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DESIGN AND DEVELOPMENT OF AN AUTOMATIC BRAKING SYSTEM IN AUTOMOBILES USING ULTRASONIC SENSORS

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Abstract
Application of advanced breaking system using ultrasonic sensor in automobile is undertaken. An ultrasonic setup is placed in front of the vehicle and the setups consist of an emitter and a receiver. Ultrasonic emitter always emits the ultrasonic waves, whenever an obstacle is detected then the wave gets reflected and the receiver receives the signal. Reflected wave sends the signal to the Arduino Uno from that, based on distance of object, it actuates the buzzer or brakes. Ultrasonic Braking System (UBS) car provides the glimpse into the future of automotive safety. With the Ultrasonic Braking System (UBS), we can prevent more accident and save more lives.

Keywords: Advanced braking system, Ultrasonic sensor, Ultrasonic emitter, Ultrasonic wave, Arduino Uno.

Introduction

Automatic braking systems are called different things, but the concept is the same. Technically, the concept is two systems working together: forward collision warning and automatic braking (Hasan et al 2018). In automation field, designers have proposed several enhancements. A precise short-range radar system was developed for anti-collision applications where automatic braking is applied in response to detection of a collision risk where a very high probability of detection is accompanied by a very low level of false alarms. A brake strategy for an automatic parking system of vehicle has proposed brake controller which work with the automatic parking system and make the process of parking smooth and stable. Autonomous Antilock Braking System (AABS) system which can take over the traction control of the vehicle is developed for a four wheel vehicle. ABS is a braking system that maintains control over the directional stability of the vehicle during emergency braking or braking on slippery roads by preventing wheel lock-up. Attempts made time in past to improve braking systems to achieve best accident prevention methods. This includes the existing systems in current automobile industries. The novel approaches published in literatures were reviewed (Deaton, J. P. 2008) .

Forward Collision Warning (FCW)

If a collision seems to be imminent, a Forward Collision Warning (FCW) system gives an audible warning which allows the driver time to take action and possibly prevent an accident. It is strictly a warning system only, and does not take any automated measures, such as applying the brakes, to avoid or mitigate a collision (Hiroshi, O.et al. 1994).

Forward Collision Mitigation (FCM)

A Forward Collision Mitigation (FCM) system will warn the driver and slow the vehicle simultaneously. FCM should not be confused with Forward Collision Warning (FCW). A warning system will only warn the driver, but not take any automatic action to mitigate – reduce the chances or effects of – a collision. An FCM will automatically apply the vehicle's brakes as the computer calculates the situation (Dhawan, A.P .2022).

Forward Collision Avoidance (FCA)

Complete avoidance of a collision is the goal of a Forward Collision Avoidance (FCA) system. This approach is obviously the most challenging, and is probably more semantic than realistic. People like to think of avoiding a collision, so a system named as such is bound to sell better than one that simply says it will reduce the severity of a collision. Ideally, an FCA system tries to get you out of a collision altogether using technology such as automatic braking and even assisted steering. But if eventually you end up crashing, the system will make it less severe (Van, N. N et al 2008).

Systems Working Together

An automatic braking system is actually several systems that work together to achieve one of two things: collision avoidance or collision mitigation. Sensors detect and deliver situational data to a computer that calculates what is needed to brake in time and either avoid or mitigate a collision.

Automatic braking systems use laser, radar, and/or cameras to monitor driving speed and detect objects in the vehicle's path. Some of these systems can even evaluate road conditions, such as rain or snow, and include them in their continuous calculations that allow them to be constantly on guard and prepared for a short stopping situation or possible collision (Shimazaki,K et al 2018).

Existing Methods of Accident Preventions (Jessica.B 2019).

Pre-Sense Plus the full version of the system (Pre-Sense Plus) works in four phases. In the first phase, the system provides warning of an impending accident, while the hazard warning lights are activated, the side windows and sunroof are closed and the front seat belts are tensioned. In the second phase, the warning is followed by light braking, strong enough to win the driver's attention. The third phase initiates autonomous partial braking at a rate of 3 m/s^2. The fourth phase decelerates the car at 5 m/s^2 followed by automatic deceleration at full braking power, roughly half a second before projected impact.

