A Dynamic Collision Avoidance System

ECE4007 Senior Design Project

Section L03 Team Road Rage
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Executive Summary

To reduce the number of motor vehicle collisions, Team Road Rage will design and build a system that detects and alerts drivers of impending collisions. 26.5% of all collisions are front-to-rear, and 64% of those are due to driver inattention. The team's design intends to reduce rear-end collisions by ensuring the driver is alerted of potential collisions ahead of time. The system searches for conditions likely to result in a rear-end collision with a leading vehicle. It analyzes road conditions to determine braking distance, and warns the driver with visual and audio alerts before the collision becomes inevitable. The design will include a laser rangefinder that allows the system to detect objects up to 300 yards away, and its output is relayed to an Arduino microcontroller. The Arduino also interfaces with temperature, humidity, and rain sensors, and reports all of the acquired data to a computer, which is responsible for estimating braking distances. The system processes input from a USB camera using computer vision algorithms to detect vehicles and better understand the rangefinder data. The driver's reaction time is estimated using the Comprehensive Optimal Velocity Model, and is taken into consideration when determining when to issue an alert. The system issues alerts via a mobile device running Android 2.3, which is connected to the vehicle's stereo system. The mobile device displays visual alerts on its screen and plays audio alerts through the vehicle's speakers. This system improves upon existing systems by taking into account road conditions and the driver's reaction time. Since each car model brakes and handles differently, the proposed design is intended to be implemented via OEM during vehicle production, taking into account the vehicle's specific performance specifications. The expected outcome of the design is a fully-functional prototype that will cost $1760.

1 Introduction

The Road Rage team will design a real-time collision detection system that alerts drivers of potential collisions to reduce traffic fatalities and delays. The team requests $1760 to develop and demonstrate a working prototype of the concept.

1.1 Objective

Team Road Rage will design and build a system comprised of sensors and software processing that detects and alerts drivers to vehicular collision. The system searches for conditions likely to result in a rear-end collision with a leading vehicle. The design determines the gap between the driver and the nearest leading car using a laser rangefinder and computer vision. After processing changes in distance between the two vehicles, the system detects current road conditions to accurately calculate the minimum braking distance. If a collision is imminent, the system then alerts the driver visually aurally using an Android mobile device connected to the vehicle's speaker system. Since driving and braking characteristics vary from car to car, the system is intended to be sold to auto manufacturers via original equipment manufacturers (OEMs). The manufacturers can then integrate the design into new cars at the time of production at the factory.

1.2 Motivation

According to the National Safety Council, 26.5 percent of all vehicle crashes are front-to-rear-end. Although these crashes are responsible for only 4.3 percent of traffic-related fatalities, they are responsible for one-third of all crash-caused delays, resulting in 157 million vehicle-hours of delay annually. According to police reports, 64 percent of these rear-end collisions were the result of driver inattention, 14 percent were a result of following too closely, 3 percent were due to poor visibility and 2 percent were due to poor judgment [10]. Our project seeks to greatly reduce the number of preventable rear-end collisions by implementing a system that will alert the driver of an impending collision, providing just the amount of time required for the driver to react.

While collision avoidance has been an active area of research for several decades, most applications have been related to its use in autonomous (driverless) vehicles [11]. Currently available technologies, such as the driver assistance packages outlined in Table 9, offer lane departure warnings and try to estimate when a driver might be distracted, but are unable to adapt to the driving habits of different users under various circumstances and weather conditions [2] [4] [6] [9]. Our system could easily be incorporated into future driver assistance packages while minimizing costs through the use of a one-dimensional laser rangefinder and a low-resolution camera. This differs from other systems which use expensive, scanning laser rangefinders or multiple cameras for depth perception [11] [12] [13] [14].

1.3 Background

Collision avoidance systems is an area of active research among auto manufacturers, and currently several solutions are available to consumers in high-end luxury vehicles, such as those offered by Honda, Mercedes-Benz, Toyota and Audi (see Section 7.1). These systems are still in their infancy, and most of the progress in collision avoidance has been confined to closed-course testing of a very wide range of solutions, most of which utilize technologies such as radar [15] [16] [17] [18], LIDAR (a type of radar which uses light) [19] [20], computer vision (extracting information from a camera's video output) [21] [22] and various combinations of the three [15] [23] [24] [25] [26] [27] [28] [29] [30] [31].

