Networked Systems Laboratory

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LIDAR Guided Autonomous Car

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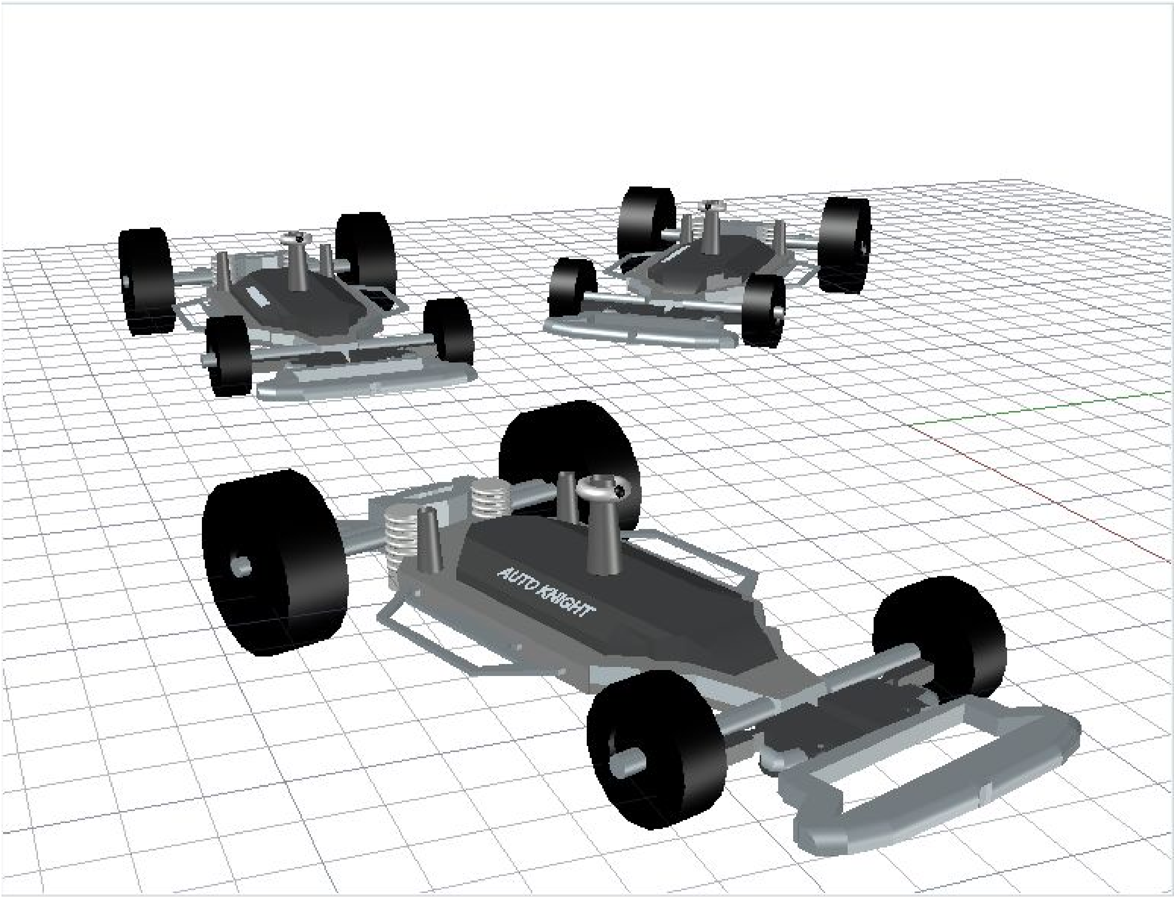

Abstract

In the United States, over 37,000 people die in car crashes every year. 1,600 of these people are below the age of 15, 2.35 million people are injured, and the overall cost to the U.S is over 230 billion USD every year. Around the world, road crashes are the leading cause of death between the ages of 15-29. 1.3 million people every year, an average of 3,287 people everyday, and 20 to 50 million are injured as a result. This makes road crashes responsible for 2.2% of all deaths, making it the ninth leading cause of death around the world. The overall cost is estimated to exceed 518 billion USD every year[1].

This grim description of the world's auto accidents shows a great need for increasingly automated cars capable of preventing crashes. Car manufacturers are adding more and more safety features like blind spot detection and automatic braking. One feature that has yet to been implemented in commercial models is short range communication networking. To increase safety, cars would send each other data about their relative positions and velocities to ensure they all remain a safe distance from one another. In the event of a an accident, the cars could communicate with one another and circumnavigate any debris efficiently.

