RoboGoat Design Report
Intelligent Ground Vehicle Competition

US Naval Academy Team

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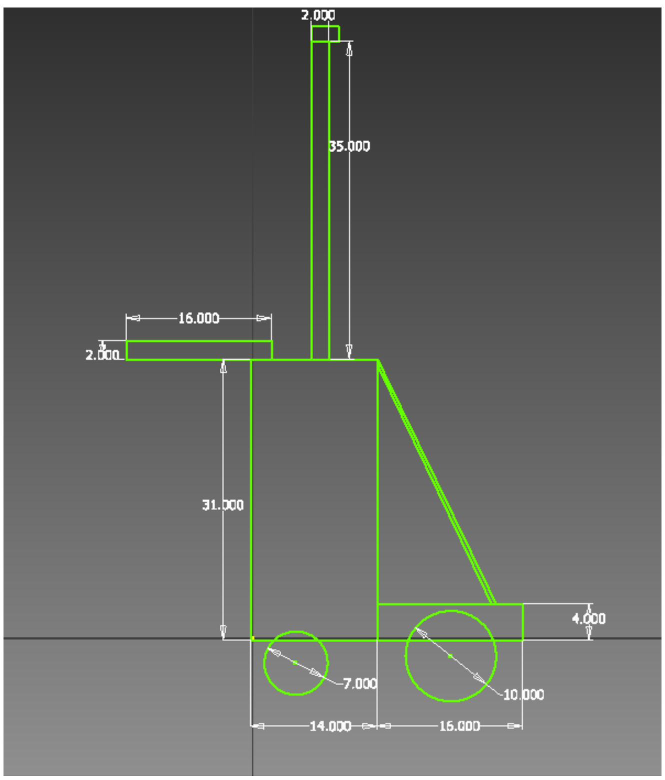
This document serves to summarize the design and construction of the US Naval Academy's senior design project: The RoboGoat. It will give an overview project as a whole then focus on the biggest changes made this year. The two major foci for this legacy project were the use of a new method for path planning and creating code for the flags at the finish of the course.

INTRODUCTION

The RoboGoat is the United States Naval Academy's competitor in the Intelligent Ground Vehicle Competition (IGVC) that is held at the University of Michigan each summer. The Naval Academy has been participating in the competition since 2009, placing 20th out of 20 with the inaugural design. Since then RoboGoat has placed as high as 2nd overall, establishing its place as a successful veteran of the competition, making the 2015 team goal to improve upon the design to ultimately win the competition. To improve and advance the RoboGoat for competition into the Intelligent Ground Vehicle Competition, where the goal is to navigate an obstacle course quickly, safely, and autonomously.

DESIGN PROCESS

With this project being a legacy project, most of the design portions of the RoboGoat will stay the same. There are, however, a few features that will change. The main design changes the group plans to incorporate include raising the height of the camera with an extendable arm, and changing the angle of the solar panels to increase the field of view. The figure below shows the design for the final projected physical look of the RoboGoat.



This however did not stay as the completed final design of the RoboGoat. The RoboGoat had to be changed. Specifically it was decided that the slanted solar panel would be laid flat along the base of the powered wheel chair. This did not interfere with the camera view, so it was not necessary to slant the new solar panel. In addition it was decided to create a new GPS mount to go along with the top of the perforated tubing. The camera also ended up being lowered to fit the best field of view from the tests conducted. The figure below shows the final design of the RoboGoat.

Below is the Pairwise Comparison Chart. The main objectives for this project are expanding the field of view and creating a new algorithm for path planning, so extensive and maneuverable are the top two objectives. The group found durable to be more important out of the other objectives because without a stable camera, the RoboGoat will not keep the field of view necessary.

Objectives	Extensive (FOV)	Maneuverable	Durable	Small	User Friendly	Lightweight	Score	Weighted
Extensive (FOV)	X						5	**6**
Maneuverable		X					4	**5**
Durable			X				3	**4**
Small				X			2	**3**
User Friendly					X		1	**2**
Lightweight						X	0	**1**

Functions and Morphological Chart

There are four main functions of the RoboGoat to successfully navigate the course. The RoboGoat must:

Detect Obstacles

Detects Lanes Lines

Detect Waypoints

Decide the Best Path

In determining the preliminary designs for the RobotGoat and means for the functions required, the group created metrics for each of the objectives and rated the designs and means against those metrics. In bold are the objects and underneath explain the points given for accomplishing an objective. The table below shows the Morph Chart where the group determined which means the group would use for each of the functions required. Underneath the Morph Chart is the means-selection table for each function comparing the means to the objectives.

