Development of a Land-Based Autonomous Vehicle

Team 22

Midterm 1 Report

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October 30, 2015

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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 vehicle navigate a course while remaining in a predetermined path. While adhering to the constraints, which are given later, 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.

ACKNOWLEDGMENTS

Team 22 would like to thank our advisor, Dr. Gupta for the time and effort he has given us. Without him our research and development would be aimless.

We would also like to thank the Aero-Propulsion, Mechatronics and Energy Center along with Dr. Shih who has kindly funded us with this project. Dr. Shih has also collaborated with the Florida Institute of Technology to make this a new and challenging experience for us, as we have to communicate with another team at another university.

We are thankful for the FIT team for accepting this challenging competition with us.

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

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 a Land-Based Autonomous 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.

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 Land-Based Autonomous Vehicle 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. There is too high of a demand for vehicle operators in industry.

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, negotiating 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 Figure 6. 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 Functional Analysis

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. In designing this concept, the following requirements were taken into consideration. While safety is undoubtedly the most important aspect, product performance for consumer satisfaction is necessary.

3.2 Mechanical Engineering Design Concepts

3.2.1 Steering

3.2.1.1 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.

3.2.1.2 Skid Steer

Skid steering is similar to differential steering in that to execute a turn the outside wheel must rotate faster than the inside wheel. Where skid steer differs from differential steering is that four fixed wheels are present as opposed to two fixed wheels. When a turn is executed one of the pairs of wheels, front or rear, act as differential steering would while the other pair skid without causing motion themselves. This gives skid steering its name.

Skid steering is favorable because since it bears similarities to differential steering multiple members of Team 22 have experience with the programming for it. The negatives associated with skid steering is it requires four wheel motors and provides less accurate turning due to having two sets of driving wheels.

3.2.1.3 Tank Tread

Tank tread steering consists of a set of tracks on opposite sides of the vehicle, each driven by a motor. Steering is accomplished in similar fashion to skid steer and differential steering. The key difference between tank tread steering and skid steering is the amount of surface area in contact with the ground.

Tank tread is favorable for the same reasons as skid steering. The negatives of tank tread steering are weight, complexity, and the fact that with more surface area in contact with the ground it requires a larger force to overcome friction. This would require stronger motors to allow the same speeds as the wheeled alternatives.

3.2.1.4 Steering Fans

The concept for steering fans is focused on the intelligent ground vehicle being a “hovercraft”. That is to say that in lieu of wheels or tank tread being in contact with the ground the vehicle would ride on a cushion of air produced by a fan directed into a pouch below the platform of the vehicle. The steering would be accomplished by varying the speeds at which the two fans rotate, similar to differential steering.

The positives of steering fans are that they would be theoretically lightweight and controlling them would be similar to methods used by members of Team 22 previously. The negatives that come with the use of steering fans are that in order to generate enough lift to support all of the system components, as well as the payload required to be carried, would require a massive fan motor, which in turn would increase cost and weight of vehicle.

3.2.1.5 Ackerman Steering

The Ackerman steering concept would require a single driving motor, an open differential made from bevel gears, a ring gear, and a pinion, and a stepper motor. The single driving motor would power the open differential, providing power to the wheels, and the stepper motor would be used to turn a single wheel to provide direction for the vehicle. This design is the most similar to the vehicles that occupy the streets of the world today.

The positives of this steering method are that it only requires a single driving motor and drivetrain components are common amongst everyday vehicles. The negatives associated with this method are the weight that comes along with the use of a differential, the programming complexity compared to other methods, and the responsiveness of the system compared to vehicles that have steering occur at the driving wheels.

3.2.2 Body Structure

3.2.2.1 Tubing Frame

A tubing frame consists of multiple hollow members assembled in a truss type fashion to form a rigid structure. This concept would be coupled with body panels to provide a sealed environment to protect the vehicle’s components from the elements.

The positives associated with a tubing frame include weight, ease of manufacture, tubing is available through multiple sources at reasonable prices (depending on material). The negative aspect of a tubing frame is the requirement of body panels to help protect the interior.

3.2.2.2 Sheet Material

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. The negatives of a sheet material frame are the weight associated with having solid material covering the entire body as well as providing structural support for internal parts, as well as the availability of material in large enough sections.

