

# Cilantro

## Old Dominion University

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## Introduction

The Department of Electrical and Computer Engineering of Old Dominion University will be sending an intelligent vehicle to compete in the Intelligent Ground Vehicle Competition as part of a Senior Design project. The team has worked on improving the vehicle submitted in the 2016 year in order for it to qualify in competition, a task not achieved by previous teams. The hardware structure of the vehicle was redesigned for stability and weather resistance. Additionally, components were introduced or discarded for improved functionality and performance, or due to product discontinuation. Previous teams' progress on lane detection, obstacle avoidance, mapping, GPS waypoint navigation as well as system integration was very limited, therefore this team put a lot of focus on the software design of this vehicle.

## Team Organization

|                        | GPS Navigation | IMU       | LIDAR     | ROS     | Camera    | Hardware  |
|------------------------|----------------|-----------|-----------|---------|-----------|-----------|
| Michael Micros         | Secondary      | Secondary |           | Primary | Primary   |           |
| Ntiana Sakioti         | Primary        |           | Secondary | Primary | Secondary |           |
| Matthew Phelps         |                | Primary   |           |         |           | Primary   |
| Christian Lurhakumbira |                |           | Primary   |         |           | Secondary |

Table 1: Team Organization Chart

The table above shows the distribution of the workload for this project. Each group member has been assigned subjects that will be a primary focus, partially based on their majors. In addition to the primary focus, each member is also assigned a secondary subject to focus on, thereby designating two people to each unit of the project. This is to ensure that if problems arise there will be another member that will be able to assist. In addition, it helps to expedite the completion of each section by having two people working cooperatively on a common goal.

## Design Concepts and Goals

The main design goal for Cilantro's hardware, was to create an organized, easy-access, stable and weatherproof design. Additionally, the new hardware design allows for a more modular design, with all the peripheral components easily interconnecting. Certain components were used

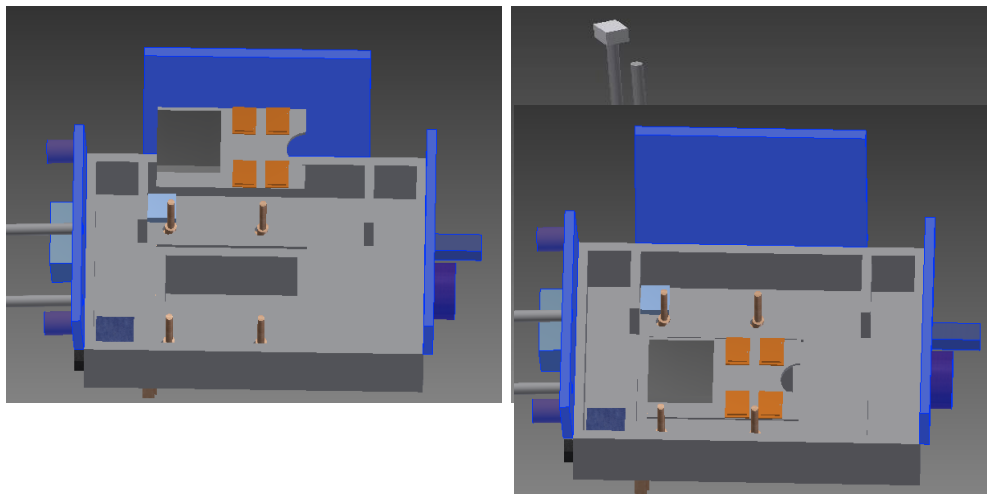
as previously due to their availability and familiarity, while new ones were purchased to achieve functionality not possible with previous components.

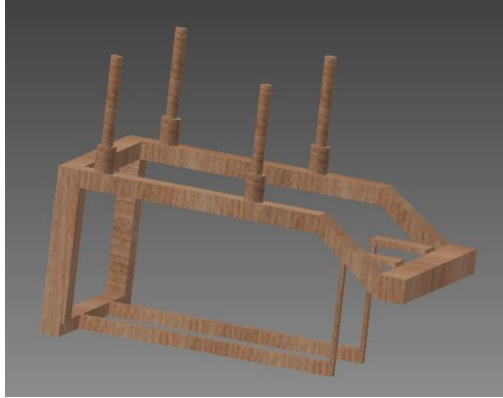
The primary goal for the vehicle's software design was to accomplish individual component functionality, ideally followed by full system integration. The lack of testing until the competition was an issue we had to tackle this year in order to come closer to the goal of qualification. Additionally, lane following and obstacle detection were the competition tasks we primarily focused on developing and testing.

