UCF

COLLEGE OF ENGINEERING AND COMPUTER SCIENCE

EEL 4914 Senior Design I
Divide and Conquer V2.0

Autonomous Vehicle Demonstrating Real-Time Programming

Sponsored by Dr. Guo

Group 20 - *“The Knights Who Say ‘Ni’”*

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Project Narrative Description

Statement of Motivation

Real time operating systems (RTOS) is an up-and-coming area of research that could be revolutionary within the computing and embedded systems domains. Due to the high demand by the automotive industry to pursue groundbreaking technology, which could lead to self-driving automobiles, our group was motivated to pursue this project through the applications of embedded systems, communications, and due to an interest in the platform's competitive element. While this specific implementation of RTOS could be considered trivial, the work can easily be carried over into a computing or scheduling setting.

Project Goals and Objectives

The objective of this project is to design a fully autonomous car that is capable of making decisions that will allow it to navigate a reconfigurable track without collisions. This project will set itself apart by being as close to fully autonomous as achievable by not requiring any "learning input"—i.e. driving through a course first or having the route preplanned—and will instead use its various sensors to make navigational decisions.

In addition, there is also a competitive factor in which multiple cars can race each other at events, which would require the vehicle to have the ability to navigate quickly while still guaranteeing that the group's vehicle will not collide with its competitor(s).

Project Function

The function of this project is to utilize an RTOS to implement navigational capabilities. The vision of this project is to have a vehicle that can traverse a course that could feature twists, turns, hazards, and even dead ends, and would be able to navigate through the course as fast as possible without colliding. Translating the work into a "real-world" problem looks as simple as having a processor that responds in real time to different flags and interrupts in a system while still operating efficiently and correctly. This work could easily be applied to existing technologies such as Roomba or other autonomous vehicles already in production.

3-D Imaging Camera

This will be the featured sensor to interpret obstacles. This project features a 3D camera that has distance sensing capabilities. Ideally the camera will feed a constant stream of image data or distance measurements to the GPU or MCU, thus allowing the MCU to determine the appropriate course of action. After analyzing the cameras specifications, our group discovered that the camera supports multiple video qualities, as well as framerates, and is capable of interacting with Robotic Operating Software (ROS) and can provide output of a point cloud with distance measurements from 0.5 to 20m. This point cloud can be sent to a GPU to be further analyzed, and then the analysis can be later transferred to the MCU.

Image Processor

The image processor we chose is the Jetson Tx2, which will take raw data from the 3-D camera and provide data to be processed by the MCU to avoid collisions. Depending on the camera's specifications and capabilities, as well as the direction that the project goes in, the data will either be constant image frames or object distances. The image processor may be utilized to perform calculations on the frames to provide more detailed information about the rates at which objects are approaching and further assist the MCU in determining the most appropriate decision that it will make.

Sensors

Multiple secondary sensors will be utilized to facilitate collision avoidance and course navigation. These sensors could include inertial measurement units (IMUs), rotary encoders, PID controllers and linear distance measurement devices, among others. The main two sensors will be the IMU and the rotary encoder, as the ROS package that we will use can calculate the position, velocity, and acceleration of the unit, which will be crucial to the MCU's decision making.

MCU

The MCU will be the brain of the design that will take the inputs from the aforementioned sensors, interpret the data and provide output commands to the vehicle to navigate and avoid collisions. The MCU will be constantly taking in data the GPU feeds it and will have to adjust the motor, speed controller, and steering servos accordingly. Additionally, the MCU will monitor any wireless communications and await a manual override signal—which will be supplied by the user (if necessary) as a failsafe technique—and will then "listen" to the user's instructions in lieu of making its own.

Power System

The power management PCB will provide regulated DC power to all subsystems. The power system's input will be a rechargeable lithium-polymer (LiPo) or Nickel Metal Hydroxide (NiMH) battery pack operating at 8.4 VDC and providing a current in between 3000 and 5800 mAh. The power system will also be featured in the system's failsafe, mentioned below.

Failsafe

An electronic failsafe will be designed to mitigate liability associated with the operation of an autonomous vehicle. The failsafe will function in two separate ways.

The first operation will be to act as a user-controlled override of the steering and speed functions of the vehicle. The existing remote-control functions provided with the initial vehicle will be integrated into our design, thus allowing an operator to seamlessly take control of the vehicle to avoid injury to individuals or damage to property. This option brings the autonomy level from a 4 down to a level 0 ([1]).

The second operation of the failsafe will be as an electronic "kill switch" that immediately disconnects power to the motor, thereby disabling any powered vehicle movement, but still allowing the vehicle to process and steer away from obstacles. This operation is important in case the vehicle travels outside the range of the existing remote-control functionality present in the original vehicle. This option will alter the autonomy level from a 4 to a level 3 ([1]).

