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Development of Automated Braking System for Collision Avoidance of Vehicles

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ABSTRACT:

The main objective of this paper is to develop an automated braking system to avoid frontal collision of the vehicle due to driver's inattentiveness. The working model comprises of automated braking system which includes ultrasonic sensor, bike brake system, high torque motor, microcontroller, motor driver, battery, double acting cylinder and solenoid valves. An algorithm is proposed for automated braking system. The proposed working model is validated with experimental results. The ultrasonic sensor is validated for distance measurement and the sensor predicts the distance with an error of 3.31%.

KEYWORDS:

Ultrasonic sensor; Automatic braking; Collision avoidance; Distance measurement; Automotive vehicles

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1. Introduction

In today's world with the advancement of science there has been drastic improvement in the automobile sector also. But this advancement has also led to the increase in the number of vehicles in the world. Automobile sector has improved in every aspect be it comfort, speed, control, etc. but one of the major factor which defines the automobile sector is safety. According to National Highway Traffic Safety Administration (NHTSA) an estimated 40% of all car accidents are due to rear-end collisions due to driver's fault. Automated braking systems become more and more important than ever in modern vehicles for assisting drivers in emergency driving situations. These systems comprise the combination of camera and radar or stereovision system for vehicle detection. Complex algorithms and added costs made these systems less attractive to the market.Nowadays various automotive sensors have been developed to monitor the engine parameters and safety of passenger car applications such as collision warning, collision avoidance and driver assistance [1-2].

Researchers studied the performance of vacuum brake system for light commercial vehicles [3]. Authors have attempted to generate electricity during braking using a recovery mechanism called regenerative braking. The kinetic energy of the disc rotor is transformed into thermal energy using a thermoelectric generator [4]. Automated braking system is necessary to reduce collision avoidance of any vehicles. The key supporting technologies such as machine vision, radar, magnetic referencing, high accuracy digital maps, etc. provide information about lane boundaries and roadway scene ahead of vehicles. Ultrasonic sensors were used for distance measurement and emergency braking applications. Authors proposed a methodology using ultrasonic sensor to measure distance from ground which can be applied for headlight levelling and active suspension system [5].

Researchers have proposed a hypothesis on collision avoidance assist method for stopped vehicles in front using brake control of active interface vehicle [6], collision avoidance between cyclist and heavy goods vehicle [7] and precision stopping methodology for heavy duty vehicle equipped with pneumatic brake system [8]. Ultrasonic sensors were used for distance measurement for long range applications [9]. A sensor fusion concept based on capacitive and ultrasonic technique is used for distance measurement in automotive application [10]. However, the measured result is enhanced by including the correction factor. Authors proposed a methodology for emergency braking system using ultrasonic sensor for urban traffic applications [11] and pedestrian protection [12]. Not much work is carried out in using the ultrasonic sensor for automated braking system to prevent collision avoidance of automotive vehicles.In this paper a new automated brakes system is developed which can be easily incorporated in old as well as new vehicles. The model comprises of ultrasound sensor, micro controllers and braking system. The proposed model detects an incoming obstacle and automatically applies brake to avoid collision of automotive vehicle.

2. Methodology

Distance measurement of an object in front or by the side of a moving entity is one of the emerging techniques used in automotive vehicle to prevent collision. Ultrasound sensors are versatile in distance measurement, which uses ultrasound waves that works in both air and underwater applications. The methodology proposed is to slow down the speed of the vehicle by automatically actuating the braking system is divided into detection of the vehicle and automatic braking system. These sensors provide the fast and cheapest solution for distance measurement. The working principle of ultrasonic sensor is given in Fig. 1. The ultrasonic waves are sounds of frequency above 20 kHz. The ultrasonic transducer emits an ultrasonic wave pulse in a medium of air or water. The emitted wave pulse is bounced back as the reflected wave and reaches the receiver. The object distance is calculated on the basis of wave travel using,

$$D = tc/2 \quad (1)$$

Where D is object distance (m), t is wave travel time (s) and c is ultrasonic sound velocity (m/s). In the proposed system, an alert system is placed which alerts the passenger about the close proximity of the vehicle/hurdle in the path of the vehicle. Ultrasonic sensors are the sensors used for sense the object (vehicle/hurdle) and then send signal to the controller. The controller difference action based on distance, the hurdle initially alerting the driver by a buzzer and then braking when the distance between the two vehicles becomes very less.