The effects of this feature have incredible potential. Car related deaths would plummet since the cars would relay data to minimize damage, less people would be injured or disabled in accidents, and people would spend less on repairing their vehicles, which could lead to lower insurance premiums for everyone as well. A short range communication network could also decrease travel times and allow passengers to spend more time at their destinations and less time getting there.

Currently, other technologies are being utilized to create self driving vehicles. One of the biggest areas of research is deep learning, which uses multiple Graphics Processing Units (GPU) to process raw data that is analyzed by neural networks. In 2016, NVIDIA developed a self driving vehicle that used a convolutional neural network (CNN) to map pixels from a front facing camera. The result was a vehicle that can drive in a standard driving environment (e.g., a paved road or highway) and environments with little to no guidance (e.g., a parking lot or an unpaved road with no lane markings)[2]. Volvo is using NVIDIA's DRIVE PX2 in 100 self driving vehicles to test them in real world conditions[3]. In September of 2017, Tesla announced a partnership with AMD to produce a new chip for the autopilot on their self driving vehicles, such as the Tesla Model S[4]. Intel also announced it would be working with Waymo, formerly known as Google's self driving car, to implement a better self driving vehicle[5].

1. Project Goals

With input from our principal sponsor, Dr. Fallah, one of his Ph.D students, Nitish Gupta, and a fellow Ph.d researcher fellow, Behrad Toghi, we plan on creating two to five smaller scale vehicles that utilize wireless communication to navigate around one another safely. These cars will then be used by Dr. Fallah in his laboratory to improve upon the technology The cars will be small so they can be tested in Dr. Fallah's lab, low cost, send highly accurate data to one another in real time, and have communication ranges and maximum speeds relative to the final size of the product.

The vehicle network will model concepts of "deep learning" in machine intelligence; that is, to form a neural network between units in order to react cooperatively to each other's motion. By utilizing sensor input, the vehicles may project a data signal to all receiving units, simultaneously. Thus, each unit will predict the collective path(s) to avoid a collision scenario.

LIDAR, SONAR, and camera sensor inputs paired with probability algorithms are the operative means of achieving computer vision. A LiDAR scanner introduces laser range sensing capabilities to each unit, allowing a multi-planar representation of the vehicle's surroundings at each rotation of the LiDAR mount. By utilizing an infrared camera calibrated to LiDAR sensitivity, one may receive the signal reflected off of the surroundings and model the real-time position and orientation of nearby objects. SONAR may be utilized in addition to LiDAR for accurate short-range applications.

Methods of communication must be considered; to form a viable network, DSRC (Dedicated Short Range Communication). Outfitting the vehicles with modules capable of broadcasting a DSRC high-frequency signal 5.9 GHz optimizes the transmission of signals due to the "unlicensed" nature of this spectrum. In 1999, the Federal Communications Commission designated the 5.9 GHz band to be used exclusively by intelligent transportation systems; the standard of which is denoted within IEEE 802.11p.

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2. Requirement Specifications

2.1. Communication Requirements

- 2.1.1. The vehicle-to-vehicle data communication range must be at least 10 meters in any direction.
- 2.1.2. The signals sent between units will be transmitted at a frequency of approximately 5.9 GHz to achieve exclusivity of frequency bandwidth

2.2. Physical Requirements

- 2.2.1. The chassis of each car will be approximately 1/16th that of the size of an average car.
- 2.2.2. The cars must be able to move at a speed equivalent to 30 miles per hour multiplied by the scale of the car e.g a car that is 1/16th of the size of a Toyota Camry must move at 1.875 miles per hour.
- 2.2.3. Vehicle chassis equipped with a rechargeable electric battery.
- 2.2.4. Motor capable of producing power to reach desired speed.
- 2.2.5. Vehicle module capable of steering, forward and backward motion.

2.3. Sensor Requirements

- 2.3.1. LIDAR sensors must be positioned such that a 360 degree field of vision is given around the car.
- 2.3.2. LIDAR must be able to detect anything within the minimum communication range.
- 2.3.3. SONAR must must be able to detect anything within the minimum communication range.

2.4. Power Requirements

- 2.4.1. The unit must be able to run for at least 20 minutes before it needs to be recharged.
- 2.4.2. Battery must be able to simultaneously provide appropriate operating voltage to all modules on the chassis.