A. Pre-Sense Rear A second system, called (Pre-Sense Rear), is designed to reduce the consequences of rear-end collisions. The sunroof and windows are closed and seat belts are prepared for impact. The optional memory seats are moved forward to protect the car's occupants.
B. Collision Warning with Brake Support Ford's Collision Warning with Brake Support was introduced in 2009 on the Lincoln MKS and MKT and the Ford Taurus. This system provides a warning through a head up display that visually resembles brake lamps. If the driver does not react, the system pre-charges the brakes and increases the brake assist sensitivity to maximize driver braking performance. Ford demonstrated its Obstacle Avoidance Technology (OAT) relying on a mix of sensors, including a camera tucked behind the rearview mirror, to scan the road for vehicles and pedestrians and steer away if the driver does not take any action.

Various attempts by researchers:

Coelingh et al. (2010)describes one of the latest AEB systems called Collision Warning with Full Auto Brake and Pedestrian Detection (CWAB-PD). It helps the driver with avoiding both rear-end and pedestrian accidents by providing a warning and, if necessary, automatic braking using full braking power.

- Neil et al. (1996) introduces the field of safety-critical computer systems for any engineer who uses microcomputers within real-time anti-lock braking systems in automobiles, to flyby- wire aircraft, to shutdown systems at nuclear power plants. It is, therefore, vital that engineers are aware of the safety implications of the systems they develop.

- KanShimazaki et al. (2018), study on new computer-controlled, interactive brake pad friction tester is presented by. This study seeks to clarify the general public's understanding of automatic braking system.
- Jessica et al. (2019), evaluated real-world effects of rear automatic braking and other backing assistance systems were evaluated. Negative binomial regression was used to compare police-reported backing crash involvements per insured vehicle year in 23 US states.
- Jingliang et al. (2017), analyzes the drivers braking behavior in typical V-B conflicts of China to improve the performance of Bicyclist-AEB systems. Naturalistic driving data were collected, from which the top three scenarios of vehicle-bicycle (V-B) accidents in China were extracted.
- Hiroshi et al.(1994), developed an automatic braking control system for automobiles applying a three-layer neural network model. This system enables the vehicle to decelerate smoothly and to stop at the specified position behind the vehicle ahead.
- Isermann et al.(2008), obtained experimental results of Anti-collision system with automatic braking and steering. Collision-avoidance, driver-assistance system are described with automatic object detection, trajectory prediction, and track following, with controlled braking and steering.

Principal Components of Ultrasonic Sensor (Dey, A.K 2018).

Ultrasonic detecting and ranging devices make use of high-frequency sound waves to detect the presence of an object and its range. These systems either measure the echo reflection of the sound waves from objects or detect the interruption of the sound beam as the objects pass between the transmitter and receiver. An ultrasonic sensor typically utilizes a transducer that produces an electrical output pulse in response to the received ultrasonic energy.

The normal frequency range for hearing of humans is roughly around 20 to 20,000 hertz. Ultrasonic sound are the sound waves that are above the range of human hearing capability and, so have a frequency above 20,000 hertz. Any frequency which is above 20,000 hertz may be considered as ultrasonic. Most of the industrial processes, including almost all the sources of friction, create some ultrasonic noise. The ultrasonic transducer produces ultrasonic signals. These signals propagate through a sensing medium and the same transducer can be used to detect the returning signals. Ultrasonic sensors usually have a piezoelectric ceramic transducer that converts an excitation electrical signal into ultrasonic energy bursts. These energy bursts travel from the ultrasonic sensor, bounce off objects, and are returned towards the sensor as echoes. Transducers are the devices that convert electrical energy to mechanical energy, or vice versa. The transducer converts the received echoes into analog electrical signals that are outputs from the transducer. The piezoelectric effect refers to the voltage produced between surfaces of a solid dielectric (no conducting substance) when some mechanical stress is applied to it. On the other hand when a voltage is applied across certain surfaces of a solid that exhibits the piezoelectric effect, the solid undergoes a mechanical distortion. Such type of solids typically resonates within narrow frequency ranges. Piezoelectric materials are generally used in transducers. For example, they are used in phonograph cartridges, strain gauges, and microphones that produce an electrical output from a mechanical input. Also, they are used in earphones and ultrasonic transmitters that produce a mechanical output from an electrical input. Ultrasonic transducers operate to radiate ultrasonic waves through a medium such as air. Transducers generally create ultrasonic vibrations with the use of piezoelectric materials such as certain forms of crystal or ceramic.

