Parking Path Programming Strategy for Automatic Parking System

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Abstract

The paper provides a simple parking path programming strategy for automatic parking system (APS). The control strategy employs the minimum turning radius of the vehicle by means of a distance infrared sensor to determine the parking path. The programming strategy can simplify the analysis of the parking path; therefore, there is no need to apply any expensive sensors and complex mathematical calculation to determine the parking path. In the experiment, a four- wheel model vehicle has been tested in combination with an microprocessor (ARM 9) and a distance infrared sensor. A vehicle could be safely and correctly parked in the parking space by following these routes.

Index Terms

ARM 9; Inverter; Model Vehicle; Parallel Parking Route

Introduction

In a modern society marked by continuous technological innovations, improving public safety systems is considered a barometer of true growth; and the same for the aid system used for parking safety. Of these, back-up warning is the most commonly used in preventing collisions caused by various factors such as blind angle or blurred vision. This article proposes an optimized route scheme for roadside parking, while considering the surrounding environment and the positioning of vehicles. Various choices involved in positioning sensors include infrared rays, distance infrared sensor, ultrasonic radar and image processing, through which the evasion of obstacles during vehicle positioning can be completed through the feedback data of the sensors. Generally speaking, the surface of objects in the sensor environment may have various shapes such as arc, angle and so on, and these should be analyzed via different calculations. The obstacles can be detected by distance infrared sensor, and visual observation. The use of various sensors will increase the sensing force for the motions of a vehicle and provide it with the ability to adapt the environment and complete the work.

In general, the body of the vehicle is square-shaped, with four wheels and two variations limiting the motion: linear (forward and backward) and turning variation (change of direction). When the turning angle is limited, it also limits the curvature of the route, leading to the change of tangent direction of the vehicle. Previous studies have provided designs and research rules for the parking route planning and orbit. For instance, the triangular function design has been used for tracking and controlling the orbit in order to follow the reference of the orbit route by the feedback linearity of the input status; which controls the steering angle and forward position through the motion formula of the vehicle, allowing the vehicle to complete the parking action within the shortest route. Another work studies the curvature radius for the parallel parking of vehicles on the roadside, as proposed through the Non-Holonomic system. The first research method provides a five-stage multinomial route orbit through the limits of slope and curvature as this multinomial has certain correlation with the curvature of vehicle motions. In contrast, the second research method uses an independent moving robot to realize the 3-step strategy: (1) designing a route in the current system model; (2) splitting this route until it can be connected to all terminals via the shortest route; and (3) executing the optimized program to shorten the route. The last method is the SCC-Path (Simple Continuous Curvature Path), in which the orbit motion of the vehicle is deduced through the Non-Holonomic method. The process of motion uses continuous turning curves to meet the actual vehicle motions and determine the correct route of orbit planning. However, these methods require lengthy periods of orbit planning and need to control the rotating angle repeatedly for path tracking. The drawback is that it will cause the life time of tires to be shorter. The paper proposes a simple algorithm for parking. As long as the distance between the vehicle and boundary of parking space is obtained, and the minimum rotating radius can be refer to achieve parking behavior. Based on the descriptions above, the proposed method has advantages of simple operation and life time increment of tires.

