A Hands-Free Trunk Opening and Closing System

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Abstract

The era of the unmanned smart car is coming soon. The paper will propose an intelligent hands-free system to open and close trunk by identifying the master's motions, complete the prototype design, and finish its real car test. In the system, we use smartphone to start up the hands-free function, and then use an infrared distance sensor and two ultrasonic sensors to identify the master's command motions. The features of the system are as follows. (i) It can detect the master's command motions easily and correctly. (ii) Due to the safe design, the automatic trunk opening or closing is very safe to the master. (iii) The system is robust to the light conditions, the colors of the master's pants and shoes, and different brands of cars. (iv) Because it is simple and cheap, it is very suitable to be widely installed in a general car.

Keywords: smart car, trunk opening, prototype design.

1. Introduction

Due to the human eagerness for comfort and safety and the highly developed technologies of automobile, electronics, control, telecommunication, informatics, sensor, etc., the era of the smart car is coming. The technologies⁽¹⁻¹⁴⁾ of the smart car can be classified into the following categories: 1) the unmanned system, 2) the driver assistance system, 3) the active collision avoidance system, 4) the operation automation system, 5) the inter-vehicle wireless communication system, etc.

The unmanned car⁽¹⁻³⁾ can let people get around easily and safely, without tired, drunk or distracted driving. For example, the Google unmanned car has been on the road, and the Taipei and Kaohsiung cities in Taiwan have allowed the unmanned small bus to be driven in the specific areas.

The driver assistance system^(1,2,4-6) helps drivers perceive the surrounding environment that will enhance

driving safety and convenience. The representative products include adaptive cruise control system, automatic parking system, traffic light and road sign detection system, inclement weather processing technology, on-road obstacle detection system, night vision system, 360 degree panoramic video stitching system, real-time navigation system, etc.

The active collision avoidance system^(1,2,7-10) protects the car from collision with people or cars. The products on the markets include lane departure warning system, blind spot warning system, forward collision warning system, pedestrian and motorcycle detection system, driver inattention monitoring system, etc.

The operation automation system^(1,2,11,12) starts up the designed functions according to the environmental changes. Some brands of car corporations have adopted the following systems: unfocused raindrop detection system, hands-free trunk opening/closing system, automatic windshield wiper control system, automatic high/low beam lights control system, light sensitive control system, etc.

Finally the inter-vehicle wireless communication system^(1,2,13,14) provides the function of car-to-car information exchange and allows users to connect different network in car.

To open and close trunk without using the hands in the category of operation automation system, Professor Su⁽²⁾ proposed the hands-free trunk lift gate system. The proposed system adopted CMOS sensor to acquire frames and identified the master's command motions from the acquired frames. The video approach is sensitive to light conditions. To acquire meaningful frames in the night, the system should design the light source and decide when to turn it on. Moreover, if the color between the master's pants and shoes and ground surface is similar, it will increase the difficulty to identify the master's command motions.

In the paper, we abandon the CMOS sensor approach and adopt infrared distance sensor and ultrasonic sensor to realize the hands-free trunk opening and closing system.

2. The Hands-free Trunk Opening and Closing System

2.1 System Architecture

To open and close trunk without using the hands, the hands-free trunk opening and closing system (HTOCS) is proposed. The schematic system architecture of HTOCS is shown in Figure 1. In the system, the infrared distance sensor is sited on the rear bumper and in a backward direction, the ultrasonic sensors are placed under the rear bumper and in a downward direction, and the intelligent decision algorithm (IDA) is developed to analyzing the signals acquired by the above sensors. When it is not convenient for masters to open or close the trunk by hand, they can stretch out their foot to the underside of the rear bumper and then withdraw it to give the command to the system. By analyzing the signals acquired by the infrared and ultrasonic sensors, IDA can decide whether to open or close the trunk or not. Notice that the hydraulic opening/closing mechanism shown in dashed red box in Figure 1 is outside the design of HTOCS.

Fig. 1 System architecture of HTOCS.

2.2 Intelligent Decision Algorithm (IDA)

In HTOCS, the intelligent decision algorithm (IDA) shown in Figure 2 is proposed to analyze the sensed signals. To describe IDA, we adopt the notations $d_{ir}(t)$, $d_{us_l}(t)$, and $d_{us_r}(t)$ to denote sensed distances at time t from infrared distance sensor, left ultrasonic sensor, and right ultrasonic sensor respectively. Moreover, $StateFlag$ is used to denote the current ON/OFF state of the trunk.

After the bluetooth pairing is complete and the function of bluetooth control is started up, IDA acquires $d_{ir}(t)$, $d_{us_l}(t)$, and $d_{us_r}(t)$ from infrared and ultrasonic sensors and computes

the initial average ultrasonic values D_{us_l} and D_{us_r} from 10 samples excluding the maximum and minimum values. Then IDA orderly checks whether the criterion of Step i , $i=1, 2, 3, 4$, is satisfied. The criterion of each step is as follows.

