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Sensor-Based Robotic Model for Vehicle Accident Avoidance

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The best approach for a robot to move in an uncertain environment requires integrated unmanned functions and remotely controlled instructions. We consider the implementation of collision prediction and avoidance system in the mobile robot. The control unit is instructed from the remotely controlled device and the range sensors, which are mounted on the front and back sides. According to the required need, a specific operation is selected and performed. The algorithm based on the sensory information is developed with the distance control approach. The efficiency of the robot is improved by increasing smoothness in motion, removing jerks, achieving accuracy in the navigation, and controlling the distance from the object. To demonstrate such a low cost system, experimental tests have been carried out in the indoor and outdoor environments by moving the robot among different vehicles and objects. Finally, simulation and experimental results have displayed the authenticity of the proposed robotic system.

Keywords: Navigation, Collision Avoidance, Vehicle Accident Prediction, Sensor, Microcontroller.

RESEARCH ARTICLE

1. INTRODUCTION

Maintaining a specific safe distance from the object is primarily about instructing the mobile robot to achieve the desired goal. To attain such objectives, one possible choice is to use the sensors. Algorithms are utilized to attain information about the environment through the sensors to allow for a more flexible execution. Recently, numerous efforts have been put in the integration of the multiple sensors into the robot because the advanced robots need more information about the surrounding environment.[1–5] This study demonstrates the multiple sensors system and the mobile navigation. The robot can get range information around itself from the sensors. This information is used for inspection of the environment around the robot like: detection of an entity, notice of danger of the collision, and identification of the object position.

Worldwide, a lot of people are killed and injured in the road crashes each year. Even with all the developments in the motor vehicle safety technology, the number of people killed in the automobile accidents keeps on rising. A vision for future research is outlined in the area of intelligent driver training systems for enhancing the road safety.[6] Accident causes include: driver fatigue (frequently yawning, misjudging traffic situation, drunk driving, using of drugs), looking at somewhere else, playing with music, reading documents, using cell phones, driving in fog, and traffic high lights.[7] Some precautions have been made to reduce traffic accident, which contain: Seat belt, child safety seat, air bag, speed limitation, and by a physical change in the vehicle design.

Intelligent transportation system (ITS) and collision warning system (CWS) have been presented for safety technologies to warn drivers about collision event in advance.[8,9] vehicle collision avoidance and warning systems using seat vibrator interface and other techniques have been demonstrated to reduce the number of traffic accidents and their injuries.[9–11] By mounting sensors, light alarm, sound alarm, and vibration module in the vehicle represent an alarm sign to alert the driver. Vibration module supports to alert the driver in a noisy environment. This security system helps a great deal in increasing road safety and reducing collision.

In traffic accidents, rear-end collision is one of the important issue. To solve this issue, CWS and collision avoidance system (CAS) have been demonstrated.[12] In this

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system, the time to collision (TTC), which is the time would take the cars to collide at their current speed, can be calculated by[12]

$$TTC = \frac{D}{V_t - V_l} \tag{1}$$

where D is the distance between the vehicles, V_t is the speed of the trailing vehicle, and V_l is the speed of the leading vehicle. The time gap (TG), which is the time it would take the trailing vehicle to cover the current distance to the leading vehicle, can be determined by[12]

$$TG = \frac{D}{V_t} \tag{2}$$

In our system, the vehicle can be controlled by human as well as automatically. The main issue for collision safety is to control the speed of the vehicle. The natural tendency for self-protection is that drivers usually reduce the speed of the vehicle in the uncertain conditions for decision making. The speed of the vehicle is automatically controlled by distance measurements through the sensors.

The proposed approach consists of two modes: manual mode and prevention mode. Manual mode contains same hardware and software for the vehicle, which has been already placed in it. However, for the prevention mode, an extra hardware and software is installed. The hardware, which includes: sensors, alarms, and control unit, for prevention mode is interrelated with the hardware of the manual mode. In the prevention mode, instructions are sent to the predefined apparatus in the vehicle.

Actually, we implemented the proposed system on a robotic model. The unique work on the mobile robot is based on the sensor method, which acquires information from the sensors to update the robot position. In the unknown environment, the robot gets the position information from the sensors. From this information, the mobile robot maintains its goal without crashing. The robot does not require any human contacts other than using a remote control device for commanding to the microcontroller. As soon as, the detection of a vehicle is confirmed, light and sound alarms are activated giving a signal of detection. The proposed approach can be used for security purpose to prevent automobile accidents, and it can be used in industrial applications for ranging purposes.

