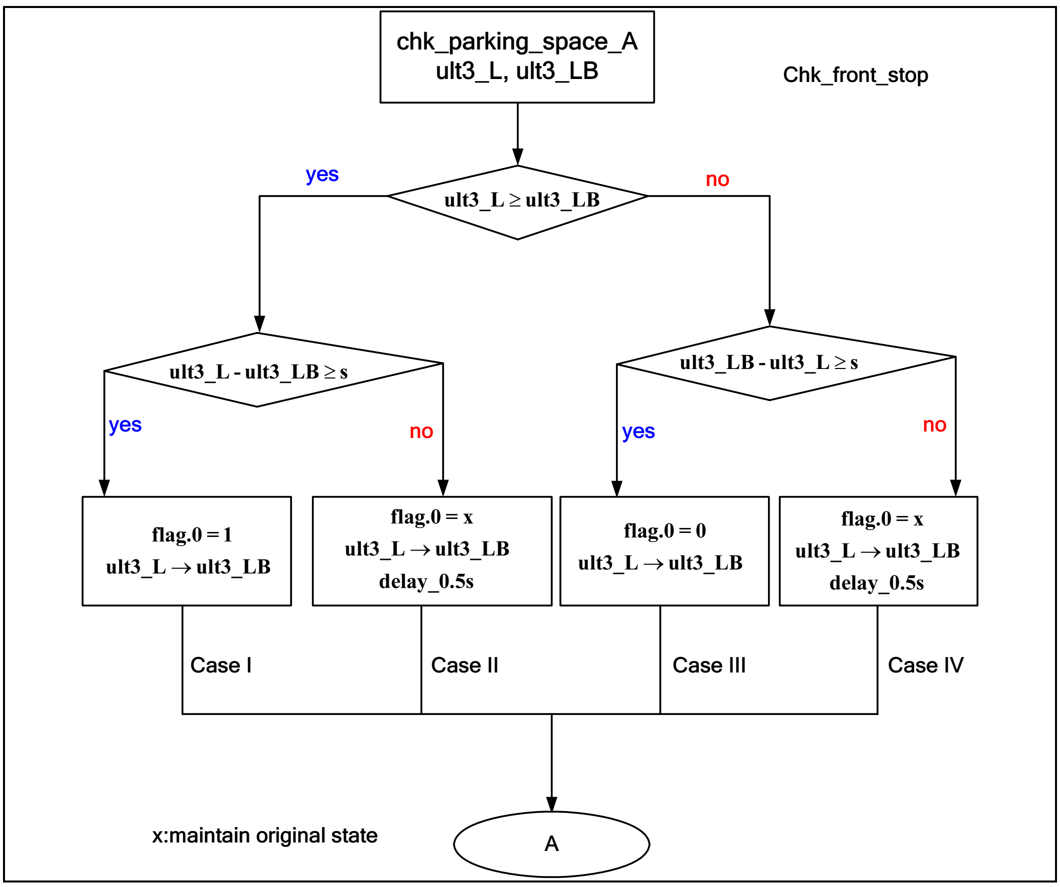

Figure 9. Flow chart of parking zone detection module A

When the wheeled robot moved backward constantly, once it met the stop condition that $flag = 1$, it would enter the second stage of roadside parking algorithms. The wheeled robot adopted *mr_backward_uR* to drive the right and left wheels to spin towards the right rear. At the time, the right rear ultrasound and the rear ultrasound were started, respectively, and their reading values were *ult3_L* and *ult2_L*, respectively. At the point, the car turned slowly to the right rear and then entered the parking zone, as shown in Figure 10. Once the right side ultrasound detected and found that the distance with the front car was less than b and the rear ultrasound detected and found the distance with the wall was less than a, (that is, the conditions $ult2\_L < a$ and $ult3\_L < b$ established), the car no longer turned to the right rear, but entered the next stage of roadside parking.

Figure 10. Conditions for the car to spin towards the right rear and stop

In the third stage, the wheeled robot adopted the mr_backward_bL module to drive the right and left wheels to spin to the left rear so as to make the right and rear ultrasound detect the distance to the wall, so that the subsequent car would be able to return to the middle position, parallel to the wall, and achieve the automatic parking. As shown in Figure 11, the practice was to read the distance between ultrasound and wall (ult2_L); when the distance value was less than setting threshold c, namely, $ult2\_L < c$, based on the wheeled robot experimental results, the right ultrasound could detect the distance to the wall successfully. Then, the wheeled robot continued to rotate towards the left rear, enter the next phase, and return to the middle position, and parallel to the wall.