## Hardware Design

The basis for our design begins with an electric wheelchair frame and motors. This provides for a base, propulsion, and solves the problem of how to provide onboard power. Using two 12 V batteries in series will provide an onboard power source that supplies 24 volts to power the various components. Step-up/step-down voltage regulators will be used to step-down voltages where necessary to power sensitive components such as a motherboard or Arduinos. The electric wheelchair frame also gives us access to a secondary market of motors and provides a stable secure base on which to build upon.

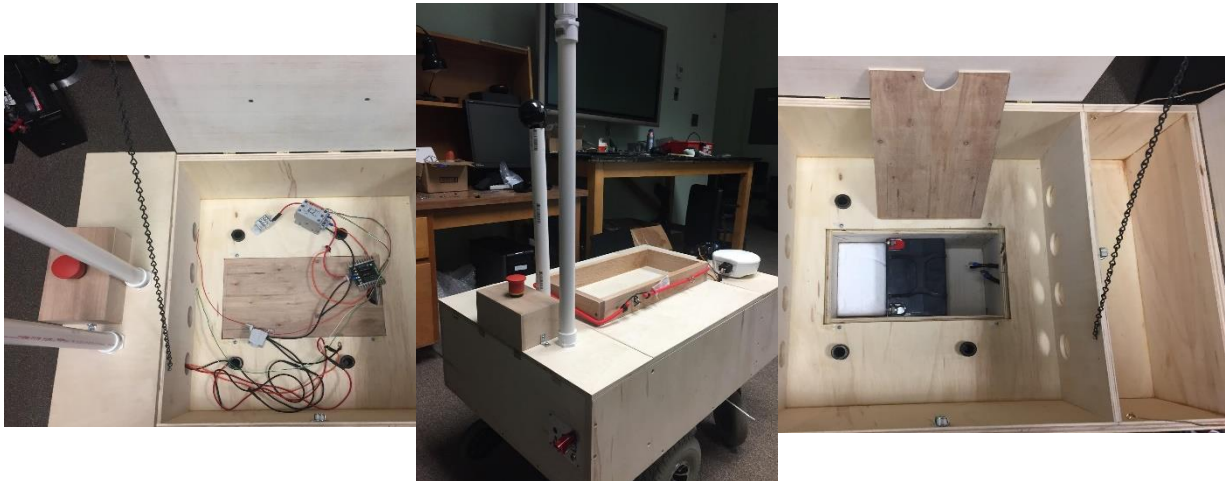
Our next step was to design and implement an enclosure for the vehicle. We examined the old frame of the vehicle to identify key problem areas and reviewed the IGVC rules along with potential conditions in which the vehicle might traverse to determine the requirements of the enclosure. From looking at the old frame we decided that the enclosure must be modular, allow for ease of access to components, and securely hold all electronics. This would alleviate problems experienced with the old frame that made testing and adding/removing components troublesome while providing a more stable and secure platform. The enclosure was designed to meet minimum sizing requirements of 3' by 2', along with staying well below the maximum 6' height requirement, to allow for a more compact vehicle for obstacle avoidance. An emergency stop button was located at the center rear as required and housing all the sensitive components inside the enclosure provides for weather resistance and protection from other environmental hazards.





*Figure 1: Design Work of the IGV Enclosure*

The design process for the enclosure began in Autodesk Inventor. The design was started by using the wheelchair frame to carefully measure and construct the base chassis of the wheelchair in Inventor. This allowed for the design to be built to scale to allow for visualization during the design process. The enclosure was then built upon this framework creating a design that could be easily secured, protect delicate components while allowing for ease of access, and provide for a durable and stable test bench. The various components were also built to rough scale to view how their placement would affect the design. The design work in Inventor can be seen in Figure 1.