3.2.2.3 3D Printed

3D printing is the process of placing melted material in layers to form a desired shape. It is commonly done with ABS plastic but recently the process has been adapted for use with metals.

The positives of doing a 3D printed body would be that manufacturing would require little to no input, set it and forget it. This could also be considered a negative aspect because of the amount of time 3D printing takes, for a vehicle of the required size for the intelligent ground vehicle competition it would take days of running to complete. Another positive is that 3D printing would allow for a very complex design without the need for special training to manufacture it. However, the cost of running a 3D printer, especially on the scale that we would need, is highly expensive and disproportionate to the alternative body solutions.

3.2.2.4 Floating (Hovercraft)

The floating frame concept would consist of a platform resting on top of a skirt that would inflate with air.

On a positive note this concept would require little material since the point of it is to be light weight. However what little material is required needs to be to certain specifications to allow the skirt to function correctly. This is because as seal is needed between the skirt and the platform and the skirt also must be air tight. The manufacture of this concept would be difficult because of the skirt, no members of Team 22 or the machine shop staff have experience working with fabric at length. Also the thrust needed to lift the system would be difficult to achieve with motors within the teams budget.

3.2.3 Materials

3.2.3.1 4130 Steel

4130 steel, also known by its industry name of Chromoly, is a high strength alloy steel commonly used for tubing frames in race vehicles. It is used in race vehicles because the strength to weight ratio is considerably higher than that of plain carbon steels.

The positive aspects of 4130 steel are that it is easily bent, cut, notched, and welded, is readily available, and has a high strength to weight ratio. The negatives are that compared to alternative materials it is relatively heavy.

3.2.3.2 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. The negatives are that it is weaker than steels and is more difficult to weld than steels.

3.2.3.3 ABS Plastic

ABS plastic is commonly used in 3D printing applications. With the rise in popularity of 3D printing as of late it has become available through many outlets online. Sheet material of ABS plastic is also available.

The benefit of using ABS would be that it is very light and very shapeable. The negative aspects of ABS plastic are that it would require an adhesive to assemble multiple parts and it is not as rigid as metal alternatives.

3.2.3.4 Wood

Wood is a common material used in everything from tables to buildings to bridges. There are many different species of wood with different properties of strength, flexibility, and density. The most common wood that is the best candidate for our application would be pine.

Positive aspects of using would are that it is relatively light weight, very easy to cut, decent strength, and screws can be used to affix it. Negatives are that wood is prone to splitting, is susceptible to the elements (dry rot, wet rot, bowing in the heat etc), and is also flammable.

3.3 Evaluation of Mechanical Engineering Design Concepts

3.3.1 Criteria for Mechanical Engineering Design Concepts

Team 22 decided that the criteria that mechanical engineering design concepts should be judged on should vary between the different sub sections. Steering is to be evaluated in the categories of programmability, ease of control, weight, and cost on a scale from zero to ten. Body structure is to be validated based on its manufacturability, weight, availability, and cost on a scale from zero to ten. Material selection is guided by the principles of machinability, weight, availability, and cost on a scale from zero to ten. Where zero is least suitable for the category and ten is the most suitable for the category.

Table 1 – Pugh matrices for Mechanical Engineering designs concepts

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

3.3.2 Selection of Optimum Mechanical Engineering Design Concepts

From the criteria stated in section 3.3.1 Team 22 has decided upon having a vehicle steered by differential steering, having a body structure formed from a hybrid of a tubing frame and sheet material, and constructing it from aluminum 6061. These decisions will influence the remainder of the designs that will need to be completed before fabrication will begin.

3.4 Electrical Engineering Design Concepts

3.4.1 Processor

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 deemed cost and weight the most important aspects of material selection and product selection. In doing research Team 22 discovered a variety of microcontrollers that can possibility be used to meet all design specifications.