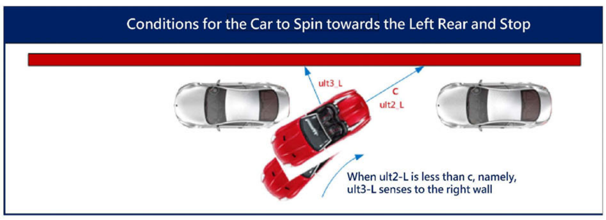

Figure 11. Conditions for the car to spin towards the left rear and stop

In the fourth stage, the wheeled robot stilled adopted the turning radius of the mr_backward_bL module to drive the right and left wheels to spin to the left rear so as to return to the middle position, parallel to the wall, and achieve automatic parking, as shown in Figure 12. The algorithm compared the reading of the previous ultrasound (ult3_LB) and the ultrasound (ult3_L). In the parking process, the right side ultrasonic distance measuring value decreased gradually; if it was greater than or equal to the previous range of value ($ult3\_L \geq ult3\_LB$), it showed that the wheeled robot returned to the middle position, parallel to the wall, and stopped. In addition, the robot might stop when the rear ultrasonic ranging value was less than or equal to the threshold value d, showing it was too close to the rear car, and it must stop retreating immediately.

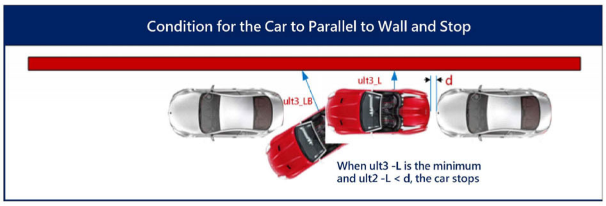

Figure 12. Condition for the car to parallel to wall and stop

The last phase was to adjust the position of the wheeled robot in the parking zone and ensured it was in the middle of the two cars, as shown in Figure 13. In this paper, the practice was to read two ultrasonic ranging values, and take their average code. When the front ultrasonic ranging value was greater than the rear ultrasound, the wheeled robot would move forward, and stop until $ult1\_L \leq code$. When the front ultrasonic ranging value was less than the rear ultrasound, the wheeled robot would move backward, and stop until $ult2\_L \leq code$. The above steps were the five stages of the roadside parking algorithm proposed in this paper. The detailed process was shown in Figure 14 and Figure 15.

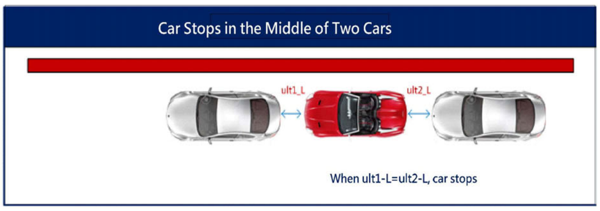

Figure 13. Car stops in the middle of two cars

3.3 Reverse Parking Algorithm

Prior to the reverse parking algorithm, the SWMR still needed to detect the parking interval width. Once the wheeled robot detected a large enough parking space, and regarded it as the parking zone target, it began to perform the reverse parking algorithm. In the first phase, the wheeled robot adopted mr_backward_uR turning radius to drive wheels to spin towards the right rear, start the rear ultrasound, and read the measurement value of ult2_L. At this point, the car turned towards the right rear slowly and entered the parking zone, as shown in Figure 16. Once the rear