*Figure 2: Completed Construction of IGV Enclosure*

The construction of the enclosure closely followed the original Inventor design, deviating only to provide better design decisions, or solve issues that occurred during construction. The enclosure features a 3-hinged cover design with a 3' by 2' sized frame. The back cover has placement areas for a manual E-stop button, lights, and two PVC pipe holes to mount an antenna and camera. The middle cover has a raised lip that is slightly larger than 8" x 18" with eye screws to secure the 20-pound payload with a bungee cord. The front cover includes space for mounting a LIDAR along with a GPS and incorporates a notch in the cover to easily allow passage of the GPS's large cord to the inside of the enclosure. The design decision around the use of 3 hinged covers easily allows access to the "brains" of the vehicle, such as the motherboard and Arduinos which will be secured in the center compartment, without requiring the removal of other components or excessive amounts of cordage that would be required to open a singular hinged cover. This can be seen in Figure 2. Two divider walls with four large openings for wiring separate the 3 compartments while providing a quarter inch lip to support each cover. A final compartment resides below the center enclosure. This area is large enough to contain the two large 12 volt batteries, provides holes in which the wiring for the electric motors can pass through to the inside, and has a cover which allows the power and motor wires to pass through and is secured by fasteners. The battery cover will also serve to maximize room in the middle compartment and will be a base plate for the motherboard and other small components to be secured on with standoffs. This will allow for easy removal of those components when necessary.

To further optimize our hardware design, an IMU that connects directly to the motherboard with the use of a USB was purchased along with a new LIDAR that does not require code to manually rotate to scan the surrounding environment, as well as connects straight to the motherboard with a USB. These minor modifications eliminate the use of 2 Arduino Uno microcontrollers and make the design more efficient. A comparison of the previous and current hardware layout is shown in Figure 3 below.

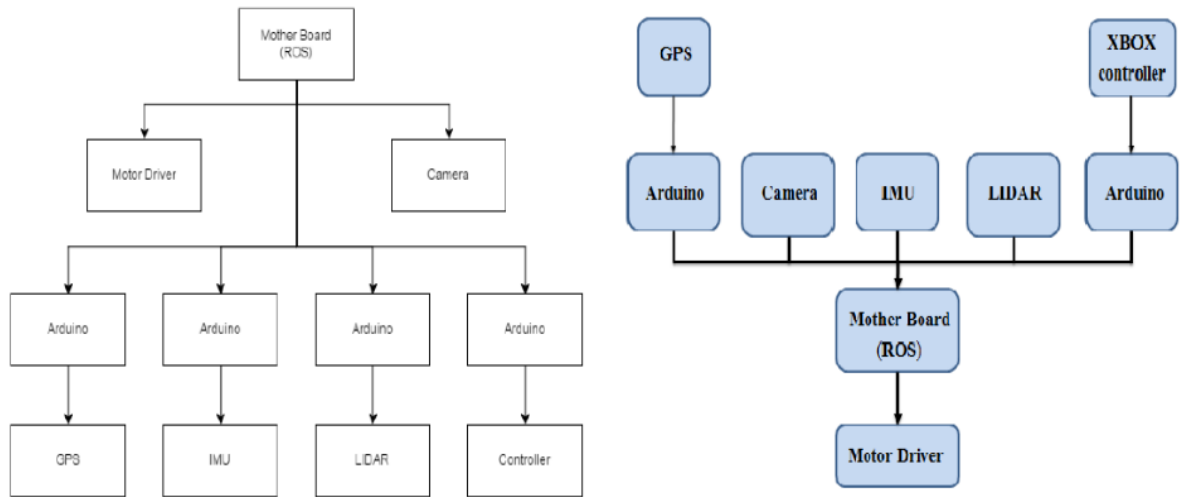


Figure 3: Comparison of project starting point and the new design

## Software Design

As mentioned previously, a camera in conjunction with OpenCV will be used to perform the most important function of the IGV - lane following. A program using OpenCV will analyze images sent from the camera to detect the lane to be followed. It will then send the necessary information for decision making, i.e. if the lane curves, to ROS. The LIDAR will be used to aid in performing obstacle avoidance and will be programmed to scan for obstacles at a range of 120 degrees ahead of the vehicle and a maximum distance of 6 meters. If the LIDAR detects an obstacle, it will send the obstacle's distance and angle to the ROS for the appropriate decision making to avoid the obstacle.

