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A STANDALONE SMART BRAKING SYSTEM FOR AUTOMOTIVE VEHICLE

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Abstract*- Automatic Braking system is a dynamic safety device applied to automotive vehicles in order to mitigate the collisions between two vehicles or between a vehicle and an obstacle. This paper represents a standalone collision warning model for cars which aims to decrease the impact speed and the risk of collision. This system is designed for collision warning with automatic braking. In this system, a long range sensor continuously monitors the front vision of the vehicle and provides a warning signal to the driver. When the obstacle is detected within set distance, the main processor commands the buzzer module to alert the driver by sending the logical signal. Investigation was done by considering default velocity, real velocity with time. This system can ensure real life safety by the reduction of severe injuries in cars. The main advantage of this system is to alert the driver when there is a possibility to collision with other objects and to change the track to avoid collision.*

Keywords: automatic braking, standalone, buzzer module, collision warning.

1. INTRODUCTION

Automobile crashes are one of the main causes of death around the world. The number of motor vehicles gets increased with the slower expansion of the road network and this causes many challenges such as traffic congestion and high rate of road accidents and fatalities. For this reason, automotive safety has achieved an increasing amount of interest from the governments, general public, and the car industry [1]. Traffic safety at intersections has always been a serious concern due to the complex driving environment where traffic flows from different legs merge and diverge [2]. Rear-end collisions, when one vehicle's front strikes another vehicle traveling in the same direction as the striking vehicle, are a frequent and costly collision mode [3]. Rear-end collisions account for almost 30% of automotive crashes [4]. Implementing collision avoidance for road driving is a complex task because it requires not only an accurate perception of the road environment and but also prompt execution of control actions which can satisfy the kinematics constraints of the controlled vehicle [5]. A long-term solution to reduce road accidents and fatalities is the development of an intelligent vehicle that senses its surrounding environment, navigates on its own and takes fast decisions to maneuver in a safe manner [6]. Examples of vehicle control systems that can benefit from the knowledge of tire-road friction include antilock braking systems (ABS), electronic stability control (ESC), adaptive cruise control, and collision warning or collision avoidance systems [7]. A rear-end collision avoidance system (RECAS) could reduce accidents by assisting drivers during emergencies through autonomous braking [8]. Proper threat assessment is important to make a decision for intervention in a RECAS. Antilock braking systems (ABS) are closed loop devices designed to prevent locking and skidding during braking. Recent advances in antilock braking systems and traction control systems include the use of wireless accelerometers, development in the control software that take into account the dynamics of the tyres and suspension, the estimation of parameters such as lateral acceleration and wheel slip and the use of adaptive control and fuzzy logic [9]. In an automatic braking system, brake is applied automatically which helps the driver to mitigate or avoid accidents. This system decreases the impact speed and also the risk along with it. The warning component of smart braking system aims to warn the driver close to the last point where corrective action could avoid the collision. The brake assist and automatic braking components, however, are meant to mitigate the severity of a collision, activating only when the collision is unavoidable. The development of “smart cars” requires new sensors that are able to measure distances in the range of a few centimeters to a few meters [10]. Many authors have investigated the use of ultrasonic sensors based on the well-known time of flight technique [11-16].

This paper represents a new approach to develop a standalone collision warning smart braking system for automotive vehicles where the front area of the vehicle is endlessly supervised with the assistance of a long range sensor. Ultrasonic sensor, servo motors (brake and clutch), LED indicators and buzzer modules are the different components of the system which follow the command given by arduino (main processor) to reduce the risk of collision. This system is useful for both electric vehicles and internal combustion engine operated automotive vehicles. The system is assembled with braking system regardless of operation mode. The experimental result shows that this system has significant potential to mitigate or reduce rear-end collisions.

2. BRAKING SYSTEM SETUP AND METHODOLOGY

The block diagram for the smart braking system is represented in Fig.1. It includes a distance measurement sensor, an alarming sensor, arduino as main processor, brake and clutch system and a LED warning system. An ultrasonic sensor is used to sense the distance which receives and transmits an ultrasonic signal. Arduino processor (ATMEL Atmega 2560) executes the process of decision making by commanding the clutch to engage or disengage following the code. In order to make a connection with other supporting parts of the vehicle, commands are given by arduino to the servo motors (brake and clutch) to rotate the vehicle precisely in angular direction. Alarming system (buzzer) warns the driver before collision and helps to change the track to reduce the risk of collision. Arduino also commands the RGB (Red Green Blue) LEDs to indicate whether any obstacle is detected or not and the vehicle behind this one is allowed to move forward or not by changing the colour. Both the LED warning and buzzer system are included into the decision making process. A battery is used to power the arduino from which it is transferred to the power control board and the DC motor.