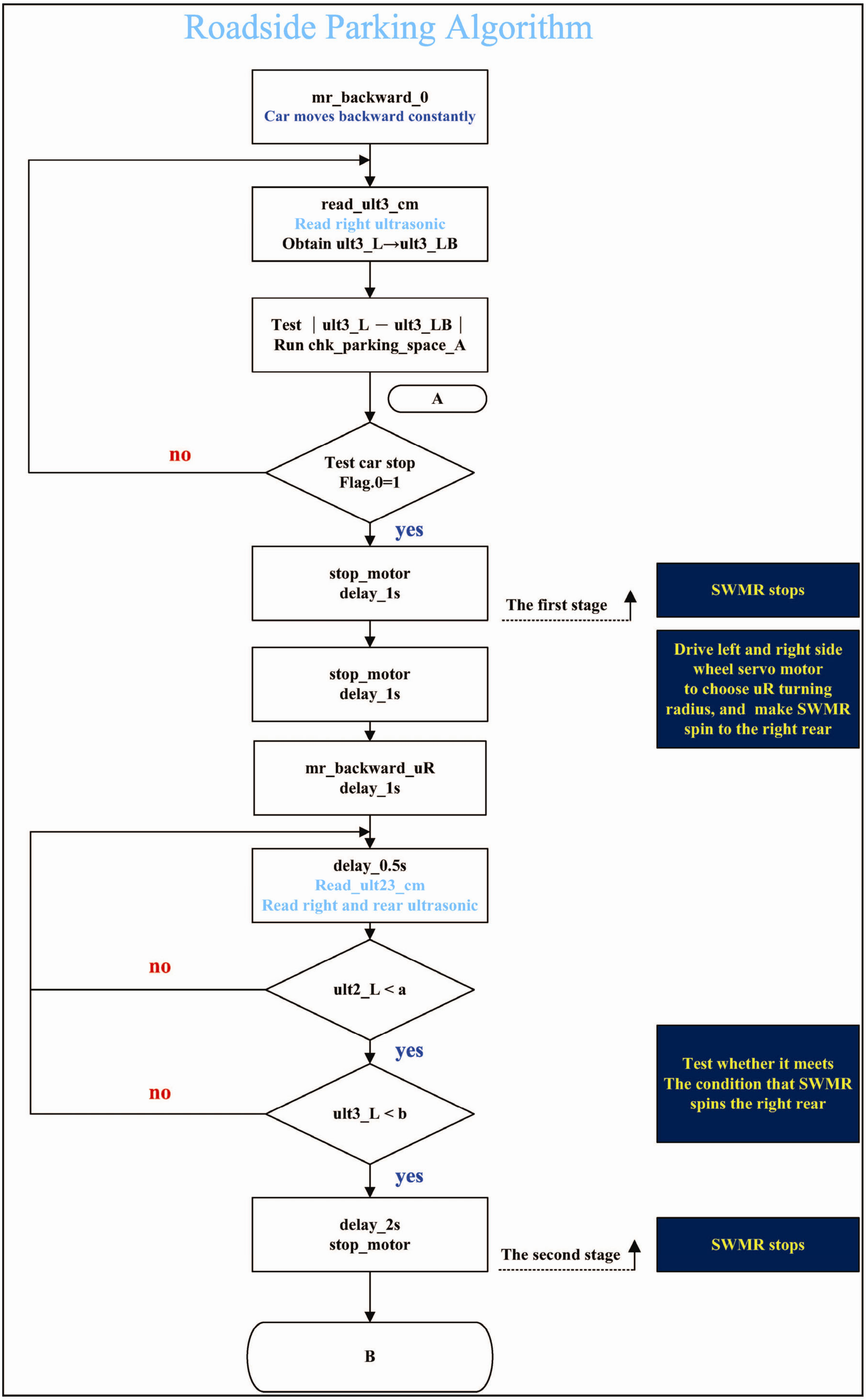

Figure 14. Roadside parking algorithm (I)