Parking Strategy

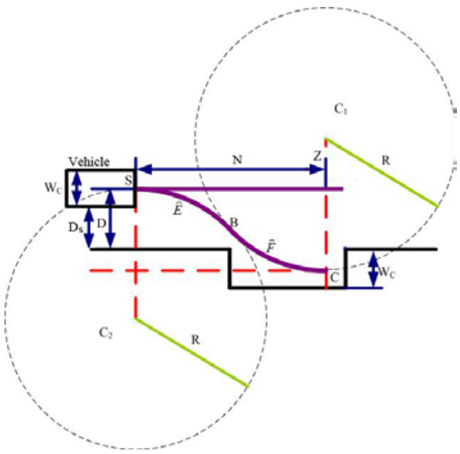


FIGURE 1 PARKING ORBIT

As indicated in Figure 1, the parking orbit proposed in this article has four steps with which the parking process can be completed. Before the basic vehicle dynamic analysis, there are three assumptions, first of which is that the vehicle must be driven by the front wheels, and the rear wheels must be paralleled; and the second is that there is no gliding between tires and ground, while thethird, the angle of the two front wheels must be the same as the turning angle; the last, the center of the rear bumper is the main reference point. Hence, the vehicle dynamic analysis will be processed through the statements above. The first step measures the side distance D_s with the distance detection radar; while the second step determines the distance M from the start point Z to point S by the known distance D_s, which requires entering the vehicle back-up mode; and the third step determines the arc distance E from start point S to point B from the known distance D_s. When the vehicle moves from point S to the turning point B, it will enter the final phase. Given that the rotating distance for the two sections is the same, the vehicle back-up distance needed from points B to C can be determined to complete the action of parking. The method proposed in this article uses the maximum steering angle of the vehicle since the demand for the steering angle of the parking action can create two circles, namely, C_1 and C_2 (using the minimum rotating radius of the vehicle R). When the center point of the circle C_1 is fixed, and the two circles C_1 and C_2 create a tangent line (point B), the starting point of the reverse steering angle of the vehicle can be determined. This means that the parking action can be easily completed as long as the starting point of the vehicle parking and the vehicle reverse steering angle are known.

The change of back-up starting point as indicated in Figure 2 will create different back-up starting points (S_1, S_2 to S_n) with the change of distance between the center of the rear bumper and the site D (D_1, $D_2 \ldots D_n$). Moreover, the moving distance M from the original point Z to the starting point will also change (M_1, $M_2 \ldots M_n$).

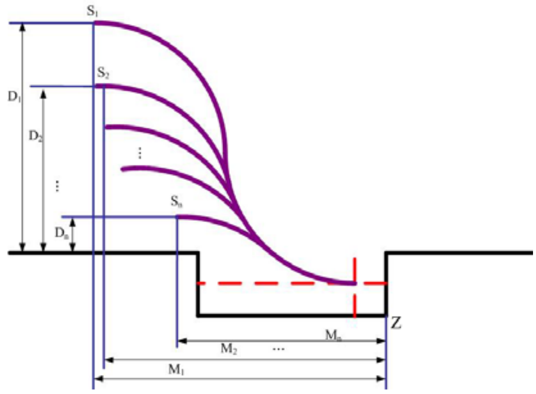


FIGURE 2 CHANGE OF BACK-UP START POINT

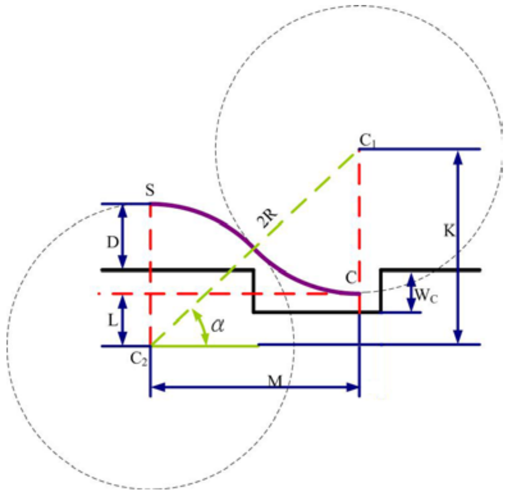


FIGURE 3 RELATIONSHIP OF THE VEHICLE BACK-UP STARTING POINT

The decision determining the vehicle back-up starting point must first be discussed. As indicated in Figure 3, the vehicle back-up starting point S to the vehicle back-up end point C can form a group of back-up routes (represented by purple arc lines). The center points of C_1 and C_2 can form a right triangle wherein 2R is the hypotenuse and α is the included angle. The relationship among α, D, and N can thus be determined using the trigonometric function theory:

$$\alpha = \sin^{-1}\left(\frac{2R-(W_C/2)-D}{2R}\right) \quad (1)$$

$$D = D_s + \frac{1}{2}W_C \quad (2)$$

and

$$N = 2R\cos\left[\sin^{-1}\left(\frac{2R-\left(W_C/2\right)-D}{2R}\right)\right] \quad (3)$$

$$M = N + P_d \quad (4)$$

Where D_s is the distance measured by distance infrared sensor, W_C is the car width. P_b is the safe marginal distance of the reversed vehicle; M is the required distance from the starting point Z to the vehicle back-up starting point, W_C is the width distance of the vehicle, and R is the minimum rotating radius of the vehicle. The data presented above can be obtained in advance.

