Final Report

Team 22

Development of an Autonomous Ground Vehicle for the Intelligent Ground Vehicle Competition

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We are thankful for the FIT team for accepting this challenging competition with us and are eager to learn from this experience.

We would finally like to thank the FAMU-FSU College of Engineering for providing their abundant resources to us.

ABSTRACT

The Intelligent Ground Vehicle Competition compels engineering students to use the skills they have gained through study and apply them in real life applications. This competition requires that an autonomous ground vehicle navigate a course while remaining in a predetermined path. One of the biggest obstacles that are faced during this project is how to interface microprocessors and sensors. The sensors need to be able to detect the obstacle and know the position relative to the AGV and relay that information to the microprocessors in a short amount of time. The types of sensors that will be used will be LIDAR and image processing sensors. The second biggest challenge is working with a team that is not in the same location. The Florida Institute of Technology is located in Melbourne, Fl so communicating with them is not done in person. It is imperative that communication between the two teams is kept up to date and done effectively.

While adhering to the competition constraints given by IGVC, components of the vehicle have been selected. The frame will be made out of aluminum 6061 square tubing and differential steering will be the method of steering. The frame will be equipped with mounts and brackets that will hold the payload as well as house the electrical components. The electrical components that have been selected are the NI MyRio 1900 and Raspberry PI 2 microprocessors, long range infrared and ultrasonic sensors for obstacle detection, a Pixy camera for image processing, and a lithium ion polymer battery for power

1. Introduction

The Aero-Propulsion, Mechatronics, and Energy Center has tasked Team 22 to collaborate with the Florida Institute of Technology in the design, manufacture, and programming of a vehicle to compete in the Intelligent Ground Vehicle Competition that is held in Michigan each year. The Development of an Autonomous Ground Vehicle project is focused on designing and fabricating a vehicle that can detect and maneuver around obstacles within a course. The course that the vehicle must navigate is not predetermined, therefore it is essential for the vehicle to possess some way of perceiving the course around the vehicle to enable it to traverse the obstacles. This report will further explain the IGVC and its' background. Then the material selection process will be explained in detail. With this information, a final vehicle design can be proposed.

2. Project Definition

2.1 Background Information on the Intelligent Ground Vehicle Competition

The Intelligent Ground Vehicle Competition (IGVC) offers a design experience for students at the very cutting edge of their engineering education and started in 1993. It is multidisciplinary, theory-based, hands-on, team implemented, outcome assessed, and based on product realization [1]. It comprehensively includes the most recent technologies influencing industrial development and major subjects of significant interest to students. This Intelligent Vehicle's design and construction is a two semester senior year design capstone course and likewise an extracurricular activity from which participating students can earn design credit [1]. Roles practiced during the project development are team organization and leadership, roles such as business and engineering management, language and graphic arts, and public relations are also practiced during this period.

During the course of the project development, students have opportunities to solicit and interact with industrial sponsors who provide component hardware and advice, through which they get an inside view of industrial design and opportunities for employment [1]. Shown in Figure 1 below is a picture 2013 IGVC, in which an autonomous vehicle moving within the lane is about to avoid an obstacle [2].

Figure 1: An autonomous vehicle moving within the lane and about to avoid an obstacle during 2013 IGVC [2].

2.2 Need Statement

The AGV for IGVC project is an undertaking of the Florida Agricultural and Mechanical University-Florida State University (FAMU-FSU) College of Engineering cooperating with the Florida Institute of Technology (FIT) to compete in the Intelligent Ground Vehicle Competition (IGVC). The FAMU-FSU side of the cooperative is funded by the Aero-Propulsion, Mechatronics, and Energy (AME) Center. The Advisor and contact at the AME Center is Dr. Nikhil Gupta.

An autonomous ground vehicle can be used in many industries. AGV's can be used in warehouses to retrieve packages or other items. The obstacle avoidance feature would allow for the AGV to reach its destination and perform its task without any collisions. If an AGV were to be scaled up to full-sized vehicles then the need for career drivers such as semi-truck driver would not be needed.

2.3 Goal Statement

The goal of this competition is to develop a land-based autonomous vehicle that can detect and navigate around obstacles in its path. Due to the time constraint of this project, there is a primary goal and a secondary goal. The primary goal is to make a competition ready vehicle, but since that is a major task, the secondary goal is to have a functioning robot that is able to participate, and successfully qualify, in the straight away at the beginning of the competition.

A fully autonomous unmanned ground robotic vehicle must negotiate around an outdoor obstacle course under a prescribed time while maintaining a minimum of speed of one mph over a section and a maximum speed limit of five mph, remaining within the lane, navigating flags and avoiding the obstacles on the course [3].