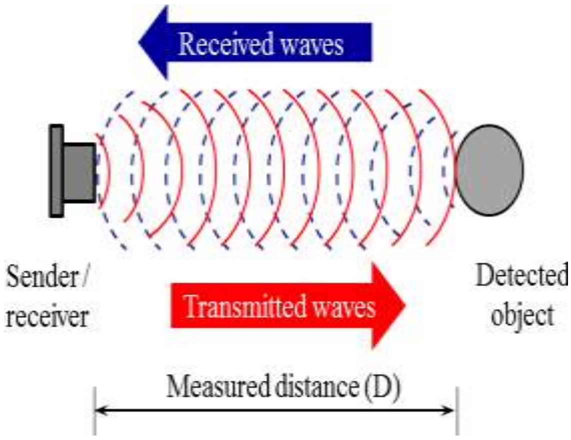

Fig. 1: Working principle of ultrasonic sensor

2.1. Detection of vehicle

This is the first step in the proposed method i.e. to detect the incoming hurdle this is done to detect the obstacles and hurdles. To achieve this ultrasonic sensors are used. The sensor consists of both transmitter and receiver, the transmitters sends the signal which gets reflected by any obstacle which comes in its way these reflected back ways are received by the receiver which then sends to the microcontroller which in turn slows down the vehicle and avoid collision. This analogue signal i.e. the distance of the vehicle is then converted into digital signal which is then sent to the microcontroller. The main objective to use ultrasonic sensors is because it is cheap and easy to install an easy to configure. Ultrasonic sensor uses air as a medium to propagate, as speed of sound is 340 m/s at a frequency of 200 khz which is impossible to hear by normal human ears. Hence the transmission and receiving of wave's takes place at very fast rate which is required for fast detection and slowing down of the vehicle. The sensor is attached to the microcontroller which is in turn connected to the motor driver connected to the motor and the pneumatic cylinders.

2.2. Automatic braking system

Using Eqn. (1), the distance of the object is measured. The measured distance is taken as the input for automated braking system. The automated braking system proposed in this work is designed to prevent the frontal collision of the vehicle. The working principle of this automated braking system is as follows:

I. The sensor fixed in front of the vehicle senses the distance of the incoming vehicle and sends signal to the microcontroller.
II. The distance measured by the sensor is categorized into three stages I, II and III.Stage I: Safe, Stage II:Alerts the driver, Stage III:Apply brake automatically.
III. Stage I: The distance of the incoming vehicle from the sensor installed vehicle is beyond the pre-set value.
IV. Stage II: The incoming vehicle entered the pre-set value of sensor measuring range. The microcontroller alerts the driver by keeping buzzeron.
V. Stage III: The incoming vehicle is in the critical stage. i.e. the driver didn't responded for the buzzer on and hence the microcontroller sends a signal to the apply brake automatically.

The algorithm used for automated braking system is given in Fig.2. After the detection of the incoming vehicle/obstacle, as the incoming vehicle comes in close proximity of the sensor installed vehicle first the buzzer alarms and alerts the driver. Even then if the driver doesn't respond/reduce the speed of the vehicle then automatic braking slows down the sensor installed vehicle hence avoiding collision.

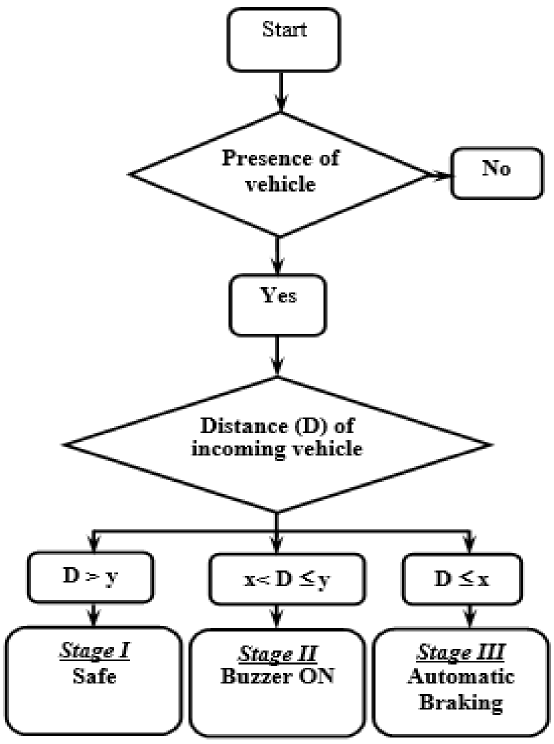

Fig. 2: Algorithm used for automated braking system

3. Experimental setup

A working model comprises of the following components as given in Fig. 3 and Fig. 4:

- Bike brake system
- High torque motor
- Arduino microcontroller
- Motor driver
- Battery
- Double acting cylinder
- Solenoid valves
- Frame

In this model the range of the ultrasonic sensor used in the model has a range of 100 cm. The power to motor gets disconnected and the braking actuates when obstacle come close to the sensor. In real time the disconnection of power to the running motor can be related to engaging of the clutch, hence cutting of the power from the engine and transmission, simultaneously actuating the brakes of the vehicles. In this work a single wheel braking is being used to depict the motion of the wheel of the vehicle. The pneumatic braking system is used actuated by double acting cylinder. The automation of the brakes is achieved by using arduino microcontroller which receives input signals from the ultrasonic sensors and gives output i.e. actuation of the brakes by the help of the pneumatic braking system by a double acting cylinder. The working model depicts the running of a wheel and braking in real time application. The pneumatic braking is controlled with a relay and solenoid valves controlled by signals provided by the microcontroller.