2.5. Camera Requirements

- 2.5.1. Must provide a field of vision within the minimum communication range.

2.6. *Hardware Requirement*s

- 2.6.1. Vehicle chassis equipped with a rechargeable electric battery.
- 2.6.2. On-board controller with the ability to send, receive, and process information.
- 2.6.3. On-board transceiver for wireless communication.
- 2.6.4. Controller capable of autonomously manipulating the motor and steering.

2.7. PCB Requirements

- 2.7.1. PCB will be outfitted with an LCD display that will display the direction, speed, and remaining battery life of the car.
- 2.7.2. PCB will be outfitted with 4 LEDs to indicate the car's state.
    - 2.7.2.1. The 4 states are: stopped, forward, turning left, turning right.
    - 2.7.2.2. The signal indicating what state the car is in will be sent to the LEDs via an arduino.
- 2.7.3. PCB will include temperature sensor and fan control for temperature stabilization

2.8. Software Requirements

- 2.8.1. System shall take in inputs from LiDAR sensors.
- 2.8.2. System shall process sensor input to localize itself.
- 2.8.3. System shall make use of wireless connection to communicate with other systems.
- 2.8.4. System shall take a continuous stream of video and send it to a processor.
- 2.8.5. System shall respond to obstacles in its path.
- 2.8.6. System shall find routes in coordination with other nearby system(s).
- 2.8.7. System shall be switchable between user-control and autonomy for testing.
- 2.8.8. System shall be functional in fully autonomous mode.

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3. Project Constraints

3.1. Cost

- 3.1.1. Limits the quality of modules and components
- 3.1.2. Limits the number of autonomous vehicles we can create

3.2. Power Consumption

- 3.2.1. Unit run time is limited by overall power consumption between modules

3.3. Processing Speed

- 3.3.1. Limits the reaction time of sensors and mechanic responses

3.4. Software Robustness

- 3.4.1. System intelligence limited by software

3.5. Sensor / Camera Resolution

- 3.5.1. Limits accurate modeling of surroundings

3.6. Network Strength

- 3.6.1. Limits the potential number of cooperative units

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4. Project Standards

4.1. Independence

- 4.1.1. Ensures delegation of driver / vehicle responsibility

4.2. Safety

4.2.1. Ensures the vehicle’s autonomy will abide within a given model

4.3. Power Efficiency

4.3.1. Ensures the system will operate within reasonable means of power supply

4.4. Network Security

4.4.1. Ensures local and uncorrupted transmission of data between units

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5. System Block Diagram

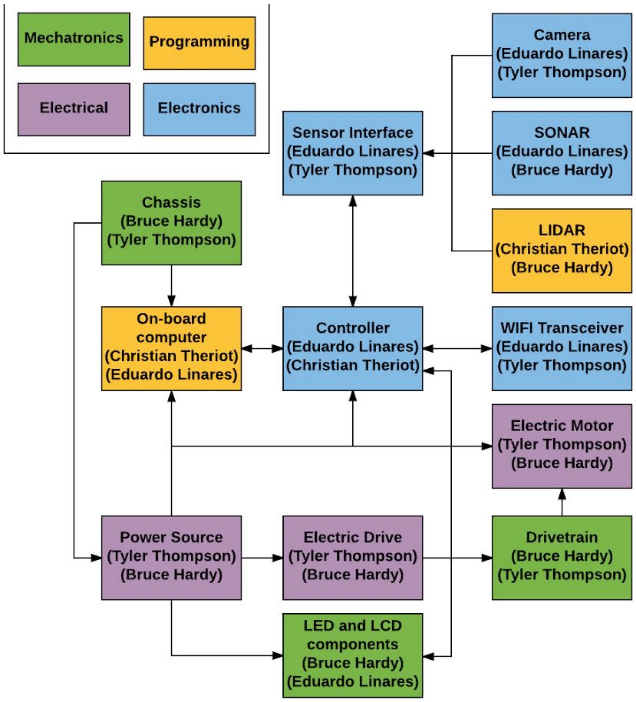

Fig. 1

6. Team Roles

Team Member	Primary Role	Secondary Role
Tyler Thompson	Electrical	Mechanical
Bruce Hardy	Mechanical	Electrical
Eduardo Linares	Electronic	Programming
Christian Theriot	Programming	Electronic

