A New Driving Assistant for Automobiles

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Abstract—**This paper introduces an inexpensive car security system which addresses the needs for broader area coverage around the vehicle and stronger indication signals to drivers. The new driving assistant features simple ultrasonic-based sensors, implemented at the two front corners and the two blind spots of the vehicle. In order to report the close-by objects to the driver, the system employs a multitude of feedback devices, including tactile vibrators attached to the steering wheel, audible signals, and an LED display mounted on the dash board. The sensor system and the feedback devices are controlled in real-time by microcontrollers over a wireless communication network. The final prototype system was installed and tested on a ride-on toy car.**

Keywords – ultrasonic sensors, wireless communication, acutators

I. Introduction

Every year in the United States alone, approximately six millions automobiles accidents take place [1]. A great portion of these automobile accidents is caused by the drivers' lack of concentration while operating their vehicles. Some drivers tend to keep themselves busy at doing other concurrent activities, such as tuning the radio, eating, talking to other passengers or making cellular phone calls. Other drivers simply are incapable of maintaining their focus on driving due to fatigue level or health problems. For those drivers who are apt to lose concentration on the road, a driving assistant, which monitors road conditions and issues appropriate warnings during hazardous situations, would be greatly needed.

II. Problem Statement

A. Survey on the Exisiting Technology

The existing driving-aid devices on the market employ various forms of sensors system, such as laser, ultrasonic, radar, infrared, and CCD cameras, for obstacle detection. One particular design of parking sensors [2], places four ultrasonic sensors at the lower edge of the rear bumper of the car. One design of blind-spot detectors, discussed in [3], allocates one multi-beam radar sensor on each side of the vehicle.

The existing driving-aid devices also utilize various types of indicators, ranging from beeping sounds to LED lights. Parking system designed in [2] uses piezo-speakers whose beeping frequency increase as the car approaches an object. The blind-spot detector, as mentioned in [3], implements alarms and mounts LED icons on the rear view mirrors.

B. Observed Areas for Improvment

In the meantime, the in-depth survey on the currently available driving-aid devices suggests two possible areas for improvement. First, no existing system offers an inexpensive method to protect the entire vehicle. Most simple devices only monitor a specific area of a vehicle. In contrast, sophisticated devices, such as the ones that use radar or video camera, cover most areas around a vehicle but are rather costly to implement. Secondly, indications in the form of light and sound cannot be effectively perceived by drivers in extreme circumstances. For example, when a driver happens to fall asleep, beeping sounds and LED flashes are no longer adequate to wake up the drivers.

III. System Overview

The goal of the driving assistant is to identify objects around the vehicle and report their presence to the vehicle driver in real-time. To demonstrate the concept, a simple prototype system is built to cover, specifically, the two front corners and the blind spots on both sides of the vehicle. While the blind spot areas are the most likely to be neglected by vehicle drivers, the two front corners result in the highest accident rates [4].

The entire system is divided into four functional units:

1) The **Sensor Network** periodically scans the designated zones of the car for foreign objects.

2) The **Indicators** are to be triggered to signal the driver the presence of any foreign objects.

3) The **Microcontrollers** include one main controller, responsible for activating the indicators, and one controller at each sensor, responsible for reading the sampled data of that particular sensor.

4) The **Wireless Transceivers** function as a communication channel between the main controller and the sensor controllers. The transceivers facilitate 2-way communication.

Fig. 1, based on the work of [5], shows the relative locations of the four functional units in the driving assistant. The entire prototype system is installed on a ride-on toy car according to the layout shown in the figure.

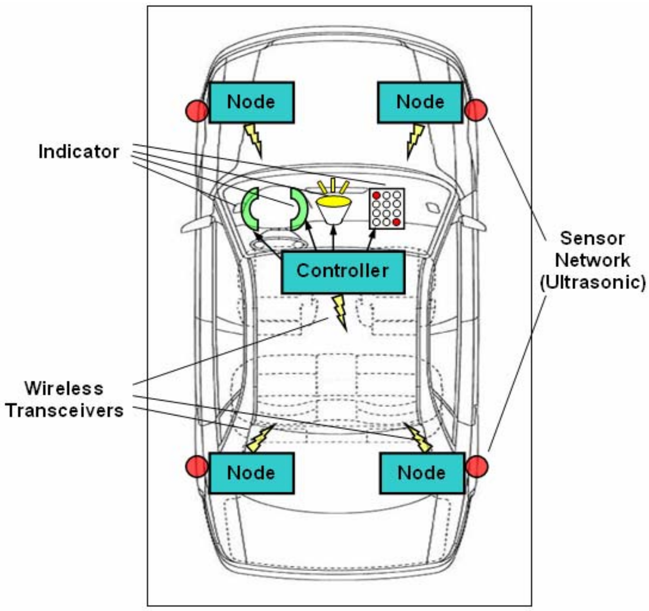

Figure 1. Functional Units in the Driving Assistant

IV. Implementation Details

This section describes the four functional units of the driving assistant in detail.