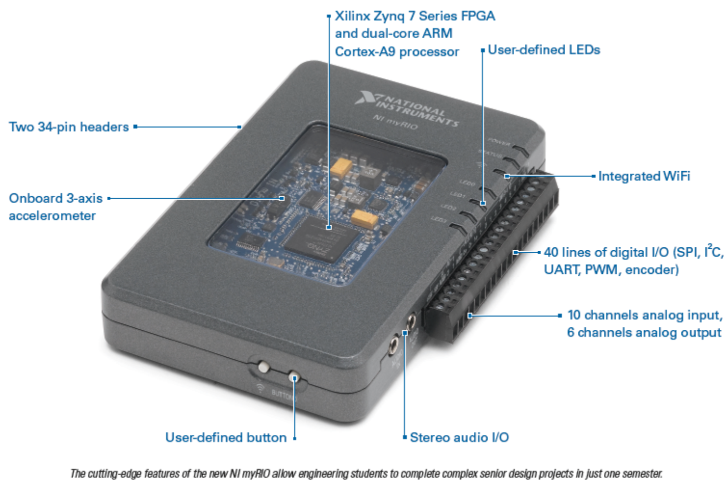

Figure 2: NI MyRio 1900 interface

3.4.1.1 NI MyRio 1900 [4]

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.

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 14 W. 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. It is home to 256

MB of nonvolatile memory and 512 MB of DDR3 memory along with a 667 MHz processor. The Rio requires 6-16 V DC power to operate. This National Instrument allows for more user-friendly “plug-and-play” access because all drivers are included and it requires minimal programming for attachments. The cost surely reflects the convenience and luxury of this product, at approximately $200 per unit excluding software license for educational and commercial purposes and approximately $500 or more per unit excluding software license for noncommercial or evaluation uses.

3.4.1.2 Raspberry PI 2[5]

Much like the myRio, the Raspberry PI 2 is a low power microprocessor also used to design control, robotic. The interface, as shown in the figure below, 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.

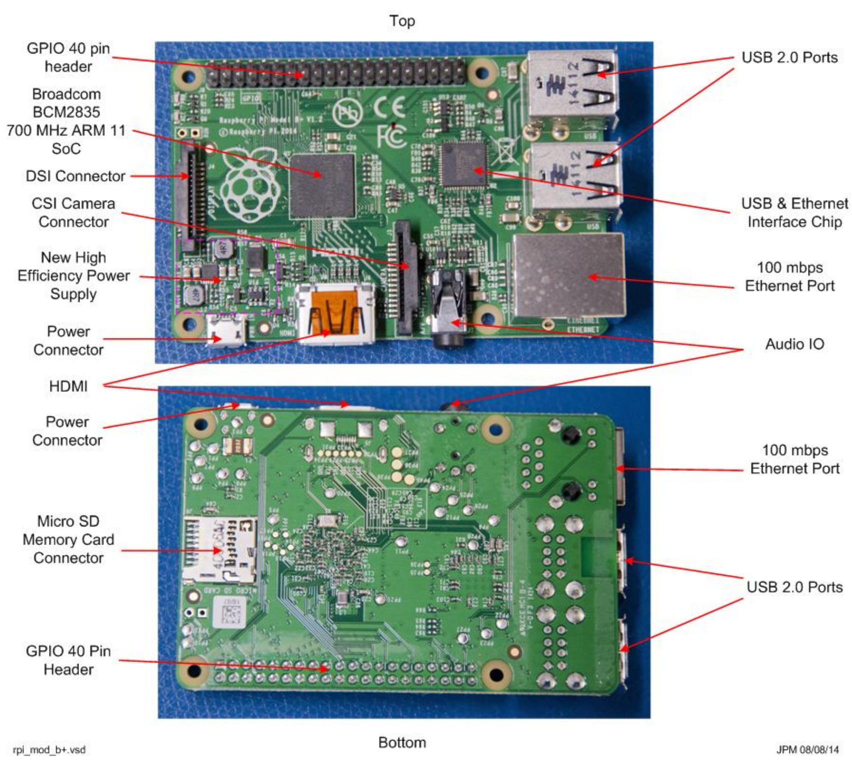

Figure 3: Raspberry PI 2: Model B interface

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. 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. The Raspberry PI requires 5 V DC power to operate. In addition to being low power, this microcontroller is also low cost, at approximately $35 per unit, and utilizing several programming platforms.

3.4.1.3 Arduino[6]

Similar to the Raspberry PI, Ardunio Uno is a low power microcontroller based on ATmega328P. The interface, as shown in the figure below, features 14 digital I/O pins, 6 analog inputs, 16 MHz quartz crystal, ICSP header.

