DESIGN OF AN AUTONOMOUS GROUND VEHICLE BY THE UNIVERSITY OF WEST FLORIDA UNMANNED SYSTEMS LAB FOR THE 2015 INTELLIGENT GROUND VEHICLE COMPETITION

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Department of Electrical and Computer Engineering

EEL4930 Unmanned Systems

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INTRODUCTION

The purpose of the project is to design a durable, low cost, modular, three wheeled autonomous ground vehicle with the ability to navigate an outdoor course in varying weather conditions with limited prior knowledge of the course. The vehicle will maintain a minimum speed of 1mph, and will be capable of reaching speeds well over 10mph, however will be limited to 5mph as according to the IGVC competition specification. The autonomous vehicle will navigate toward a desired GPS waypoint that may be given to the vehicle wirelessly before the vehicle begins the course and will reach said GPS waypoint within a 2.5 meter accuracy.

Team Composition

The team consisted of three electrical engineering majors two of which were juniors, Daniel Gray and Benjamin Heintze, and one of which was a freshman, Crystal Adams. The team’s software was implemented by a software engineering student, Perry Journey, who is in his junior year of college, with assistance from Daniel Grey. Team lead for this project was Perry Journey. Course advisor for EEL4930 was Dr. Brad Regez. All systems design and implementation in this vehicle project were efforts of these four students in a 5 month time frame.

Electrical System

The electrical systems student engineer for this project was Benjamin Heintze. The electronics of the robot will be powered by two 12v 12AH lead acid batteries. Lead acid batteries were chosen for their ability to sustain the high current draw from our twin 750watt electric motors. Charging time, overall cost, ruggedness, and battery lifetime were also factors in the decision to use lead acid batteries. The batteries are arranged into one battery pack which consists of two 12V 12AH batteries wired in series to provide 24V 12AH. A single mechanical E-Stop switch will be located at the top of the vehicle, and will provide an immediate disconnect of power between all systems on the vehicle and the 24V 12AH battery pack.

Power distribution onboard will rely on the Sabertooth motor controller, and a single 12V buck power converter. As shown by figure 1 the 12V buck converter will supply power to the Arduino Due which will power the PixHawk. The vehicle's 24V 750W DC motors will rely on power from the SabterTooth motor controller.

The Sabertooth motor controller receives direct power(24V) from the battery pack. Initially the vehicle power distribution relied on a RoboteQ MDC2230, however as the project progressed the Sabertooth 2x25 motor controller presented itself as a more cost effective option.