An additional area of research that our project utilizes is that of traffic theory, which attempts to mathematically describe traffic flow. For over sixty years, various models have been proposed for modeling traffic flow. The first to gain significant attention took into account the differences in velocity between two vehicles [32]. More models were then proposed that took into account speed difference with a lead car [33], headway distance [34] and an "optimal" velocity [35]. One of the most recent models, the Comprehensive Optimal Velocity Model (COVM), incorporates both the headway and velocity differences between vehicles [36]. We will be basing our system on this model, but will incorporate additional, empirically determined parameters about the driver's sensitivity to changes in headway and velocity.

The use of computer vision for detecting and tracking lanes and vehicles is an active area of research, particularly because of its applications in driver awareness systems and autonomous (driver-less) vehicles [37]. Methods for detecting lane markers include various thresholding techniques [38] [39] and the use of line-detection algorithms (i.e., the Hough transform) [40]. We will be employing a unique algorithm designed specifically for this project, which examines recent frames to get an "average" image of the road. An adaptive thresholding technique, along with RANSAC curve fitting, will then be used to extract the locations of the lane markers. For detecting vehicles on the road, many have utilized distance-measurement techniques, such as radar or LIDAR, with reasonable success [41]. Others have resorted to the use of computer vision due to its relatively low price. Several methods have been proposed, such as searching for symmetrical objects [42] [43] or searching for various features, such as tail-lights [44]. We will be searching for certain Harr-like features determined *a priori* from various training data. This method is similar to the one proposed by [45].

Methods for alerting the user of impending collisions have also attracted quite a bit of interest. While several have proposed visual or tactile feedback methods [46], many make use of audio cues to warn the driver of impending collisions [47] [48]. These audio queues are quite diverse, and range from abstract tones to "audio icons," such as the sound of screeching brakes [49]. We will be utilizing an unobtrusive, but noticeable, tone so as not to annoy the driver.

2 Project Description and Goals

The goal of Team Road Rage is to create a collision avoidance system that warns the driver of impending collisions well before they happen based on data gathered about a lead vehicle.

Team Road Rage's collision avoidance system consists of the following components: an Android device, a laser rangefinder, computer, web camera, rain and temperature sensors, and an Arduino microcontroller. An Android device acts as the warning system and information display for the user. The laser rangefinder measures the distance from the lead vehicle. The computer is responsible for computer vision algorithms that process images received by the webcam and is supplementary to the function of the laser rangefinder; the computer also relays information and warnings to the Android device. Rain and temperature sensors gather environmental data to get an idea about weather conditions. The Arduino microcontroller collects data from the laser rangefinder and weather sensors and relays that data to the computer.

The projected features of this project are

- Predictions of impending collisions
- Warnings that leave the driver with more than sufficient time to avoid collisions
- Information about distance from a lead vehicle on display for the driver to see
- Weather sensors that introduce accountability for inclement weather conditions
- Weatherproof enclosure to protect external parts
- Diagnostic Graphical User Interface (GUI) for detailed sensor data and calibration
- Costs around $1760

3 Technical Specifications

The project makes use of several key components. In particular, a laser rangefinder, a USB camera, an Arduino Mega ADK, a rain sensor, a temperature sensor, an Android device, a DC-DC converter and a laptop computer will be used. Following is an overview of the technical specifications for each.

3.1 Laser rangefinder

Table 1 contains the specifications for the laser rangefinder. The data rate of 10Hz (calibrated) ensures that the distance measurements are constantly up to date. This rate is crucial for especially for high speeds where there may be large discrepancies between each sampling.

Table 1. Laser Rangefinder Specifications [50]

Component	Specification
Connectivity	RS232
Data Rate	~10 Hz for calibrated operation ~200 Hz raw counts for uncalibrated operation
Accuracy	+/- 1 m on 1x1 m2 diffuse target with 50% (+/-20%) reflectivity, and up to 300 yards
Dimensions	32 x 78 x 84 mm
Power Supply	7-9 V

3.2 USB Camera

The USB camera is used for vehicle detection. Its dimensions shown in **Table 2** allow for it to be mounted up behind the windshield on the inside of the vehicle. The sensor resolution provides adequate clarity of vehicles ahead of it and compensates for closer vehicles that extend behind the minimum distance of detection of the laser rangefinder.