This paper is organized as follows: Section 2 explains the accident perdition and avoidance approach; Section 3 gives a detailed description of distance control algorithm for mobile robot navigation. Experimental results are discussed in Section 4. Finally, conclusions and directions for the future work are summarized in Section 5.

2. ACCIDENT PREDICTION AND AVOIDANCE APPROACH

This work presents a strategy to control the motion of the manually controlled robot, which can take decision autonomously from the range data. The idea behind the development of such a system is that the controller receives the information from different sources and manages different actions. The system is divided into three main parts: sensors framework, security unit, and motor module, as shown in Figure 1. Security unit is developed using a microcontroller (AT89C52). The decisions are made by this unit or by commanding this unit.

The distance sensors are utilized for mapping the surroundings. Our main objective is to prevent accidents from the forward and backward directions. For this purpose, we used four distance sensors. They provide range information from the front and back sides. The arrangement of the sensors on the robot is a critical issue to navigate the robot accurately. Therefore, two distance sensors were placed on the front side, and others are mounted on the back side. Mostly, automobile accidents occur in such a way that the vehicle hits the object from the front side. The sensors at the front handled this situation. If a sensor failed to give range information, the security action was performed through the remaining sensor. Similarly, the sensors at the back side sent range measurements to the security unit, and safety functions were performed. To acquire better result, the range sensors were placed vertically to detect horizontal movement.

A vehicle having four wheels with two DC (direct current) motors was used. One motor was fixed for the forward and backward motion, and the second motor was mounted for the left and right movement. As soon as, the

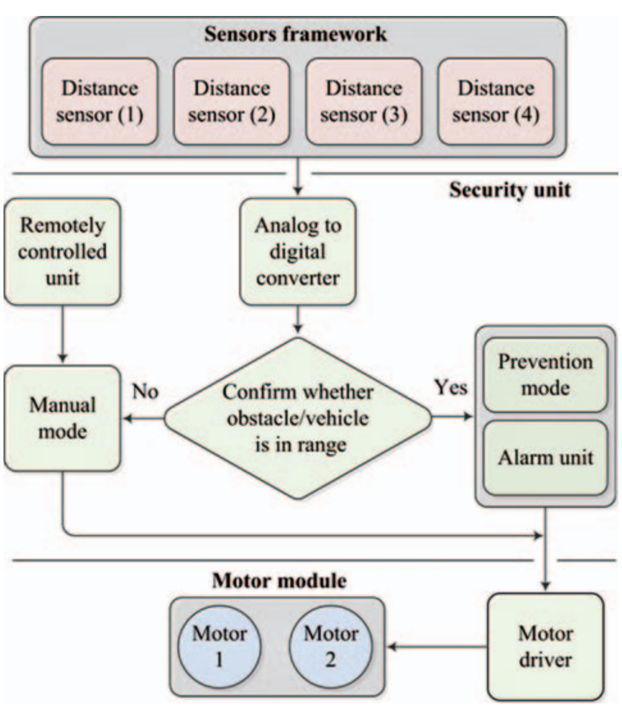

Fig. 1. System description showing sensors framework, security unit, and motor module.

sensors detected an object, the security mode was activated to perform collision prediction and avoidance operations.

The entire overview of the collision prediction and avoidance system (CPAS) is illustrated in Figure 2. CPAS was separated into two modes: manual mode and prevention mode. Manual mode is the human interface mode. In this mode, the robot motion was controlled through a remotely controlled device. Backward, forward, left, and right movements were made through this device.

In the prevention mode, the manual mode was remained activated at all times. Commands were sent to different modules in this mode. It was activated when an object came in the range of the sensors, and forward, backward, and stop functions were performed. Sound and light alarms were started when the object was in the range of 40–80 cm from the front or back sides. After the warning, if the object was out of range, warning alerts were deactivated. Similarly, if the object came in the range of 20–40 cm, stop function was carried out. To activate backward function, object must be at a distance of less than 20 cm. To prevent collision from the back side, the distance sensors from the back side sent instructions to the security unit, and respected security operations were executed. If all the sensors indicated the presence of the object, the robot was stopped.