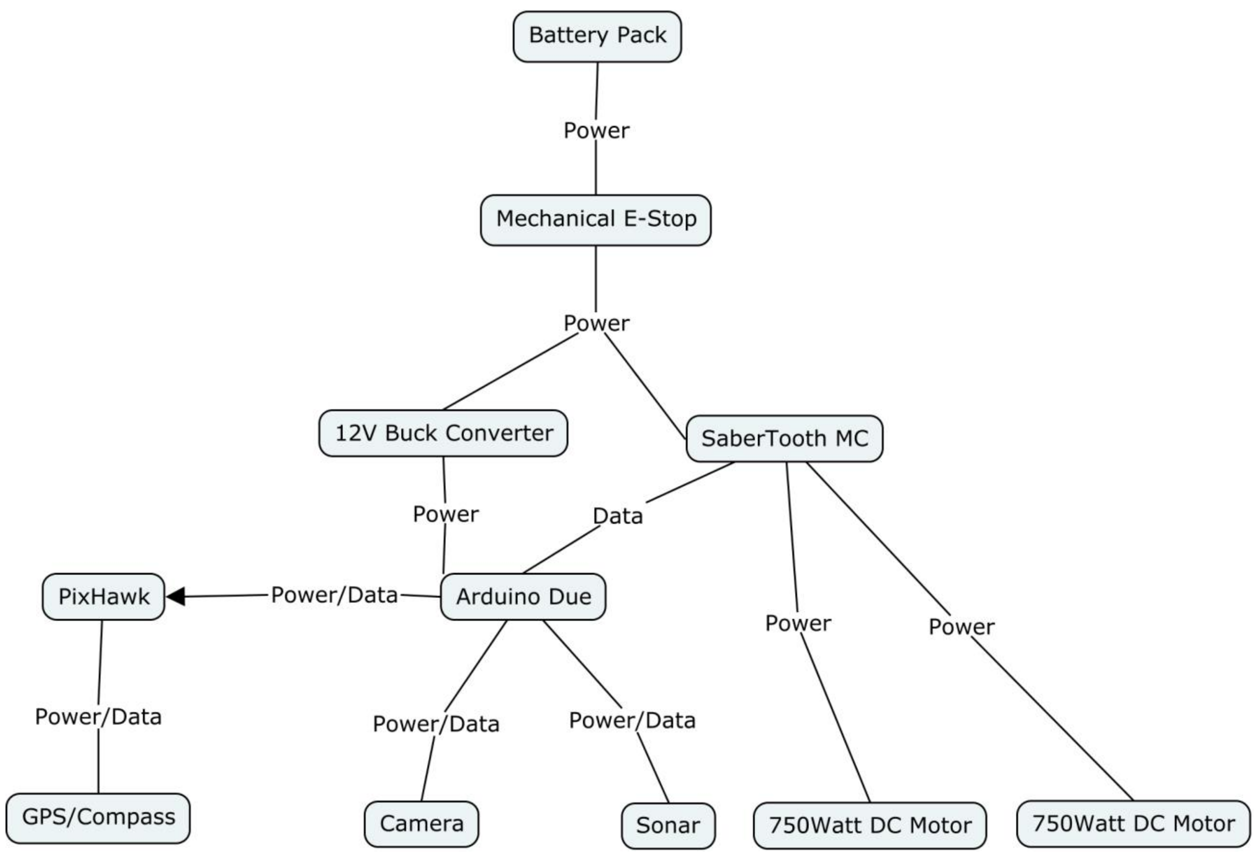

Figure 1: Electrical Systems Concept Map

In-house designed Buck Converter

A power distribution circuit is needed power various loads on the platform. These loads include 24 Volt Motor Control Unit, 7-12 Volt Arduinos, and various 5 Volt outputs. All of these loads are powered by 24 Volt 24 amp hour battery. Additionally connections for each of these components need to be soldered onto the board including Anderson pole, USB, standard pins, and barrel connection. In order to complete the task the circuit contains 2 dc to dc converters, a connection for the 24 V output, and a LED. The DC to DC converter chosen was a buck converter because the loads would be drawing a high amount of amps between 2 and 5 amps. The more standard and simpler linear dropout regulator (LDO) would overheat with this type of amperage. So then, the buck converter chosen was the LT1074 because of its relative simplicity and the ability simulate the circuit in LTspice with the exact component. The circuit design itself also includes various resistors and capacitors, an inductor, and a diode. The LT1074 requires a feedback resistors in order to determine the output voltage of each DC to DC converter. For example the 5 Volt output requires a 2.7k Ohm resistor while the 10 Volt output requires a 7.8k Ohm resistor. An inductor is also need with a capacitor for the low pass filter. A diode was added to prevent a buildup of electrons at the output pin. Capacitors are need at the input and output to smooth out the input voltage and output ripple. When soldering, the input capacitor must be as close as possible to the input in order to get the best output possible from the LT1074. Lastly a 1.2k resistor is required to supply 20 mA to the LED. The simulator chose was LTspice as previously stated. It was used because of it know accuracy, simplicity, and compatibility of Linear Technology's products. The results were 5, 10, and 24 Volt outputs with an input current of 500mA to 3 Amps per buck converter.

Computers and Sensors

The systems engineer student for this project was Daniel Gray. The vehicle consists of two computer systems, with each containing subsystems of sensors. The first of the computer systems is a single Arduino Due based on the Atmel SAM3X8E ARM CortexM3 CPU. Subsystems of the Arduino Due include a camera for image processing, and several sonar sensors for range finding. The second computer system is the Pixhawk autopilot for which the primary use is its GPS and digital Compass sub system. The Pixhawk system also provides our LED indication light to indicate, at the highest point of the vehicle, that the vehicle is active.