Table 2. USB Camera Specifications [51]

Feature	Specification
Connectivity	USB
Dimensions	7” x 5.5” x 7.5”
Sensor Resolution	2 MP

3.3 Arduino ADK

The connectivity specifications shown in **Table 3** for the Arduino ADK allows interfacing with an Android device and a computer through USB protocol, the laser rangefinder through RS232 serial communication, and the temperature sensors through serial communication.

Table 3. Arduino ADK Specifications [52]

Feature	Specification
Dimensions	4” x 2.1”
Power Supply	7-12V
Clock Speed	16 MHz
Connectivity	USB, Serial

3.4 Rain Sensor

The rain sensor, attached to the windshield of the vehicle, uses its infrared beams mentioned in **Table 4** to detect the presence of rain.

Table 4. Rain Sensor Specifications [53]

Feature	Specification
Sensor Operation	Invisible infrared beams (880 nm)
Window transmittance requirement	12% - 100% at 880 nm
Dimensions	4.45” x 2.45” x 1.15”
Power Supply	10 - 16V

3.5 Temperature Sensor

The temperature sensor, as specified in **Table 5**, is used to determine if the environmental conditions are cold enough to warrant precautions against icy roads.

Table 5. Temperature Sensor Specifications [54]

Feature	Specification
Operational Temperature	-67 to 257 °F
Accuracy	+-0.9 °F (from 14°F to 185°F)
Power Supply	3 to 5.5 V (through data line)

3.6 Android Device

Auditory warnings will be produced by a mobile phone running the Android Operating System, which will be connected through the headphone jack mentioned in **Table 6** to the automobile’s auxiliary port and allow warnings to be played over the car speakers.

Table 6. Android Device Specifications [55]

Feature	Specification
Audio output	3.5 mm headphone jack
Screen Size	3.7 inches
Dimensions	4.56 inches x 0.54 inches x 2.36 inches

3.7 DC-DC Converter

DC-DC converter allows for conversion of DC voltage from 6-34 V to 5-24 V as shown in **Table 7.** The USB connectivity is so that the DC voltage conversion rate is programmable to fit the requirements of the device connected.

Table 7. DC-DC Converter Specifications [5]

Feature	Specification
Connectivity	USB
Dimensions	135mm x 37mm
Input Voltage Range	6-34 V
Output Range	5-24 V

3.8 Computer and its GUI

The computer hosts the GUI that displays data on the computer screen, mentioned in **Table 8**, such as sensor information or real time video stream from the USB camera. The GUI also allows for the calibration of the laser rangefinder and the camera.

Table 8. Computer and its GUI Specifications [56]

Feature	Specification
Video display	Real-time camera video, image processing and distance overlays
Interface	Access to modify calibration and operating parameters
Computer Display	15.6 inches
Connectivity	USB

4 Design Approach and Details

Our design approach utilizes a traffic-flow model which will be used to predict information about a driver's reaction time. This information, along with estimates of the coefficient of friction between the road and the tires, will be taken into account to estimate a total stopping distance. The total stopping distance, along with data, such as a lead vehicle's speed and deceleration, will be used to determine whether or not the driver is following too closely for the given speed and conditions. A custom computer vision algorithm is utilized to detect a lead vehicle in the current lane.

4.1 Design Approach

Detecting Potential Collisions

The primary function of our system is to determine the risk of a collision, and once that risk exceeds a certain threshold, notify the user through an audible alert. In order to define the level of risk at any given moment, we will be utilizing an extended version of the Comprehensive Optimal Velocity Model

(COVM), proposed by Tian et al. [36]. The model attempts to make predictions about traffic flow based on the following formula:

$$\frac{dv_n}{dt}(t) = \kappa[V_1(\Delta x_n(t)) - v_n(t)] + \lambda V_2(\Delta v_n(t))$$

At any given time, t, the speed of the following vehicle is given by $v_n(t)$. The headway between a lead vehicle and a following vehicle is given by $\Delta x_n(t)$ and the difference in the velocities of the two vehicles is given by $\Delta v_n(t)$. κ and λ were treated as constants in [36], but we will dynamically determine these values, as outlined below. Unlike other models, such as that proposed by [35], the COVM has been shown to remain stable under a wide range of conditions, including scenarios in which sudden braking or acceleration may occur. This stability is critical, as we require that our system be able to react to situations in which a lead vehicle brakes suddenly. With this model, we can predict how a driver will react to changes in a lead vehicle's headway or velocity, and if we determine that a collision will occur without immediate action being taken, an alert will be issued.