7. Software Operational Flowchart

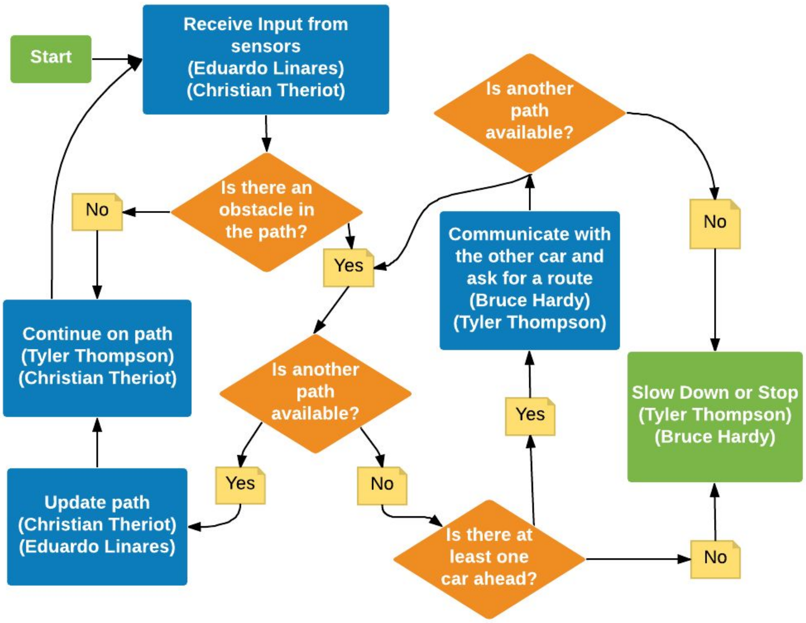

Fig. 2

A green box represents an initial or terminal state
A blue box represents a process or method
The orange parallelogram represents a decision

8. Software Class Diagram

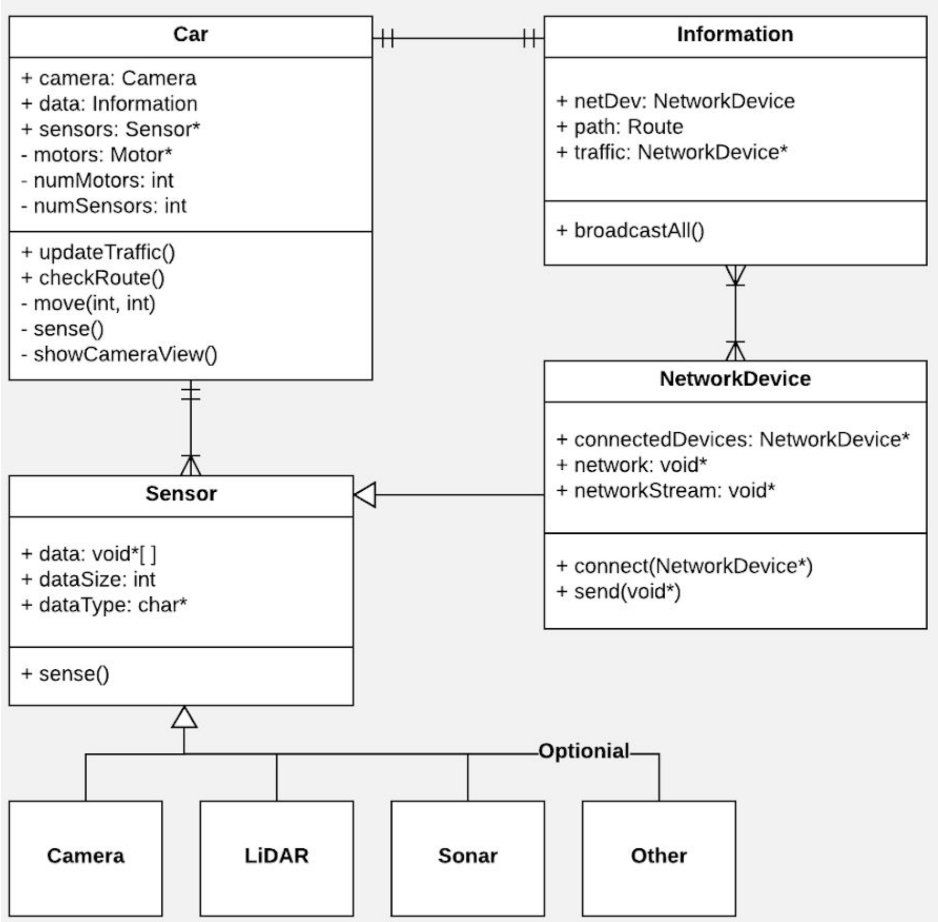

Fig. 3

A double-bar indicates <u>only one</u> instance of the connected class is present.
The triangle with one line over it indicates <u>at least</u> one instance is present.
The white triangle points to the base class for inheritance.