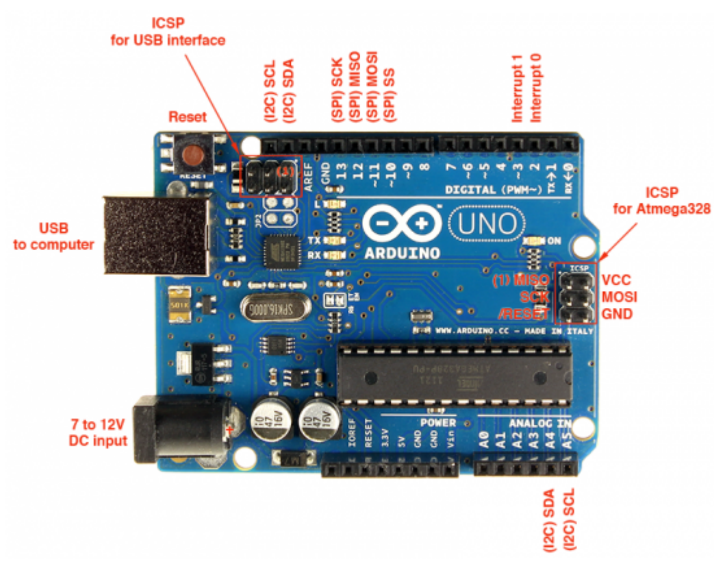

Figure 4: ArduinoUno interface

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 again a minor system failure to overpower the device with more voltage or current then that of its threshold. The vehicle must be agile enough to maneuver around obstacles; therefore, the weight is a major concern. Coming in at around 25g (1.6 oz) the device is the lightest because it is a microcontroller. It houses 2 KB of SRAM and 32 KB of Flash Memory with a clock speed of 16 MHz. The Arduino requires 7-12 V DC power to operate but cannot exceed 20 V. In addition to being low power, this microcontroller is also low cost, at approximately $25 - $80 per unit.

3.4.1.4 MSP430

The Texas Instrument MSP430 is a mixed-signal microcontroller designed for low cost and low power consumption much like the arduino. 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 again a minor system failure to over power the device with more voltage or current then that of its threshold. The vehicle must be agile enough to maneuver around obstacles; therefore, the weight is a major concern. Coming in at around 25g (1.6 oz) the device is the lightest because it is a microcontroller. It houses 8 KB of SRAM and 128 KB of Flash Memory with a clock speed of 25 MHz. The MSP430 requires 1.8-3.6 V DC power to operate but cannot exceed 5 V. In addition to being low power, this microcontroller is also low cost, at approximately $13 per unit.

3.4.2 Sensor

In addition to the processor, Team 22 devised a way use sensors to detect objects and lane path for ease of maneuvering. Sensors will be present on a 360-degree scale of the vehicle.

3.4.2.1 Long Range Infrared

Object and lane path detection are key components of the autonomous vehicle. The long rang IR sensor will be used to detect the actual distance of an obstacle from the sensor using light. The long-range sensor needed will be provided; therefore, cost is not major concern accuracy is. The provided laser will have 40-meter range detection. Infrared sensors are not the most accurate and cannot be used outside in the sun. Although they lack in accuracy, the cost of these sensors is right around $20.

3.4.2.2 Ultrasonic

An Ultrasonic sensor uses sound instead of light to detect objects; therefore, it can be used more accurately with a variety of weather conditions. In using this type of sensor, Team 22 must be concerned with accuracy and cost. The major issue with an Ultrasonic sensor is “ghost echo”, where strange patterns cause a ghost effect. Ultrasonic sensors are the most accurate and can be used outside or inside. Much like the infrared sensor, the cost is within reason, at around $30.

3.4.2.3 Radar

Unlike infrared and ultrasonic sensors, Radar uses radio waves to determine the range of an object. A radio wave that is reflected from the object will be transmitted to the receiver radar that processes the waves to determine the characteristics of the object.