A. Sensor Network

PING)))™ ultrasonic sensors from Parallex [6] are selected to build the sensor network. As discussed in [7], while infrared sensors and radar sensors are possible alternatives, infrared sensors lack the accuracy of their ultrasonic counterparts due to ambient noises and infrared radiation, and radar sensors are rather expensive and complicated to implement because various image processing techniques are involved.

Four PING)))™ sensors are installed to scan the left blind spot, right blind spot, left front corner and right front corner, respectively.

The following source code generates an 8 µs pulse to trigger the PING)))™ sensor. The code is written for PicOS, [8]-[10], which is the embedded operating system of the MSP430F1611 microcontroller used for this project.

```
_BIC (P5SEL, 0x02);
_BIS (P5DIR, 0x02);  //set pin direction to output
//generate an 8 us pulse
p = 5;
while (p--)
_BIC (P5OUT, 0x02); //set pin to low for 8 us
p = 5;
while (p--)
_BIS (P5OUT, 0x02); //set pin to high for 8 us
p = 5;
while (p--)
_BIC (P5OUT, 0x02); //set pin to low for 8 us
```

The next piece of source code measures the returned ultrasonic echo pulse. The parameter *tmp_high*, which has the hypothetical unit *count*, measures the duration of the echo pulse.

```
_BIC (P5DIR, 0x02);  //set pin direction to input
while (((P5IN & 0x02) == 2) || ((P5IN & 0x02) == 3))
        tmp_high++;   //measure echo pulse
```

To verify the performance of the PING)))™ ultrasonic sensor, experiments are carried out to determine the maximum detection range and maximum detection angle of the sensor. Using the source code introduced previously, sensor readings are complied for test objects placed at various distance. As a result, *count* and object distance are determined to have a linear relationship, with an approximate slope of 31 count/cm. The experiment also shows that when the distance exceeds 200 cm, the noise in the data samples increases quite significantly and the measurement becomes unreliable. Using a pencil with 0.4 cm diameter as the test object, the detectable angles as shown in Table I, are found to vary between 10˚ to 25˚ for object-to-sensor distance of less than 60 cm.

The ride-on toy car has a width of approximately 60 cm. By intuition, the area surrounding the car can be designated into three zones as described in Table II. Based on the results of Table I and II, the total areas of coverage by the sensor network are illustrated in Fig. 2.

B. Indicators

Three different indicators are implemented in the prototype system: an LED display, two tactile vibrators mounted on the steering wheel and an audible buzzer. In particular, a 5X8 LED matrix, the 3V vibrator motors from Jameco Electronics and the 2.4kHz magnetic buzzer from CUI Inc. are selected.

Of the three types of indicators, the vibrators and the buzzer generate more direct stimuli than the LED display. Flashes of LED lights can only be perceived if the driver looks directly at the LED display.

In the case when no obstacles appear in zone 1 and zone 2, the vehicle is safe, so none of indicators need to be activated.

TABLE I. Maximum Detection Angle at Various Distances

Distance (cm)	10	20	30	40	50	60
Angle (deg)	24.0	22.0	20.0	15.0	11.0	8.0

TABLE II. Zone Designation

Zone	**Distance from Car (cm)**	**Number of Car Widths**	**Level of Danger**
0	> 60	> 1	Safe
1	30 - 60	0.5 - 1	Mildly dangerous
2	< 30	< 0.5	Very dangerous

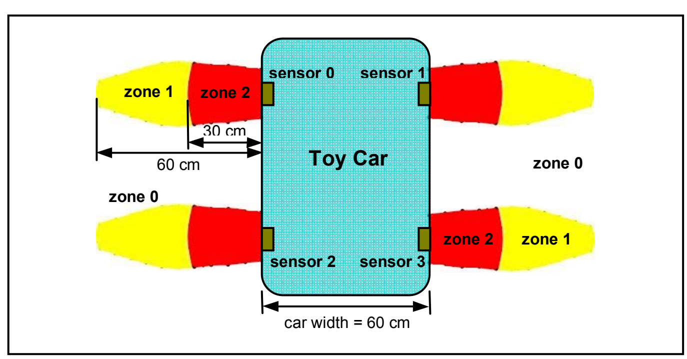

Figure 2: Areas of Coverage by the Sensor Network

In the case when an object is present in zone 1, the vehicle is considered "mildly dangerous". The LED indicators are turned on to generate "mild indications" to the driver.

In the case when an object falls into zone 2, the vehicle is considered "very dangerous" since the closest foreign object is within half a vehicle away. In addition to the LED indicators, either the vibrators or the buzzer are turned on to issue "strong indications" to the driver. Table III summarizes the activation of the indicators as an object appears in each zone.