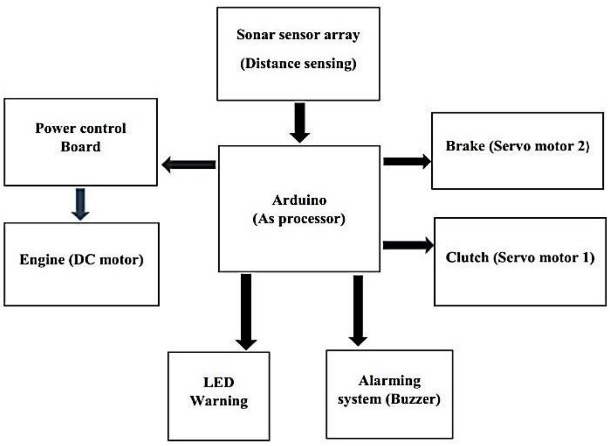

Fig. 1. Block diagram of smart braking system

3. DISTANCE MEASUREMENT

In the present study Piezoelectric type ultrasonic transducer has been used which transmits and receives an ultrasonic signal of required intensity. The velocity of ultrasonic wave propagation is a function of temperature and in air medium its value is 340 ms^{-1} at 15°C, similar to sonic velocity. The velocity (V) is computed as a function of temperature (T) as shown by Eq. (1).

$$V = 340 + 0.6\,(T - 15)\,ms^{-1} \quad (1)$$

The pulse echo or time-of-flight method of range measurement is subjected to high levels of signal attenuation when used in an air medium, thus limiting its distance range. If the effect of temperature is avoided for the room temperature and the velocity of the sound to the air medium is considered 340ms^{-1}, then the equation for distance measurement is given by,

$$S = V * T / 2 \quad (2)$$

Where, S is the distance between sensor and the measuring surface, V is the velocity of sound wave in the travelling medium and T is the time required to travel the sound wave from sensor and echo back to sensor

A sensor is capable of measuring a maximum distance of 4m and the maximum time (T_{md}) required to travel this distance is 23.53 milliseconds. By calculating the time required for the sound wave to travel from sensor to object and back to the sensor, the distance can be measured following Eq. (2). In order to calculate the time a 16 bit counter of the arduino was started at the beginning of the TTL (transistor-transistor logic) signal sending by the trig pin. The timer was stopped in the ISR (Interrupt Service Vector) vector routine and sampled the counter value to a variable. The counter was then reset at the last of the vector routine. The time and critical prescaler are calculated by following Eq. (3) and Eq. (4) respectively.

$$Time = (16\ bit\ timer\ value / CPU\ frequency) \quad (3)$$

$$T_{md} = \frac{Timer\ value * Prescaler}{CPU\ frequency} \quad (4)$$

For, maximum time 23.53ms, CPU frequency 16MHz, timer value maximum 30000, the prescaler is 12.54. From arduino datasheet, prescaler 32 at this range can be used. Both time and distance can be calculated using the above equations. At the same process, four sensors are used to measure distance continuously. The distance is calculated in the main loop.

4. DECISION MAKING

The flowchart of decision making of the arduino is shown in Fig. 2.The decision making procedure is executed in the arduino processor. There are basically three conditions which indicate the start, slow and brake command. Three variables are declared at the start of the code which can change the distances to execute the commands. If the distance is greater than 45 cm, then the processor commands the clutch to engage, if less than 45 cm and greater than 15 cm then the command is to slow the vehicle by disengaging the clutch and lastly when the distance is less than the 15 cm, the brake is engaged by the command of the processor. Decision making also includes the optional buzzer sound system for warning the driver and automatic LED indication. When the obstacle is detected within 45 cm, the main processor (arduino) commands the buzzer module to alert the driver by sending the high logic. Also, it commands the RGB LEDs to change the colour from green to red alerting the vehicle behind this vehicle.