2.4 Objectives

Objectives of this project need to be put in place and achieved in order to successfully complete the project. These objectives, with estimated time of completion, can be seen in the Appendix. These time scales are subject to change as the project progresses. The critical objectives are:

- Frame Design
- Motor selection
- Sensor selection
- Processor selection
- Integration

2.5 Constraints

Below are the requirements that the intelligent ground vehicle must meet in order to consider it as a valid design and as well qualify for the Intelligent Ground Vehicle Competition (IGVC). A small semi-rugged outdoor vehicle is required for the competition, the requirements to be met includes[3]:

- Design: The vehicle must be designed such that it is mechanically propelled on its direct contact (traction) with the ground through the wheels.
- Width: Two feet is the minimum width required and four feet at maximum.
- Height: Apart from the emergency stop antenna, the height of the vehicle must exceed six feet
- Length: The vehicle must be at least three feet long with maximum length of seven feet.
- Propulsion: The power required for propelling the vehicle must be generated onboard.
- Speed: At minimum the speed of the vehicle must be one mph and five mph at maximum.
- Mechanical E-stop location: The E-stop button required must be red in color, push to stop and one inch diameter at minimum. Even if the vehicle is moving, the button must be easily identified and can be safely activated with its location at the center rear of the vehicle with minimum height of 2 feet from the ground and four feet at most. The E-stop must not be software controlled, but must hardware based and on activation must be able to bring the vehicle to a prompt and full stop.
- Wireless E-stop: For a minimum of 100 feet the wireless E-stop must be effective. Hardware based E-stops that cannot be controlled using software is required. The wireless E-stop is expected to bring the vehicle to a quick and complete on activation.

- Safety Light: At any time when the vehicle power is turned on, an easily viewed solid indicator light must be recognized on the vehicle. A solid light which turns to flashing when the autonomous is activated and again turns solid when the autonomous mode is off is required.
- Payload: The vehicle must be able to carry a load of 20-pound securely mounted on the vehicle. The specifications of the payload is 18 inches long, 8 inches wide and 8 inches high.
- Lane following: The vehicle must be capable of detecting and following lanes.
- Obstacle Avoidance: The vehicle must be capable of detecting and as well avoiding obstacles.
- Waypoint Navigation: Vehicle must show its capability of finding a path to a single two meter navigation waypoint by maneuvering its way round the obstacle.
- Budget: The amount of money estimated for the completion of this project is 3,000 dollars.

3 Design and Analysis

3.1 Competition Criteria Overview

For a successful competition qualification, minimum criteria must be met: (1) Vehicle must detect and follow lanes; (2) Must detect and avoid obstacles; (3) Must find a path to a single two meter navigation waypoint by navigating around an obstacle. While safety is undoubtedly the most important aspect, product performance for consumer satisfaction is necessary.

Figure 2 shows a block diagram of the proposed design.

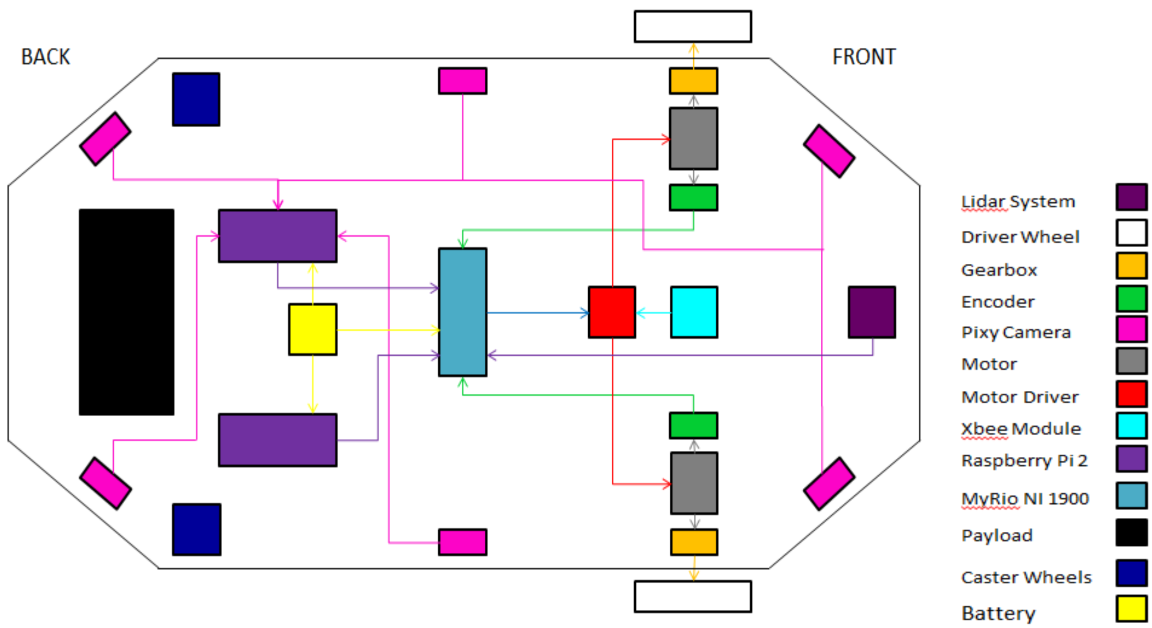

Figure 2: Block Diagram for proposed AGV design

Using a house of quality, it was determined that the most important characteristic was the microprocessors. The seocnd most important characteristics were the sensors and how the sensors will interface with the microcontrollers. Pugh matrices were then used to determine the materials selected for the final design. The house of quality and the pugh matrices can be found in the appendix.