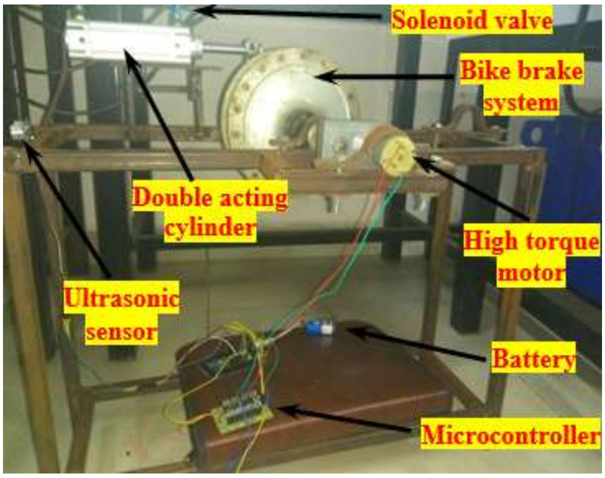

Fig. 3: Experimental setup for automated braking system

Fig.4: Close-up view of ultrasonic sensor used in the model

4. Validation of proposed working model

The proposed ultrasonic sensor is tested for its distance measurement. The object/obstacle is placed at different locations (distances). By knowing the actual distance and travel time of the ultrasonic waves, measured distance measured is calculated using Eqn. (1). Travel time of the signal data is obtained from the arduino microcontroller. Three measurements were taken for each distance and the average of the measurement is given in Table 1. The average absolute error of the measurement is 2.31%. Fig. 5 shows the plot between actual distance and measured distance. Further understanding of distance measurement using ultrasonic sensor is possible if the interaction is captured by a suitable model. Regression analysis is performed to find out the interactions between the process parameters. The analysis is performed by assuming the factors and response are linearly related to each other. The general representation is given by,

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \varepsilon \quad (2)$$

Where Y is the response, β_i is the regress of the ith factor and denotes residuals.

Table 1: Comparison of actual and measured distance

Actual distance(cm)	Time travel(μs)	Measured distance(cm)	Absolute error(%)
8	511	8.76	9.50
10	625	10.71	7.10
15	913	15.65	4.33
20	1121	19.22	3.90
25	1475	25.29	1.16
30	1714	29.39	2.03
35	2009	34.45	1.57
40	2314	39.68	0.80
45	2631	45.12	0.27
50	2897	49.68	0.64
55	3198	54.37	1.15
60	3485	59.25	1.25
65	3773	64.13	1.33
70	4060	69.02	1.40
75	4347	73.90	1.47
80	4634	78.79	1.52
85	4922	83.67	1.57
90	5209	88.55	1.61
95	5496	93.44	1.65
100	5784	98.32	1.68
		Avr. Abs. error	2.31