Movement Algorithm

The primary software engineering student for this project was Perry Journey. The vehicle's next movement is continually being calculated with aid from GPS, compass, camera, and sonar units in order to optimize system performance. By utilizing the algorithm displayed in figure 2 the vehicle needs not to build a map of its surroundings, and therefore requires less system resources to run further reducing the overall cost of the vehicle. This algorithm achieves its goal primarily through brute force navigation, and lacks a way to intelligently choose more efficient paths. This algorithm has several disadvantages that will occur in more complex environments such as open road environments where navigations that have more than one route choice occur. This algorithm also relies on voltage regulation to the motors and GPS to regulate vehicle speed, which may make the vehicle's speed less accurate depending on the environment it is running in.

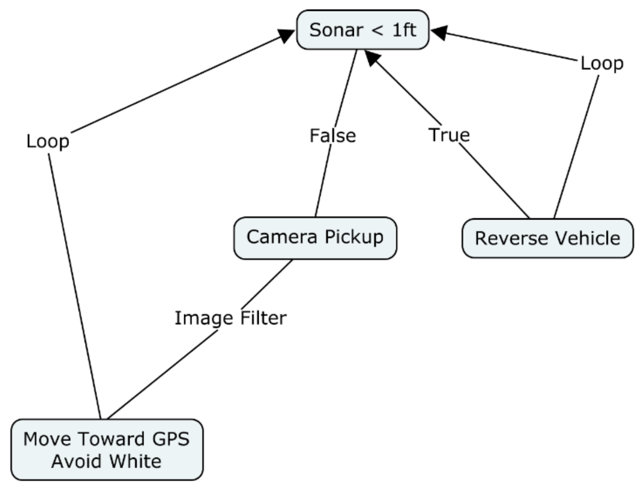

Figure 2: Movement Algorithm

CAD Design

CAD design was primarily completed by previous students of the team. The chassis design went through three major design iterations. The first had four wheel drive and independent suspension for each wheel. This was too expensive and difficult to build. We then removed the suspension from the design to cut costs and make construction easier. We built this version. Upon initial testing of the four wheel drive robot with no suspension, we learned the robot had difficulty turning. Our third and final design change was removing the rear two wheels and replacing them with a single caster. This three-wheeled design with the front two wheels driven was constructed and tested. It satisfied all design constraints

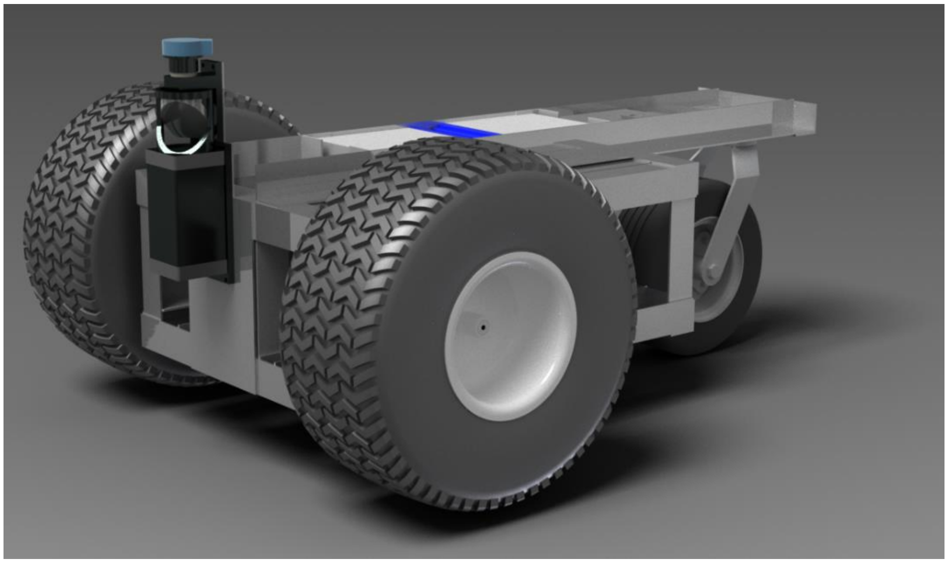

Figure 3: Final Chassis Design three-wheeled configuration

Frame Design

The main body of the unit is made from aluminum frame secured by nut and bolt. The design allows for a light weight structure but also provides adequate strength to carry a load and protect the embedded systems. A hole in the center of the vehicle allows for additional, more vulnerable cargos, to be stored. The three wheel design allows for a tight turn radius and better navigation through congested areas. The three wheel system is operated by differential steering, which varies the two main wheel speeds to maneuver the unit as shown in figure 3.