3.2 Electrical System

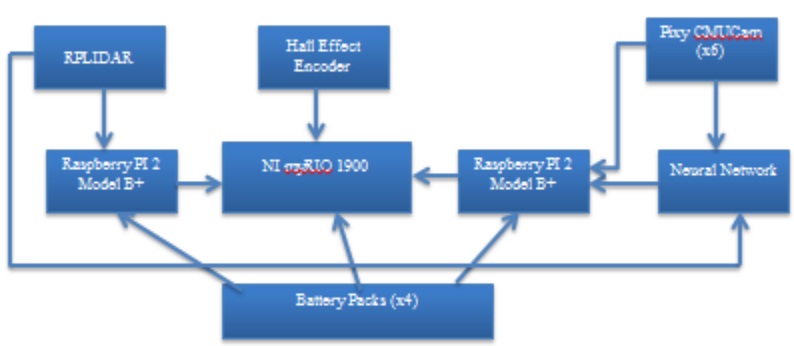

Figure 3: Electrical Flow Chart

3.2.1 Processors [4] [5]

The Intelligent Ground Vehicle competition calls for a fully autonomous vehicle that can detect and avoid objects and lane paths, navigate to waypoints. From these requirements, it did not take long to realize perception was going to be needed to achieve maximum functionality. Thus, the concept of utilizing a processor in order to control the sensors and motor of the vehicle was introduced. Team 22 has chosen to use the NI myRIO 1900 and the Raspberry PI 2 Model B+ microprocessor for the controlling of sensors and motors.

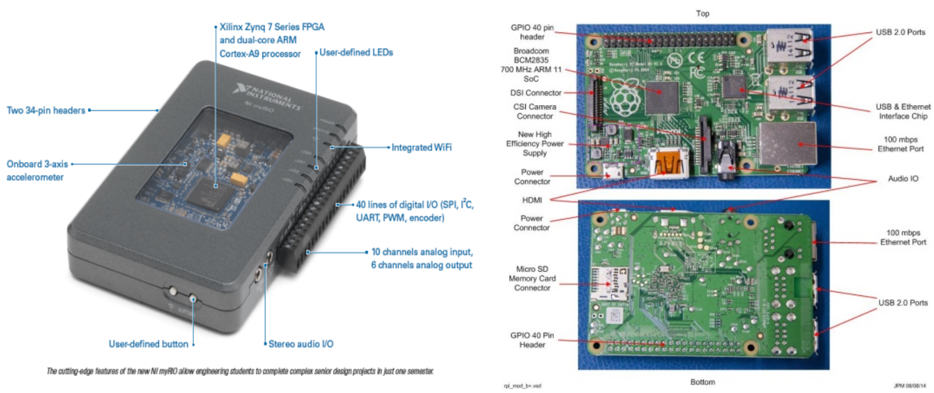

Figure 4: NI MyRio 1900 (Left) and Raspberry Pi 2 (Right)

The National Instrument myRIO 1900, is a portable reconfigurable input/output device that can use to design control, robotics, and mechatronics systems. The interface, as shown in the figure below, features two 34-pin headers, Xillinx Zynq 7 Series FPGA, dual core Cortex-A9 Processor, User-defined LEDs, Integrated WiFi, 40 digital I/O lines, 10 analog input channels, 6 analog output channels, Stereo audio I/O, and an onboard 3-axis accelerometer. It is home to 256 MB of nonvolatile memory and 512 MB of DDR3 memory along with a 667 MHz processor. The vehicle must be agile enough to maneuver around obstacles; therefore, the weight is a major concern. Coming in at around 193g (6.8 oz) the device is rather heavy.

The myRIO requires 6-16 V DC power to operate; therefore, lithium ion batteries will be connected to power it.

Team 22 chose the myRIO because of it's the ability to power several components with a power output of ± 15V; it allows for more user-friendly "plug-and-play" access with all necessary drivers included and it requires minimal programming for accessories; the software utilized for configuration, LabView, allows for real-time testing and course navigation all from the computer. When taking this device into consideration, Team 22 made sure not to overlook the safety of the power consumption needed. It would cause complete system failure to over-power the device with more voltage or current then that of its threshold of 14W.

In addition, the Raspberry PI 2 is a low power microprocessor also used to design control, robotic. The interface features 40 GPIO pin header, CSI camera connector, 100 mbps Ethernet port, USB 2.0 ports, High efficiency power supply, and a Broadcom BCM2835 processor, quad-core ARM Cortex A7 CPU. The vehicle must be agile enough to maneuver around obstacles; therefore, the weight is a major concern. Coming in at around 45g (1.6 oz) the device is rather lightweight. It is home to 1 GB RAM and a 900 MHz processor.

Although myRIO can support the power consumption of several of the AGV's component; team 22 has decided to create a central networking unit in which several low power Raspberry PI 2 Model B+ will be connected to a central "brain", the myRIO in order to split the power load. The Raspberry PI requires 5 V DC power to operate; therefore, lithium ion batteries will be connected to power the device.

Team 22 chose the Raspberry PI 2 Model B+ because of its multiplatform functionality; the GPIO Pin layout; low power consumption and its compatibility with the electrical components chosen for the vehicle. When taking this device into consideration, Team 22 made sure not to overlook the safety of the power consumption needed here as well. It would cause minor system failure to over power the device with more voltage or current then that of its threshold of 14 W.