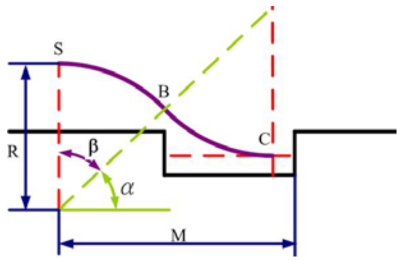


FIGURE 4 RELATIONSHIP BETWEEN *B* AND *A*

When the starting point S is determined, it will determine the position of the tangent point B from the relationship between α and β. In the figure 4, the relationship between α and β can be observed as indicated in Equation (5):

$$\beta = 90 - \alpha \quad (5)$$

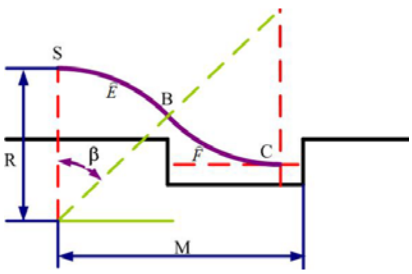


FIGURE 5 RELATIONSHIP BETWEEN *B* AND ARC LENGTH

Finally, the position of point B can be determined from the relationship between β and α. The arc length is indicated in Figure 5. $\hat{E}$ equal to $\hat{F}$ is an arc that takes the minimum rotating radius R as the radius. Therefore, $\hat{E}$ can be obtained as long as β is known, as indicated in Equation (6):

$$\hat{E} = 2\pi R \times \left(\frac{\beta}{360}\right) \quad (6)$$

Where β can be determined from Equation (5), and the distance from points S to B can be determined by substituting it with Equation (6). Therefore, the position of point B can be determined.

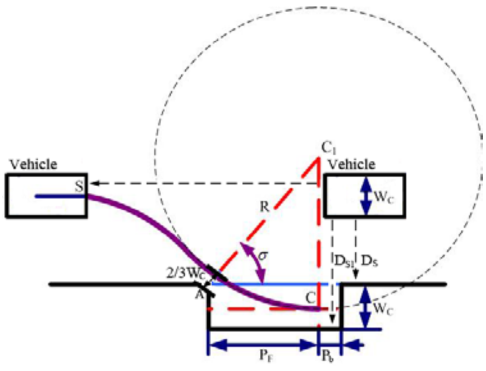


FIGURE 6 ILLUSTRATION OF PARKING SPACE

After the parking path is determined, the parking space should be estimated whether it is larger enough to accomplish parking behavior. Figure 6 shows the size of the parking space. When the vehicle moves forward, the sided ultrasonic radar of the vehicle can measure the distance of D_S and D_{S1}. Therefore, the width of the parking space can be calculated, and also its the actual size of can be estimated by forward distance. The following content will mention about the calculation of size for a parking space. Referred to Fig.6, the minimum width of the parking space is equal to the width of the vehicle (W_C). To avoid the front edge of the vehicle crashing point A of the parking space, the minimum distance from the front edge of the parking space to the circle center, C_1, should plus a rotating radius, R, for safety distance margin that should be larger two third than the original width of the vehicle; hence, the crashing situations can be avoided. σ can be obtained by using trigonometric function theorem. As shown in Eq. (7):

$$\sigma = \sin^{-1}\frac{R-(2W_C/3)}{R+(2W_C/3)} \quad (7)$$

The equation of σ and P_F can be expressed in Eq.(8):

$$\cos\sigma = \frac{P_F}{R+(2W_C/3)} \quad (8)$$

At last, Eq.(7) is substituted into Eq.(8), and the minimum length of the parking space can be determined.

$$P_{F(min)} = (R+(2W_C/3)) \times \cos\left(\sin^{-1}\frac{R-(2W_C/3)}{R+(2W_C/3)}\right) \quad (9)$$

Known from Eq.(9), the size of parking space is relative to the minimum rotating radius of the vehicle. If the rotating radius is smaller, the parking space can also be smaller. Here is an example for the proposed paper by using an experimental vehicle. The minimum rotating radius, R, is 95 cm, besides, the width and length are 20 cm and 40 cm, respectively. This information is referred to the profile of the vehicle. Because the width of the vehicle is determined, the minimum width of the parking space will be determined, which is 20 cm. The length of the parking space is 71.2 cm by using Eq. (9).

$$P_{F(min)} = \left(95+\left(40/3\right)\right)\times cos\left(sin^{-1}\frac{95-\left(40/3\right)}{95+\left(40/3\right)}\right) = 71.2 \quad (10)$$

Algorithm

Fig .7 shows the block diagram of the auto parking system which consists of sensors, wheel encoders, MCU, user interface, steering wheels, and speed controllers. The software algorithm is developed by the structure of the system in this paper.