A GPS and IMU will be used to aid in GPS waypoint navigation. Knowing the current location and desired location the GPS will send the heading and distance of the desired location to the motherboard (ROS). The IMU will be programmed to calculate the actual heading, which will be sent to the ROS to aid in calculating the desired change in heading to reach the GPS waypoint.

The Robot Operating System (ROS) will perform the decision making for the vehicle, based on information received from the peripheral components described above. ROS is comprised of independent nodes that communicate using a publish/subscribe messaging model. Publisher nodes publish information without specifying any recipients, while subscribers receive messages they have registered interest in. Each peripheral component will have a publisher node, while ROS will have corresponding subscriber nodes for each peripheral, as well as a publishing node for the motor driver. Based on data received from each node, ROS will then determine the best course of action to ensure that lane following, obstacle avoidance, as well as GPS waypoint navigation are performed in that specified order.

## Testing and Results

### Image Processing

The software utilized to perform image processing is the OpenCV library that is available in both C++ and Python. The Python version was used to detect lines in sample images that would be similar to the conditions of the competition. The code that performs the lane detection was obtained from George Sung's github ([https://github.com/georgesung/road\\_lane\\_line\\_detection](https://github.com/georgesung/road_lane_line_detection)) and will be modified to adjust for the conditions of the competition. The current software is able to detect lines and overlay the predicted direction of those lines on the original images. Some preliminary results can be seen in *Figure 4*.

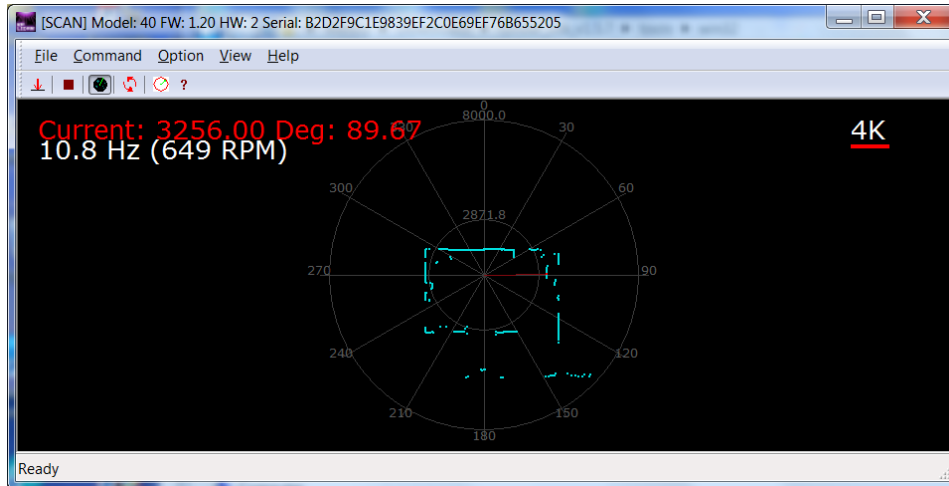


*Figure 4: Preliminary Results of OpenCV detecting lines in sample image*

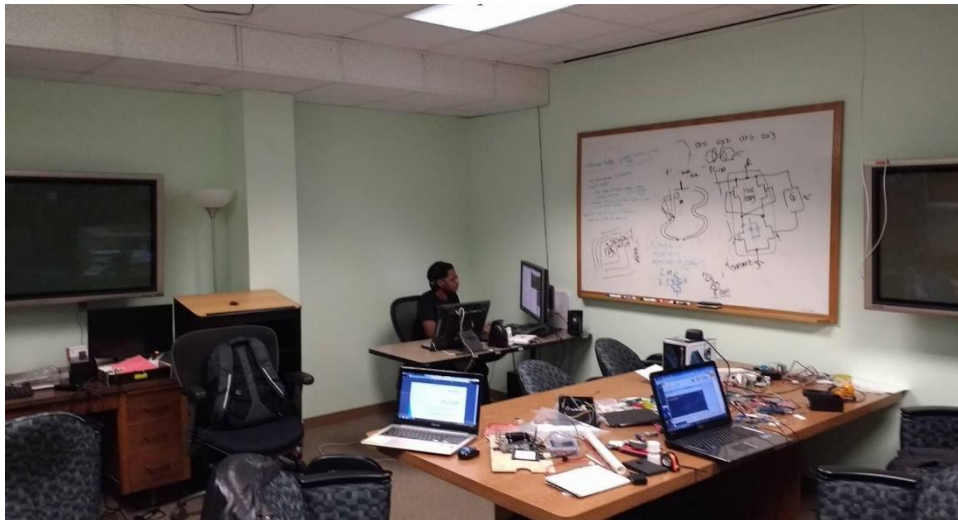
What remains to be done, is extract the detected lines and communicate them in a meaningful way to the Robot Operating System, in order to adjust course.