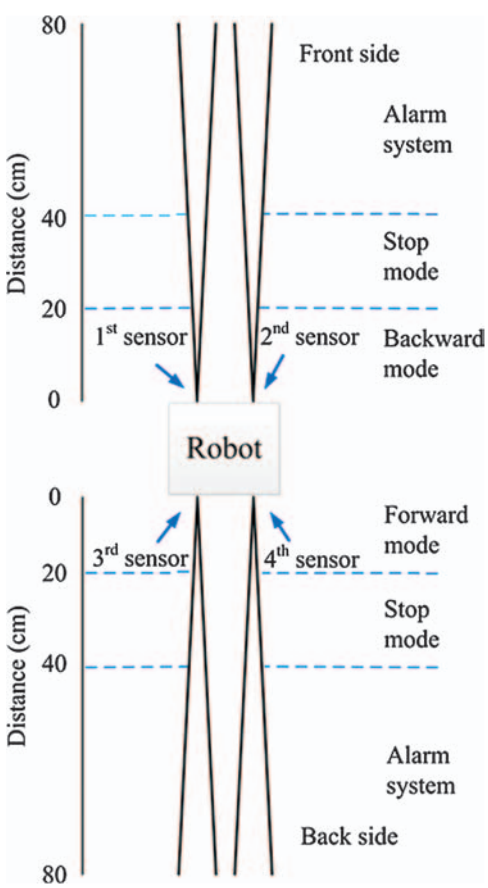

Fig. 2. Overview of the CPAS for the mobile robot.

3. DISTANCE CONTROL ALGORITHM FOR MOBILE ROBOT NAVIGATION

Simulation was performed in Proteus™. Changeable analog voltage source was used to perform the same tasks as that of the distance sensor. To convert incoming analog signals from the sensors into digital, analog to digital converter (ADC), ADC0808, was used. This unique conversion is accomplished by giving commands to the address pins of the ADC. All components were tested one by one. For assimilation testing, all components were interfaced, and the results were acquired. The microcontroller was used because of its simplicity for programming purposes.

In Figure 3, we show pseudo code to describe CPAS. An array of hexadecimal numbers was the result of interfacing the microcontroller with the ADC. It was obtained by varying voltages of the analog voltage source, and the output of eight bits digital data was noted. If any sensor detected the object, the eight bit data was compared with an early mentioned array of hexadecimal numbers. If it was from the array, the prevention mode was activated.

In the pseudo code, "a" corresponds to the pre-mentioned array of hexadecimal numbers, and analog to digital conversion is represented by "ADC." while "b," "c," and "d" indicate the digital eight bit values at the distance of 20 cm, 40 cm, and 80 cm, respectively. "getdata1" and "getdata2" are the eight bit digital data, which were obtained from the front sensors, and "getdata3" and "getdata4" were achieved from the back sensors. "motor1" indicates the DC motor, which is used for forward and

```
a = 1...........b...........c...........d;
ADC = 1;
ADC = 0;
w = getdata1;
x = getdata2;
y = getdata3;
z = getdata4;
if w,x,y,z = 0 then
          manualmode();
      {   for j = 1...........d
      |       { if w,x = 1...........b then
      |       |           motor1P = 0 & motor1N = 1;
      |   do  { else if w,x = b...........c then
      |       |           motor1P = 0 & motor1N = 0;
      |       | else if w,x = c...........d then
      |       {           alarm = 1;
else  {   for j = 1...........d
      |       { if y,z = 1...........b then
      |       |           motor1P = 1 & motor1N = 0;
      |   do  { else if y,z = b...........c then
      |       |           motor1P = 0 & motor1N = 0;
      |       | else if y,z = c...........d then
      |       {           alarm = 1;
      {   manualmode();
go to 2
```

Fig. 3. Pseudo code for the CPAS algorithm.

backward motion. The alarm unit contains the sound and light alarms. It is represented by "alarm" in the pseudo code.

The hardware circuit diagram of the system for monitoring, managing, and decision making is shown in Figure 4. Security unit was developed by connecting remotely controlled unit, ADC, and motor module with the microcontroller. On-chip oscillator was used for the microcontroller. ADC used the clock frequency, which was utilized from the microcontroller. After the conversion, security unit performed its own functions regarding to the motion of the robot. A dual full-bridge motor driver (L298) was used to accept logic levels and to drive the DC motors. Two enable pins of the motor driver were used to enable or disable the motors independently. To give proper power to each unit, their divisions were made: 5 V for the sensors, 9 V for the motor module, and 5 V for the microcontroller board.

Remotely controlled unit had two main divisions: transmitter and receiver. The transmitter sent the encoded data using radio frequency, and the receiver received the decoded data. The transmitter module contained an encoder (PT2262), and a decoder (PT2272) was utilized on the receiver side. The receiver element was directly connected with the microcontroller. The microcontroller performed respected operations from the attained information, which was received through the receiver.