Requirements

Requirements	
Autonomous	Lightweight
Collision Avoidance	Fit within specs
Real time navigation	Battery operated
Liability	Communications

Table 1 - Customer Requirements Table

Autonomous - The vehicle will not need any assistance making decisions—unless the user provides an override.

Collision Avoidance - The correctness of our design will be based on navigating without running into obstacles, the track, or potentially other racers, if applicable. This will be done by using proximity sensors that will detect objects within twelve inches.
Real Time Navigation - The vehicle will use its sensors and camera to make "on the go" decisions without any prior navigational input.
Liability - To decrease liability risks associated with an autonomous vehicle, failsafes will be designed and implemented.
Lightweight - Due to vehicle loading restrictions and end goal racing aspect, project components will need to be lightweight so as to not impede the vehicles movement performance. The estimated weight of the total vehicle will be less than ten pounds.
Fit within specs - In order to meet the project and course goals, our design will need to fit all power, communication, and autonomous specifications.
Battery Operated - All devices and accessories will be powered by the LiPO or NiMH battery. At full capacity the estimated runtime of the vehicle will be greater than ten minutes.
Communications - Our override techniques will be FCC-compliant. We will be using unlicensed frequencies, most likely in the range of 2.4 GHz.

Constraints

Constraints	
Time	Cost
Dimensions	Weight
Computing Power/Memory capacity	Safety

Table 2 - Project Constraints Table

The first project constraint will be time. As the timeframe allotted is fixed and non-flexible, our team will have to allot and manage time efficiently in order to accomplish the scope of the project within the allowed timeframe. Our team will need to make sure that ample parts and models are ordered with enough time to have them shipped, prototyped, and tested before the project's presentation. Our goal is to have all of: the PCB designs, sensors, hardware modifications, and wireless communication components ordered by the end of December.

Funding is also a concern as multiple components are cost prohibitive and being provided by our sponsor. Smaller components, the PCB, MCU and associated wiring will be financed by the individual team members and we will attempt to stay under $500.

Physical dimensions of the host vehicle will dictate the size and scope of the electronics that we are able to install onto the platform. The vehicle's chassis is not overly large—around .15 m^2—and so if more space is needed our team will have to find innovative solutions to solve the size problem.

Weight is a constraint due to the loading capacity of the host vehicle as well as to maintain a competitive edge for the end goal of racing the autonomous vehicle. The car should maintain a weight less than 15 pounds in order to stay competitive and house all of the necessary components.

Computing Power/Memory Capacity is a constraint due to a large number of computations and visual processing that will be required for the object avoidance and mapping functionality of the project. The TX2 has a GPU with 8GB of memory on board, and so this will provide the ceiling for our processes in terms of memory capacity.

Safety is another constraint. Due to the autonomous nature of our project, our group must integrate specific safety precautions in order to mitigate liability in the case of interference or a “glitch” in the system.

Related Standards

Standards	
FCC - Frequency, Communications	IEEE - Robotics, Power
FDOT - Road regulations	NCSL - Autonomous vehicle legislation
NHTSA - Autonomous Safety	

Table 3 - Related Standards Table

Automated Vehicles for Safety

The NHTSA has a list of multiple definitions and regulations on automated vehicles, as well as the history of car safety with an emphasis on how the future trend of automated vehicles. The biggest feature of the NHTSA site is that it defines different "levels" of automation. For this project, the most appropriate level is a level 4, which is defined as being "capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle." ([1]) The current proposal is to have two sets of overrides which can demote the vehicle to either a level 3—where the "driver is a necessity, but is not required," and "must be ready to take control of the car at all times with notice"—or a level 0 where the driver "performs all driving tasks". The details of each failsafe technique are described above.

Autonomous Vehicles | Self Driving Vehicles Enacted Legislation

The NCSL is a third-party organization that reported on all of the legislation passed at the state and national levels regarding autonomous vehicles. This will help the project when it comes to testing the vehicle as there are specific regulations about where the car can and cannot operate. Additionally, if the project happens to scale up into full-sized cars, this will be an excellent guide in making safety and equipment decisions.

Radio Control Radio Service (RCRS)

This standard has to do with wireless communications and what frequencies are allotted to the public and which are privatized. This project will be engineering wireless communication between the user and the vehicle, and so it is imperative that we utilize the proper frequency bands in order to avoid either receiving the wrong signals or interfering with other broadcasts.

IEEE Standard Ontologies for Robotics and Automation

IEEE has published and maintained multiple standards of wireless communication. By utilizing these standards, our communications will be more effective and more organized. These standards will also give us a basis to guide us as we write our drivers and protocols.