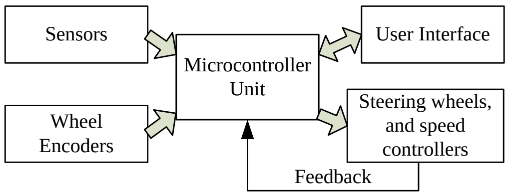
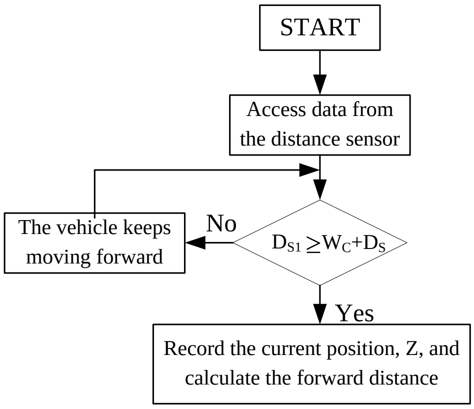
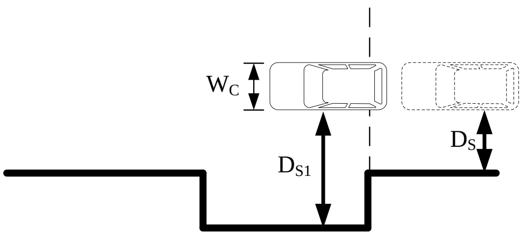


FIGURE 7 BLOCK DIAGRAM OF APS



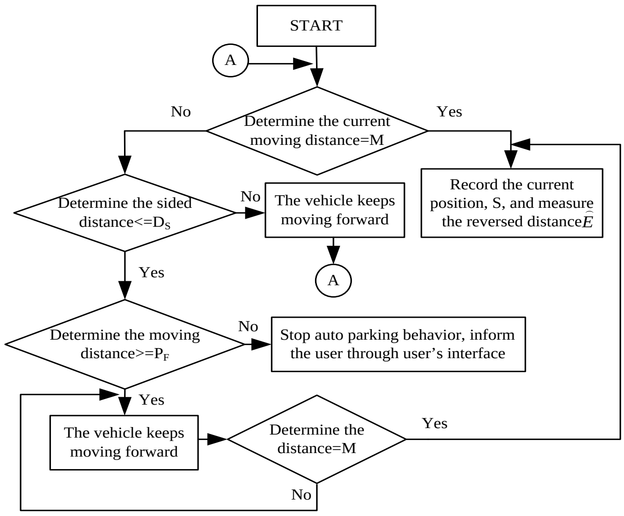
(a)



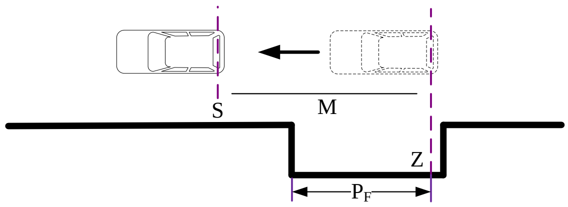
(b)

FIGURE 8 (A) FLOW CHART OF THE 1ST MOVEMENT (B) ILLUSTRATION OF PARKING BEHAVIOR

As following, the flow chart and the parking illustration will explain the principle of the entire auto parking behavior. At first, when the MCU receives the auto parking command by the user's interface, the MCU will trigger the infrared sensor to calculate the distance (D_S) between the vehicle and the edge of the parking space. Also, Eq. (3) and Eq.(4) can calculate the forward distance(M) of the vehicle. Later, the vehicle starts to move and detect the distance of the edge for the parking space to meet $D_{S1} \geq W_C+D_S$. Once the equation is established, it means that the correct position, Z, is reached. On the other hand, the vehicle keeps moving and detecting the distance D_{S1} again, as shown in Fig. 8 (a) (b).