The value for $v_n(t)$ will be read from the OBD-ii port in the vehicle through the OBD scanner. The value of $\Delta x_n(t)$ is the distance reading reported by the rangefinder, and the second derivative of this value is $\Delta v_n(t)$. The determination of values for κ and λ will be unique to each driving session, and will be empirically determined by finding the least-squares solution to the above equation, given the actual values measured for $\frac{dv_n}{dt}(t)$. Knowing these values will allow us to acquire constants that relate to relative reaction time and sensitivity to changes in depth, which enables the system to adapt to situations in which the driver may be impaired due to a variety of circumstances, such as sleep deprivation or poor visibility.

In order to estimate the time it will take for a collision to occur, we can use the following equation, given Δx for t_0 and its preceding two samples:

$$\Delta x(t) = \Delta x(t_0) + [\frac{\Delta x(t_0) - \Delta x(t_0 - 1)}{dt}]t + \frac{1}{2}[\frac{\Delta x(t_0) - 2\Delta x(t_0 - 1) + \Delta x(t_0 - 2)}{dt^2}]t^2$$

To determine the stopping distance for a given speed, we must consider the coefficient of friction between the tires and the road. We will use information from the rain and temperature sensors to estimate this value. While there is little correlation between the atmospheric temperature and the friction coefficient, we will use the temperature sensor to choose one of two formulas. If the temperature is freezing or below, we can use the following approximation from:

$$\mu = -0.1409 \ln(m) + 0.6318$$

where m denotes the percent of moisture in the atmosphere present on the road [57]. This value will be roughly estimated based upon measured precipitation. For conditions above freezing, we will be using experimentally determined values acquired under controlled conditions by [58]. Once we have determined the coefficient of friction, we will make use of the following formula to determine the stopping distance, L_b:

$$L_b = \frac{v^2}{2\mu g}$$

where v is the vehicle's velocity and g is the acceleration due to gravity. This should roughly correspond to the distance the vehicle would travel without the braking torque overcoming the force of static friction, which should be the case for a vehicle equipped with anti-lock brakes (ABS). Once the values for κ and λ have been determined, the driver's reaction time can be estimated and incorporated into the previous equation for the time of collision. At that instant, an audible warning will be issued from the Android device through the car's speakers.

Detecting the Presence of a Lead Vehicle

While the aforementioned model should be sufficient for determining the potential for collisions and warning the driver in time, it makes the assumption that there is a lead vehicle present, directly ahead of the following vehicle. Our system must be robust enough to be able to respond to situations in which there is no lead vehicle, or a lead vehicle suddenly appears (from a lane change). Since the laser rangefinder reports distance readings to anything ahead of it, not just vehicles, and we must determine whether or not the data is valid. This will be accomplished using computer vision. First, the current lane will be detected, using a method similar to that proposed by [45]. Next, vehicles will be detected by searching for Haar-like features that match characteristics found in our training data. When a vehicle is detected, its location will be followed for several frames, and if it is determined to be in the same lane as the following vehicle, it will be classified as the lead vehicle and the aforementioned method for predicting collisions will be employed.

4.2 Codes and Standards

1. RS232 or Serial Port is a 25-pin serial connector which communicates data from the laser rangefinder to the rest of the system. It features
    - Highly customizable pin conventions
    - 8-bit data transmissions [59]
2. USB (Universal Serial Bus) is a ubiquitous 4-pin serialized connector and handshake standard for communication between the webcam, Arduino, and computer. It features
    - Self-powering connector
    - Vast interoperability, library interface to Arduino
    - 480 Mbit/sec transmission rate [60]

3. I2C (Inter-Integrated Circuit or two-wire interface) interfaces the temperature/humidity sensor to the Arduino and is a popular IC-level interconnect between micro-controllers and device drivers. It features
    - 400 Kbits/sec data transmission
    - Configurable master/slave instances
    - Supported by the Arduino “Wire” library for rapid prototyping. [61] [62]
4. The Class 1 (eye-safe) laser standard applies to the laser emission cavity in the laser rangefinder. It specifies
    - A laser wavelength of 905 nm +/- 10nm
    - Low enough power output to prevent harmful exposure [63]
5. *Manual on Uniform Traffic Control Devices*, published by the U.S. Department of Transportation, outlines:
    - Normal pavement markings are “4 to 6 inches wide”
    - “Broken lines should consist of 10-foot line segments and 30-foot gaps”
    - Minimum highway lane width of 12 feet [64]
6. ISO-9141-2 is an OBD-ii protocol used by Chrysler and many European and Asian vehicles. Communication occurs on a single, bidirectional line without handshake signals.
    - Operates at 10.4 Kbaud
    - Message length is restricted to 12 bytes, including CRC [65]