### Obstacle Detection

In order to determine the nature of the data generated by the LIDAR, our team performed certain measurements. The LIDAR returns the distance of objects in millimeters, as well the detected object's angle in reference to the LIDAR. The figure below is the result of the LIDAR scanning the room in which our research lab is located. The 4 walls of the room are easily distinguishable in Figure 5. It is important to note that the 2 dots in the top left corner of the room represent Malik and the computer monitor that can be seen in Figure 6.



*Figure 5: Output of LIDAR scanning the IGV research lab*



*Figure 6: Image demonstrating the layout of the research lab*

## **Magnetometer**

Heading data has also been successfully taken from a magnetometer. The readings from the magnetometer can be seen in figure 14. There are however many factors which throw off the data from these readings. These include “hard iron” interference from objects that produce magnetic fields, “soft iron” interference from objects that may distort the earth’s magnetic field such as the wooden enclosure, and tilt giving incorrect readings. Hard and soft iron distortion must be calibrated for each environment the magnetometer is placed in while tilt compensation will require the use of an accelerometer or a stable flat environment. Through the use of the raw compass readings of the x and y values the compass is calibrated to remove bias from the readings of the magnetic fields depending on the environment. This can be found by averaging the minimum and maximum values to use as an offset to ensure that the maximum value equates the minimum value. Finally the declination between magnetic north and true north must be taken into account.



This value varies depending on geolocation and changes as the magnetic poles drift every year. This however can be found from data available on the the National Oceanic and Atmospheric Administration's (NOAA) website under the National Center for Environmental Information (NCEI) or through the use of a current declination map. Locations to the east of the agonic line, the imaginary line through which a compass points true north, will in the US have westerly declination and easterly declination to the west. To account for magnetic declination in Norfolk, VA the compass heading must add 10.85 degrees to the heading or 7.55 degrees for the competition in Rochester, Michigan.

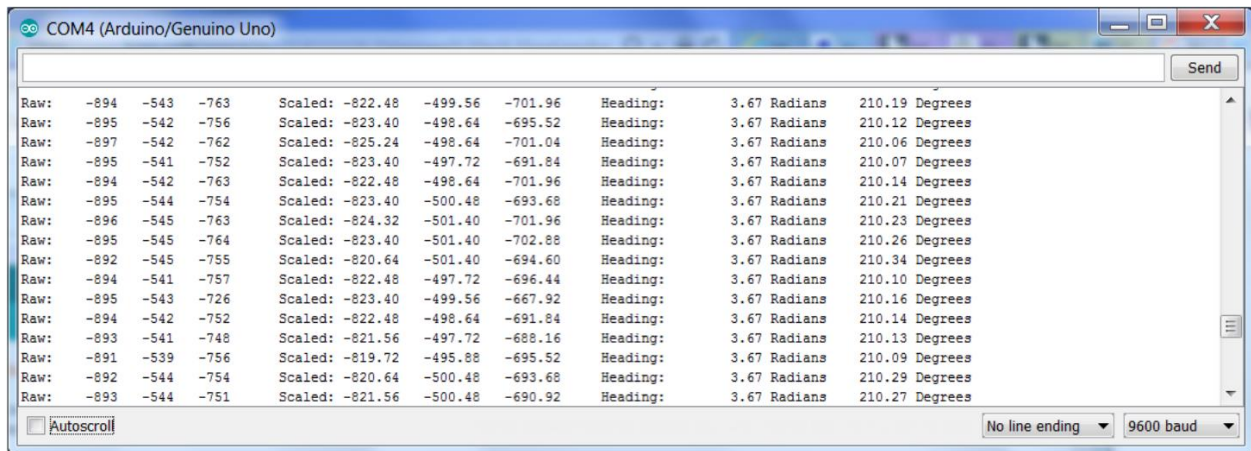


Figure 13: Compass readings from Magnetometer