Effective Use of Ultrasonic Sensor (Jingliang, D et al 2017).

Ultrasonic sensor transmits ultrasonic waves from its sensor head and again receives the ultrasonic waves reflected from an obstacle. By measuring the length of time from the transmission to reception of the ultrasonic wave, it detects the distance and hence the position of the object. Ultrasonic signals are like audible sound waves, except that the frequencies are much higher than them. Our ultrasonic transducers have piezoelectric crystals which resonate to a desired frequency and convert electric energy into acoustic energy and vice versa. The below illustration shows how sound waves, transmitted in a conical shape, are reflected from a target back to the transducer. Accordingly, an output signal is produced to perform some kind of indicating or control function. A certain minimum distance from the sensor is required to provide a time delay so that the "echoes" can be interpreted. Some variables which can affect the operation of ultrasonic sensing include, target surface angle, reflective surface roughness or changes in temperature or humidity. Targets can have any kind of reflective form. Even round objects can be targets.

Principle of Ultrasonic Detection [Divya et al (2010)]
Sound is a mechanical wave travelling through the mediums, which may be solid, liquid or gas. Sound waves can travel through the mediums with the specific velocity depending on the medium of propagation. The sound waves which are having high frequencies reflects from the boundaries and produces distinctive echo patterns.
Ultrasonic detection is most commonly used in industrial applications to detect hidden tracks, discontinuities in metals, composites, plastics, ceramics, and for water level detection. For this purpose, the laws of physics which are indicating the propagation of sound waves through the solid materials have been used since ultrasonic sensors using sound instead of light for detection.

Materials
Generally, the Ultrasonic Braking System exists in two forms, the manual and the automatic. The manual option serves as more of a warning system to the driver. In the case of a collision, the ultrasonic sensor detects the obstacle and alerts the driver of a possible collision with the aid of a buzzer and a warning light but does not actuate the brakes while in that of the automatic, the ultrasonic sensor detects the obstacle of a possible collision and alerts the driver of a possible collision with the aid of a buzzer and warning light and actuates the brakes when the driver fails to do so (Isermann, R et al 2008).
The considered option is Automatic and the materials are

I. Arduino Uno
II. TT Gear Motor
III. Servo Motor
IV. L23d Motor Driver
V. Jump Wire
VI. Ultrasonic Sensor
VII. Lithium Ion Battery

Source: Arduino L293D. Fig 1: Arduino Uno

Arduino Uno:
Arduino Uno is a microcontroller board based on the **ATmega328P**. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started

Source: Shimazaki, K et al. (2018). Fig 2: Gear motor

Gear Motor:

DC motor is the most common type of engine that can be used for many applications. We can see it in remote control cars, robots, and etc. This motor has a simple structure. It will start rolling by applying proper voltage to its ends and change its direction by switching voltage polarity. DC motors speed is directly controlled by the applied voltage. When the voltage level is less than the maximum tolerable voltage, the speed would decrease. For this particular project, we will be making use of the tt gear motor

Source: Dey, A.K(2018). Fig 3: Servo Motor

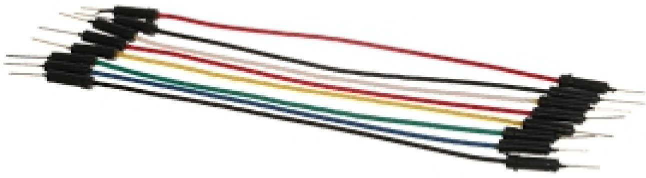
Servo Motor:

Servo motor is a simple DC motor with a position control service. By using a servo you will be able to control the amount of shafts rotation and move it to a specific position. They usually have a small dimension and are the best choice for robotic arms.