Block Diagrams

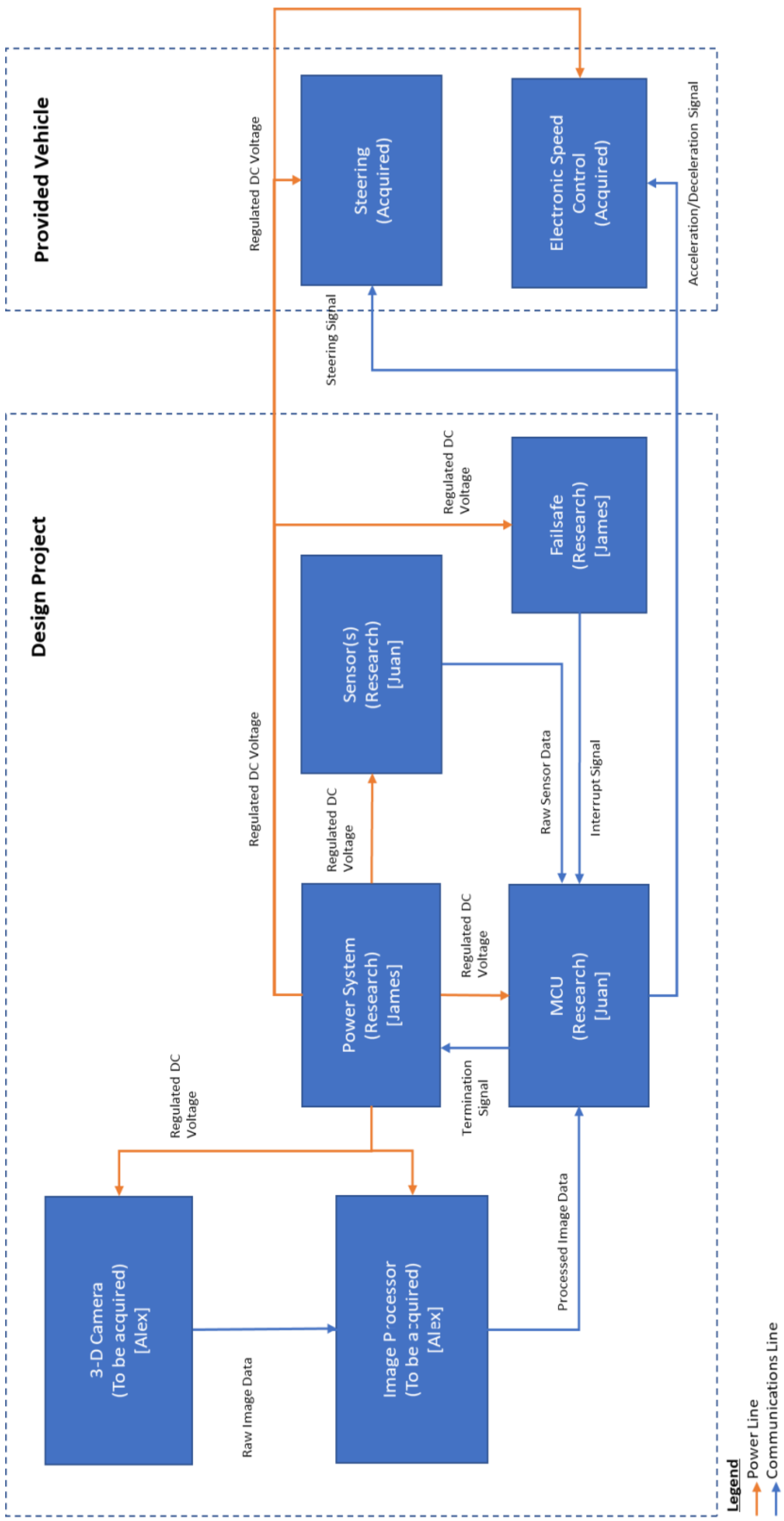

Figure 1 - Project Block Diagram

Project Prototype Illustration

Figure 2 is a mock representation of the future project, and is based on another project that had a similar goal.

Figure 2 - Project Mock Design Representation

Project Financing

The main source for financing will be UCF professor Dr. Guo who is sponsoring the project. Dr. Guo will fund the majority of the parts listed in the table below. Minor parts will be purchased by the group members.

Project Funding

Item	Budget ($)	Status	Source
RC Car Chassis	290	Acquired	Dr. Guo
NVIDIA Jetson Tx2	300	Acquired	Dr. Guo
ZED Stereo Camera	450	Acquired	Dr. Guo
Carrier Board	175	Acquired	Dr. Guo
Razor IMU	36	Acquired	Dr. Guo
Rotary Encoder	13	Acquired	Dr. Guo
Additional Sensors	150	Research	Group
PCBs	75	Research	Group
Electrical Components	100	Research	Group
Miscellaneous	150	Research	Group
Total (Rounded Up)	1800		

Table 4 - Project Funding Table

Initial Project Milestones

The following table illustrates the scope and deadlines of the project.

