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Project Design Report

USE OF ULTRASONIC SENSORS AND ARDUINOS IN PARKING ASSISTANCE SYSTEMS

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Abstract

The essential objective of the design project conducted was not only to produce a working parking assistance system using an Arduino circuit board and supporting components, but also to research into the functional uses and future of sensors in vehicles and parking systems. In the research and design conducted, it was found that ultrasonic sensors are quite useful integrated into parking assistance systems, and while they are in use in currents production vehicles, there is great room for improvement in the future. This includes the use of ultrasonic sensors for assistance to the human operator to notify them of potential obstacles and incidents, but even further into the future, it will be very pivotal in helping potentially driverless cars and, possibly closer in the future, automated parking systems in partial-driverless cars. With the rising use of Artificial Intelligence (AI), the rise of automated vehicle driving and parking systems will be the prime component in keeping car manufacturers in the lead in safety competition.

KEYWORDS

Arduino, ultrasonic sensor, parking assistance, safety, future goals

1 | INTRODUCTION

With America being a personal-vehicle dominant country, the need for parking lots, garages, and driveways is very much at the essential basis of infrastructure and city planning. As of a census conducted in 2022, the ratio of personal vehicles owned in the United States to the total population is approximately 0.837. Additionally, 91.7% of household own at least one vehicle [1]. With this, parking lots are quite necessary in the current climate of transportation. As a matter of fact, there are between 3 and 8 parking stalls per vehicle in America, and approximately 5% of all urban land in the United States is covered by surface parking lots [2]. It can be deduced from this data that parking is an integral part of driving, and parking accidents have the potential to make up a large majority of incidents and vehicular damages. In actuality, the number is near 20% of all motor vehicle crashes occurring in parking lots or garages, and

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91% of those crashes involve backing up; this then leads to near 60,000 people annually sustaining injuries from parking incidents [3].

A presumption can be made in the current level of vehicular advancement that most, if not all, of these parking lot accidents can be attributed to human error. This would include failure to recognize hazards in any field of view (including blind spots), slow reaction time to oncoming traffic or pedestrians, or any behaviors hindering safe parking situations deriving from human thinking and attention. As with most recent technological advancements, the basic premise of decreasing and eventually getting rid of these issues is to introduce automation and autonomous driving (AD). Motoyama et al [4] analyses the possibility of an automatic, cloud-based system for a smart city involving parking databases with ultrasonic sensors ion the forefront of the tools used.

All AI-based systems rely on inputs and arguments to be successful, and an autonomous vehicle (AV), especially a parking system, will rely heavily on sensor-based information to make decisions or to better inform the human operator of their surroundings. As a small stepping stone to an AV, an Arduino can be used to create small electrical systems that represent what could be used in a larger application such as vehicular automation. Specifically, an Arduino-based ultrasonic sensor assistance system can represent what later becomes an integrated AD parking system.

2 | MATERIALS AND METHODS

The design of this ultrasonic sensor assistance system using the Arduino uno board as its prime component. The Arduino is a popular microcontroller that can be used for many applications, including household automation, robotics, and several others. It has been used in several other large projects with fascinating applications including ultrasonic radars, door-locking systems, and plant disease detection robots, to name a few [5]. Thus, the advantages and fascinating applications of the Arduino in the past led to use of its hardware in creation of the ultrasonic parking sensor application. All the parts used in the description, design, and build come from the ELEGOO Uno Super Starter Kit shown in Figure (1).

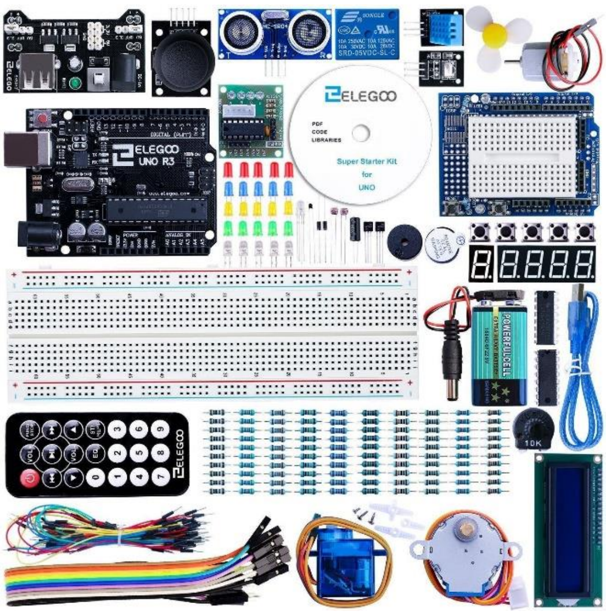

Figure (1) ELEGOO Uno Super Starter Kit parts visualized.