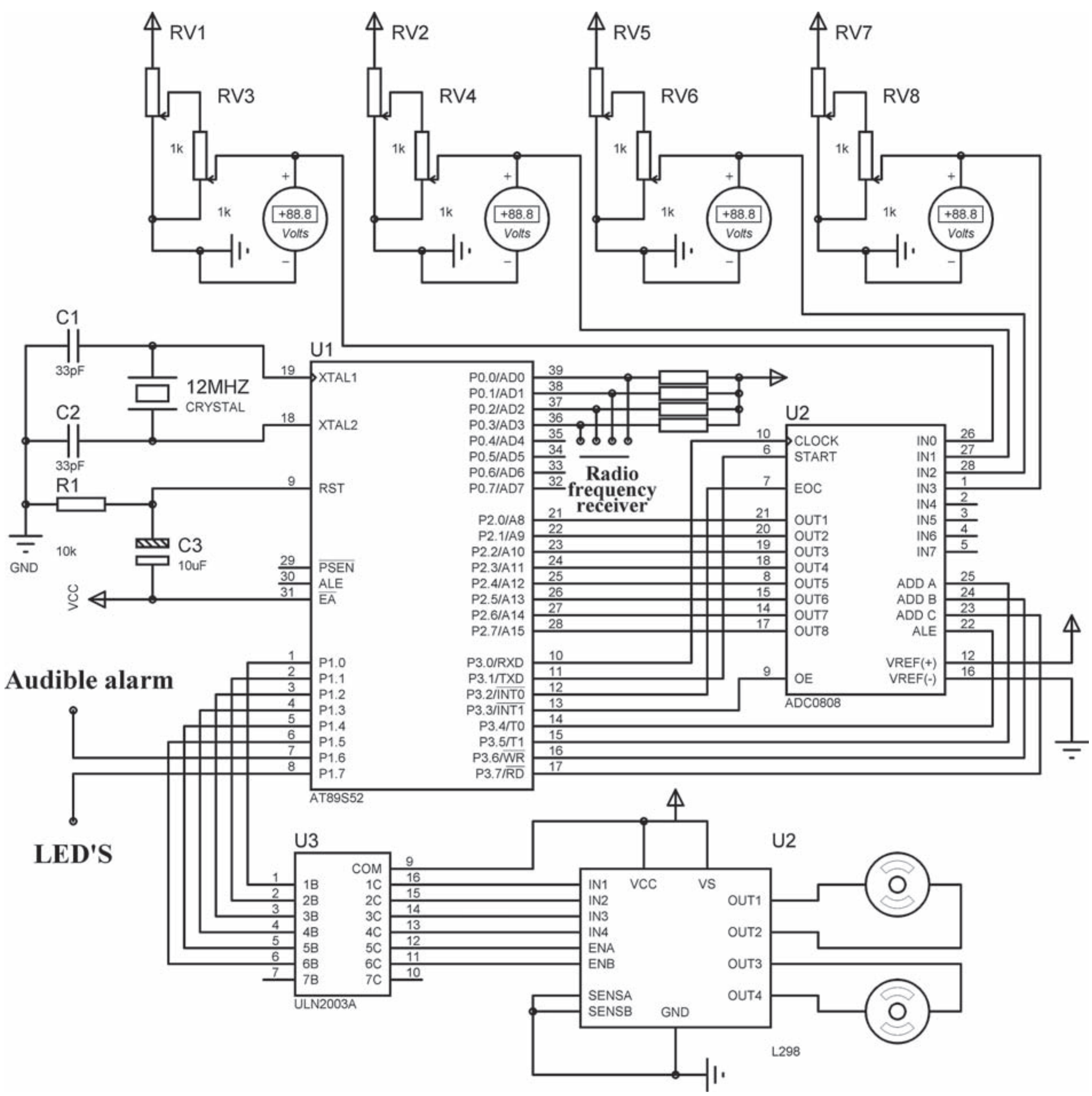

Fig. 4. Schematic of the hardware circuit, which is used to test the range sensors.

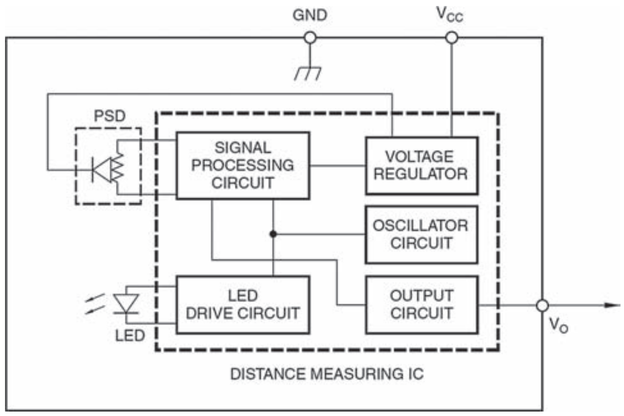

Fig. 5. Block diagram showing the distance measuring from the range sensor.

