REGULAR ARTICLE

Ultrasonic Sensor System for Autonomous Parking

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Smart parking sensors and technology make it easier for vehicles to find available parking places, increasing parking efficiency. This study focuses on vehicles safety by developing preventative systems that use ultrasonic sensors when the vehicle is in reverse mode. The sensors at the vehicle's bumper automatically activate and identify obstacles up to 3.5 m away when the gear is changed to reverse mode. The brake system will automatically engage if the system detects an obstruction within 40 cm, causing the vehicle to stop instantly. These systems are often installed to varied sorts of vehicles which may avoid casualties and also to offer confidence to the driving force during re-verse mode. This paper gives the literature on the use of smart parking sensors, technologies, and applications and assesses how well they work in open parking lots.

Keywords: Reverse mode, Safety, Parking distance control, Obstacle avoidance, Autonomous parking, Ultrasonic sensors.

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1. INTRODUCTION

The objective of this paper is to evaluate the applicability of smart parking sensors, technologies, and applications at open parking lots. Every year, thousands of people are died or critically injured as a result of a vehicle backing up in front of them. Usually, a back-over incident happens when a vehicle is backing out of a driveway or parking space. According to the National Highway Traffic Safety Administration (NHTSA) vehicles backing up cause injuries to over 6,000 people each year, 2,400 of those are children, and quite 100 of them will die as a result of their injuries. Consequently, it would be beneficial to develop this prototype as a way to prevent fatalities and boost the confidence of drivers who want to park their cars backwards.

With today's automation and tried-and-true technologies, new models of vehicles are offering park assist features that assist with autonomous parking by using sensors and guiding systems. In order to increase the safety of all driverless vehicles, vehicle to vehicle (V2V) technology could be implemented to all types of vehicles [1, 2]. A range of technologies, including GPS, sensors, V2V, etc., would be required for an autonomous driverless vehicle. A decision support system that employs smart parking sensor to identify parking occupancy information may be yet another feasible alternative; this would enable drivers to make well-informed decisions about where to park their vehicles [3].

There has already been a significant amount of research done to increase parking effectiveness at closed parking lots, which are paid parking lots that enable parking space reservations. There are online applications provide smart parking services in closed parking lots [4]. Yet there is relatively little literature on a parking lot, the open parking lots which do not enable reservations, are freely accessible for just a short period of time and are frequently located outside take up a lot of area. Hence, there is still a search gap that needs to be filled in order to improve parking efficiency at an open parking zone. If better decision aids are provided to drivers, it is anticipated that their behavior will be efficient.

Ultrasonic sensors are equipped in vehicles to avoid parking crashes. These types of ultrasonic sensors make use of ultrasonic frequencies more than 20 kHz which are beyond human hearing range to detect objects and it is currently equipped in every latest generation vehicle. These Sensors are independent of all target object properties. After the authorizing of these ultrasonic sensors in the vehicle the overall parking crashes is reduced to 70 % and saved a lot of useless expenditure to the insurance companies [5].

2. METHODOLIGY

The compatibility and expenditure of sensors and

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technology determine their suitability. The object detection, controller, and linear actuator operated phases make up the three stages of this prototype's development. If an impediment is detected by an ultra-sonic sensor during reverse parking at a specific distance, the sensor will transmit information to the controller. The controller will command the ARDUINO SHIELD linear actuator to break the line with high pressure, slow down the vehicle and stop it. Fig. 1 depicts the automatic prevention system's block diagram and architecture when the vehicle is in reverse mode.

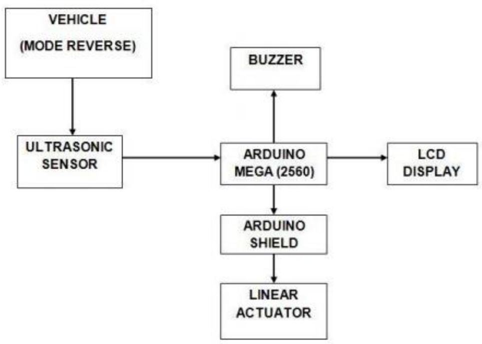

Fig. 1 – Automatic Prevention System block diagram and design

Basing on working mode, frequency etc., there are many classifications of the ultrasonic sensors but as per the construction wise three models available one is embedded model, separated transducer model and the other one is SMD Type MA40.