3.2.2 Obstacle Detection Sensors [6]

In addition to the processor, Team 22 devised a way use sensors to detect the position and distance of the objects. The initial idea was to develop our own LIDAR system using an infrared sensor and a stepper motor, but after calibrating a few IR sensors, Team 22 found that the accuracy would be more efficient in purchasing a RPLIDAR system.

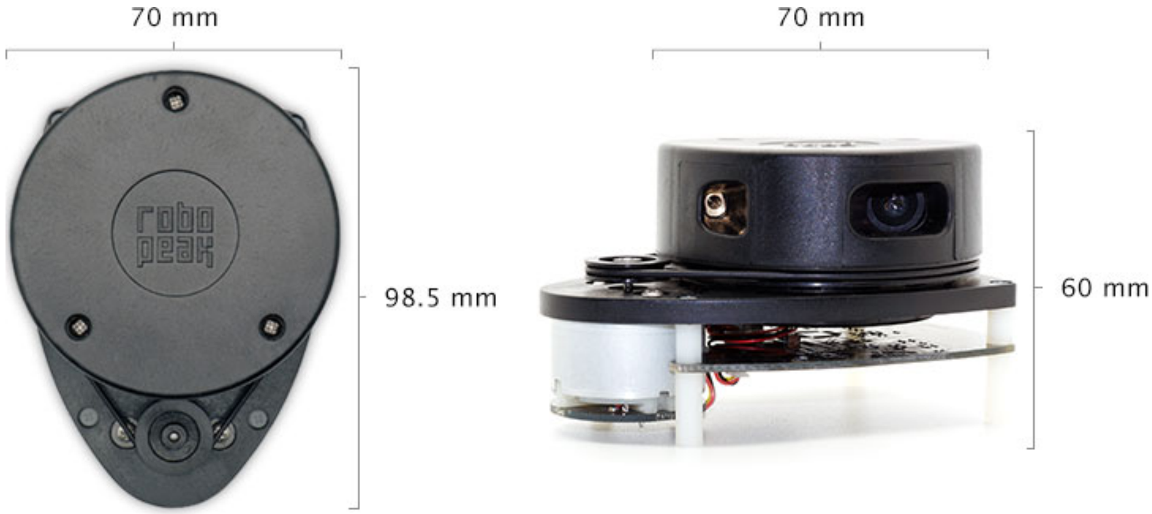

Figure 5: RPLIDAR System

The RPLIDAR A1M1 is a 360-degree 2D laser scanner that features a high-speed laser triangulation vision system. This LIDAR has a configurable scan rate through the PWM module ranging from 2 Hz to 10 Hz. At a rate of 5.5 Hz, 2000 samples/sec can be achieved. A1M1 can detect for a range more than 6 meters, with a 1-degree angular resolution and 0.2 cm distance resolution.

The RP emits a modulated infrared laser signal to be reflected by the object to be detected. Vision acquisition within the LIDAR will sample the returning and the DSP embedded in RPLIDAR starts processing the sample data, a start flag, quality, output distance value, angle value between the object and the RPLIDAR. Through processing the sample data is output through a communication interface.

5V is required to operate the RPLIDAR; therefore, it will be connected via USB or UART to the Raspberry PI. A 2D plot of sample data will be acquired after each scan and will be transmitted to the neural network for processing. Team 22 chose the RPLIDAR A1M1 because of it 360 degree laser scanning capabilities; its affordability; detection range. Its plug and plug via USB allows for easy configuration and integration.

3.2.3 Lane Detection Sensor [7]

Perception is used to detect lane paths. When taking this type of vision into consideration, key factors such as safety, resolution, and cost, and weight were deemed most important. Safety is the number one goal of an engineer when finding the best solution. The Pixy CMUCam 5 will be used for image processing.

Figure 6: Pixy CMUCam5

The Pixy CMUCam 5 is an image sensor with a powerful processor that can be programed to only send the information you are looking for so your microcontroller is not overwhelmed by data. This camera features a Omnivision OV9715 image sensor with a 1/4 inch, 1280 x 800 NXP LPC4330 Dual-Core Processor at 204 MHz. The pixy can process up to 50 frames per second, detecting 100 plus objects at a time. It is home to a Standard M12 lens with a 75 degrees horizontal and a 47 degree vertical FOV (Filed of View).

The Pixy Cam requires 5 V to operate; therefore, it will be connected to a Raspberry PI 2 to power it. The Pixy will use image acquisition to analyze the image taken and transmit data back to the neural network for processing.

Team 22 chose the pixy cam because it is a teachable camera that uses hue and saturation to detect objects. It remembers seven different color signatures, to find hundreds of object simultaneously. The points of possible failure for this camera come with the lens. This point of failure would be a major downfall to the vehicle in that without vision, the autonomous car no long will be able to detect the lane path or the objects. In addition to the safety concerns, there were concerns with the resolution of the camera. Considering the overall weather conditions that may be encountered, the vehicle calls for a camera that is not effected by light. It remembers seven different color signatures, to find hundreds of object simultaneously

3.2.4 Speed Detection Sensor [8]

The Hall Effect two-channel encoder features a 4 Pin header and generates 7 pulses per revolution. It weighs approximately 0.05 lbs. The Hall effect encoders require 5V to operate; therefore, it will be connected to the myRIO. The encoders will then be connected to the R2775 Motors that control the vehicle.