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The first essential components used outside of the microcontroller Arduino itself are the solderless breadboard and jumper wires. The solderless breadboard is a very practical way to customize wiring techniques and produces the ability to do multiple different projects and orientations of wires on the same breadboard, saving costs in prototyping and design stages of this as well as other projects. The jumper cables are mainly male-to-male wires that connect to the embedded pins on the Arduino and the pre-designated ports aligned in a grid pattern on the breadboard.

The main component as well as the basis for this project idea is the ultrasonic sensor. The specific model of ultrasonic sensor used in the construction of this circuit is ELEGOO HC-SR04 Ultrasonic Sensor. Marian [6] provides a detailed list of the following specifications relating to the ultrasonic sensor used. The device is a non-contact measuring device that has an operational distance range between 2 centimeters (cm) and 400 cm. The accuracy of this model is approximately 3 millimeters (mm), which, in relation to vehicular measurements and spacing is quite accurate. As seen in figure (3), the sensor itself is quite compact, and it can be placed in a multitude of places around a vehicles outer profile. The angle of measurements provided by one ultrasonic sensor is around 15 degrees, so it would be necessary to make use of multiple, or several different sensors to fully account for blind spots and all degrees of obstacle detection.

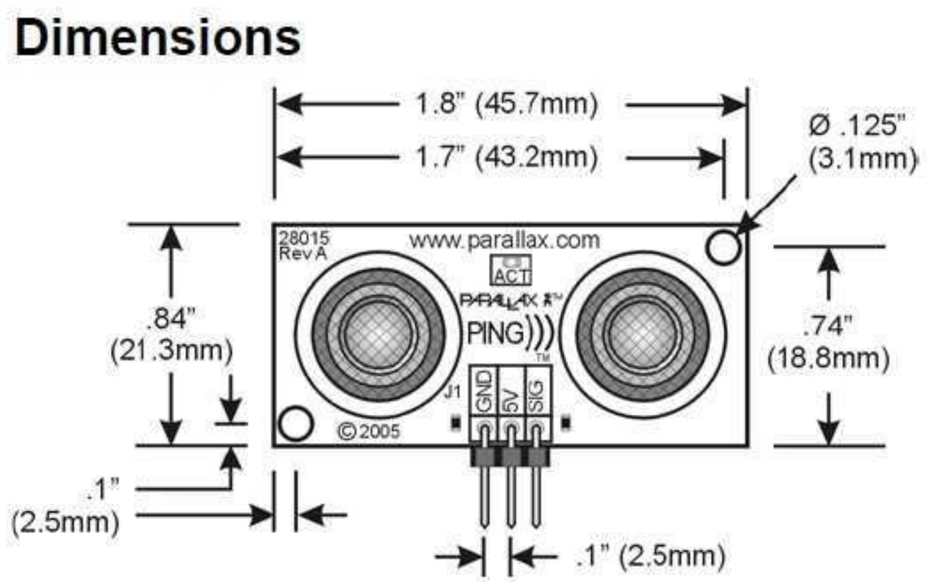

Figure (2) ELEGOO HC-SR04 Ultrasonic Sensor visual and dimensions.

The relay of the sensor values must be visualized for optimal use of the human operator, and for the human in the vehicle even despite a possible AV. It is essential that, especially in the early stages of AD, that the human be at a minimum aware of what is going on and what the vehicle is doing and how the AI is making decisions. The display of the sensor values and warning signals will help the human operator currently, and in the future it can be used to evaluate the logical ability of the AI to make decisions based on sensor data. For the data visualization in this project, a combination of an Liquid Crystal Display (LCD) screen and a multicolor Light-Emitting Diode (LED). The light will be showing green when there is no object in the vicinity that could pose harm to the vehicle. Immediately after an abject enters the range of the ultrasonic sensor detection, it will begin a gradient change from solely green to solely red if the object is at the minimum distance allowed by the system. The LCD screen will

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always display the detected distance from the ultrasonic sensor to give a spatial idea of how far out the obstacle is in relation to the color gradient recognition.