3. MODELS

3.1 Embedded Transducer Model

The Fig. 2 shows embedded sensor BOSCH OEN 3D0 919 275 D. In the embedded kind of sensor both transmitter and receiver are embedded on the same piezoelectric crystal, the transmission of the ultrasonic sound detection of echo signals are entirely controlled by microchip internally. The embedded kinds of sensors are built more efficient than exciting two ultrasonic transducers it is better to excite a single transducer.

Fig. 2 – Embedded transducer model

3.2 Separated Transducer Model

Fig. 3 Shows HCSR04 model ultrasonic sensor. Basically the sensor comprises of two transducer components which are known as the transmitter and receiver, consists of two piezoelectric crystals, the transmitter and receiver are nothing but piezoelectric transducers which can convert electrical pulses into ultra-sound and vice versa. The transmitter generates ultra-sonic sounds based on the electrical pulses given to it and the receiver detects the reflected signals which are also known as echo signals, the echo signals in this are detected by the receiver were further converted into electrical signals and given to the miniature circuit boards.

Fig. 3 – Separated transducer model

3.3 SMD Type MA40H1S-R Transducer Model

MA40H1S-R is an Ultrasonic transducer. It transmits ultrasonic waves to the air and receives ultrasonic waves by one transducer. It is used to detect an object or distance to target by travelling time of reflected sound. MA40H1S-R enables us to mount on narrow space or improve design by its features. Fig. 4 shows the construction of SMD Type MA40H1S-R transducer model

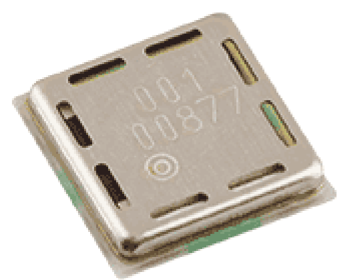

Fig. 4 – SMD Type MA40H1S-R transducer model

4. CONSTRUCTION

The ultrasonic sensors are made to work in all atmospheric conditions so in order to reach the industrial standard the sensors are made in an encircled manner; the whole sensor is summarized with aluminum metallic casing which helps the sensor to be robust against all weather conditions. Practically all the piezoelectric crystals used in transducers are made up of ceramic materials which can exhibit a mechanical flex when an electrical field is applied on the crystal. The transducer's internal design is depicted in Fig. 5. Here;

a) Piezoelectric ceramic: In this sensor Lead Zirconate Titanate (PZT) is used to manufacture the piezoelectric transducer.

b) Lead wire: This is one of the conductors which is robust against ultrasonic vibrations, having more ductility and tensile strength which carries excitation energy to the piezoelectric transducer.

c) Diaphragm: Diaphragm is a flexible part of metal where the piezoelectric crystal is attached to it which will microscopically oscillate to and from to generate ultrasonic waves [7].

d) Cable: cable is made up of high-quality copper material to maintain the signal strength as far as possible and the polymer cover on the cable protects the cable from mechanical stress and avoids unwanted noise interferences from the surroundings.

e) Metallic case: It is made up of aluminium metal which protects the sensor from all weather and harsh environmental conditions.

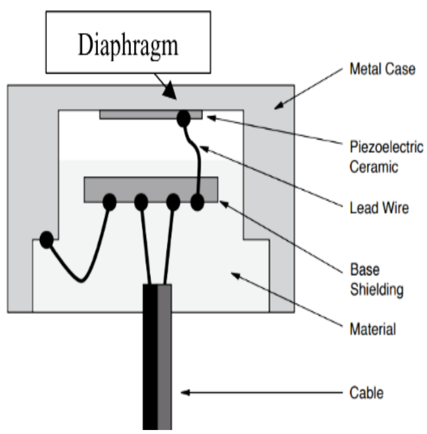

Fig. 5 – Internal construction of the transducer

5. WORKING PRINCIPLE

The operating principle behind the ultrasonic sensors is piezoelectric effect [8]. Piezoelectric effect is the ability of a certain material by which it can generate ultrasonic sounds based on the applied electrical pulses, this action is completely reversible, if we apply mechanical stress on a piezoelectric crystal it can generate electrical pulses, this unique property of piezoelectric crystals allowed us to manufacture such a unique kind of sensors. Figure 6 and Figure 7 shows the piezoelectric phenomena of the Lead Zirconate Titanate (PZT) piezoelectric ceramic crystal [9]. The Ultrasonic sounds are nothing but mechanical longitudinal waves which propagates as a set of compressions and rarefactions travel-ling along in the direction of wave in the medium. In order to create such a mechanical wave, the sensor needs a flexible surface which is technically called as diaphragm.