Figure 7: Hall Effect encoder

The sensor varies its output voltage in response to the magnetic field. A magnet is attached to the shaft and the encoder is placed near the moving magnet. Each time the wheels rotate, the sensor produces a pulse; these pulses are then counted along a specific time interval. The data produced is then transmitted to the myRIO to measure the angular speed. By competition rules, each vehicle must maintain a speed between 1-5 Mph throughout the duration of the course. Team 22 chose to utilize the Hall effect encoders because they allow the speed of the autonomous vehicle to be monitored and adjusted automatically.

3.2.5 Wireless E-stop [9]

Competition constraints require a wireless emergency stop that will bring the vehicle to a quick and complete stop. The wireless E-stop must be effective for a minimum of 100 ft and hardware based. With these design constraints, team 22 was able to configure a radio frequency module that will allow for maximum functionality.

The XBee model 802.15.4 multipoint wireless networking radio frequency (RF) module is a 0.960 by 1.087 inch module that operates at a frequency of 2.4 GHz. The module features an outdoor range of over 300 feet line of sight, which is optimal for the task of sending a signal over a course with a maximum diameter of about 223 feet. With a transmit current of 45 mA on boost mode and a receive current of 50 mA while drawing 3.3 volts, the XBee has a data rate of 250k bits per second (bps) and handles errors through retries and acknowledgements. With signal strength and signal interference being the major concerns when designing the E-stop, Team 22 chose this module because it allows for a signal to be resent until the vehicle stops. The module will continue to transmit that sign until the receiver acknowledges the message with a receiver sensitivity of -92 dBm. The weight of this module is also nearly negligible on the frame only adding 0.10 ounces of weight to the vehicle. The RF module will be connected in line with the motor controller to kill power when a positive control signal is sent to the module to activate an electronic solenoid.

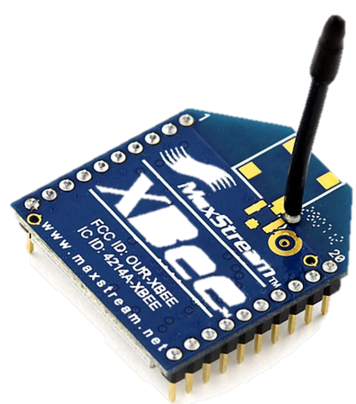

Figure 8: XBee Wireless Controller

3.2.6 On-Board Power [10]

In designing this concept, a major concern was how Team 22 is going to generate efficient on-board power. The IGVC has put a constraint on the vehicle of no combustion engine; therefore, Team 22 had to figure out the best options for battery power. Weight, capacity, and voltage are the major concerns and have to be taken into consideration for power selection.

Lithium Ion batteries are used where high energy density and lightweight is of prime importance. For Team 22, weight is a major concern when designing the vehicle. Due to the relatively low self-discharge, low maintenance and high energy density, lithium ion batteries are of the most useful. The state-of-charge will subject lithium batteries to aging when not in use. Lithium Ion battery packs will be used to power the motors and microprocessors. Our Florida Institute of Technology colleagues will provide further specifics on power generation.

3.3 Mechanical System

3.3.1 Differential Steering

Differential steering requires two motors to be providing forward motion of the vehicle, one wheel attached to each with a caster wheel present elsewhere to establish stability. Differential steering is accomplished by varying the rate at which each wheel rotates with respect to the other. For example, if a left turn is desired the right wheel needs to spin faster than the left. This is because during the execution of a turn the two wheels each have their own arc which they travel around and the radius of the arc outside wheel is greater than the radius of the arc of the inside wheel. For the outside wheel to travel its arc length in the same amount of time that the inside wheel complete its travel the outer wheel must rotate at a higher rate than the inside wheel.

This is favorable because it only requires two wheel motors, multiple members of Team 22 have experience with programming differential steering, and it provides accurate turning.

3.3.2 Tubing-Sheet Metal Hybrid Frame

The positives associated with a tubing frame include weight, ease of manufacture, tubing is available through multiple sources.

A body made from sheet material would provide good protection for internal components from the outside world and the pieces of it would fit together in a similar way to a puzzle, but in three dimensions.

The positives of a sheet material body are the sealing it would provide and the ease of manufacture, all parts could be cut with high precision on machines such as a laser cutter or waterjet.

3.3.3 Aluminum 6061

Aluminum 6061 is a common alloy that is used in everything from kitchen fixtures to precision lab equipment. Aluminum 6061 machines better than 1100 series aluminum, welds better than the higher strength 7073 aluminum, and is higher in strength than 2024 aluminum.

The benefits of using aluminum 6061 for our application are that it is strong enough to withstand any impact that the land based autonomous vehicle would incur at its maximum speed of five miles per hour, it is exceedingly light compared to other metals used for structures, is one of the most common materials to find, and has a very high machinability.

