

Vehicle Collision Avoidance System

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Abstract

This paper will present and discuss in detail a vehicle collision avoidance system prototype that will alert drivers to their surroundings and potentially hazardous driving situations. This system is needed to reduce the number of vehicle accidents on the road. Such a system would lead to improved efficiency of the road usage and limit human as well as economic losses. The proposed system will use ultrasonic sensors to provide blind spot coverage, while utilizing long-range radar to detect possible frontal collisions.

Although many of today's popular car manufacturers feature a vehicle collision warning system, these systems are expensive, fairly inaccurate, and cannot be universally implemented. The system will be implementable on a variety of standard cars with easy installation. While the system will not provide any autonomous action to avoid collisions, it will warn the driver through both audible and visual warnings. The system will be evaluated through rigorous testing in order to develop an algorithm that encompasses most of the countless circumstances encountered on the road. Once the system is implemented, the system will accurately detect the presence of surrounding vehicles with minimal false positives and the driver will be alerted to any possible accident, giving him or her adequate time to respond.

Problem

According to the National Highway Traffic Safety Administration (NHTSA), in the United States, there were over 5.6 million motor vehicle accidents in 2012, leading to nearly 34,000 fatalities and 2,632,000 injuries¹. The majority of vehicular collisions and deaths occur on roads with higher speed limits. In fact, NHTSA data from 2012 shows that around 90 percent of crashes that year involved vehicles on roads with speed limits of 30 mph or greater². A staggering 25,510 deaths resulted from these high-speed crashes, a number far too high to overlook². According to another study by the NHTSA, implementing a transportation communication system could prevent three quarters of vehicle crashes³. Not only can such a system increase safety on the roadways, but it could also lead to increased efficiency of road usage. With less accidents and potential traffic control, congestion on roadways could be virtually eliminated. To prevent motor vehicle fatalities, limit economic loss, and increase road usage efficiency, a vehicle collision avoidance system is vital.

Objective

The objective of this project is to design and implement a vehicle collision avoidance system. The system will monitor the surrounding area of the motor vehicle for other vehicles and warn the driver if any unsafe situation arises. For example, part of the system will alert the driver of any vehicles present in their blind spot. Another feature of the system will have the road ahead of the car monitored for any vehicles and warnings outputted if the car is bearing down on a vehicle in front of it too fast. These will all be possible by using sensors on the vehicle's exterior to detect surrounding vehicles. When a situation is deemed dangerous, the driver will be alerted with both audio and visual cues broadcasted within the car. An audible sound will beep faster in more critical circumstances, with visual indicators growing in strength as well. For a visual representation of the vehicle's surroundings, a small display will provide a top-down view of the car, with detected objects positioned appropriately on the screen. To increase the effectiveness of the system even more, a wireless communications network will be formed between vehicles, exchanging pertinent vehicle and roadway data such as vehicle speed, location, and heading, and approaching road hazards.

Literature Survey

A literature survey was conducted in order to gain a better understanding of the potential obstacles that come with the implementation of a vehicle collision avoidance system. Doing so revealed a few key problematic areas that the proposed system should address. These technological barriers include developing accurate sensing methods, implementing effective driver warning systems, and carrying out comprehensive vehicle-to-vehicle communication.

The first order of business within a vehicle collision avoidance system is detecting the location of all nearby vehicles. This task can be carried out in numerous ways, however some are more widely implemented than other. One popular method uses sensors that are installed on various sections of the vehicle to monitor areas where collisions are more likely to occur. This sensing can be done using various technologies such as radar and video⁴. Radar is most useful in long-range detection for frontal collision avoidance, while other methods are sometimes used in short range detection¹. There is a stark contrast in the use of radar as opposed to video. Radar is an active type of detection, in that the energy that the sensor detects is the same energy that it emits. Video on the other hand is passive, meaning that it simply receives light from its surroundings. Active detection systems are often more expensive because they require more equipment. On the other hand, they are typically more reliable than passive systems because the image processing required to process a video of the road is very complex and prone to false positives, with sensitivity to weather conditions contributing to its ineffectiveness as well⁵. Needless to say, radar is not without its own complexities either. Determining the frequency band to use has been a topic of debate for a few years now, although most researchers seem to agree that 77 GHz is appropriate, especially for long-range applications⁶. Research has also been done into the type of waveform that the radar should emit. Various forms of frequency modulation have been used to improve radar quality and efficiency^{7,4}.