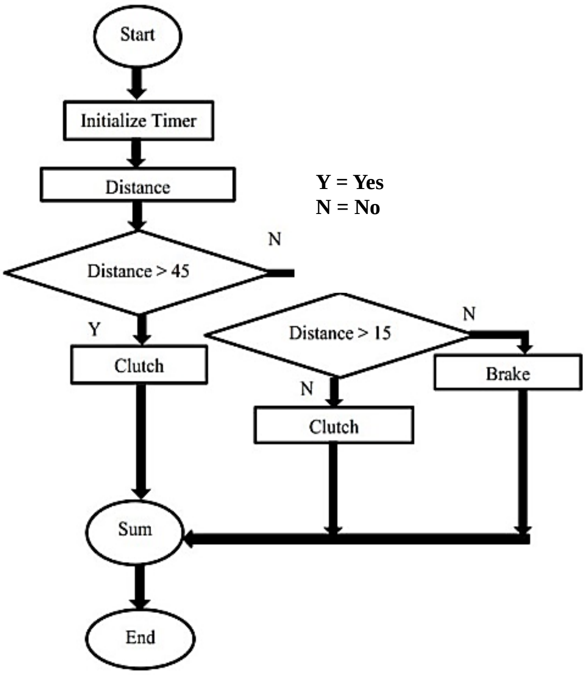

Fig. 2. Flowchart of decision making of the arduino

5. CLUTCH AND BRAKE SYSTEM

Figure 3 represents a prototype of the braking system. After the completion of distance measurement and decision making, it is important to communicate with the peripherals and supporting organs of the vehicle to work and execute the commands of the main processor. Among three types of commands, one is to command the servo motors. Servo motors are utilized for rotation in an angular way with precise movement. Atmega8A microcontroller is integrated with two servo motors in order to generate Pulse-width modulation (PWM) signals with separate duty cycles. The tasks are separated from the arduino is to reduce the CPU stress. Also, the other PWM channels are not sufficient to generate the resolution of the PWM required to produce the precise movement of the servo motors. At first, for the clutch system, the PWM duty cycle of the servo motor is set to 1ms to produce the 0 degree angle with the horizontal axis. In this state the belt is loosely connected with the main engine shaft. So, any motion of the main engine shaft does not make any movement of the vehicle. This state is known as clutch disengages state. When the sensors are found out that no obstacle is detected within the given range, then the arduino commands the clutch servo motor to engage the clutch by producing the PWM signal with the 1.5ms duty cycle positioning the servo shaft 90 degree with the horizontal axis. In this position, the belt is tightened and rotation of the main shaft rotates the wheel shaft. This state is known as clutch engaged state.

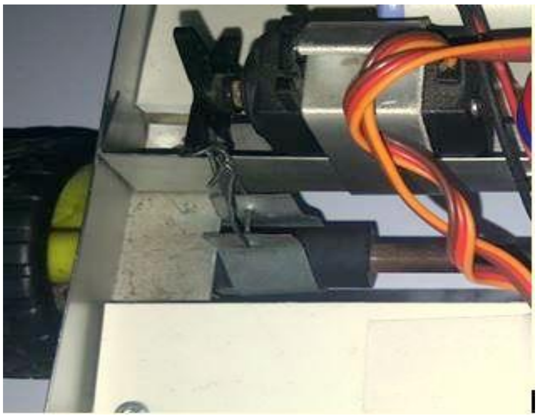

Fig. 3. Braking system of the prototype.

The command execution is similar to the clutch system. Initially, the clutch system is disengaged by generating the PWM signal from the Atmega8A with the duty cycle of 1ms. When clutch is needed to be engaged, the generated PWM duty cycle is changed to 1.5ms by the command of arduino.

6. ALERT SYSTEM

This system consists of a piezoelectric buzzer, NPN transistor and pulls down resistor. The transistor is used to multiply the current rating flowing through the buzzer. When arduino calculates a distance less than 45cm, then the buzzer signal pin of the arduino goes to logic high and the buzzer creates sound by vibrating the piezo crystals. The main advantage of this system is to alert the driver when there is a possibility to collision with other objects and to change the track to avoid collision.