3.3.4 Motors [11]

Team 22's goal when selecting a motor was to select one with a high enough torque output to move the vehicle while simultaneously having high enough speed to allow the robot to remain in the rule regulated 1~5 mph.

Under these constraints team 22 selected the Andymark PG27 Planetary Gearbox with RS775 Motor and Encoder. This motor comes equipped with a two stage planetary gear set for an overall gear ration of 26.9:1 and hall effect encoder so that team 22 would not have to shop around and compare compatibility. The output torque from the gearbox is 6.3 ft*lbf, which is greater than the 4.1 ft*lbf torque needed for the vehicle to climb a 15% gradient , this gradient was used for calculations because it is the maximum gradient on the course as dictated by the Intelligent Ground Vehicle Competition rule book. This motor also has an unloaded speed of 198 rpm, when under load it is predicted to have a speed of approximately 125 rpm. When this speed is coupled with the eight inch wheel diameters chosen for the AGV's drive wheels that gives a theoretical top speed of approximately three mph.

Figure 9: AndyMark PG27 motor

3.3.5 Motor Drivers [12]

Team 22 elected to use two of the Pololu Simple High-Power Motor Controller 18v25 based on their motor selection. Two separate motor drivers were chosen so that in the event of failure of one channel both channels would not need to be replaced, thus decreasing the cost of repairing the unit. The selected motor driver is rated for 25 A continuous output, which is greater than the stall current of the motors selected which is 22 A so that the motors may be used at their full potential.

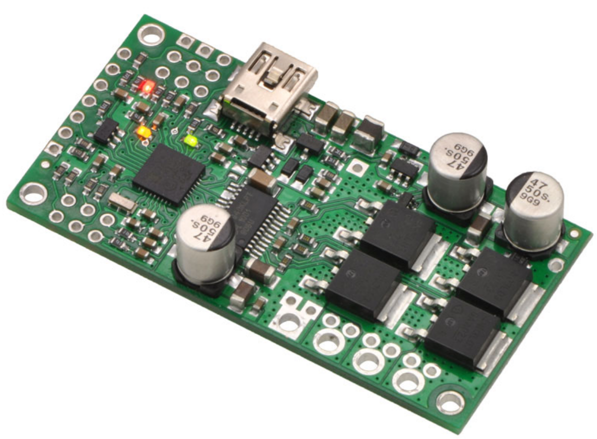

Figure 10: Pololu Simple High-Power Motor Controller 18v25

3.4 Programming

Neural networking is an information-processing paradigm that is based off of the biological nervous system. It is composed of a large number of highly interconnected processing elements that work in unison to solve specific problems. Much like people, the network learns by example; therefore, configuration for a specific application, such as pattern recognition or data classification is achieved through a learning process. Adjustments to the synaptic connections that exist between the elements will allow the neural network to learn.

The neural network will be the brain of the Autonomous Ground vehicle. It will be a JavaScript based algorithm that will be loaded onto the Raspberry PI 2 microprocessor. Information collected from the Pixy Cam and the RPLIDAR will be analyzed and processed through the neural network to teach the vehicle the course layout and the objects that will be avoided during each run. The detection range for the neural network is approximately 10 meters.

In collaboration with the Florida Institute of Technology colleagues, the decision for a lane and object detection algorithm was needed. This particular algorithm was chosen because of it's ability to learn. A neural network is not just a complex system, but a complex adaptive system, meaning it can change its internal structure based on the information flowing through it. Typically, this is achieved through the adjusting of weights.

3.5 Cost Analysis

Table 1: Cost of Electrical Components

Item	Cost
(x1) NI myRIO 1900	$200
(x3) Raspberry PI Model B+	$75
(x6) Pixy CMUCam	$453
(x1) RPLIDAR	$400
(x4) Lithium-Ion Battery Packs	$100
Total	$1,328

Table 2: Cost of Mechanical Components

Item	Cost
Aluminum Square Tubing	$135
Sheet Aluminum	$100
(x4) PG27 Planetary Gearbox w/ RS775 Motor and Encoder	$340
(x4) Pololu Simple High-Power Motor Controllers 18v25	$220
(x3) 8” Pneumatic Drive Wheel	$111
(x3) 4” Caster Wheel	$12
Total	$918

4 Risk Assessment

For this Autonomous Ground Vehicle aspects of the risk and reliability assessment include physical risks as well as project risks. As for physical risks, the AGV will weigh close to 60 lbf and be traveling at near five mph, therefore presenting a threat of injury upon collision with a person or property. It is obvious that, as an autonomous robot, precautions will be taken to help reduce the risk of damage to persons and or property. These precautions include two emergency stops, one mounted on the robot and one remote controlled, as well as a warning light to alert those around it when the robot is powered on and in autonomous mode

In addition to these physical risks, there are also risks to the success of the project, and with careful planning and testing may can be avoided. One potential obstruction would be the failure of the neural network. This could come as a failure of the programming or failure of the concept. If the programming is not functional for its purpose then the neural network as a concept may not be evaluated. If the concept of the neural network fails, then the group may fail to have a final product ready for the IGVC Competition.