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9. House of Quality

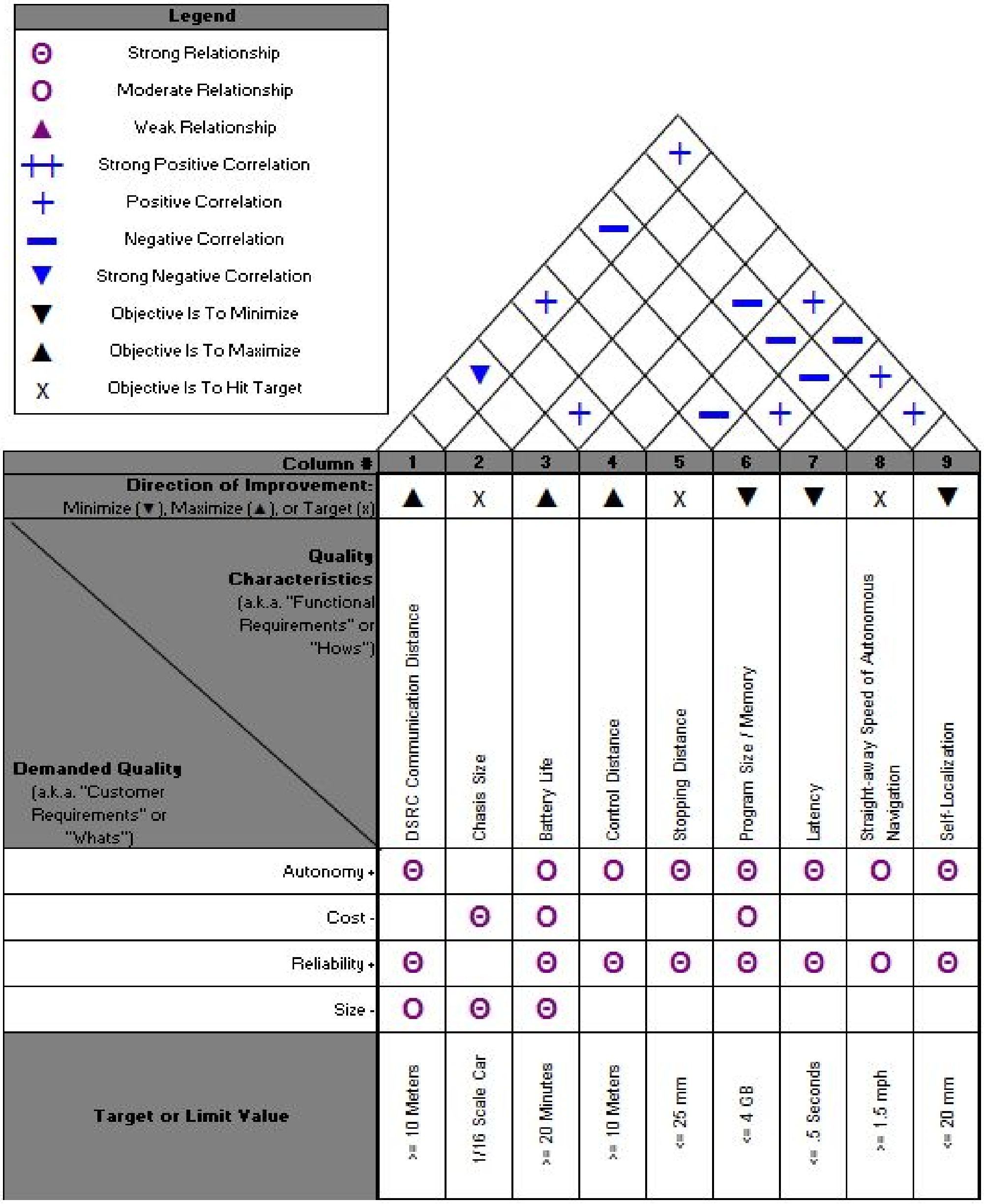

Fig. 4 The vehicle-to-vehicle DSRC communication, stopping distance, and straight-away speed of the autonomous vehicle mode quality characteristics will be verified to the panel during the design showcase demonstration.