(a)



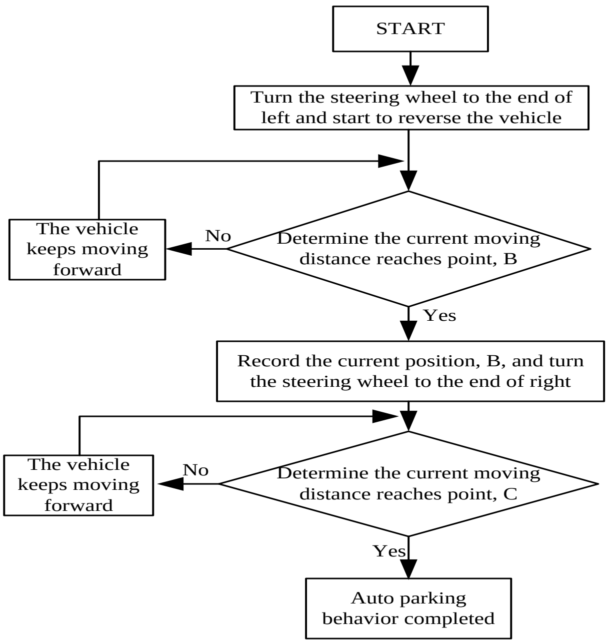
(b)

FIGURE 9 (A) FLOW CHART OF THE 2ND MOVEMENT (B) ILLUSTRATION OF PARKING BEHAVIOR

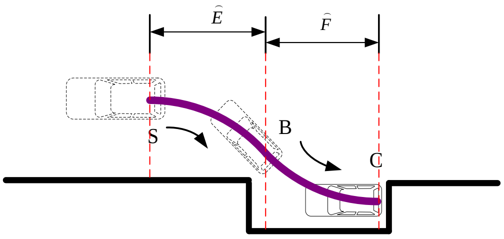
Next, when the vehicle moves back to reach to position, Z, the forward distance for the vehicle starts to be calculated. To compare with the moving distance and M obtained from the path formula, it helps to judge the forward distance on whether it reaches S or not. Once the forward distance and M are equal, it shows that the vehicle arrives to the destination exactly. If not, the vehicle keeps detecting until the forward distance and M are the same, as shown in Fig. 9(a) (b). When the vehicle reaches S, the MCU starts to calculate the reversed distance to make sure that $\hat{E}=\hat{F}$. Besides, the vehicle can determine the parking space which is larger enough or not.

For example, when the vehicle moves forward, the sided distance sensed by the infrared sensor has to meet D_S. Therefore, the length of the parking space, D_S, can be determined, and Eq. (9) will determine whether the parking space is larger enough or not.

Finally, step 3 and 4 will be the accomplished parking behavior in the end. When the vehicle enters into starting point, S, the steering wheel will be turned to left to the end. Thus, the vehicle switches to reversed parking mode. In the meantime, the MCU will also calculate the distance until the vehicle reaches the reversing point, B. If the vehicle reaches B, the MCU will command the vehicle to turn right of the steering wheel to the end. Then, the vehicle starts to be reversed to move into the parking space. The whole parking behavior is accomplished. Therefore, due to the importance of the reversing point, as shown in Fig. 10(a)(b), the flow chart is about how to find a reversing point.



(a)



(b)

FIGURE 10 (A) FLOW CHART OF THE 3RD AND 4TH MOVEMENT (B) ILLUSTRATION OF REVERSED PARKING BEHAVIOR

Through the description above, the proposed parking strategy can help to park the vehicle into the parking space accurately with only two times rotating behavior. Hence, the MCU does not need to compute complex formulas. With respect to the sensor part, there is no need to use any expensive sensor (ex, a CCD sensor). It only requires a distance-infrared sensor to achieve the goal. Hence, the cost of the system can be lowered.

Experimental Results

Table I shows the related data of the experimental vehicle in the paper. When the distance from the side of the vehicle to the edge is determined (D_s = 20 cm), M = 120 cm, $\widehat{E} = \widehat{F}$ = 62.78 cm can be obtained by using equation (4) and (6). Referred to the parameters, the parking path can be drawn with AUTOCAD software, as shown in Fig. 11. Therefore, the proposed method can achieve parking motion simply. As shown in Fig. 12, it is the auto parking illustration of an experimental car whose proportional scale is 1/10. The first step of the APS is to utilize the distance infrared sensor to detect the distance between the vehicle and the boundary, as shown in Fig. 12(a) (D_s = 20cm). Referring to these experimental results, the moving distance of the vehicle can be calculated. The second step is to restart the distance infrared sensor by adopting a comparative method to determine the start location (point Z), as shown in Fig. 12(b). When the start and destination are determined, the vehicle will return a value generated by speed of the vehicle, which will help to determine the moving distance. Next, when moving to the right location (point S), the vehicle must stop immediately, as shown in Fig. 12(c). Then, the vehicle starts to turn right for backing the vehicle until it reaches the reversing point (point B), as shown in Fig. 12(d). At last, the vehicle start to turn left for backing the vehicle into the parking space (point C), as shown in Fig. 12(e).