4.3 Constraints, Alternatives and Tradeoffs

Alternatives

An alternative to sensors for detecting weather conditions is to use the android device to receive weather forecast information from a service like the National Weather Service (NWS). However, weather information from such services is often reported with delay whereas the sensors offer instantaneous measurements.

Alternatives to the laser rangefinder would be radar or Light Detection and Ranging (LIDAR). Radar distance finders are popular and cheap but only available in short distances; long distance radar is far more expensive than the laser rangefinder. LIDAR is a much better alternative to the laser rangefinder but is also ruled out due to not only its price but also due to the tedious calculations that LIDAR technology would entail.

Constraints

One debilitating limitation of the Early Collision Avoidance System is the conditions necessary for adequate visibility. Both computer vision and the laser rangefinder cannot operate under low visibility conditions such as fog. The laser rangefinder is also limited by surfaces with poor reflectivity (dirty cars).

Other objects that may share the road with vehicles include cyclists and pedestrians. The narrow field of view of the laser makes it impossible to detect, not to mention measure, the distance from a small object like a pedestrian or cyclist.

Tradeoffs

LIDAR or radar technology would have been the ideal technology to work with instead of laser but as mentioned previously, the price and the calculations required to harness the potential of either technology would have likely significantly delayed progress on other aspects of the project.

Using a weather service in place of weather sensors to detect weather conditions does not only provide delayed information but also introduces the problem of reliability. The android device is reliant upon cellular data service which is in turn reliant on the availability of cellular coverage.

5 Schedule, Tasks and Milestones

Please refer to the Gantt chart in Appendix A for project schedule and milestones. To maintain optimal progress, the team should have something done by blank, something done by blank, and a functional prototype by November 15. Meeting completion dates as suggested by the Gantt chart is crucial to troubleshooting the device prior to project demonstrations during the second week of December.

6 Project Demonstration

To demonstrate successful operation of our system, we will install all of the components in an actual vehicle and test it on the highway and local roads. In order to prove that the system is operating correctly, we will implement a series of tests in which another team member (Ryan) drives a lead vehicle ahead of the vehicle in which the system is installed. We will then implement a series of maneuvers, such as sudden braking and lane changes. Specifically, the lead vehicle will create situations that involve sudden braking, gradual breaking and sudden lane changes, and the system will implement alerts as necessary. We anticipate that the advisers will go with us on at least one of these outings to witness the system first-hand.

To test the prototype throughout the design process, we will routinely drive the car in traffic, gathering data from the installed sensors. We will record that data so that we can not only test the system in real time, but later simulate the drive if we make changes to the software. We will use this prerecorded data to create a simulation, which will be demonstrated before the rest of the class. There will also be a brief video of the system in operation on a local highway to show that it functions in real-time.

7 Marketing and Cost Analysis

7.1 Marketing Analysis

Marketing

Since the Warning System for Collision Avoidance requires the installation of many device components, it will be difficult for "teen" drivers to implement the system in their personal vehicles by themselves, especially if they lack the necessary expertise. Moreover, the cost of the overall system rose significantly with the inclusion of the laser rangefinder and the laptop. For the above reasons, aftermarket installations consumer base is expected to be extremely narrow and such a product likely won't survive. In turn, the Warning System for Collision Avoidance's target audience is high-end automobile manufacturers such as BMW, Lexus, Audi, Mercedes-Benz and Bentley. The intention is to manufacture the vehicles with the system built-in before they are shipped to consumers.