In addition to the main functional pieces that make up much of the circuit, there are a few other supporting pieces that are also needed. The first, and most important, are the 220-ohm resistors to prevent the LED light from getting damaged or destroyed from the current in the circuit. In addition to the resistors protecting the circuit components, there is also a potentiometer in conjunction with the LCD screen to control the resistance and voltage in series with the screen.

The methodology behind the decisions made to use certain materials and ideas lie in multiple different areas. The first thought of how to display ideas comes from current vehicle technology. The traditional production vehicle released in today's market has a center screen in the front seat with displays always showing, as shown in figure (3). When in reverse, which is when over 90% of parking incidents occur, the screen shows a camera view of the area behind the car with color coded area signifying how close the vehicle is to contacting obstacles. One feature that is not as prevalent is a constant distance display of the closest obstacle to the vehicle, which is the motivation for having the LCD screen included in the circuit. It is important for the color mapping to show the danger with common pattern recognition, but having a measurable number available will help a driver conceptualize better in their mind how far something truly is away.

Figure (3) Common Configuration of Car Screen (Note: No Distance Value).

In today's day of technology and the internet, it could easily be found that multiple other groups have worked on similar projects. The basis of the project created in this project is a combination of multiple different Arduino builds aiming for a similar use. The user "thediylife" on instructables [7] produced a very similar design in the past to what this project was aiming to create. The goal of their project was to designate parking the car in the correct spot every time and to save that distance value into the collection, with the LED light to designate if it is within the correct range of distances for that spot. To pivot off this, this project uses a very similar

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wiring diagram, but the essential function is to read the distance and consistently update the value on the LCD screen showing how well the vehicle is going into the parking spot. Thus, the code used for this application will be different, producing different outputs.

The wiring diagram was produced using Tinker CAD based off a similar diagram but considering the different needs for this project. As seen in figure (4), the diagram is not excessively complicated, and it could be put together by almost all individuals proficient in wiring and circuit board applications.

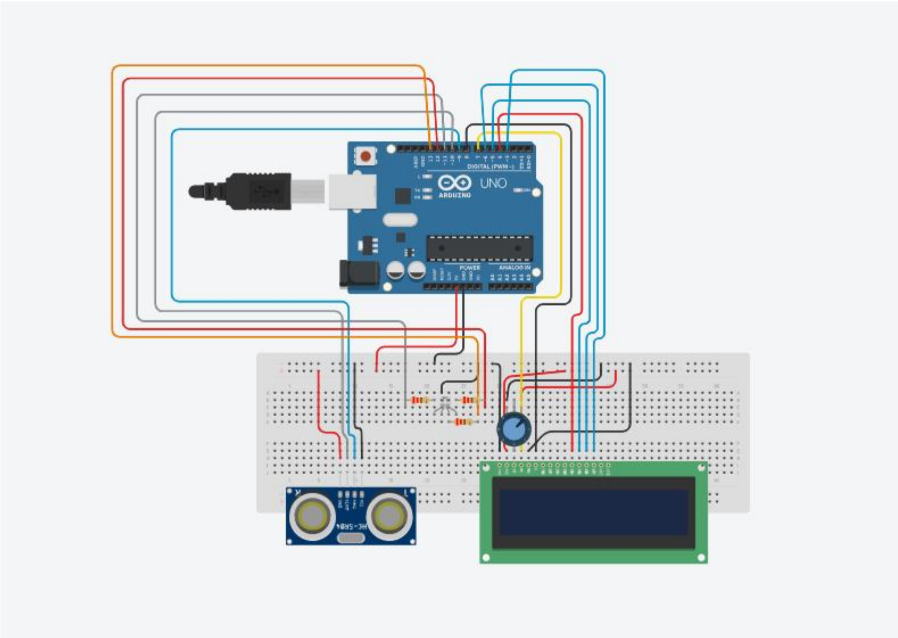

Figure (4) Circuit wiring diagram for parking assistance system.

3 | RESULTS AND DISCUSSIONS

The results of this design endeavor coupled with the research that went in to discovering the need for such devices and the future of similar technology is quite important to improving parking lot safety and minimizing the cost of residual damages in parking areas. For the physical device, the circuit worked quite well, although there were some things that had to be altered based on the parts at-hand in terms of their functionality as well as coding complexity and computational costs. For the LCD display, it worked with no adjustments: the screen displayed “distance: xx cm” and changed with each measurement conducted by the ultrasonic sensor. The potentiometer had to be adjusted with the screen to optimize the output of display readability. However, even with the optimization, the LCD display had a less than ideal visual of the words, which can be improved upon with better parts, different orientations, etc. With the LED light in the near vicinity, it would be very difficult for a theoretical driver to read the distance value in this iteration of the parking assistance device, thus potentially cancelling out one of the essential goals of the project itself.