Another method of detecting other vehicles that is on the rise involves car-to-car communication and GPS. The theory behind this is that all the cars on the road have a personal WiFi device that allows them to communicate with other vehicles. The vehicles repeatedly send data about their location and speed based on a GPS device. This data lets each car create a live map of its surroundings and analysis of that map lets each car determine any potential collisions⁸.

Collision warning systems have been shown to improve inattentive or distracted driver response time in rear-end collision situations. However, most previous rear-end collision warning research has not directly compared auditory, visual, and tactile warnings⁹. It is also not clear how effective these warnings are when the driver is engaged in other tasks, such as talking on a cell phone¹⁰. Several different tests have been done to determine how different types of warnings affect the reaction time of the driver. In these tests sixteen participants in a fixed-base driving simulator experienced four warning conditions: no warning, visual, auditory, and tactile in three different conversation conditions: none, simple hands free, and complex hands free. The warnings activated when the time-to-collision reached a critical threshold of 3.0 or 5.0 seconds. Driver reaction time was captured from a warning below critical threshold to initiation of the brakes. The results of these test concluded that drivers who received a tactile warning had the shortest mean reaction time and had a significant advantage over drivers who received none and drivers who received only a visual warning⁹. Auditory warnings also significantly outperformed visual warnings when no conversation was occurring but during both simple and complex conversation those who received the visual warning had a shorter reaction time. Tactile warnings however, did not have

much of an advantage over auditory warnings when no conversation was occurring but during simple and complex conversation the auditory warnings were only slightly better than no warning at all⁹.

From this study, it was determined that visual, audible, and tactile warnings are all viable warning methods. Although tactile warnings produce low reaction times, the difficulty of installing a tactile warning system offsets its effectiveness. Therefore, using both visual and audible warnings should suffice for the proposed system.

System Overview

The proposed system will utilize a forward radar sensor and six ultrasonic sensors around the car to track the surroundings of the car for potential collision. The processing of this data will be done on a BeagleBone Black processor and data will be sent to a Raspberry Pi to process the data for a visual display and an Arduino for processing for audible warnings. The block diagram of the proposed system is shown below in Figure 1.