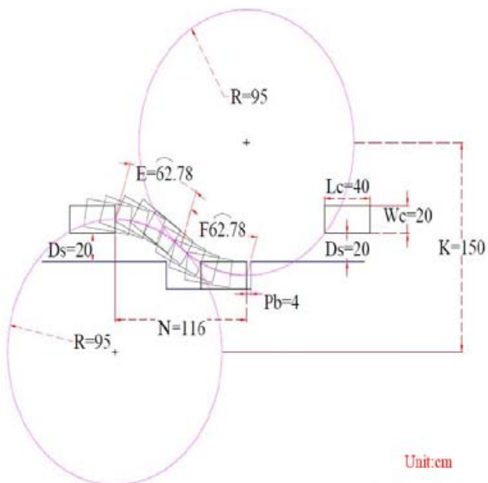
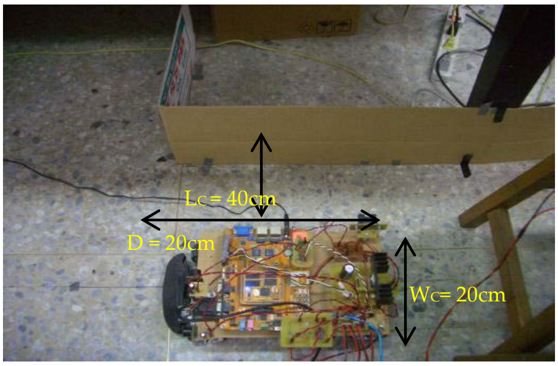


FIGURE 11 THE PARKING PATH

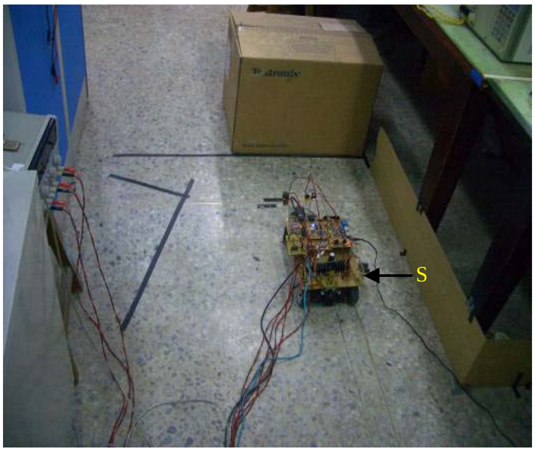
TABLE I THE RELATED PARAMETERS OF THE EXPERIMENTAL VEHICLE

Specification	Parameters (cm)
Car of width (Wc)	20
Car of length (Lc)	40
Minimum rotating radius (R)	95
The safe marginal distance of the reversed vehicle. (Pb)	4



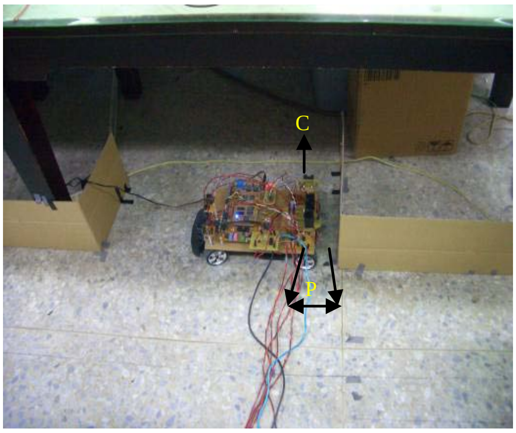
(a)

(b)



(c)

(d)



(e)

FIGURE 12 (a) ~ (e) KEY WAVEFORMS OF THE AUTO PARKING

Conclusion

The paper offers a simple auto parking strategy. Auto parking behavior can be achieved easily. The distance between the vehicle and boundary of parking space be detected, referring to the minimum rotating radius. In addition, auto parking behavior will be accomplished without any control of extra rotating angle. An experimental vehicle with auto parking function has been developed. According to the experimental results, APS is satisfactory and available.

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