The coding section of the design build was sourced from generative AI, using it to leverage time management and allowing it to build a basis for the commands needed. The original goal, as mentioned earlier, was to have the RGB light gradient shift as the object in the ultrasonic sensor varied from a faraway safe range to a dangerously close value. This would, of course, begin at green for the safe side and then eventually change to fully red at the danger setting. In

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practice, it was found that this method would not actually end up portraying what the original goal was to display. With an LED light that only has red, green, and blue, the color combination for a mid-range level threat to the vehicle did not have the specific coloration and mood that would match with a human's correlation. This is because red and green mix together to make a brown color. In the future, if advancements are made, it will be important to have a light containing red, yellow, and green. This could portray a range from full red varying to orange, yellow, light green, then green, respectively for ranges. This variation of colors is what is commonly used in current production cars, and it is what humans most clearly associate good, medium, and bad with due to traffic lights and other signs and signals.

To pivot off this issue, the code was altered to simply have a threshold of what distance was deemed safe, corresponding to green, along with a danger setting, corresponding to red. In figure (5) and figure (6), one can see the different light settings along with the distance reading displayed on the LCD screen.

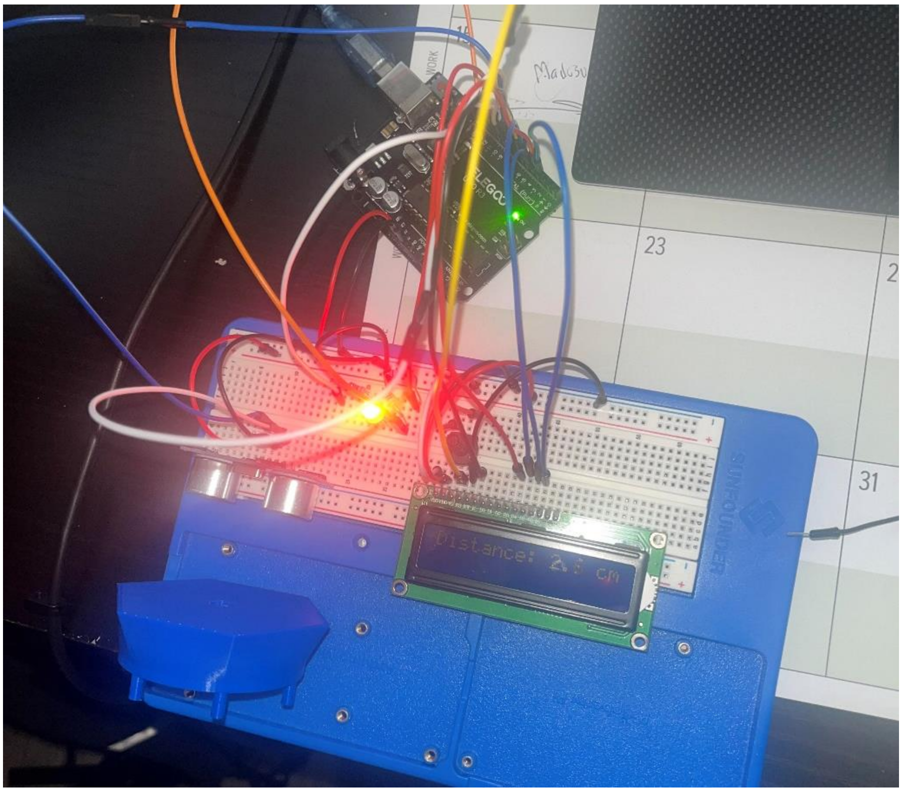

Figure (5) “Danger” setting of ultrasonic parking sensor (“Distance: 2.6 cm”).