Milestone	Due Date
Divide and Conquer 1.0	20 SEP 2019
Design Review	02 OCT 2019
Divide and Conquer 2.0	04 OCT 2019
Design Review	31 OCT 2019
60 Page Draft Document	01 NOV 2019
Design Review	12 NOV 2019
100 Page Document	15 NOV 2019
Design Review	30 NOV 2019
Final Document	02 DEC 2019
Order Parts	DEC 2019
Committee Selection	FEB 2020
Project Build	FEB 2020
Final Presentation	APR 2020

Table 5 - Project Milestones Table

Decision Matrix

As a team we decided to pursue “Autonomous Vehicle Demonstrating Real-Time Programming” due to the fact that it is an up and coming technology that it could potentially grow exponentially due to the high demand to make automobiles autonomous. Learning this type of technology can escalate our chances of securing an exciting career.

Since this technology is essentially new to us, the aspect of learning a new coding language, learning to do image processing, learning RF technology and being able to develop it gave us the motivation to work with this project.

During our undergraduate schooling we underwent through courses that helped us develop and understand embedded systems and digital signal processing which are essential parts of the project chosen. As individuals we have undertaken different elective courses that has made us more familiar with real time systems, linear systems, digital communications and power systems. All of which will take part in developing an autonomous vehicle.

Since the project will feature some high-end technology which includes a 3D camera, cost is one of our constraints. The fact that the project is being sponsored by UCF via Dr. Guo heavily influenced our decision to tackle this project.

As one of our group members is an RC enthusiast, the platform provided by UCF and Dr. Guo is a robust RC vehicle design and was considered well suited to carry our autonomous vehicle design components. Due to the vehicle’s “off-road” capabilities, it should be able to handle the additional weight better than some of the other commercially available vehicles and still be able to perform well in a racing capacity. The inclusion of a commercial-off-the-shelf (COTS) radio receiver will also enable the team to keep costs down when integrating the receiver into the failsafe of the autonomous vehicle.

QFD: House of Quality
Project: Autonomous Vehicle
Revision: 1.0
Date: 10/03/2019

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

Correlation roof: + (between columns 1 and 2)

Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Customer Requirements (Explicit and Implicit) / Functional Requirements	3-D Camera	Proximity Sensor	Overall Weight	RTOS	Run-time	Max Speed				Our Product	Competitor #1: *Product Name*				Row #
					Column #	1	2	3	4	5	13	14	15	16						
					Direction of Improvement	▼	▼	▼	◇	▲	▲									
1		22%	10	9	Avoid obstacles	●	●													1
2		18%	8	3	Navigate a course in real time	○	○													2
3		16%	7	9	Image processing	▽			●											3
4		11%	5	9	Reliable					●										4
5		2%	1	9	Lightweight			●												5
6		20%	9	3	Battery Operated					○										6
7		11%	5	9	Fast						●									7
14																				14
15																				15
16																				16

Customer Competitive Assesment: 0 1 2 3 4 5 — Our Product, Competitor #1, Competitor #2, Competitor #3

	1	2	3	4	5	13	14	15	16
Target	1.64 feet min.	12 inches min.	< 10 pounds	< 1 second	> 10 minutes	> 10 MPH			
Max Relationship	9	9	9	9	9	9			
Technical Importance Rating	268.89	253.33	20	140	160	100			
Relative Weight	29%	27%	2%	15%	17%	11%			
Weight Chart									
Our Product									
Competitor #1: *Product Name*									
Column #	1	2	3	4	5	13	14	15	16

Technical Competitive Assesment: 0 1 2 3 4 5 — Our Product, Competitor #1

Template Revision: 0.9 Date: 4/23/2010
Christopher Battles

Table 6 - House of Quality Table

References:

[1] Matthew.lynberg.ctr@dot.gov. "Automated Vehicles for Safety." *NHTSA*, 12 Aug. 2019, https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

[2] "Autonomous Vehicles | Self-Driving Vehicles Enacted Legislation." *National Conference of State Legislature*, Lexis Nexis, 9 Sept. 2019, http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx

[3] "Radio Control Radio Service (RCRS)." *Federal Communications Commission*, 13 Sept. 2017, https://www.fcc.gov/wireless/bureau-divisions/mobility-division/radio-control-radio-service-rcrs

[4] "IEEE Standard Ontologies for Robotics and Automation ." *1872-2015 - IEEE Standard Ontologies for Robotics and Automation - IEEE Standard*, IEEE, 10 Apr. 2015, https://ieeexplore.ieee.org/document/7084073