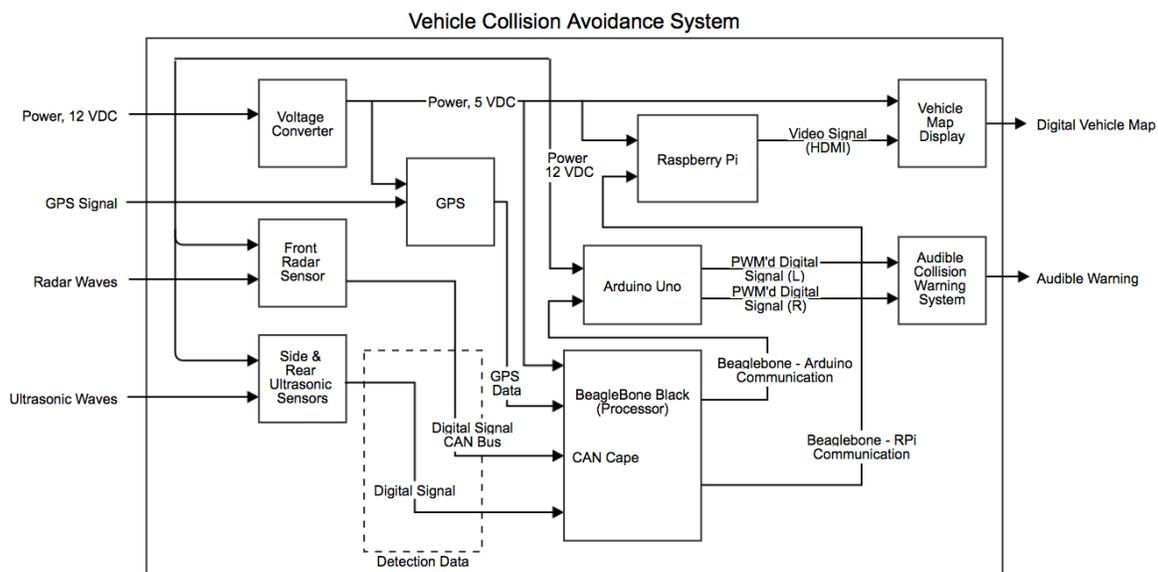


Figure 1: Block Diagram of the Proposed System

Radar

The radar sensor will be used to detect forward collisions. A Delphi ESR v9.21.21, seen in Figure 2, will be used for this application. The ESR is a radar sensor that simultaneously maintains a wide field of view at mid-range (60 meters) and a long-range view (174 meters) for multiple vehicle detection and tracking in front of the vehicle. The radar can track up to 64 objects simultaneously which will allow for collision warning even in busy environments.

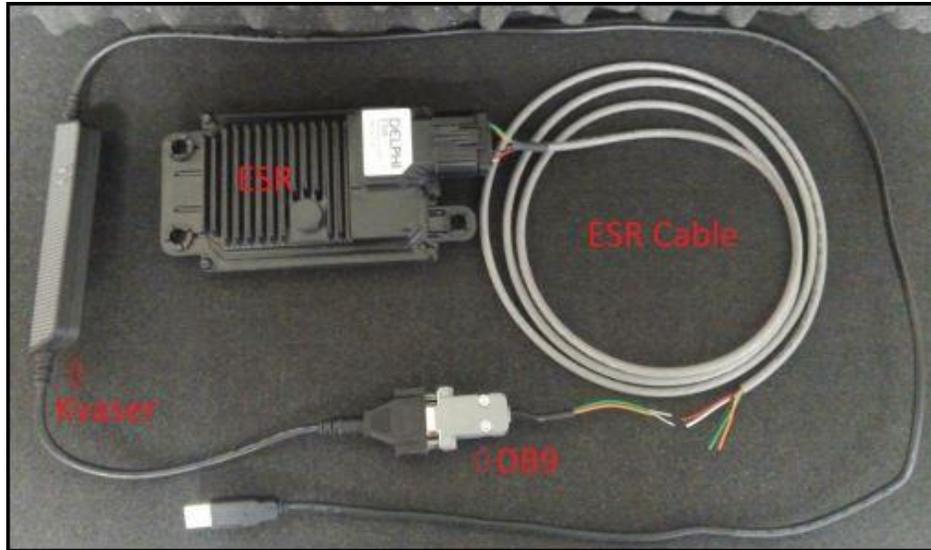


Figure 2: Delphi ESR with Cables

Ultrasonic Sensors

Radar is a suitable choice because of its commonality and great accuracy, but ultrasonic is inexpensive and has the ability to function in all environments seen on the road like rain, fog, and dust. The detection range for ultrasonic sensors is limited, however, the necessary range for the proposed system is only equal to about the width of a road lane. While cameras are very accurate and have a long detection range, they were not chosen because they are expensive and would be difficult to implement with the complex recognition algorithms needed. Therefore, ultrasonic sensors are chosen to detect all blind spots, as well as rear collisions. The ultrasonic sensors chosen for this project are the MaxBotix MB7380 sensor, seen below in Figure 3, and the MB7386 sensor. These sensors are water resistant and robust enough for all roadway environments. The MB7380 sensor has a detection range of five meters, which is more than enough for detecting blind spots when highway lane width in the United States is twelve feet. The MB7386 sensor has a detection range of ten meters, which is adequate for detecting rear collisions.