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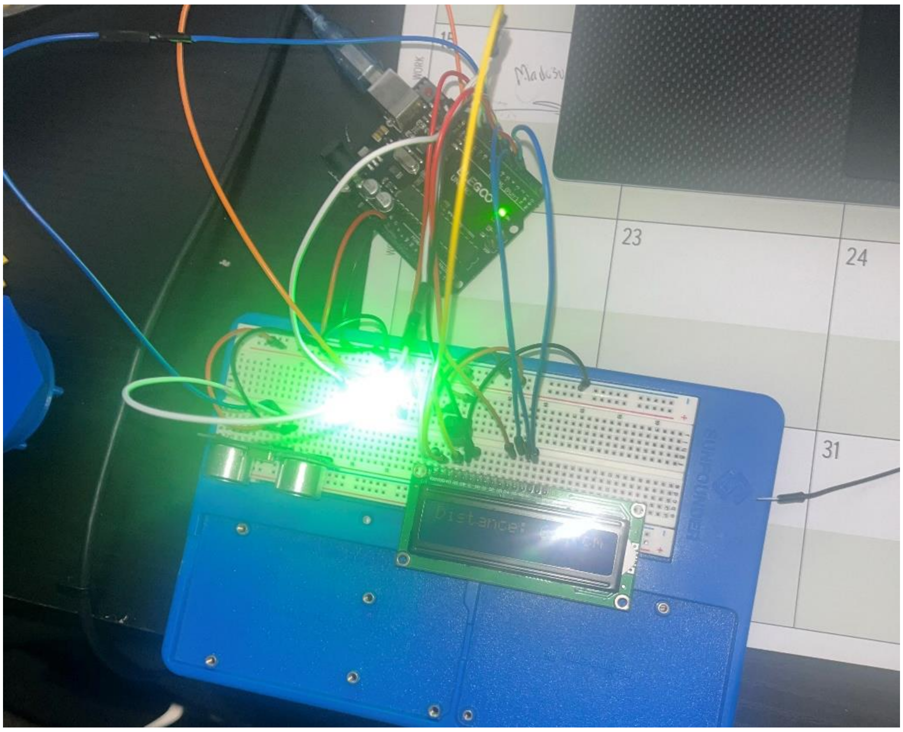

Figure (6) “Safe” setting of ultrasonic parking sensor (“Distance: 6.9 cm”).

The original distance values for “safe” and “danger” were set to be over 100 cm and under 10 cm, respectively. This also had to be adjusted for functionality, as the ultrasonic sensor on hand was struggling to produce accurate measurement values. This could have been due to prior use, as in wear, or it could have been slightly broken. It had previously been used in an ultrasonic radar in which the four metallic prongs were bent to fit a different orientation, so it is very possible the bend back to straight could have messed with the solder connections and other functionalities. However, it was successfully ready close-range values, so to produce the working prototype, the values had to be adjusted to 6.5 cm on the high end and 3 cm on the low end. This worked very well for the demonstration, and with better supplies and improvements, can be used in more practical applications.

The prototype produced in this design endeavor is a microcosm of not only the current technology integrated into common production vehicles, but also the future of sensor devices and how they can be used in AD and other applications. Although the final device created did not end up being exactly what was specifically intended, it is a good stepping-stone toward the practical use of ultrasonic sensors in coupling with both light visuals and real measurements displayed.

The implementation of backup cameras began quite some time ago, with the first production vehicle to have one beginning in 1991. However, there were no standardizations implemented until 2014 by the National Highway Traffic and Safety Administration [7]. Since then, parking lot incidents and accidents caused by parking lot maneuvers, especially backing up, have reduced with each iteration of assistance technology. From the introduction of sensors alone, involvement of crashes with backing up reduced by 28 percent, compared with parking cameras alone reducing incidents by 5 percent [8]. To advance on the initial iterations of just one assistance medium, a combination of parking sensors, a rearview backup camera, and the addition of an auto-braking system reduced backing crashes by a whopping 78 percent [8]. The

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automatic braking system is something that is very likely built off the addition of ultrasonic sensor technology, as the values stored from the sensors would have to be used to control the braking system. Even the project produced in this discussion, the if loop used for the light variation of color could be used as a trigger to activate an auto braking system once the ultrasonic sensor data value dropped below a certain threshold.

The current climate of parking assistance and ultrasonic sensor-based systems are aimed at assisting the human driver in roadway operation and, specifically, parking. This is still important, as the AI and AD systems are still in a young state. However, looking into the future, these assistance systems will evolve each iteration into a fully automatic system, and it appears that an automatic parking system will be the forefront of AD applications. This is simply because it will be much simpler to delve into the machine learning aspect of parking as opposed to the inconsistent and frequent decision-making required for on-road and freeway driving. There are several manufacturers that have working prototypes for a self-parking system, whether they involve remote control or zero input from the driver.