5.1 Working Modes

Working modes by which every ultrasonic sensor works is Diffusion mode, Reflex mode and Thru-beam mode [10].

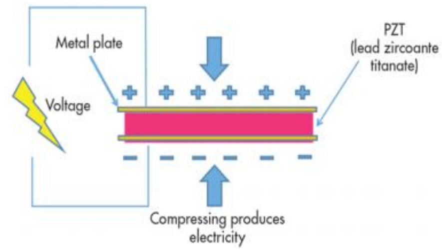

Fig. 6 – Piezoelectric phenomena (mechanical energy to electrical energy conversion)

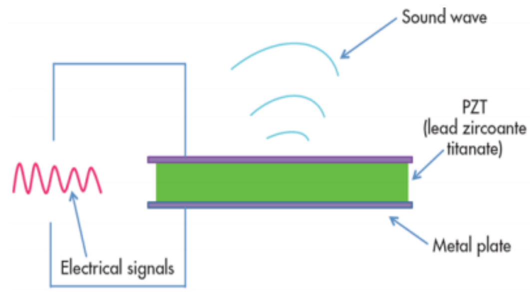

Fig. 7 – Piezoelectric phenomena (electrical energy to mechanical energy conversion)

a) Diffusion mode: In diffusion mode the ultrasonic waves get reflected from the target object towards sensor. This mode is well suited for the objects which are flat and perpendicular to the incident ultrasonic beam.

b) Reflex mode: In reflex mode the sensor is switched to continuously receiving mode.

This is especially used to detect soft objects which can absorb ultrasonic sounds.

c) Thru-beam mode: In Thru-beam mode the transmitter continuously radiates ultrasonic waves and the receiver receives the signals whole time but when an object interrupts the signal transmission between the transmitter and receiver, the sensor detects the object.

The ideal use for this mode of operation is the detection of objects less than 5 cm.

6. DETECTION AND DISTANCE MEASUREMENT CALCULATION

Typically, ultrasonic sensors measure the reflected signals to assess their objectives. These sensors use ultrasonic waves to estimate the separation between objects by timing the transmission and receipt of ultrasonic signals. According to the sensor working mechanism it works in two steps one is detection and another is Distance measurement.

a) Object detection: In this method initially, ultrasonic waves get transmitted into air when these waves hit an object, it reflects the signals which are called as echo signals, when these echo signals are received by the receiver the sensor detects the target object. In case if there is no object available then no echo signals were generated this indicates the absence of object. Fig. 8. Shows the place of object near the sensor.

b) Distance measurement: Moving onto the distance/range measurement, Range is nothing but distance between Object and the sensor, in order to find the distance, time of flight is needed to calculate the distance. Time of flight is the amount of time it takes for an ultrasonic wave to travel from the transmitter to the receiver, we can get the time of flight from the speed equation (Fig. 9).

$$\text{Speed} = \text{Distance Time} \quad (1)$$

For instance, considering the time of flight as 10 ms. The velocity of the sound in air is 344 m per second at 20°C.

Now transposing the speed from Eq. (1) to get the distance

$$\text{Distance} = \text{speed} * \text{time of flight} / 2 \quad (2)$$

substituting the values in Eq. (2)

$$\text{Distance} = 330 \text{ ms} \times 10 \times 10^{-3} \text{ s} / 2 = 1.65 \text{ m} \quad (3)$$