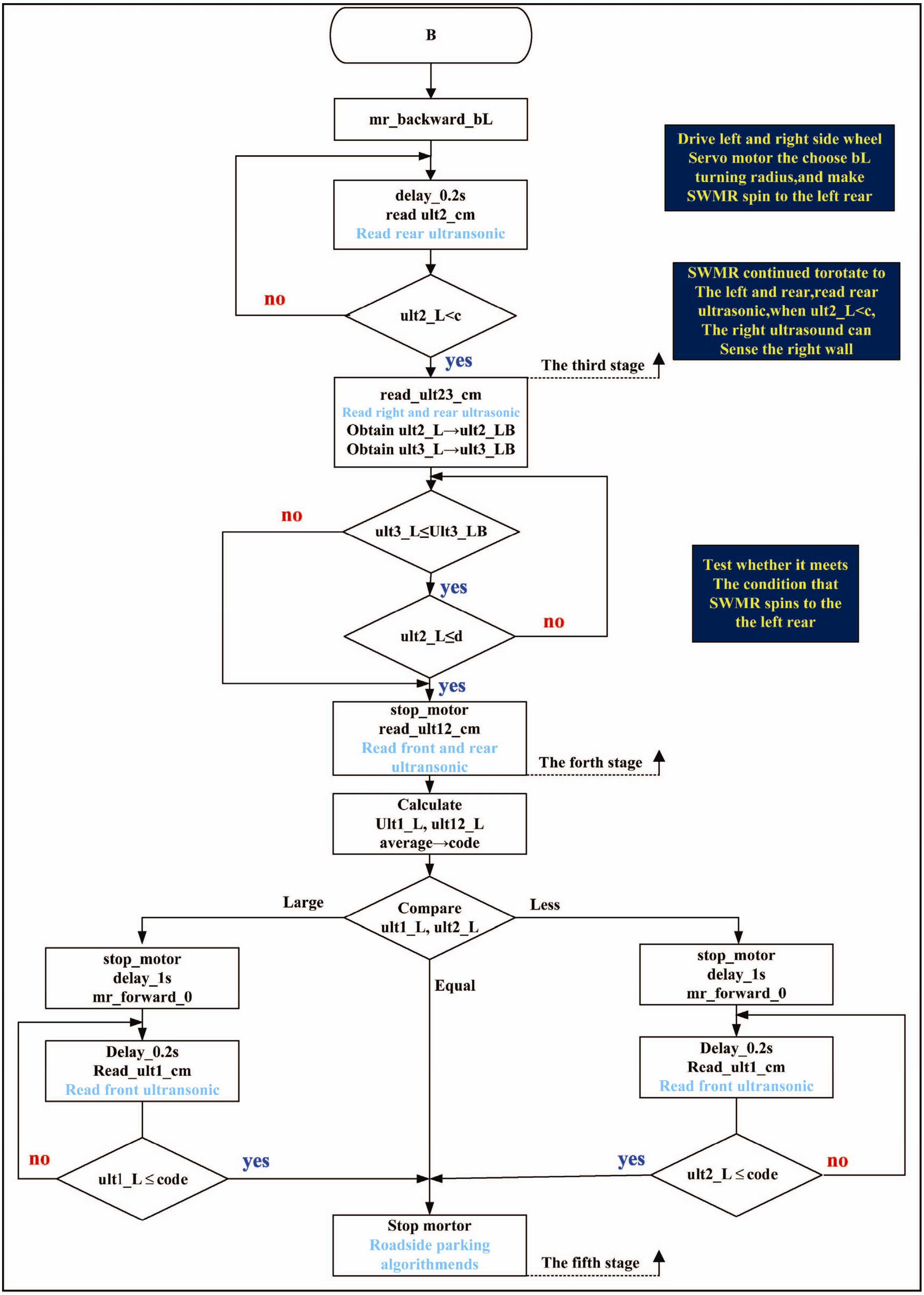

Figure 15. Roadside parking algorithm (II)

ultrasound was detected and found that the distance with the wall was less than e (the condition $ult2\_L < e$ established), the car no longer turned towards the right rear, but entered the next stage of the roadside parking.

In the second stage, the wheeled robot still used the mr_backward_uR turning radius to drive the wheels to spin towards the right rear so that the car is able to return to the middle, perpendicular to the wall, and achieve the automatic parking, as shown in Figure 17. The algorithm compared the reading of the previous ultrasound (*ult2_LB*) and the ultrasound (*ult2_L*). In the process of parking, the rear ultrasonic distance measuring value decreased gradually, and if it was greater than or equal to the previous range value ($ult2\_L \geq ult2\_LB$), it showed the wheeled robot returned to the middle, was perpendicular to the wall, and stopped.

The last phase was to adjust the position of the wheeled robot in the parking zone and ensure the robot was close to the wall, as shown in Figure 18. The specific practice of this paper was to read the rear ultrasound range value, and make the car move slowly to the rear; once the rear ultrasound detected and found the distance with wall was less than f (the condition $ult2\_L < f$ established), the car would stop immediately. The above steps were the three phases of the reverse parking algorithm. The detailed process is listed in Figure 19.