5 Methodology

5.1 Schedule

In order to ensure that Team 22, will meet the required deadlines for the competition, a project plan has been put in place. This project plan, displayed in the form of a Gantt chart, can be seen in Figure 11.

Task Name	Duration	Start	Finish
Frame Design	35 days	Tue 9/15/15	Sun 11/1/15
Motor Specifications	35 days	Tue 9/15/15	Sun 11/1/15
Sensor Specification	35 days	Tue 9/15/15	Sun 11/1/15
Processor Specifications	35 days	Tue 9/15/15	Sun 11/1/15
Market Research	35 days	Tue 9/15/15	Mon 11/2/15
Frame Material Selection	1 day	Wed 10/21/15	Wed 10/21/15
Motor Selection	9 days	Tue 11/3/15	Fri 11/13/15
Sensor Selection	9 days	Tue 11/3/15	Fri 11/13/15
Processor Selection	9 days	Tue 11/3/15	Fri 11/13/15
Finalize Design Plan	6 days	Fri 11/13/15	Fri 11/20/15
Order Materials	17 days	Mon 11/23/15	Tue 12/15/15
Frame Machining	17 days	Wed 12/16/15	Thu 1/7/16
Sensor Mounting	8 days	Fri 1/8/16	Tue 1/19/16
Motor Mounting	8 days	Fri 1/8/16	Tue 1/19/16
Coding Prototype	56 days	Tue 11/3/15	Tue 1/19/16

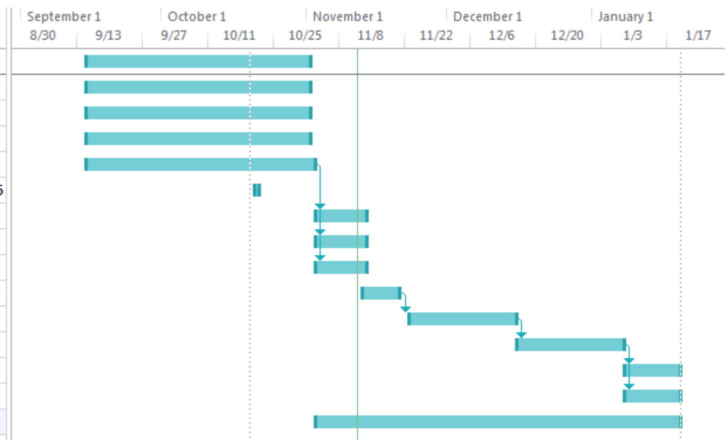

Figure 11: Gantt Chart

There are three phases to be completed in order to remain on schedule. These stages are product specification, product selection, and then product integration. In the first stage, it was deemed necessary to find the requirements of the motors, sensors and processors. These requirements can include weight, angular speed, processing speed, and accuracy. With each member contributing, minimum requirements were found of each component.

In the second stage, selecting a specific product was done by utilizing pugh matrices. In this stage communication was vital in selecting components. With each team members input, specific sensors, motors, and processors were chosen to be integrated.

The final stage is to integrate these components. The Mechanical Engineers will build the frame with necessary brackets and mounts for sensors, processors, and various other items that will be attached to the frame. The Electrical/Computer Engineers will begin to program the sensors and motors so that the vehicle will operate at peak performance.

Team 22 is currently finishing the second phase with the ordering of parts and will begin to move into the next phase of integration.

5.2 Resource Allocation

The development and implementation of the land based autonomous vehicle requires several components that need to work together in order for Team 22 successfully build a vehicle that can qualify for the IGVC competition. Before any of these components can be configured for final assembly, team member roles were assigned to each member. Each team member's responsibilities within the team will be discussed in the paragraphs following.

As Team Leader, Julian manages the team as a whole; develops a plan and timeline for the project meetings, and deadlines, delegating tasks among group members accordingly. Finalizes all documents and provides input on other positions where needed. The team leader is responsible for promoting synergy and increased teamwork. If a problem arises, the team leader will act in the best interest of the project. He keeps the communication flowing, between team members, advisors and sponsors. The team leader takes the lead in organizing, planning, and establishing meeting times. Finally, he gives or facilitates presentations by individual team members and is responsible for overall project plans and progress

As the Lead Mechanical Engineer, Dalton takes charge of the mechanical design aspects of the project including but not limited to the frame design, material selection, and element analysis. Keeps line of communication with the lead Electrical/Computer Engineer to ensure ideas mesh well. He is responsible for knowing details of the design, and presenting the options for each aspect to the team for the decision process. Keeps all design documentation for record and is responsible for gathering all reports.

As Lead Electrical/Computer Engineer, Allegra is in charge of the electrical design aspects including sensors, processors, and programming. She will keep in close communication with the lead Mechanical Engineer in order to ensure a completed design. She is responsible for conveying knowledge of all electrical components to other team members.

As Financial Advisor, Isaac Ogunrinde manages the budget and maintains a record of all credits and debits to project account. Ensures all project parts and equipment are within the specified budget. Any product or expenditure request must be presented to the advisor, whom is then responsible for reviewing and the analysis of equivalent solutions. They then relay the information to the team and if the request is granted, order the selection. A record of these analyzes and budget adjustments must be kept and open line of communication between Financial Advisor and Team Leader is maintained.