Source: : Arduino L293D. Fig 4: L23d Motor Driver

Arduino L293D Motor Driver Shield:

L293D shield is a driver board based on L293 IC, which can drive 4 DC motors and 2 stepper or Servo motors at the same time. Each channel of this module has the maximum current of 1.2A and doesn't work if the voltage is more than 25v or less than 4.5v. So be careful with choosing the proper motor according to its nominal voltage and current. For more features of this shield let's mention compatibility with Arduino UNO and MEGA, electromagnetic and thermal protection of motor and disconnecting circuit in case of unconventional voltage raise.



Source:Coelingh,E et al (2010).Fig 5: Jump Wire

Jump Wire:

A jump wire (also known as jumper, jumper wire, DuPont wire) is an electrical wire, or group of them in a cable, with a connector or pin at each end (or sometimes without them – simply "tinned"), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering.

Individual jump wires are fitted by inserting their "end connectors" into the slots provided in a breadboard, the header connector of a circuit board, or a piece of test equipment.

Source: Joshua, P et al (2010).Fig 6: Ultrasonic Sensor

Ultrasonic Sensor:
Ultrasonic transducers and ultrasonic sensors are devices that generate or sense ultrasound energy. They can be divided into three broad categories: transmitters, receivers and transceivers. Transmitters convert electrical signals into ultrasound, receivers convert ultrasound into electrical signals, and transceivers can both transmit and receive ultrasound.

Source:Dhawan, A.P (2022).Fig 6: 18650 Lithium Ion Battery

A Lithium-Ion Battery (Li-ion):
This is a type of rechargeable battery composed of cells in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge and back when charging. Li-ion cells use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode. Li-ion batteries have a high energy density, no memory effect (other than LFP cells) and low self-discharge. Cells can be manufactured to prioritize either energy or power density. They can however be a safety hazard since they contain flammable electrolytes and if damaged or incorrectly charged can lead to explosions and fires. For this project we made use of 18650 li-ion battery (Dhawan, A.P 2022).

Method.

The design parts are the hardware and the software

- Hardware: The tt gear motors are connected to the terminals provided on the motor driver with the aid of wires and then held firmly to the body of the vehicle. The ultrasonic sensor is placed in front of the vehicle and is connected to the Ground (Gnd), the 5v, The A0-A5 pin terminals provided on the motor driver while the servo motor is attached to the servo port on the motor driver. The motor driver is then connected to the Arduino Uno with the help of male head connector attached to it. The battery is placed beneath the car and is connected to the motor driver with the aid of dc switch to enable us turn on and off the power supply.
- Software: Once the connections have been made the Arduino is connected to a PC with the help the connector and the program is uploaded to it.

Summary of Operation

According to the program, the maximum speed assigned to the gear motors is 80km/hr and the sensor distance is set to 20m. When in motion the ultrasonic sensors transmits ultrasonic waves from its sensor head and again receives the reflected wave from an obstacle and sends the readings to the Arduino Uno which in turn acts according to the programming by stopping current from flowing into the tt gear motor which causes them to stop rotating causing the vehicle to come to a stop.

By measuring the length of time from the transmission to reception of the ultrasonic wave, it detects the distance and hence the position of the object. A certain minimum distance from the sensor is required to provide a time delay so that the "echoes" can be interpreted. Some variables which can affect the operation of ultrasonic sensing include, target surface angle, reflective surface roughness or changes in temperature or humidity. Targets can have any kind of reflective form. Even round objects can be targets. The model block diagram is shown below:

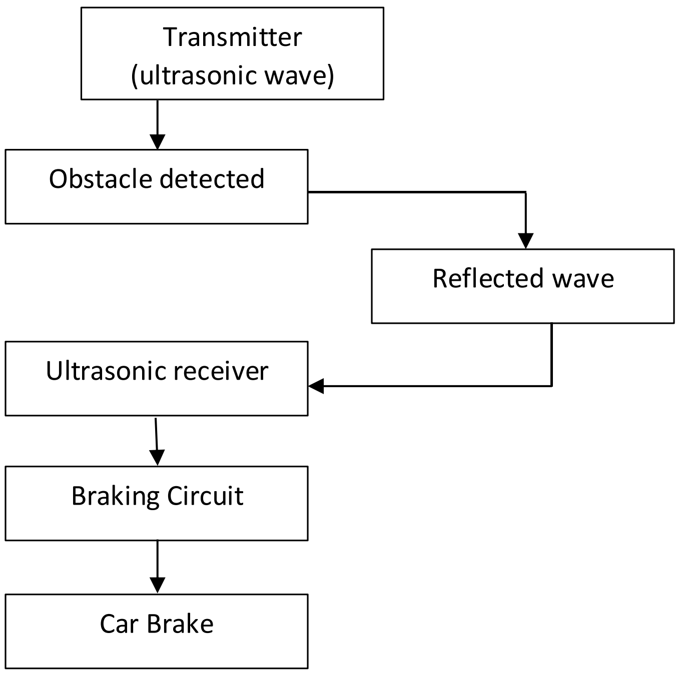


Fig 7: Model block diagram

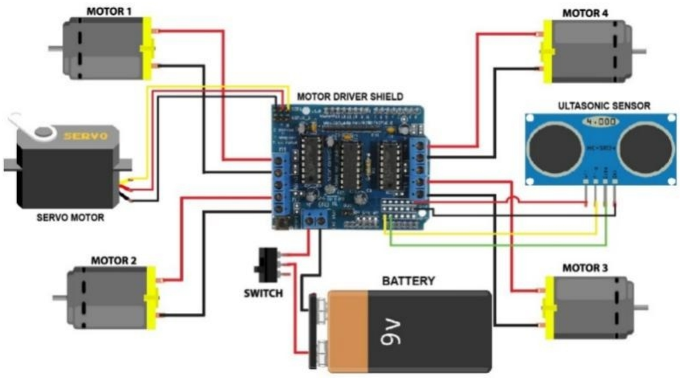
The steps required to read the distance and controlling the speed of a vehicle;

• Microcontroller makes the I/O line output. (By using the DDR x Register in AVR or TRIS x Register in PIC)
• The I/O line is made low (this may be the default state of I/O pin)
• Wait for 10uS
• Make the I/O line high,
• Wait for 15uS

• Make the I/O line low
• Wait for 20uS
• Now make it input (by using the DDR x Register in the obstacle and come back to the module. • Module will keep it low. Wait when the pulse is low, as soon as that becomes high start the timer.
• After this, wait till pulse is high and as soon as that becomes low copy the timer value and stop the timer.
• Finally we have the time required for the wave to go hit the obstacle and come back to the module.
• If the pulse width obtained is in microseconds, the distance of the obstacle from the vehicle can be calculated by the following formula:
• Distance in cm = Pulse width/58 Distance in inches = Pulse width/148
• After calculating the distance of the obstacle we will define variable speeds according to the distance of approach of the obstacle and store them in three flags

Circuit Diagram and Description of the Entire System

Fig.8, depicts the circuit diagram for the entire system :



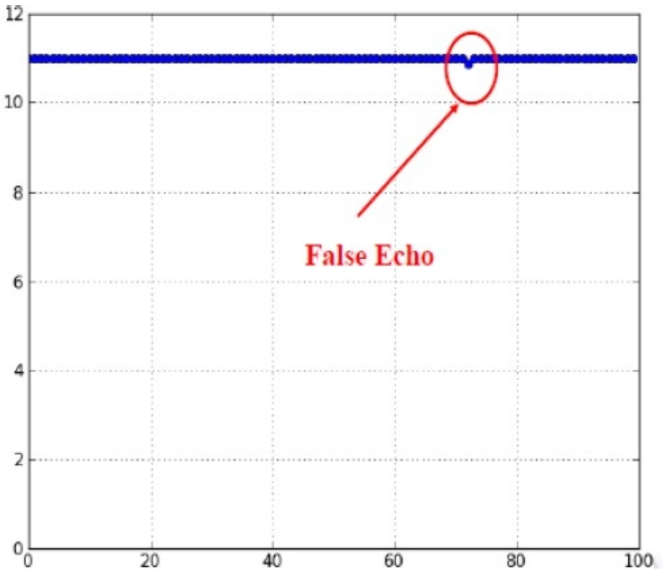
Source: Hiroshi. O et al(1994).Fig 8: Circuit Diagram

From the above diagram, four gear motors are connected to the driver shield with the help of a wire, the ultrasonic sensor is connected to the ground, A0-A1 and the 5v terminal, the 5v terminal serves as a power supply to the sensor, the servo motor is connected to the motor driver through the servo pins and the battery is connected to the driver with the help of dc switch to enable us turn on and off the circuit.