Figure 16. Condition for car to spin towards the right rear and stop

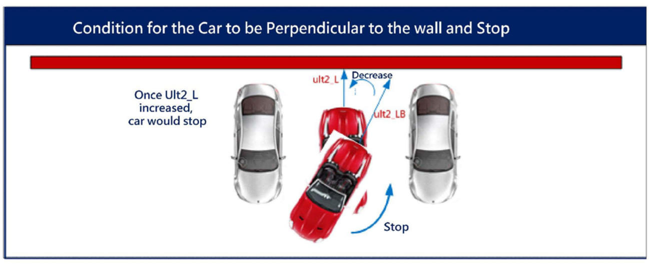

Figure 17. Condition for the car to be perpendicular to the wall and stop

Figure 18. Condition for car to complete reverse parking and stop

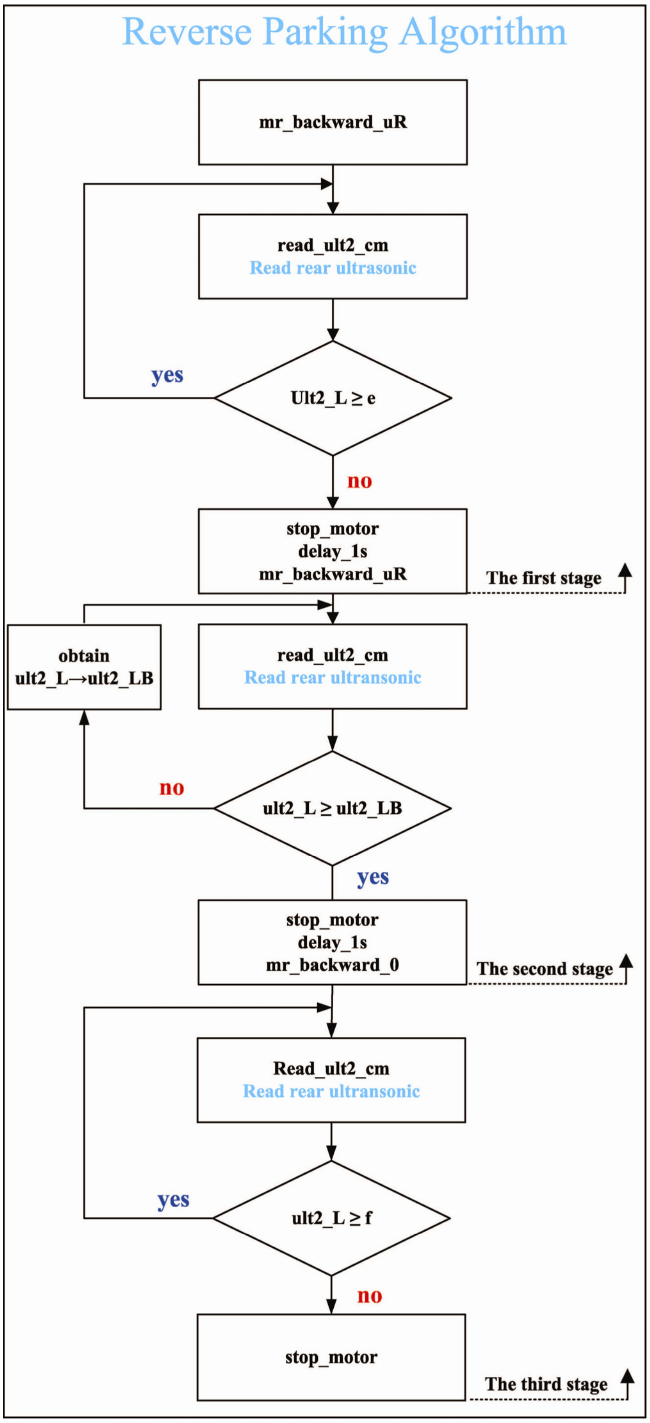

Figure 19. Reverse parking algorithm

4 Experimental Results & Functional Tests

The experiment was conducted on the site combined by six 320 × 320 mm soft mats. On the site, 3D printer was adopted to print and produce six pieces of walls dominated by red. Three sidewalls were set up at the top and bottom. Besides, the experiment made three model cars with a 3D printer and adopted them as the parked cars inside the parking space to simulate the following parking experiments, as shown in Figure 20.

Figure 20. Experiment site

4.1 Roadside Parking Function Test

In this paper, the roadside parking experiment was divided into two parts. The first part was about the judgment of the parking interval. First, the wheeled robot moved straight in the driveway, and searched enough space for roadside parking target through the right side ultrasound sensor, as shown in Figure 21 to Figure 23. The second part was about the roadside parking algorithm test, and it was subdivided into five stages. At the first stage, the car moved backward slowly, and read the information of the right side ultrasound sensor, which was taken as the criterion to judge the car stop or park at the roadside, as shown in Figure 24. At the second stage, the wheeled robot adopted the mr_backward_uR turning radius to drive the wheels to spin to the right rear, and start right side ultrasound and rear ultrasound to make the car spin slowly to the right rear and enter the parking space, as shown in Figure 25. At the third stage, the wheeled robot adopted the mr_backward_bL turning radius to drive the wheels to spin to the left rear so as to make the right side and the rear ultrasound detect the distance to the wall. At the fourth stage, the wheeled robot adopted the mr_backward_bL turning radius to drive the wheels to spin to the left rear so as to make the robot return to the middle and be parallel to the wall, as shown in Figure 26. At the fifth stage, the position of the wheeled robot in parking zone was adjusted so as to make the robot be in the middle of two cars, as shown in Figure 27. For the parking steps of stage 1-5, refer to the flowcharts in Figure 14 to Figure 15.