Looking past the autonomous parking system that appears to be nearly ready for widespread use and production, a fully AV seems somewhat farther down the road. The classification of AD is broken up into stages based on the degree of automation within the driving system. Stage 4 is defined as “fully self-operational within set boundaries, requiring no attention or assistance from a human driver, and indeed may not include features such as pedals or a steering wheel” [9]. The only thing separating stage 4 from 5 is the boundaries set on operational areas. Stage 4 vehicles are predicted to be available to consumers between the years 2030 and 2035 [9]. These will incorporate an important combination of sensors and AI.

Ultrasonic sensors are at the forefront of parking assistance and parking automation systems, but there are many other devices needed to create something advanced such as an AV. The circuit created in this project is simply a subsystem that could be applied to a larger group of subsystems making up an autonomous system. Figure (7) highlights the importance of ultrasonic sensor technology in automation and displays what else is required for safety and success.

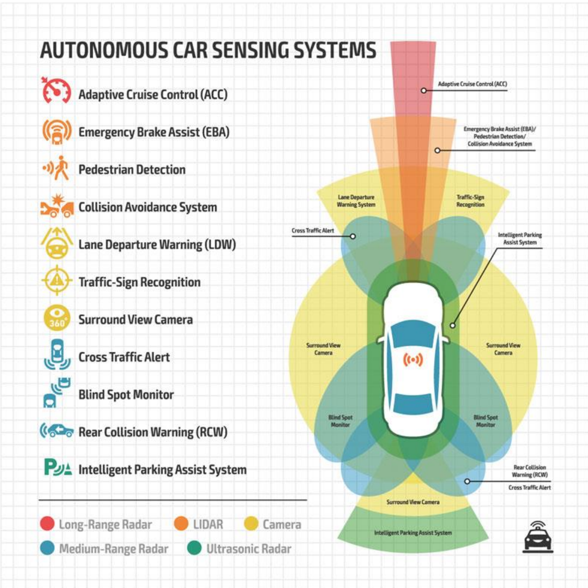

Figure (7) Layout of current AV sensors (Note Ultrasonic Radar use).

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It is important to note that there are several other types of sensing technologies required to even have the possibility of AD systems. The AI "driver" will need consistent and uninterrupted data coming from a range of sensors to be successful in making driving decisions as well as keep the passenger safe.

4 | CONCLUSIONS

There is a wide range of information digested throughout the course of this design study, both permitting the actual prototyping design of the ultrasonic sensor parking system using an Arduino as well as conceptual conversations about the future. While the construction of this circuit may appear simple compared to the current state of sensor technologies in practice, it is important to delve into the microcosms of more advanced systems to display the importance of certain fundamental aspects of sensor technologies.

The basis for this project stemmed from the statistics of danger in parking lots and consistent damage to both people and vehicles while participating in parking maneuvers. It is in the best interest of communities to work to get rid of these issues to minimize harm to people and property, and the path to success goes through both ultrasonic sensors and parking assistance systems. The circuit constructed for this project is a small adaptation prototype of what can be integrated into production cars to help a driver know whether they are in danger to themselves or others. The display of real-time distance values will increase the worthiness of the assistance system to help conceptualize the area around the car to a human operator. While the gradient shift of light from red to green for approaching obstacles did not end up working in benefit of the goals, it still has applications involving a threshold value for when an object is deemed too close, a flexible value depending on the specific application. Also, with a different orientation of LED light including a yellow spectrum, the circuit can be altered to shift from red to green in a way that mimics common correlation of human recognition.

In future applications as well as some that are currently already integrated into the production vehicle scene, the ultrasonic sensor-based circuit with a distance threshold can be applied to more than just light visualizations. For example, this can be directly used in an auto-braking system with a little bit of alteration to the code and an assembly connected to the circuit board involving the brake system. In addition, there are many ways to iterate on this small subsystem to create larger devices used in more advanced systems. The ultrasonic sensor itself will have to be used in conjunction with several other sensing technologies to eventually produce an AV that requires no human input and that is safe.

The use of sensors and camera technology has proven to make driving significantly safer, and the use of such technology in parking systems is the key factor in minimizing the number of incidents and injuries. The ultrasonic sensor has proven its value in these systems, not only in the parking assistance system created in this project, but in practice for vehicle manufacturers and research focused on creating AVs. Although it will take significant funding throughout the near future, the development of AD systems is a necessary cost for the betterment of roadway safety and will minimize the risk associated with human error involving reaction time, attention span, and blind spots that do not exist with sensor technologies being the only input.

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