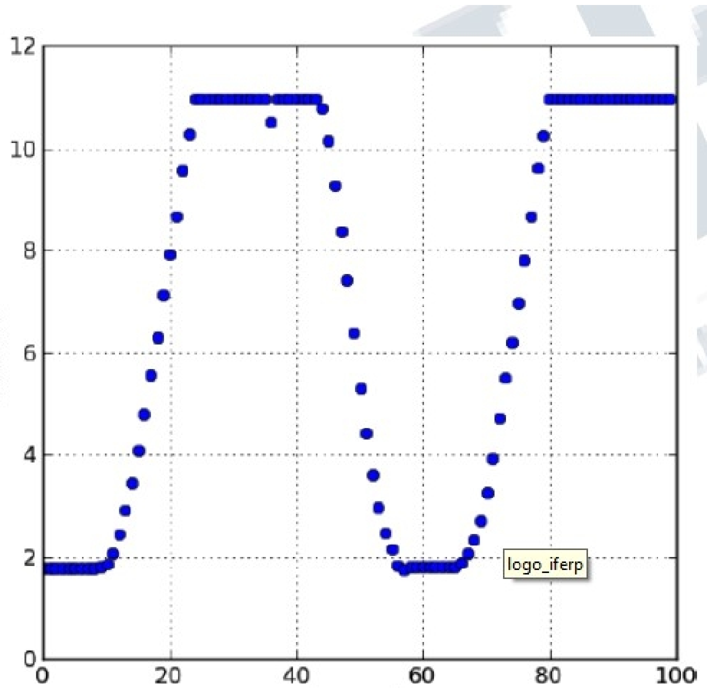
Results

Results Obtained From Testing the Sensor

An insufficiently high threshold level causes the detection of false echoes produced by turbulences and irregularities in the road, which make the control system act on the brakes unnecessarily. In contrast to this, if the threshold is too high, then detection failures can occur, meaning that no objects are detected even if they are actually there and therefore causing possible collisions. To adjust the threshold level, a hundred echoes were recorded in a range of 11 meters, with the sensor at rest and no obstacles in the front. The threshold has been reduced slowly, until at a final value of 2×10^{-4} a false echo has been detected. Figure 1 shows the measurements resulting from this experiment. After this, the threshold level has been used in a second experiment, in which the sensor is placed in a vehicle which approaches and moves away from another vehicle which is at rest. During the experiment, the distance was measured hundred times, showing the results in Figure 2. The distance was varied from about 2 meters to more than 11 meters, showing only one false echo that occurred when the distance between vehicles was higher than the range of the ultrasonic sensor used. No detection failures occurred and when the obstacle was within the range of the ultrasonic sensor, it was correctly detected always.