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10. Budgeting and Finance

Cost Constraints: The primary goal is to design the vehicle at a cost of no greater than $2500 per car and to build at least two vehicles before the project showcase. The cost analysis displayed below is for a single car.

Item	Estimated Cost
Traxxas VXL Rally RC Car	$449
Nvidia Jetson TX2 Development Board	$299
Elegoo UNO R3 ATmega328p Board	$11
ZED 2K Stereo Camera	$449
(10) WYPH Ultrasonic Module For Arduino	$15
(5) DAOKI IR Module For Arduino	$5
ZED Stereo Camera	$449
GPS Module	$13
LIDAR Scanse Sweep Sensor	$349
Tp-Link N450 Wireless Router	$30
(10) Ethernet Cable	$13
7 Port USB Hub	$27
SparkFun 9DoF IMU Breakout	$25
50000mAh Auxiliary Battery Pack For Boards	$136

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11. Milestones / Timeline

Deliverable	Customer	Due Date	Estimated Time to Completion	Steps to Complete

Divide and Conquer 7-10 Pages	Lei Wei	9/22/2017	4 hours (meetings) 10 hours (writings)	1. Meet with Dr. Fallah and Nitish 2. Write preliminary document 3. Review preliminary draft with Dr. Fallah and Nitish 4. Re-write document to incorporate criticisms from Dr. Fallah, Behrad, and Nitish
Updated Divide and Conquer	Lei Wei	10/6/2017	2 hours (meetings) 2 hours (writing)	1. Review Standards with Dr. Fallah and Nitish based on our meeting with Lei Wei 2. Finalize division of labor for the project
Finish Udacity Course of AI for Self Driving Cars	Sponsors	10/7/2017	3-4 hours	1. Log into Udacity 2. Watch videos and answer quizzes. 3. Ideally, everyone moves through the course at a similar pace and completes a 3rd of the course every week or more.
20 Page Internal Report	Group	10/13/2017	20 hours per person	Each group member produces 5 pages of new research on hardware or software implementation of an autonomous vehicle.
40 Page Internal Report	Group	10/20/2017	20 hours per person	Each person provides 5 pages of new research
60 Page Report	Lei Wei	11/3/2017	20 hours per person	Each person provides 5 pages of new research
100 Page Report	Lei Wei	11/17/2017	40 hours per person	Each person provides 10 pages of new research
Final 120 Page Report	Lei Wei	12/4/2017	20 hours per person	Each person provides 5 pages of new research
Part Orders	Group	TBD	TBD	Dependent on Sponsor
PCB design	Group	End of Fall	10 hours	Dependent on Requirements

References

[1] Road Crash Statistics. (n.d.). Retrieved September 20, 2017, from http://asirt.org/initiatives/informing-road-users/road-safety-facts/road-crash-statistics

[2] Bojarski, M., Del Testa, D., Dworakowski, D., Firner, B., Flepp, B., Goyal, P., . . . Zieba, K. (2016, April 25). *End to End Learning for Self Driving Cars*[Scholarly project]. In *NVIDIA.com*. Retrieved September 20, 2017, from http://images.nvidia.com/content/tegra/automotive/images/2016/solutions/pdf/end-to-end-dl-using-px.pdf

[3] Kontzer, T. (2016, April 13). Volvo 'Drive Me' Project to Make Self-Driving Cars Synonymous with Safety | NVIDIA Blog. Retrieved September 20, 2017, from https://blogs.nvidia.com/blog/2016/04/06/volvo-safety-self-driving/

[4] Novet, J. (2017, September 22). Tesla and AMD are working on an A.I. chip for self-driving cars, source says. Retrieved September 22, 2017, from https://www.cnbc.com/2017/09/20/tesla-building-an-ai-chip-for-its-cars-with-amd.html

[5] Marshall, A. (2017, September 21). With Intel's Chips, Google Could At Last Deliver Self-Driving Cars. Retrieved September 22, 2017, from https://www.wired.com/story/waymo-and-intel-self-driving/