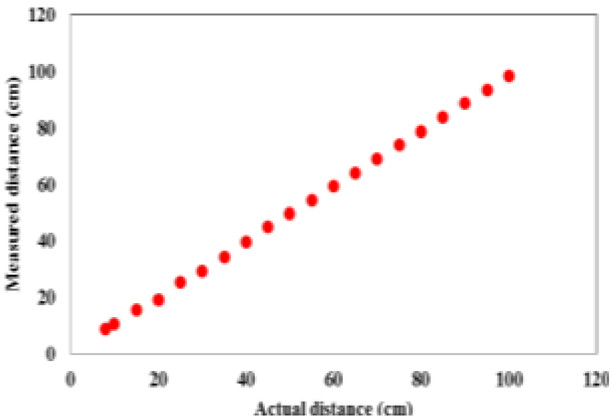

Fig. 5: Comparison of actual and measured distance

The model for distance measurement is given by,

$$Distance(D) = 0.9768x + 0.641 \quad (3)$$

The R-sq. (R^2) value for distance measurement is 99.8%. The response of the ultrasonic sensor on distance measurement is used as an input for developing automated braking system. Three different stages of distance sensing and the response are given in Table 2. The proposed automated braking system responds based on pre-defined conditions as given in Table 2 and the algorithm as given in Fig. 2 to train the system. The methodology followed in automated braking system for a distance sensing of 100 cm is described hereafter. If the distance of the object from the sensor is greater than 70 cm, there is no response from the system. If the object is in the range of 30-70 cm, then the sensor send signal to the microcontroller. Thereby the buzzer on mode is activated to alert the driver. If the sensor senses the object at a distance less than 30 cm, the microcontroller sends the signal to the automated braking system to stop the vehicle. Figs. 6(a) to (c) show the snapshots of working model for different stages of distance measurements as given in Table 2. When there is no obstacle detected (Stage I) by the sensor, the system remains unresponsive as shown in Fig. 6(a). As the sensor detects an obstacle at pre-programmed distance (Stage II), the sensor sends signal to microcontroller. The output of microcontroller is fed into buzzer and makes it to glow. The solenoid valve is not active.

Table 2: Strategy for automatic braking system

Stages	Distance between vehicles(D) (cm)	Buzzer alarm	Automatic braking
I	D>70	No	No
II	30<D≤70	Yes	No
III	D≤30	Yes	Yes

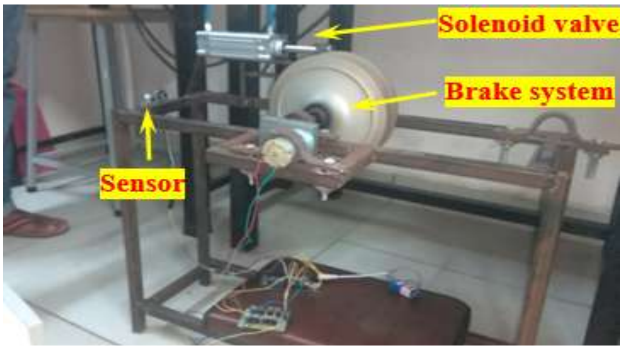

Fig. 6(a): Stage I validation: No object detected

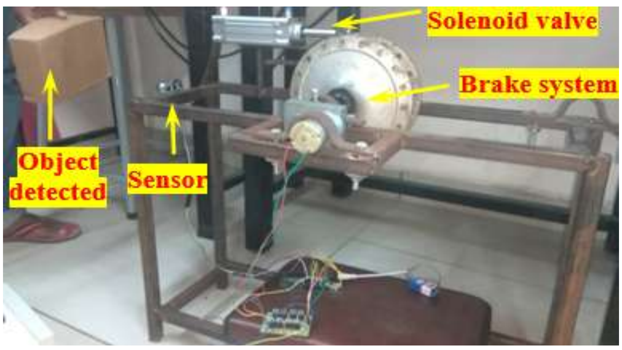

Fig. 6(b): Stage II validation: Object detected. alerts the driver

The presence of obstacle in close proximity (Stage III), the signal from microcontroller is fed into both buzzer and solenoid valve. The solenoid valve activates and stops the rotation of wheel (automatic braking). Thus the proposed automated braking system is in good agreement with the experimental results and hence the proposed system is validated.

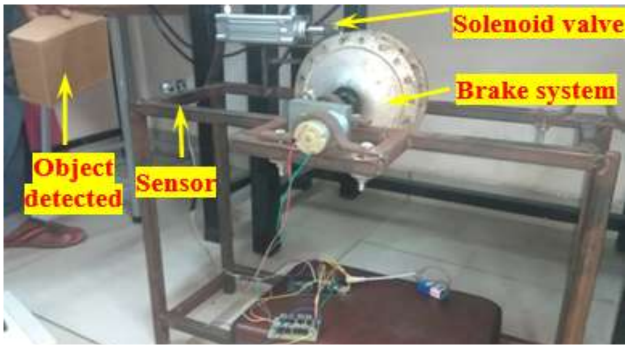

Fig. 6(c): Stage III validation: Object detected. Solenoid valve triggers and actuates automatic brake system

5. Conclusions

This paper has focused on development of a low cost automated braking system. The proposed work is validated by conducting experiments. The following are the important conclusion drawn from this work:

1. Ultrasonic sensor is used for distance measurement. The measured distance is in good agreement with the actual distance. The ultrasonic sensor predicts the distance with an average absolute error of 2.31%.
2. A mathematical equation is proposed using regression analysis.
3. An algorithm is proposed for automated braking system. The proposed algorithm detects the presence of object at threedifferent stages.
4. The automated braking system is validated with experimental results. The system responds accurately for various distance measurement values.

The proposed work can be extended for long range distance measurements applications. The proposed methodology can be utilized for collision avoidance of heavy duty vehicles, automotive used in urban traffic, pedestrian crossing, etc.

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