Figure 21. Detection of parking interval (roadside parking)

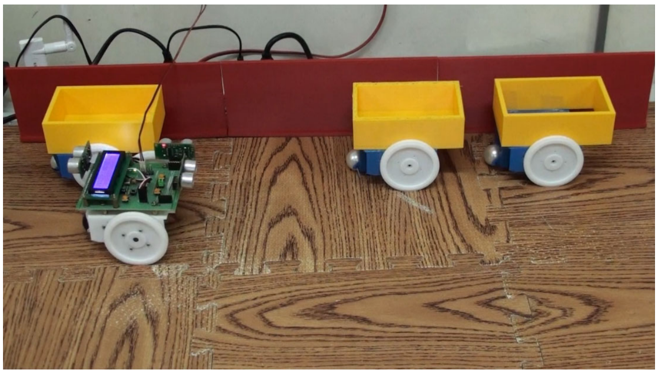

Figure 22. Judgment of parking interval (roadside parking)

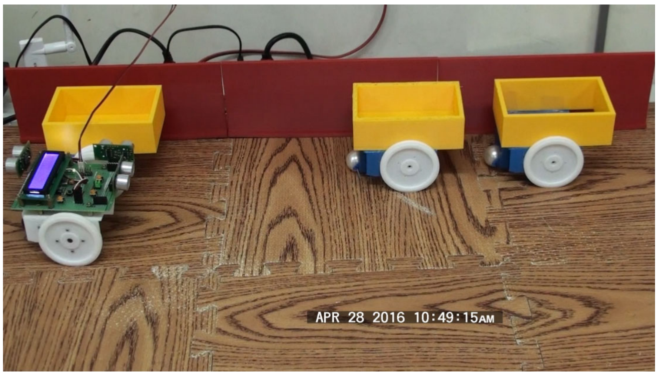

Figure 23. Completion of the detection of parking interval (roadside parking)

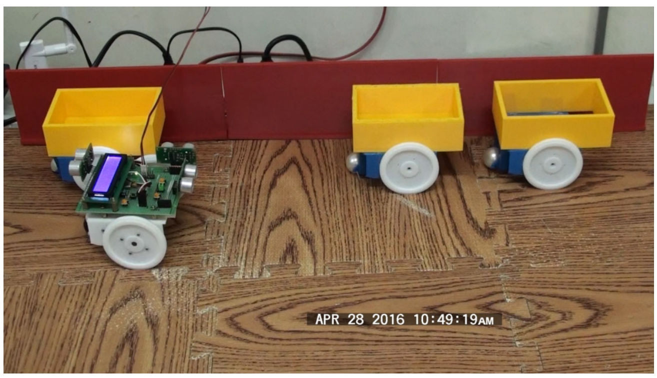

Figure 24. Completion of the first stage of roadside parking

Figure 25. Completion of the second stage of roadside parking

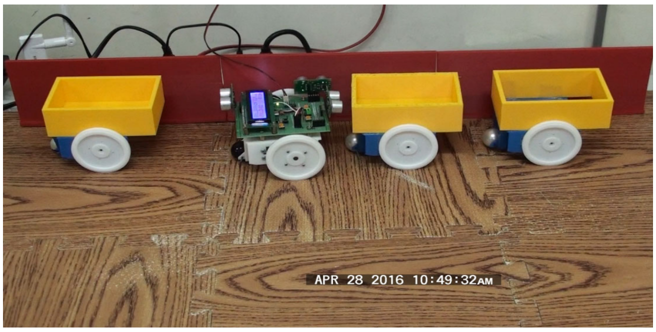

Figure 26. Completion of the third and fourth stage of roadside parking

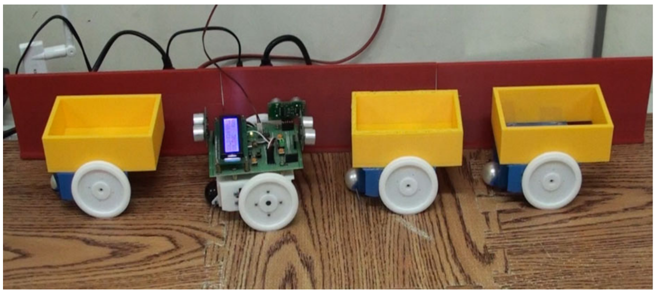

Figure 27. Completion of roadside parking

4.2 Reverse Parking Function Test

In the experiment, the reverse parking experiment was divided into two parts. The first part was about the judgment for the parking interval. First, the wheeled robot moved straight in the driveway, and searched for enough space for the roadside parking target through the right side ultrasound sensor, as shown in Figure 28 to Figure 30. The second part was about the reverse parking algorithm test, and it was subdivided into three stages. At the first stage, the car moved backward slowly, and read the information of the right side ultrasound sensor, which was taken as the criterion to judge the car stop or park at the roadside, as shown in Figure 24. At the first stage, the wheeled robot adopted the mr_backward_uR turning radius to drive the wheels to spin to the right rear, and start rear ultrasound and make the car spin slowly to the right rear and enter the parking space, as shown in Figure 31. At the second stage, the wheeled robot adopted the mr_backward_uR turning radius to drive the wheels to spin to the right rear so as to make the robot return to the middle and be perpendicular to the wall and achieve the automatic parking, as shown in Figure 32. At the third stage, the position of the wheeled robot in the parking zone was adjusted so as to make the robot close to the wall, as shown in Figure 33. For the parking steps of stage 1~3, phase refer to Figure 19 flowchart.