7. LED INDICATING SYSTEM

Light indicating systems in vehicles are used for visual advantages. In this vehicle, two RGB LEDs are used to give signal whether any obstacle is detected or not and the vehicle behind this one is permitted to move ahead or not. In this system among two light indicators, red colour is an alert message for the vehicle behind to be ready for stop at any time. The green colour indicates that the vehicle behind can move along with the vehicle and it is safe.

8. SYSTEM PERFORMANCE ANALYSIS

System performance analysis is performed by comparing default velocity with battery voltage and running time with velocity. From Figure 4 it is seen that the default velocity of the vehicle is proportional to the battery voltage. This is because the dc geared motor is utilized as the main engine. Motor speed increases with the increase of battery voltage. The wheel shaft is powered by the motor and increment or decrement of the speed affects the vehicle velocity.

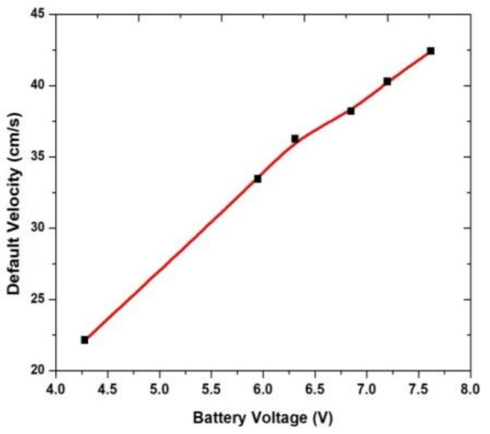

Fig. 4. Battery voltage vs. default velocity of the vehicle

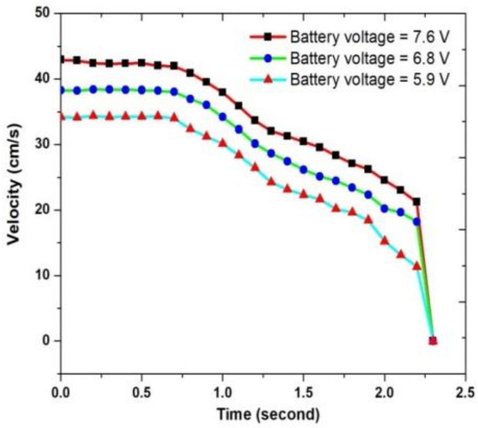

Fig. 5. Velocity vs. time of the prototype

In Figure 5 three different curvatures are shown for different battery voltages. The initial velocity of the vehicle is higher for the higher battery voltage. From the starting point the velocity is constant up to the time of 0.7 seconds. From 0.7 to 2.2 seconds the velocity decreases with time but the decreasing rate is not uniform. In this region the clutch is disengaged because of the detection of the obstacle within 45cm. At the point 2.2 seconds, the sensor detects that the obstacle is less than 15cm from the vehicle. Thus, in this point the controller commands the brake servo motor to engage the brake. Also, previously the clutch is disengaged. In this position alarm stops and red LED indicates alert for the other vehicles. From 2.2 to 2.3 seconds the brake engages and the velocity becomes zero at the point of 2.3 seconds.

9. TIME DELAY CALCULATION OF THE OBSTACLE

Time delay of the obstacle is calculated using Eq. (5).

$$t_{max}=2d/v \quad (5)$$

To calculate the time delay period, an arbitrary distance is taken as 4m. So, t_max= 2*4/340 = 0.023529sec = 23.53ms. Arduino 16bit timer runs on 500 kHz using prescaler of 32 (calculated previously) with CPU frequency of 16MHz. The timer will then take same time as the sound waves take as timer counts parallel with the sonar signals. According to the calculation, if the vehicle moves with the velocity of 340ms-1 , the vehicle will fail to stop as the time is same as the time required to calculate the velocity and to engage brake. If the factor of safety is 2 or the vehicle need to be stopped halfway after the obstacle detected, the maximum velocity at which the vehicle can run will be 1224/2=612kmh-1 which is far more than it is thought. Hence this setup is applicable for almost all the vehicles in the market.

10. CONCLUSION

In this study, an auto controlled smart braking system has been developed and the performance of the system is analyzed. Performance analysis is done by comparing default velocity with battery voltage and running time with velocity. Collision detection is performed and auto braking system is checked for minimum braking distance. An auto signal safety system was also introduced in this system which was tested successfully. This system is capable of reducing the severity of collision by giving a warning signal to the driver and thus assures real life safety.

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