Similar Products

Many new vehicles are now manufactured with collision avoidance systems pre-installed. Generally, the pre-crash systems available today are based on laser and radar range detection. The new system will incorporate computer vision, in addition to the laser rangefinder device, to detect other vehicles traveling in the same lane as the user. Cameras have certainly been in the automobile manufacturing industry for a while, but are rarely utilized in such manner. Rear-end camera applications are becoming increasingly common in modern automobiles, such as the Audi A8, to assist with back-up parking. Moreover, the Lexus LS 460L [66] is shipped with the camera-based automatic park assist system. BMW 7 Series provides night vision camera to assist with night-time driving and in dark environments [67]. Unlike our system, these do not take weather and environmental conditions into account in the alert process. Our design is also unique since it implements a customized algorithm to weigh each environmental factor in real-time before the system outputs an alert. For example, the system will notify the driver sooner when experiencing rainy weather conditions. **Table 9** lists some manufacturers which implements a similar system to the Warning System for Collision Avoidance in their vehicles.

Table 9. Manufacturers of Collision Alerts Systems and Their Features

Manufacturer	**Honda [2]**	**Mercedes-Benz [4]**	**Toyota [6]**	**Audi [9]**
Model	Inspire, Acura	S-Class, E-Class	Lexus LS	Audi A8
System Name	Collision Mitigation Brake System (CMBS)	Pre-Safe Brake	Advanced Pre-Collision System (APCS)	Pre-Sense Plus
Detection Method	Radar-based sensor	Two radar-based sensors	Infrared radar and stereo vision	Video, radar and Electronic Stability Program (ESP) sensors
Warning Type	Audio and visual	Audio and visual	Audio and visual	Audio and visual: gong sound produced and red dashboard lights
Special Features	Intelligent Night Vision on Legend vehicle lines	Anti-skidding system; automatic braking system	Monitors direction of driver's face; gently applies automatic brakes	Activates hazard lights; closes windows and sunroof; tightens seat belt

7.2 Cost Analysis

Development Costs

Engineers with some expertise are expected to be responsible for manufacturing and installing the Warning System for Collision Avoidance on high-end vehicles as they are coming off the assembly line.

An estimate for an engineer's wage is at $30 per hour. **Table 10** displays the breakdown of the engineers' labor hours.

Table 10. Expected Engineer Costs

Tasks	**Engineering Hours**	**Costs**
Integrate Hardware Components	120	$3,600
Make Laptop Preparations	15	$450
Develop Android GUI Software and Applications	40	$1,200
Develop Software for Arduino Board	40	$1,200
Develop Collision Prevention Algorithm	45	$1,350
Preparations of Demonstration and Road Test	20	$600
Final Presentation	10	$300
Weekly Meeting with Advisor	30	$900
Lecture	60	$1,800
TOTAL	**380**	**$11,400**

Projected Product Costs

The projected cost of the system will be heavily based on the cost of the hardware components and product assembly while also taking into consideration the engineers' costs. **Table 11** displays the component costs for producing the prototype.

Table 11. Cost of Prototype Components [1] [3] [5] [7] [8]

Prototype Parts	**Unit Cost**
Arduino Mega ADK	$85
Android Mobile Phone	$200
Laptop	$860
Webcam	$50
OBD II Scanner	$50
Misc. Cables	$10
DC Power Converter	$60
Laser Rangefinder	$320
Rain Sensor	$90
USB Cable Extender	$6
Enclosure	$30
TOTAL	**$1,761**

It is worth noting that the cost of the prototype will be higher than that of the manufactured products since the components for the prototype were bought in single-quantities rather than in bulk. Also keep in mind that the labor cost for production could be lower; an engineer is not necessarily needed at the factory since the product development stage is over. As such, there is no need for fringe benefits during the production process.

Based on the component costs of $1,761 for the prototype, the producers can market the product for $2,000 each and earn a profit of $239 per unit. Since high-end vehicles today are sold for $70,000 to

$90,000, this additional cost should not pose as a significant financial burden for the consumers. Since the hardware components will be ordered in bulk, a discount rate of approximately 5% can be expected. This will lower the component costs to $1,673, yielding a even higher revenue of $327 per unit for the car manufacturer. Doing so will quickly recover the initial engineer costs and reach a break-even point. The time required to reach this point depends heavily on the rate of the vehicles manufactured and sold to consumers.

8 Summary

Most equipment and components of the Early Collision Avoidance System are already in the team's possession with the exception of the laser rangefinder and the weather sensors. So as a result, focus has been placed on other components of the project. For example, the most developed part of the project is the computer GUI but would require all the components to come together to begin testing. Other components such as the Arduino board are being experimented on to gain familiarity in preparation for the arrival of the parts.

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Appendix: Gantt chart