4. EXPERIMENTAL RESULTS

To increase the safety level, high sensitive distance sensors are used in the mobile robots. By adding more sensors in the robot helps to know the environment more efficiently, but the computation load is increased. SHARP™ GP2D12 range sensors were utilized with the detection range of 10–80 cm. Block diagram to measure the distance from the range sensor is illustrated in Figure 5.[13] We have implemented the robot with four sensors. By performing a series of tests, we obtained four curves, which represent the characteristics of the distance sensor, as shown in Figure 6. Distance accuracy was measured by monitoring the robot. Approximately, similar curves were obtained.

The hardware design of the mobile robot is shown in Figure 7, where placement of different modules is indicated. The experimental tests were carried out in the real environment by moving the robot among vehicles and objects, as shown in Figure 8. Objects were moved in the front side of the robot, and the robot maintained its goal without collision. Similarly, vehicles were moved in the back side of the robot, and the robot continued its motion without crashing. Furthermore, the robot was moved through the remotely controlled device, and different obstacles were placed around the robot. Overall, the robot gave acceptable results in all situations. These experimental results indicate that the proposed approach is very helpful to avoid collision between vehicles.

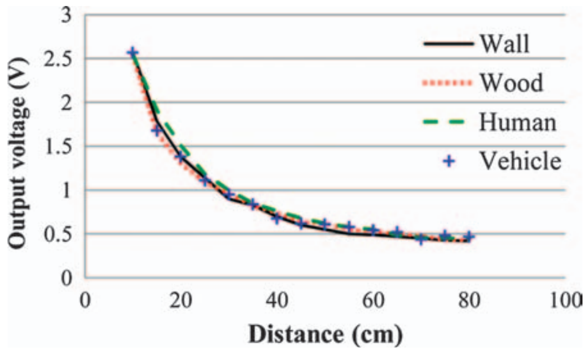

Fig. 6. Experimental outcomes of the range sensor with different objects. The plots are distance versus output voltage.

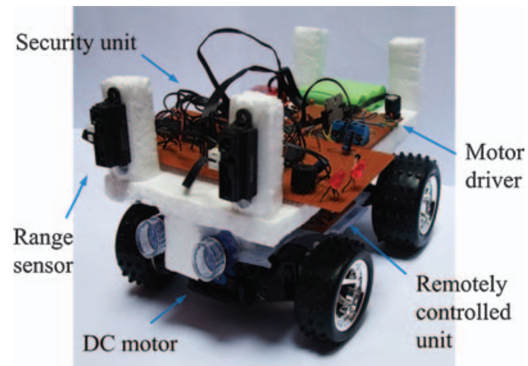

Fig. 7. The hardware design of the mobile robot showing placement of different modules.

Fig. 8. Real time experiments showing (a) collision avoidance from the front side and (b) object detection from the front and back sides of the robot.

Here, it is important to mention that we faced a problem, when two vehicles came from the front and back sides to the robot with much faster speed, there might be an accident. It can be minimized by installing this accident avoidance security system in a number of vehicles. The security system in each vehicle will take decision about the action by monitoring the objects in the surroundings. It can also be minimized by taking the decision very rapidly to change the direction of the robot.

5. CONCLUSIONS

In this paper, the accident prediction and avoidance system has been demonstrated. The proposed security system has been implemented on the wheeled mobile robot. It has been verified that the collision perdition through range measurements helps to reduce vehicle accidents. The efficiency of the robot has been improved by increasing smoothness in motion and by controlling the motion of the robot by distance control approach. The robot successfully maintained the constant distance from the obstacles in various situations.

It has been demonstrated that the collision prediction through light and sound alarms can reduce a number of vehicle accidents. Furthermore, this work gives an idea that CPAS can be used in the robots to prevent collision between them, and can be suitable in some industrial applications to carry substances behind another moving object.

Future work will focus on well-defined sensors architecture and improved version of the CPAS to achieve better results. The speed variation of the robot will be improved by estimating the speed of the followed vehicle. Furthermore, we will explore a security system that would be helpful in the automobile overtaking.

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