Multiple indicators may be activated if multiple objects appear in different danger zones. In addition, based on the users own preference, two types of operation modes, *continuous* or *periodic*, can be selected for the vibrators and the buzzer.

C. Wireless Module

The wireless transceivers chosen for use in the prototype system are Texas Instruments' CC1100EMK evaluation modules, which operates at 868 MHz frequency. Three types of packets are transmitted within the wireless channel: control packets, data packets and acknowledgement packets.

Control packets are sent from the main controller to the sensor controllers and contain instructions that affect the operation of the sensors. Control packets are 20 bytes in length. The first four bytes, denoted as *packet [0],* specify the channel ID which is set to the default value 0. The last four bytes are reserved for checksum. The second group of 4-byte unit, denoted as *packet [1]*, specifies the ID number of the intended receiver. The next group of 4-byte unit, *packet [2]*, specifies the amount of millisecond delay between each sensor samples. The next group, *packet [3]*, specifies the number of readings taken in each sensor sample. *packet[3]* may also be set to 0 to stop the sensors.

Data packets are sent from the sensor controller to the main controller and contain the measurement of the ultrasonic sensor. Data packets are 16 bytes in length. The first four bytes, *packet [0]*, indicate the channel ID, which is 0 by default. *packet [1]* specifies the sender ID. *packet [2]* contains the sensor data which indicates if an object is found in zone 2, zone 1 or no objects are found in either (equivalent to zone 0). The last four bytes of the packet serve as checksum. To avoid possible packet congestion in the channel, the sensor controllers send out data packets only when the designated zone of the sensor sample changes, instead of after every sensor sample.

TABLE III. CORRESPONDENCE OF INDICATOR RESPONSES TO EACH DESIGNATED ZONE

Sensor Number	Zone	Activated Indicator
0	1	LED 0
	2	LED 0, left vibrator
1	1	LED 1
	2	LED 1, right vibrator
2	1	LED 2
	2	LED 2, buzzer
3	1	LED 3
	2	LED 3, buzzer

Acknowledgment packets are sent by the sensor controllers to the main controller to confirm the receipt of a control packet and also sent by the main controller to the sensor controllers to confirm the receipt of a data packet. The receiver side can easily identify the acknowledgement packets because their *packet [2]* always contains the value 0.

D. Controller Unit

The main controller receives data packets from the sensor controllers, processes the packet information and activates the proper response of the indicators. The main controller also receives direct commands from the user through a series of add-on DIP switches. The available options implemented by the four DIP switches are outlined in Table IV.

The sensor controllers, on the other hand, receive controller packets from the main controller, process the packet information and sample the ultrasonic sensors.

Five MSP430F1611 development boards are required to build the main controller and the sensor controllers. The underlying software programs created for the MSP430F1611 boards are multi-thread C programs, which are compatible with PicOS. Multi-thread programs ensure that all commands are processed and all responses are generated in real-time.

V. SYSTEM INTEGRATION

The prototype system is installed on a ride-on toy car for demonstration purpose. The dimension of the car is roughly 85 cm long and 60 cm wide. The main controller is placed on the dash board of the toy car, with the vibrators mounted on the steering wheel. The sensor controllers are placed at the interior of the car while the attached sensors are placed on the exterior body. The sensors are mounted at a height of approximately 35 cm to minimize the reflection of ultrasonic waves off the ground.

Initially, all the components, circuits and microcontrollers are powered by connecting adaptors from the power outlet. To allow the system to be installed on and moved along with the toy car, portable power supplies are desired. For each sensor controller, both 3.3V, for powering the MSP430F1611 microcontroller and 5V, for power, specifically, the PING))^{TM} ultrasonic sensor, are required. As a result, the power circuit design consists of a 9V battery sourcing a 5V and a 3.3V voltage regulator connected in parallel. In the main controller, the power circuit is simpler since only a 3.3V output is required. On all the boards, a DIP power switch is added to the power circuit, so instead of adjusting the battery, the user may turn the boards on and off by using the switches.

TABLE IV. FUNCTIONS OF DIP SWITCHES

Switch #	State	Function
1	On	all sensors start scanning
	Off	all sensors stop scanning
2	On	*continuous* mode
	Off	*periodic* mode
3	On	enable buzzer
	Off	disable buzzer
4	On	enable both vibrators
	Off	disable both vibrators

VI. Results and Discussion

Table V outlines all the functionalities that are successfully implemented in the prototype system. The following sections discuss some important aspects of the system.