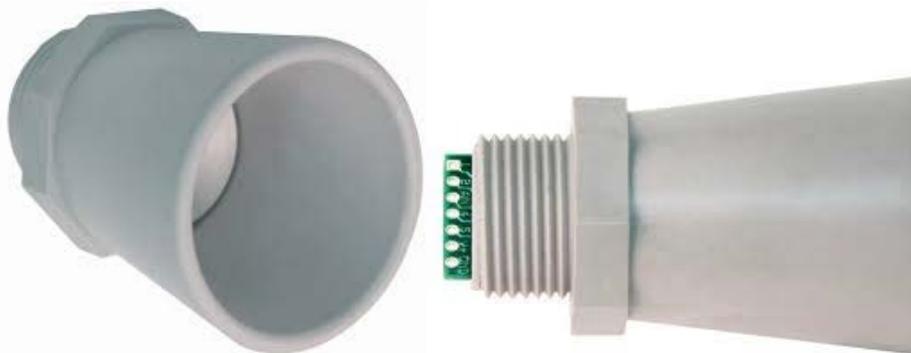


Figure 3: MaxBotix MB7380 sensor

Processing

Central processing will be carried out by the BeagleBone Black, seen in Figure 4, with its 1GHz processor. The open-source single-board Linux computer features 65 digital I/O pins that will be used to receive information from the six ultrasonic sensors. An additional add-on cape will be attached to the BeagleBone Black which features a CAN bus connection in order to receive data from the long-range radar. Multithreading programming will be implemented to handle all of the sensors' incoming data in a timely manner. A complex algorithm will be developed to determine potentially hazardous driving situations based upon the sensors' data. If the sensors detect surrounding objects or the algorithm deems the situation to be dangerous, appropriate signals will be sent to the audible and visual warning systems through serial data.

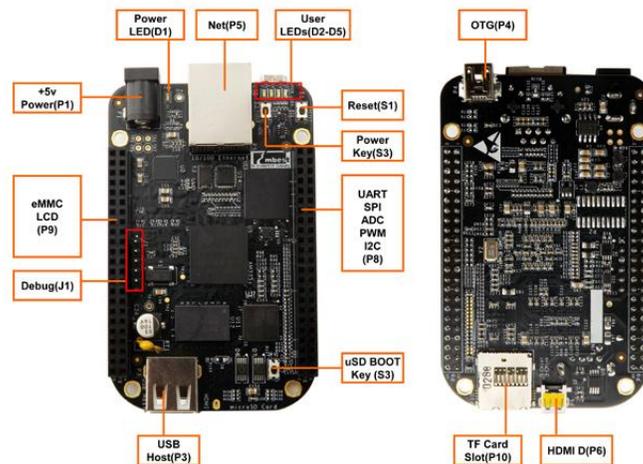


Figure 4: BeagleBone Black Revision C

Warning System

The driver will be continuously updated on the vehicle's surroundings through a vehicle map that will be rendered on a seven inch display placed on the dashboard, seen in Figure 5.



Figure 5: Vehicle Map Display - 7", 800x480 through HDMI connection

This vehicle map is basically an overhead view of the vehicle, with zones marked out surrounding the car. The interface can be seen below in Figure 6. If an object is detected by the ultrasonic sensors or front radar, the corresponding zone will be highlighted in red, indicating that an object is present. For example, a left-side zone that is highlighted will notify the driver that an object is detected along the car's left side or in its left blind spot.



Figure 6: Vehicle map rendering showing that the system sensors detect an object on all sides of the car

If the driving situation is deemed particularly dangerous, additional visual and audible warnings will be issued to the driver. A warning icon will flash on the vehicle map in the corresponding zone, as shown in Figure 7.



Figure 7: Vehicle Map with Imminent Collision Warning

The audible warning will be given through two small piezo buzzers installed in the driver's headrest. A buzzer will be positioned behind each ear, so that the buzzers can correspond to the detection zones of car. An audible warning from the left buzzer will indicate a potential collision on the left side of the vehicle. This happens similarly with the right buzzer corresponding to the right side of the car. Both buzzers sounding off will indicate a potential forward collision.