Step 1 : Whether the distance between the master and trunk is smaller than $BodyDistance$, that is,

$$d_{ir}(t) \leq BodyDistance$$

Step 2 : Whether the master stretches out his foot to the underside of the rear bumper, that is,

$$d_{us_l}(t) \leq D_{us_l} - DistanceVariation$$

$$\text{or } d_{us_r}(t) \leq D_{us_r} - DistanceVariation$$

Step 3 : Whether the master withdraws his foot from the underside of the rear bumper, that is,

$$d_{us_l}(t) > D_{us_l} - DistanceVariation$$

$$\text{or } d_{us_r}(t) > D_{us_r} - DistanceVariation$$

Step 4 : Whether the master keeps a safe distance from the car, that is,

$$d_{ir}(t) > SafeDistance$$

If the criteria of four steps are satisfied in sequence, IDA sends out the opening control signal if $StateFlag$ is zero, or the closing control signal if $StateFlag$ is one.

Fig. 2 The intelligent decision algorithm in HTOCS.

2.3 Circuit Design of HTOCS

To implement HTOCS, we use Arduino UNO R3 microcontroller board to go with the following components: GP2Y0A02YK0F infrared distance sensor, HC-SR04 ultrasonic sensor, HC-05 Bluetooth module, DHT11 temperature and humidity sensor, buzzer, LCD1602 + I2C and light-emitting diodes. The circuit design of HTOCS is shown in Figure 3. If the four steps of master's command motions are complete in sequence, the blue LED will be on and the buzzer will sound to remind the master that the trunk is going to be opened or closed.

Fig. 3 Circuit design of HTOCS.

3. Implementation Results

To demonstrate the effectiveness of the proposed HTOCS, the system is set up in two different cars, car 1 and car 2. The system parameters of *BodyDistance*, *SafeDistance*, *DistanceVariation*, *StateFlag*, and *SampleRate* are set to be 35, 50, 4, 0, and 4 respectively. After the system is set up, verifications are made. In a verification in car 1, we record the acquired distance information $d_{ir}(t)$, $d_{us_l}(t)$, and $d_{us_r}(t)$ and show them in Figure 4 for the time interval [12, 17.25]. Notice that the green, blue, and yellow lines represent $d_{ir}(t)$, $d_{us_l}(t)$, and $d_{us_r}(t)$ respectively. Moreover, the verification processes are recorded to videos and uploaded to YouTube^(15,16). The verification scenes in car 1 by day and in car 2 by night are shown in Figure 5(a) and 5(b) respectively.

Fig. 4 $d_{ir}(t)$, $d_{us_l}(t)$, and $d_{us_r}(t)$, $t \in [12, 17.25]$.

(a)

(b)

Fig. 5 (a) verification scene⁽¹⁵⁾ in car 1 by day, (b) verification scene⁽¹⁶⁾ in car 2 by night.

The initial average ultrasonic values D_{us_l} and D_{us_r} are both 28. At t equals 12, the master is 58 centimeters distant from the rear bumper. Then the master approaches the car. When $t = 13.75$, $d_{ir}(13.75)$ is equal to 34 and is less than *BodyDistance*. Hence the criterion of Step 1 is satisfied. The master stretches out his right foot to the underside of the rear bumper and $d_{us_r}(t)$ decreases. When $t = 14.25$, $d_{us_r}(14.25)$ equals 21 and is smaller than $D_{us_r} - \text{DistanceVariation}$ and the criterion of Step 2 is satisfied. Then the master withdraws his right foot from the underside of the rear bumper. When t

is 14.75, $d_{us,r}(14.75)$ equals 27. It is larger than $D_{us,r} - DistanceVariation$ and the criterion of Step 3 is satisfied. The master walks backward to keep a safe distance from the car. Until $t = 16.75$, $d_{ir}(16.75)$ is equal to 54. The distance from the master to the car is larger than $SafeDistance$ and the criterion of Step 4 is satisfied. Since all the four criteria are satisfied in sequence, the blue LED is on, the buzzer sounds, and the opening control signal is sent to the hydraulic mechanism.

Inspecting the verification videos played by the hyperlinks in References 15 and 16, the master's command motions are identified exactly either in car 1 or car 2, either by day or night, and regardless which kind of pants and shoes the master wears. The verification videos clearly demonstrate the features of the proposed HTOCS.

4. Conclusions

In the paper, the hands-free trunk opening and closing system has been proposed. It has the following features. (i) It can detect the master's command motions easily and correctly. (ii) Due to the safe design, the automatic trunk opening or closing is very safe to the master. (iii) The system is robust to the light conditions. (iv) It is robust to different colors of pants and shoes the master wears, (v) It is robust to different brands of cars. (iv) Because it is simple and cheap, it is very suitable to be widely installed in a general car.

In the future research, we will use RFID to recognize the master, and hence the mimic command motions from unrelated people can be excluded.

Finally, we believe that a smart car can greatly benefit by adopting the proposed system.

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