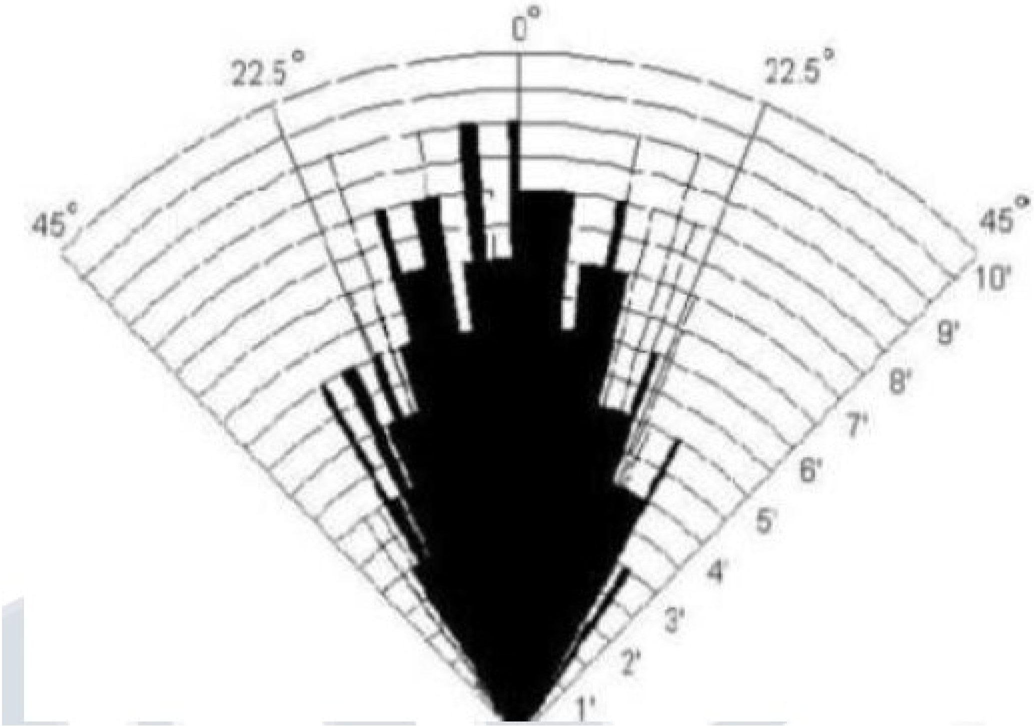


Source:Lanes, M et al(2009). Fig 9: Measurements Made With the Sensor at Rest and No Obstacles Ahead



Source: Nptellitm (2022).Fig 10:Measurements Made With the Sensor Placed In ACar Moving In Front of AParked Vehicle

A. Target Angle This term refers to the "tilt response" limitations of a particular sensor. Since ultrasonic sound waves reflect from the surface target object, the obtained target angles indicate acceptable amounts of tilt for a given sensor.
B. Beam Spread This term is defined as the area in which a round wand will be sensed if passed through the target area. This shows the maximum spread of the ultrasonic sound waves as they leave the transducer. Fig. 11,shows a typical beam spread of an Ultrasonic Sensor



Source: :Lanes, M et al(2009). Fig 11:A Typical Beam Spread Angle of an Ultrasonic Sensor

Results Obtained From Calculating Braking Distance

The braking distance is the main factor considered in this system. Braking distance for a particular speed is the distance between the point of application of the brakes and the point at which the vehicle comes to a complete stop from the present speed. It is calculated by using following formula.

Braking Distance = V / 2μg (meter)

Where V= Velocity of the vehicle (m/s) μ = Coefficient of friction of road = 0.8 g = Acceleration due to gravity = 9.81(m/s2)

In this formula the condition of brakes and the road conditions are not considered for coefficient of friction μ.

Table 1, is Velocity vs Braking Distance

Source: Van NET"s N(2008).Table 1: Velocity vs Braking Distance

Velocity(km/hr)	Braking Distance(m)
60	17.69
50	12.28
40	7.86
30	4.42
05	0.12

Conclusion

An automatic braking system based on an ultrasonic sensor is designed and the test setup is developed with distance measurement arrangement for a stationary obstacle. The working is tested and the function is documented. This system is controlling the speed of vehicle and apply brake according to whether the predetermined distance is achieved or not. The ultrasonic sensor, which is used here is cheaper and less demanding of hardware than other types of sensors that are presently used. This sensor is used to measure the distance between vehicle and the obstacle. The relative speed of the vehicle with respect to the obstacle is estimated using consecutive samples of the distance calculated. These two quantities are used by the control system to calculate the actions on both the accelerator and also the brake, thus to adjust the speed in order to maintain a safe distance to prevent accidents. As ultrasonic sensors can detect any kind of obstacle, this system can also prevent collision of the vehicle with pedestrians, or can at least reduce the injuries occurring. Since the control system does not use the absolute speed to calculate the safety distance as done by other existing systems, the interaction with automotive electronics is limited to actions on the accelerator and brake. This matter, coupled with the fact of lower cost of ultrasonic sensors, could facilitate the application and mounting of the system in many low-end vehicles, helping to improve comfort and safety and offer a hassle free driving experience at a reduced cost.

Recommendations

- Sensor distance should be shortened to increase the efficiency of the system.
- Removal of false echo in the sensor

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