3.4.2.4 Lidar[7]

Lidar, Light Detection and Ranging, is a remote sensor that uses light in the form of a pulsed laser to measure ranges to the Earth. These ranges are precise three-dimensional information that is produced by light pulses and default program data. This method includes a scanner, GPS receiver and a laser. The accuracy and precision of this method allows natural and manmade environments easily to investigate. Although Lidar makes object detection easier, the cost is a major concern. At a whopping $8,000 Lidar is an extremely expensive option, and supersedes the constraint on the budget of $3,000.

3.4.3 Vision

3.4.3.1 Pixy Cam[8]

Perception is used to detect obstacles and lane path. 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. This camera can be used for image processing. The pixy is a teachable camera that uses hue and saturation to detect objects. 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. In addition to the resolution, cost is also a major concern. Models that are rated will be approximately $75 at a weight of 25.5 g.

Figure 5: Pixy CMUcam5 interface

3.4.3.2 USB Camcorder

Camcorders incorporate a camera function, which converts signals of images of the subject into video, and a recorder function, which records and plays back the images from the recording media. Unlike the Pixy cam, the camcorder cannot be taught which objects are primary for detection. A Full HD 1080p camcorder will allow for great resolution but will also make object detection extremely difficult because order of importance in object cannot be established. Finding a camcorder that is efficient and inexpensive is obsolete. For a quality camcorder with great resolution, the cost can very from $200 - $900. With Team 22 being concerned with weight and cost and resolution primarily, the camcorders bulkiness quickly counted this selection out.

3.4.4 Power[9]

In designing this concept, a major concern was how Team 22 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, cost, and life expectancy are the major concerns and have to be taken into consideration for power selection.

3.4.4.1 Lead Acid

Lead Acid batteries are used for application that require a large amount of power and where weight is of little importance. For Team 22, weight is a major concern when designing the vehicle. Due The low energy density, lead acid batteries are unsuitable for handheld devices that demand to be compact size. This batter type is inexpensive, at a price of $25, and simple to manufacture. It requires very low maintenance and processes a low self- discharge. On the other hand, this battery type has several drawbacks including transportation restriction and its environmental unfriendliness.

3.4.4.2 Lithium Ion

Additionally, 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. On the contrary, this battery type does have its drawbacks such as, the cost, and its state-of-charge. At a manufacturing cost of about $100, it is 40% higher than that of Nickel. The state-of-charge will subject lithium batteries to aging when not in use.

3.4.4.3 Nickel-Metal Hybrids

Nickel-Metal Hybrids is used mainly for satellite applications because of their bulkiness, and high-pressure steel canisters and cost thousands of dollars to manufacture cells. NiMH has a high energy density and use environmental friendly metals but is also less durable. There are several limitations of this type of batteries as well, including service life and cost and performance. The service life of NiMH will deteriorate if it is repeatedly deeply cycled. Since high current is needed for these batteries, they are more expensive, at a price of $60 per unit.

3.4.4.4 Lithium Polymer

Similar to the Lithium Ion battery, the Lithium Ion Polymer battery offers all of the benefits as the previously mentioned lithium battery just with a more ultra-slim design and simplified packaging. It is ideal for mobile applications. Its flexible form factor allows it to be economically produced in high volume. The polymer battery is lightweight and is more resistant to overcharge. On the other hand, Li-polymer has a low energy density and is expensive to manufacture, at about $100 per unit.

3.5 Evaluation of Electrical Engineering Design Concepts

3.5.1 Criteria for Electrical Engineering Design Concepts

Team 22 decided that the criteria that the electrical engineering design concepts should be judged on should vary between the different sub sections. Processor are to be evaluated in the categories of power, weight, and cost. Sensors are to be validated based on its accuracy, weight, and cost. Vision selection is guided by the principles of resolution, weight, and cost. Power selection is governed by life expectancy, weight, and cost.

Table 2: Pugh Matrices for Electrical Design Concepts

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

3.5.2 Selection of Optimum Electrical Engineering Design Concepts

From the criteria stated in section 3.5.1 Team 22 has decided upon integrating two processors. The Raspberry PI 2 will control the sensors and motors and then will relay this information to the NI

MyRio 1900. The sensors that will be used are LR Infrared and Ultrasonic. The power generation will come from a Lithium Ion Polymer battery.

4. Methodology

4.1 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 which can be seen in Appendix A in Figure 5.

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 which can be seen in Figure X.X. 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.

4.2 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.