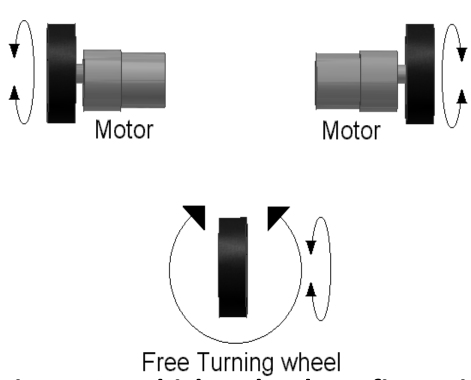

Figure 3: Vehicle Wheel Configuration

The vehicle is designed to be rugged and reliable. The vehicle's construction allows the vehicle to transport both vulnerable and non-vulnerable cargos across many different environments reliably. The vehicles large front tire size prevents it from becoming stuck in potholes or soft sand. The vehicle is also designed to be able to carry loads well above the required load specified by the IGVC competition, and in lab has demonstrated carrying payloads well over 120 pounds while maintaining speeds specified by the IGVC competition.

Speed

The robot is expected to average 5mph as specified by the IGVC competition, however is capable of achieving speeds in excess of 5mph.

Ramp Climbing Ability

The vehicle is expected to be able to climb low grade ramps with the aid of its large frontal tires, and image processing capability. The sonar sensors mounted on the top of the vehicle should prevent the vehicle from misinterpreting a ramp as an obstacle.

Battery Life

The robot is expected to operate a minimum of 1 hour continuously, with the ability to change battery packs in under a minute and continue course. Larger Battery packs may replace the current battery pack, and may occupy the internal vulnerable cargo space should extended operating times be necessary. Larger battery packs may limit the amount of cargo the vehicle may carry, decrease vehicle's top speed, and reduce vehicle's ability to navigate difficult terrain such as soft sand.

GPS and Navigation Accuracy

The onboard Pixhawk GPS system is expected to provide accurate navigation to waypoints with an accuracy of 2.5 meters.

Vehicle Cost

The vehicle's cost was the primary concern limiting all design aspects. The vehicle is designed to be rugged, versatile, efficient, and above all low cost. Below is a cost breakdown of our autonomous ground vehicle.

Product	Cost Per Unit	Units	Total Cost
Frame (6061 90deg Aluminum)	$1.20 per ft	60’	$72
12V 12AH Batteries	$39.95	2	$79.90
Arduino Due	$40.67	1	$40.67
Camera	$29.39	1	$29.39
28015 Ping Sonar Sensor	$40.67	1	$40.67
XYD-6B 24V 750W Motors	$29.99	3	$89.97
Black-Oxide Coated Steel Shaft	$21.09	1	$21.09
Air Ride Wheel with Standard Rim	$86.57	2	$173.14
Rear Wheel	$5.00	1	$5.00
Pixhawk	$199.99	1	$199.99
Pixhawk Subsystems	$118.99	1	$118.99
Sabertooth duel 25A Motor Driver	$130.00	1	$130.00
Quick-Disconnect Bushing	$16.10	2	$32.20
Misc. Cables and Connectors	$250	1	$250.00
750 Watt Electric Motor	$109.99	2	$399.98
Remote Kill Switch	$74.99	1	$74.99
Total			***$1532.98***

Estimated Work Time

Each student on the team was expected to put in a minimum of 5 hours work each week, in the 5 months leading up to competition. There were a total of 4 members on the team, resulting in an estimated hours committed to the project of 520 hours.

Instructor Sign off for this project

Dr. Brad Regez