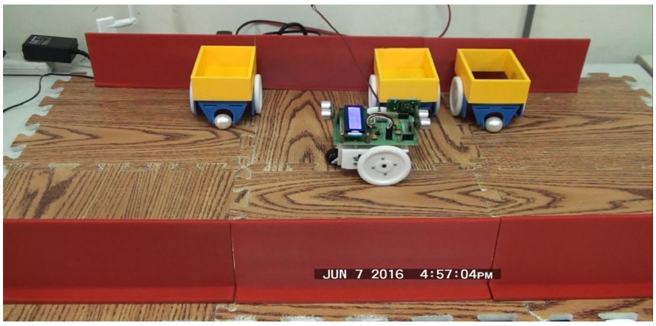

Figure 28. Detection of parking interval (reverse parking)

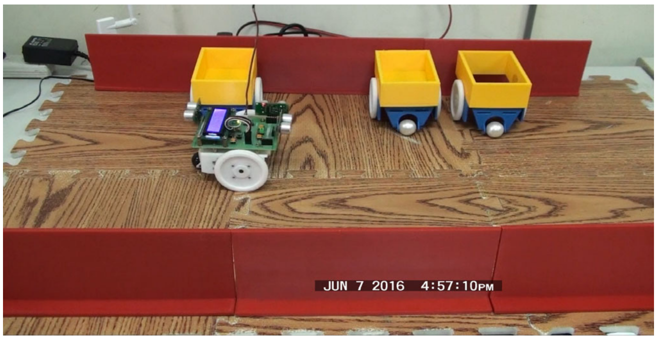

Figure 29. Judgment of parking interval (reverse parking)

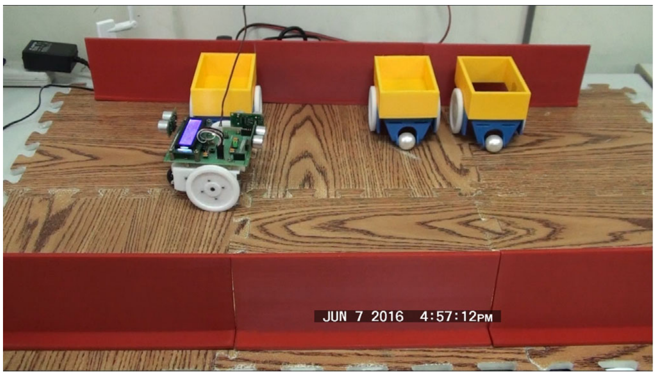

Figure 30. Completion of the detection of parking interval (reverse parking)