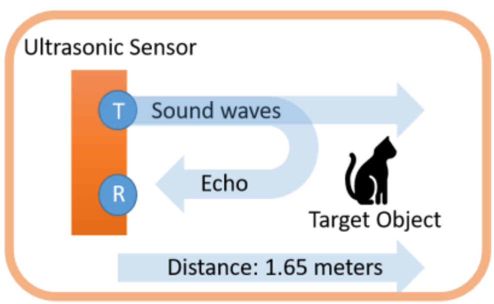

Fig. 8 – Target detection

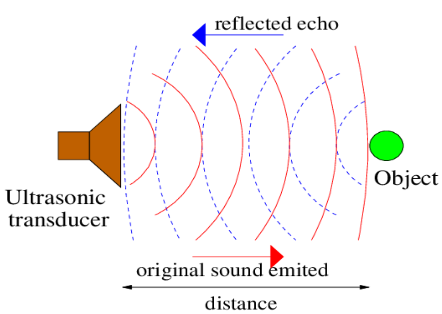

Fig. 9 – Time of Flight

7. BLIND SPOT DETECTION

Blind spot is the vacant place on the road which can't be seen by the vehicle driver from either of the mirror sources like side and rear mirrors, it is one of the critical places on the road where the vehicle driver fails to estimate the exact distance due to large dimensions of vehicle chassis. To assist the vehicle driver, parking sensors are used which can help to detect the blind spots and avoids unwanted crashes and collisions with the surrounding vehicles. Few of the blind spots depicted in Fig. 10. A single ultrasonic sensor cannot detect the blind spots if the surfaces are inclined with 45 degrees so there is a need to include more number of sensors in parallel, hence there are10 ultrasonic sensors are often installed on a vehicle's chassis to properly identify the blind spots and guides the vehicle driver to park the vehicle safely.

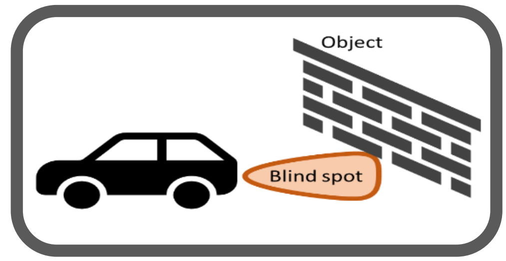

Fig. 10 – Blind Spots

8. RESULTS AND DISCUSSIONS

Fig. 11 Explains about ultrasonic sensors output which are known as beam patterns which is a plot drawn between sound pressure level (SPL) and the angular position (in degrees), The ultrasonic sensor's initial field view is 56 degrees when it is operating at 30 kHz, but when the frequency is increased to 60 kHz the field of view became 19 degrees. Hence the sensor can filter two objects and able to concentrate on single target object precisely which is located in between two objects' [11]. By comparing these beam patterns side by side operating at 30 kHz and 60 kHz, one can easily comprehend that the sensors directivity is directly proportional to the frequency that is applied to it and the operating frequency has an inverse relationship with the sensors field of view.

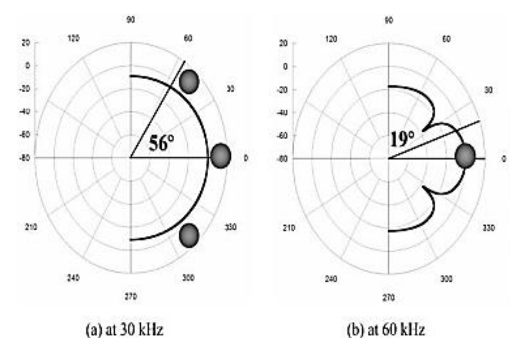

Fig. 11 – Beam patterns

9. CONCLUSION

This article outlines the use of smart parking sensors, technology, and applications for open parking lots. Due to a variety of environmental factors, none of the cur-rent smart parking technologies and applications is appropriate for open parking lots.

By this study, the current braking system will be developed and improved in order to reduce accidents while in reverse. After commissioning of this ultrasonic sensors into the vehicles the parking crashes are drastically reduced and shows a great impact and the results are impressive, but rest of the crashes can also be con-trolled by integrating these ultrasonic sensors with autonomous braking system to ensure the vehicle safety, the accuracy and performance of the ultrasonic sensors are poor therefore engineer's developed high directivity sensors to predict the exact position of sur-rounding vehicles which helps to develop advanced parking guidance systems, hence the ultrasonic sensors are going to become the future of the upcoming autonomous vehicles.

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Ультразвукова сенсорна система для автономного паркування

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Розумні паркувальні датчики та технології полегшують транспортним засобам пошук вільних місць для паркування, підвищуючи її ефективність. Це дослідження спрямоване на безпеку транспортних засобів шляхом розробки профілактичних систем, які використовують ультразвукові датчики, коли автомобіль рухається заднім ходом. Датчики на бампері автомобіля автоматично активуються та визначають перешкоди на відстані до 3,5 м при перемиканнні передачі в режим заднього ходу. Гальмівна система автоматично вмикається, якщо система виявляє перешкоду в межах 40 см, що змушує автомобіль миттєво зупинятися. Такого типу системи часто встановлюються на різні види транспортних засобів, що дозволяє уникнути жертв, а також забезпечувати впевненість водія під час руху. У даній статті наводиться література про використання інтелектуальних паркувальних датчиків, технологій і програм, а також оцінюється, наскільки ефективно вони функціонують на відкритих паркінгах.

Ключові слова: Реверсивний режим, Безпека, Контроль паркування, Автономне паркування, Ультразвукові датчики.