A. Timing Constraints of Prototype System

Total sampling time required for the sensor to measure an object at 60 cm is found to be 0.129s. The system delay, when transmitting signals from a sensor microcontroller to the main controller via the wireless network, is estimated to be 160 ms. By adding the sampling time and system delay, the total system response time, on an approaching object which just entered the danger zones (60 cm away from the sensor), is 0.289 s.

B. False Trigger of Indicators

Occasionally, the indicators may fail to respond to the most recent status of the vehicle. Many problems are capable of causing false trigger of indicators. For example, packet congestion in the wireless channel may delay the receipt of a data packet or even result in the loss of packets. Other ultrasonic waveforms and noise signals exist in the environment may affect sensor readings. Type of object surface may also influence the reflectivity of ultrasonic waves.

C. Battery Life

Because of the large voltage difference between the battery and the voltage regulators, the power circuit is not very efficient. In addition, the vibrators, especially when operating in the *continuous* mode, draw a lot of current from the power source. For the real system, car's own battery may be used as an alternative solution to power all the boards.

TABLE V. List of Functions Implemented on the Prototype System

Component	Function Decryption
Sensor Network	object detection
	distance computation
	zone designation of foreign objects
	identifying zone change of the closest foreign object
	adjusting sampling speed
	adjusting number of readings per sample
Indicators	generate continuous vibration
	generate a series of short vibration
	generate continuous beeping sound
	generate a series of short beeping sound
	turn on specific LED on the LED matrix
Wireless Module	transmit data from one controller to another
Controller Unit	receive and interpret data packets
	create and send control packets
	send and receive acknowledgement packets
	make decision to activate/deactivate indicators
	process user's selection by reading DIP switches
	power on/off by switching
Node Unit	receive and interpret control packets
	create and send data packets
	send and receive acknowledgement packets
	sample sensor
	start and stop sensor
	power on/off by switching

VII. Future Expansion

For future work, the number of ultrasonic sensors may be increased to expand the areas of converge around the vehicle. Numerical analysis techniques may be applied to filter out error readings of sensor measurement. Designing special fabric that produces tactile stimuli can be a more elegant way of implementing the vibration function on the steering wheel. Another interesting expansion would be to allow exchange of packets between systems installed on different vehicles.

VIII. Conclusion

Three innovative features are characteristic to the prototype design discussed in this paper. First of all, an ultrasonic sensor system is implemented to detect foreign objects, in areas around the blind spots and the front corners of the vehicle. The experiment shows PING)))^{TM} ultrasonic sensors are low cost solutions which yield satisfying accuracy in distance measurement. Secondly, an LED display, tactile vibrators, and a buzzer are introduced as an enhanced indicator design, which provides different levels of warnings to the driver. Lastly, a proprietary operating system, PicOS, and wireless interface, are evaluated and adapted in this project. The final prototype meets all the proposed functionalities of the new driving assistant.

The work of this project should provide the drivers with great guidance as they operate vehicles on the road. In addition, the system promises to ease the drivers' anxiety about driving and to reduce the frequency of accidents. Finally, the work of this project can be further expanded to evaluate the traffic pattern of multiple vehicles, which may potentially become a valuable asset for future studies in accident prevention and traffic control.

References

[1] Car Accidents.com, "Car Accident Stats," [Online document], 2006, [cited 2006 September 5], Available HTTP: http://www.car-accidents.com/pages/stats.html

[2] Backup-Sensor.com, "How It Works," [Online document], 2006, [cited 2006 August 26], Available HTTP: http://www.backup-sensor.com/parking_sensor.html

[3] Valeo Management Services, "Blind Spot Detection System," [Online document], 2005, [cited 2006 August 26], Available HTTP: http://www.valeo.com/automotive-supplier/Jahia/pid/1034

[4] Institute of Communications and Computer Systems (ICCS), "Integrated Drivers' Lateral Support System: The Lateral Safe Project," [Online document], 2005, [cited 2006 August 21], Available HTTP: http://www.prevent-ip.org/download/Events/20050601%20ITS%20Hannover%20papers/2683.pdf

[5] T. Suurland, "Audi A8," [Online figure], 2004, [cited 2006 September 6], Available HTTP: http://www.suurland.com/blueprints_archive.php

[6] Parallax Inc., "PING)))TM Ultrasonic Sensor," [Online document], 2006, [cited 2006 August 31], Available HTTP: http://www.parallax.com/dl/docs/prod/acc/28015-PING-v1.3.pdf

[7] Migatron Corp, "Frequently Asked Questions About Ultrasonic Technology," [Online document], 2005, [cited 2006 August 25], Available HTTP: http://www.migatron.com/overview.htm

[8] Olsonet Communications Corporation, "Pic OS," Version 1.0, 2003.

[9] Olsonet Communications Corporation, "PicOS Virtual Transceiver Interface," Version 1.0, 2003.

[10] Olsonet Communications Corporation, "Pic OS Pin Operations," Version 2.01, 2006.