As Secretary, Khoury is responsible for keeping a record of all meeting minutes, logging location and topic of meetings as well. In addition, the Secretary will be responsible for making sure that all deadlines are met for each deliverable, staff meeting, and sponsor meeting. Keeps Gantt charts up to date and accurate and realistic and coordinates with the Financial Advisor while purchasing equipment to ensure timely delivery of parts.

6. Conclusion

This project requires a great magnitude of team communication. With it being a collaborative effort between two universities effective communication is key. The proposed design will be divided into two categories: mechanical components and electrical components. The mechanical components consist of steering, frame material, and material shape. The steering mechanism will be differential steering and the frame will be Al 6061 square tubing. The electrical components consist of processors, sensors, vision, and power. Two processors will be used and they are the NI MyRio 1900 and the Raspberry PI 2. Two types of sensors will also be used and they are long range infrared and ultrasonic sensors. For vision, or image processing, a Pixy cam will be used. The vehicle will be powered by a lithium ion polymer battery.

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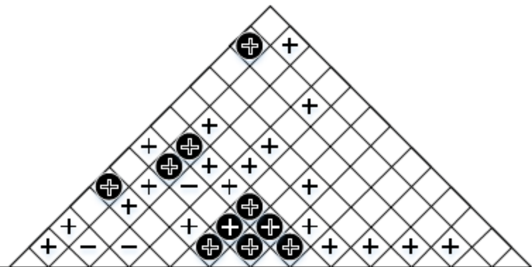
Appendix

Figure A1: Gantt Chart



Design Requirements \ Engineering Characteristics	Design Requirement Weight	Cost	Sensors	Power	Motor	Image Analysis	Programming	Microcontrollers	Interfacing	Mobility	Differential Drive	Speed Control	Weight	Body Styling
Vehicle Speed	5	1	1	3	5	1	3	5	3	5	5	5	3	1
Size	1	3	1	1	1	1	1	1	1	3	3	3	5	5
Lane Following	5	5	5	3	1	5	3	5	3	3	1	1	1	3
Obstacle Avoidance	5	1	5	1	5	5	3	5	3	5	3	3	1	1
Waypoint Navigation	3	3	3	1	1	1	3	5	3	1	1	1	1	1
Mechanical E-Stop	5	1	1	1	1	1	3	3	3	1	1	3	1	5
Wireless E-Stop	5	1	5	1	1	1	3	3	3	1	1	3	1	1
Absolute Importance		57	95	49	69	69	85	121	85	81	61	81	43	63
Relative Importance		6	11	6	8	8	10	12	10	9	7	9	5	7
Rankings		6	2	7	5	5	3	1	3	4	6	4	8	6

Figure A2: House of Quality

Figure A3: Pugh Matrices for Mechanical Components

Steering (0-10)	Programmability	Ease of Control	Weight	Cost	Total
Differential Steering	9	9	8	8	34
Skid Steer	7	7	6	6	26
Tank Tread	7	8	4	5	24
Steering Fans	2	2	9	6	19
Steering Motor	8	6	7	7	28

Body Structure (0-10)	Manufacturability	Weight	Availability	Cost	Total
Tubing Frame	8	7	8	7	30
Sheet Material	6	5	6	4	21
3D Printed	2	9	1	2	14
Floating (Hovercraft)	2	10	2	3	17

Materials (0-10)	Machinability	Weight	Availability	Cost	Total
4130 Steel	7	4	4	4	19
Aluminum 6061	8	7	9	8	32
ABS	9	8	7	7	31
Wood	7	6	9	9	31

Processors	Power	Weight	Cost	Total
NI MyRio 1900	8	5	6	19
Raspberry PI 2	6	7	7	20
Arduino	7	8	8	23
MSP430	6	8	9	23

Sensor	Accurarcy	Weight	Cost	Total
LR Inferred Red	8	9	9	26
Ultrasonic	8	9	8	25
Radar	5	7	6	18
Lidar	9	8	0	17

Vision	Resolution	Weight	Cost	Total
Pixy Cam	8	8	8	24
Camcorder	5	4	9	18

Power	Life Expectancy	Weight	Cost	Total
Lead Acid	6	6	9	21
Lithium Ion	9	9	6	24
Nickel-Metal Hydride	5	5	8	18
Lithium Ion Polymer	9	10	6	25

Figure A4: Pugh Matrices for Electrical Components

Biography

Julian Wilson - Senior, Mechanical Engineer. From Tallahassee, Florida and hopes to work in the Aeronautics Industry upon graduation

Khoury Styles- Senior, Electrical Engineering. From Baltimore, Maryland and wants to work in the computer science field upon graduation

Allegra Nichols – Senior, Computer Science Engineering. From Orlando, Florida and hopes to work in the robotics field upon graduation

Dalton Hendrix – Senior, Mechanical Engineering. From Marianna, Florida and hopes to work in the Automotive industry upon graduation.

Isaac Ogunrinde – Senior, Mechanical Engineering. Foreign exchange student from Nigeria and hopes to work in the materials field upon graduation