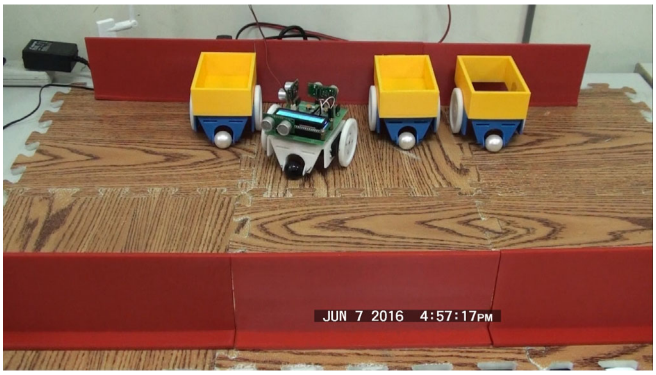

Figure 31. Completion of the first stage of reverse parking

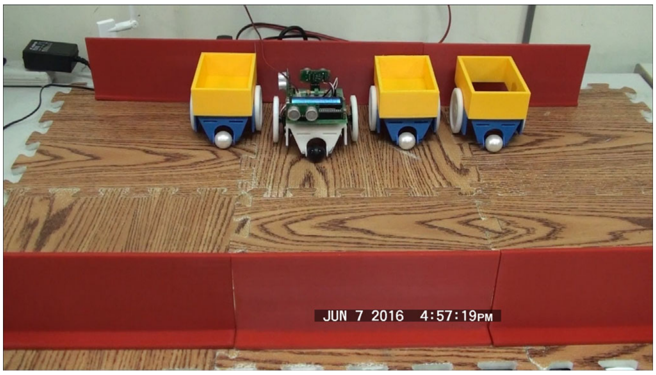

Figure 32. Completion of the second stage of reverse parking

Figure 33. Completion of the reverse parking

5 Conclusions

This study completed the design of ultrasound sensor automatic parking system design algorithm and the realization of its hardware and software. Ultrasound sensors were used to detect parking space environment information, and determine whether there was enough parking space. Besides, the study designed the control law of roadside parking and reverse parking, applied the turning radius movement patterns, and conducted detailed theoretical analysis. This experiment only used ultrasonic sensors, considered the wheeled robot as the basis of distance judgment, and conducted the parking calculation. In the process of a large number of experiments, it was found that the safety and high precision demand for automatic parking system could not be met if only ultrasonic sensors were used to capture environment parameters. Future researches will use the camera auxiliary to capture videos so as to get more accurate environmental parameters for judgment, and thus the wheeled robot can achieve perfect results in the automatic parking technology.

References

[1] S. Ma, H. Jiang, M. Han, J. Xie, C. Li, Research on Automatic Parking Systems Based on Parking Scene Recognition, *IEEE Access*, Vol. 5, pp. 21901-21917, October, 2017.

[2] Y. Wang, I. Stojmenovic, X. Y. Li, Bluetooth Scatternet Formation for Single-hop Ad Hoc Networks Based on Virtual Positions, *Journal of Internet Technology*, Vol. 6, No. 1, pp. 43-52, January. 2005.

[3] A. Rezaei, J. B. Burl, M. Rezaei, B. Zhou, Catch Energy Saving Opportunity in Charge-Depletion Mode, a Real-Time Controller for Plug-In Hybrid Electric Vehicles, *IEEE Transactions on Vehicular Technology*, Vol. 67, No. 11, pp. 11234-11237, August, 2018.

[4] C. Wang, B. Huang, W. Xu, An Integrated Energy Management Strategy With Parameter Match Method for Plug-In Hybrid Electric Vehicles, *IEEE Access*, Vol. 6, pp. 62204-62214, October, 2018.

[5] A. Mondal, S. Misra, Game-Theoretic Energy Trading Network Topology Control for Electric Vehicles in Mobile Smart Grid, *IET Networks*, Vol. 4, No. 4, pp. 220-228, July, 2015.

[6] Y. Lee, S. Chang, Development of a Verification Method on Ultrasonic-Based Perpendicular Parking Assist System, *The 18th IEEE International Symposium on Consumer Electronics (ISCE 2014)*, Jeju Island, South Kore, 2014, pp. 1-3.

[7] T. Rajabioun, B. Foster, P. Ioannou, Intelligent Parking Assist, *21st Mediterranean Conference on Control and Automation*, Crete, Greece, 2013, pp. 1156-1161.

[8] T. Cho, S. H. Seo, I. You, A Remote Control System for Cloud-Based Smart Homes Supporting Dynamic User Management, *Journal of Internet Technology*, Vol. 15, No. 6, pp. 1069-1081, November, 2014.

[9] T. H. S. Li, S. J. Chang, Y. X. Chen, Implementation of Human-Like Driving Skills by Autonomous Fuzzy Behavior Control on an FPGA-Based Car-Like Mobile Robot, *IEEE Transactions on Industrial Electronics*, Vol. 50, No. 5, pp. 867-880, October, 2003.

[10] K. Jiang, L. D. Seneviratne, A Sensor Guided Autonomous Parking System for Nonholonomic Mobile Robots, *Proceedings 1999 IEEE International Conference on Robotics and Automation*, Detroit, MI, 1999, pp. 311-316.

[11] K. Jiang, D. Z. Zhang, L. D. Seneviratne, A Parallel Parking System for a Car-like Robot with Sensor Guidance,

Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, Vol. 213, No. 6, pp. 591-600, June, 1999.

[12] H. Miyata, M. Phki, Y. Yokouchi, M. Ohkita, *Control of the Autonomous Mobile Robot DREAM-1 for a Parallel Parking, Mathematics and Computes in Simulation*, Vol. 14, No. 1-2, pp. 129-138, June, 1996.

[13] L. Zhang, D. Li, Research on Mobile Robot Target Recognition and Obstacle Avoidance Based on Vision, *Journal of Internet Technology*, Vol. 19, No. 6, pp. 1879-1892, November, 2018.

[14] S. S. D. Xu, H. C. Huang, Y. C. Kung, S. K. Lin, Collision-Free Fuzzy Formation Control of Swarm Robotic Cyber-Physical Systems Using a Robust Orthogonal Firefly Algorithm, *IEEE Access*, Vol. 7, pp. 9205-9214, January, 2019.

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