Team Leader – Julian Wilson

Lead M.E. – Dalton Hendrix

Lead E.C.E – Allegra Nichols

Secretary – Khoury Styles

Financial Advisor – Isaac Ogunrinde

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.

5. 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.

6. References

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Appendix A

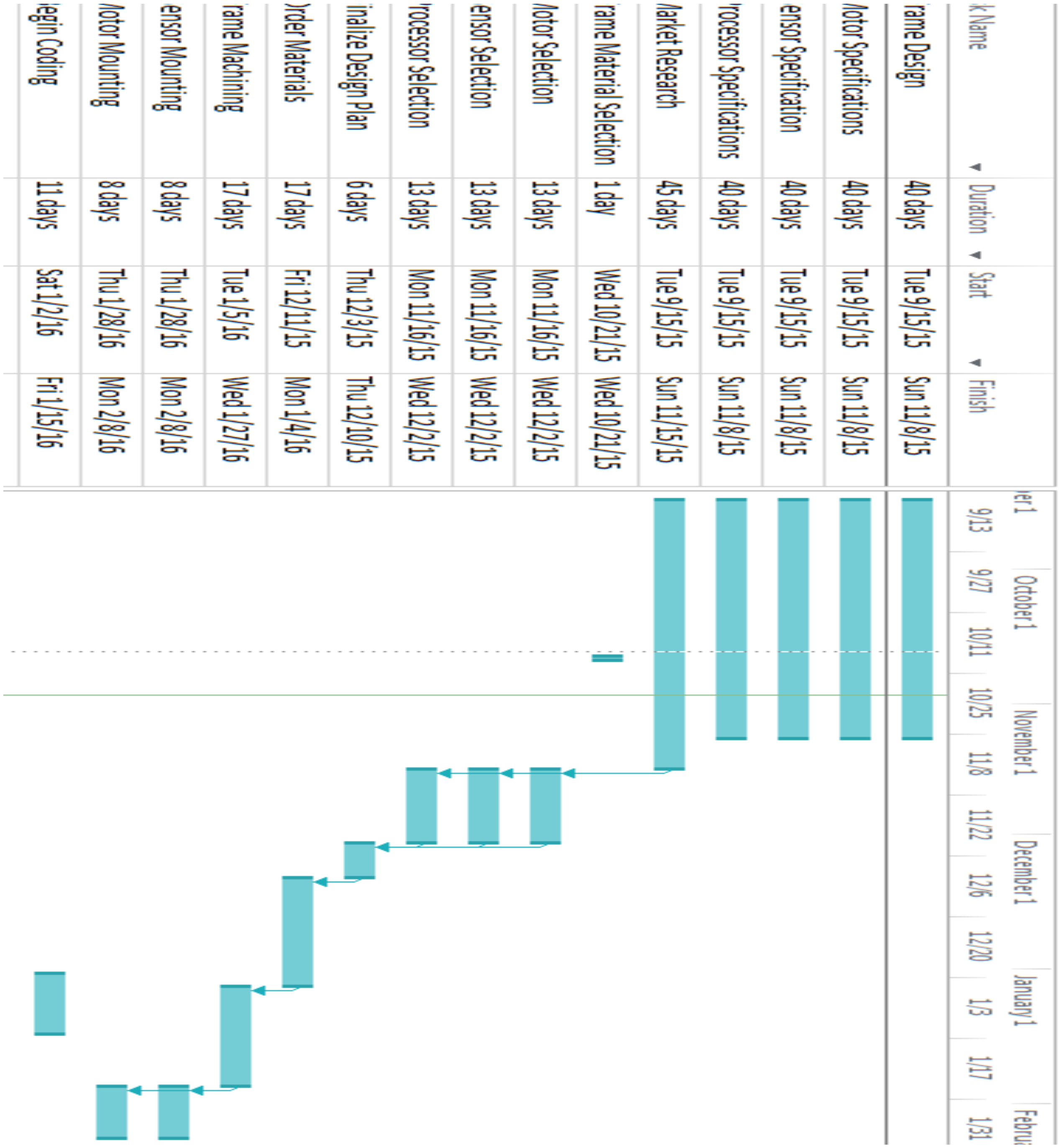

Figure 6: Gantt Chart