Testing

The proposed vehicle collision avoidance system will be built and installed on a Baja car (denoted Baja 1) available from the Mechanical Engineering Department at Ohio Northern University. It will be similar to the vehicle seen in Figure 8. Another Baja car, without a system (denoted Baja 2), will be used to test the blind spot detection, forward collision detection, and rear collision detection by driving in front of, behind, and in the blind spot of the Baja car with the detection system.



Figure 8: Baja car similar to one used for initial testing of system.

To test blind spot detection, the Baja cars will be driven positioned alongside one another, separated by approximately 5 feet, a distance similar to that found between two cars side-by-side in roadway lanes. One test will involve Baja 2 will drive in Baja 1's blind spot at a speed equivalent to Baja 1's speed. Although their speeds will be the same, Baja 2's position relative to Baja 1 will vary on different test runs, from sitting more towards the backside of Baja 1, then working its way up to the front side of Baja 1. This approach will require both ultrasonic sensors to be engaged in detection to a varying degree on each test run, and therefore reveal any dead zones. Similarly, the same type of tests can be performed, except instead of having Baja 2 move at the same speed as Baja 1, Baja 2 will now pass Baja 1 at varying speeds. It will be beneficial to know if a difference in speed between the two vehicles causes the sensors to malfunction.

The forward collision detection system will be tested by approaching Baja 2 from behind with Baja 1. Conversely, the rear collision detection system will be tested by having Baja 2 approach Baja 1 from behind. The first set of tests will have the vehicles move close together at similar speeds while the car in the back slowly inches towards the car in front. This will test the forward and rear sensors in a situation that one might find in dense traffic, where false positives are

important to avoid. The second test will have a Baja vehicle rapidly approach the second from the rear, or vice versa. This will allow us to test the front and rear sensors in a more dangerous scenario in which it is important to have the alarms go off in a timely manner.

Using the Baja cars as test vehicles will be beneficial for multiple reasons. First, the Baja vehicles are slower than regular cars, with a top speed of around 30 mph. This will allow testing to be done on a smaller, safer, and simpler scale before moving onto full-size automobiles. Additionally, Baja cars are smaller than automobiles, providing the chance to see how the system performs with objects similar in size to motorcycles. One potential worry about using the Baja cars is that they contain large gaps between their frame piping. The sensors waves can bounce off of this piping at irregular angles, which may cause the sensors to not receive waves back, and therefore, not detect the Baja car. If this problem arises, an outer solid shell may need to be applied to Baja 2. It could be as simple as attaching a flat sheet of metal to the outside of the frame, so as to provide a dependable surface for the sensors to bounce their waves off.

After adequate testing with the Baja cars, the system will be implemented on full-sized automobiles. As before, blind spot detection, forward collision detection, and rear collision detection will be tested in the same way as the Baja cars, but at higher speeds. The testing speeds will start at 30 mph and will increase in increments of 5 mph up to 75 mph. The effectiveness of the system will be recorded at the different speeds, which will help determine problematic circumstances when the system may fail or give a false positive. Extra care must be taken when using real cars because of the combination of higher speeds and dangerous circumstances that the cars are being placed into.

Conclusion

In 2012, 25,510 people died in vehicular collisions over 30 mph. To reduce these roadway fatalities, a vehicle collision avoidance system is being proposed that aims to reduce that statistic by as much as 75%. The current solution will also be relatively cheap and available to all vehicle owners to help reduce more collisions. The system will utilize radar and ultrasonic sensors to monitor blind spots, as well as provide warning of potential forward and rear collisions. All the sensor data will be processed through a BeagleBone Black processor and will output to a TFT screen with the digital map of the vehicle, showing a top-down view of the area surrounding the vehicle, including potential threats. Two speakers and a warning display will alert the driver of impending collisions or roadway hazards. With this well-defined design and test plan, the team is confident that a successful system will be delivered to accurately and decisively make the driver more aware of his or her surroundings while driving, and therefore, reduce the number of accidents on the road.

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