Functions	*Mean 1*	*Mean 2*	*Mean3*
Detect Lanes	Camera	Mulitple Cameras	
Detect Obstacles	Camera	LIDAR	Multiple Cameras
Detect Waypoints	GPS	Compass	
Decide best path	Grid method	Potential Field method	Gap method
Move along path	Differential Drive Robot	Ackerman Steering	

The group also wanted to change two design aspects of the RoboGoat. The placement of the camera and the arrangement of the solar panels. The group evaluated the different designs against the same objectives and decided on rearranging the panel design and having a contractible arm for the camera. These figures below, show the two decision matrices to determine the placement of the solar panels and camera.

Objective	Weight	2014 Version	Contractible Arm	Lever Arm
Extensive (FOV)	6	0/0	12/72	12/72
Maneuverable	5	0/0	0/0	0/0
Durable	4	4/16	4/16	2/8
Small	3	4/12	4/12	3/9
User Friendly	2	0/0	0/0	0/0
Lightweight	1	2/2	1/1	1/1
Total Score		30	101	90

Objective	Weight	2014 Version	New Smaller Panels	Re-design of Panels
Extensive (FOV)	6	0/0	11/66	12/72
Maneuverable	5	0/0	0/0	0/0
Durable	4	4/16	4/16	4/16
Small	3	4/12	4/12	4/12
User Friendly	2	0/0	0/0	0/0
Lightweight	1	2/2	3/3	2/2
Total Score		30	97	102

Final Design

Overview

This figure below shows our overall functional block diagram. The RoboGoat contains three sensors all of which are powered by the charging station. The charging station derives its powers from the 2 12 Volt batteries as well as the solar panels. The sensors then send data to the controller, which is in Matlab. This controller then sends a voltage to the Robotech, where its amplified and distributed to the motors. The sections below will go into further detail on each subsystem.

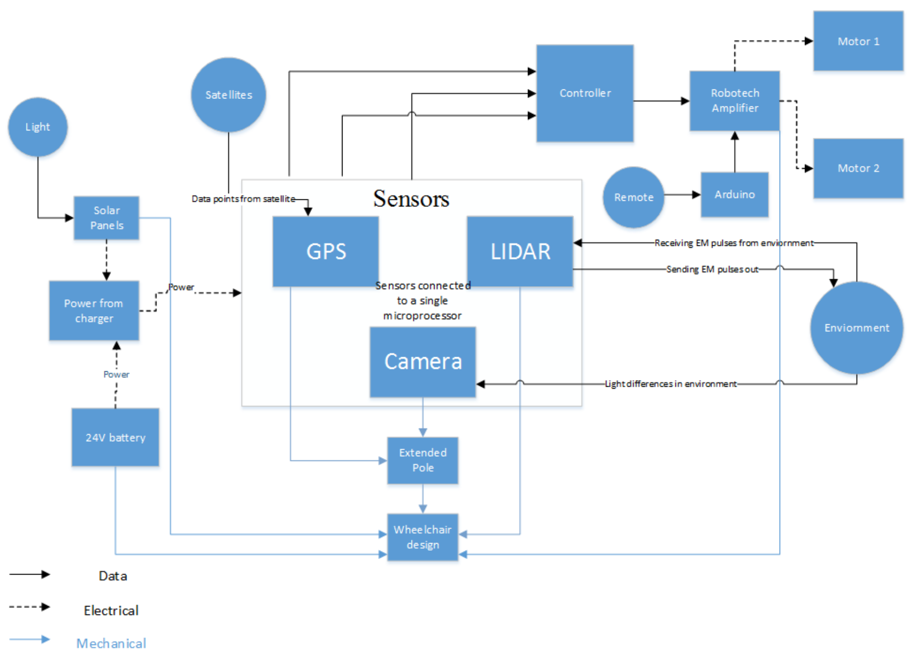


Figure 6: Full Body Diagram

Charge Controller Subsystem

This subsystem is the Charge Controller which serves multiple purposes on RoboGoat. The first purpose is to regulate the power generated by the solar panels going to the battery. Secondly, the controller acts as a switch between the battery and the computer that runs the control law. The solar panels need to be rated above 24V because of this.

Sensors Subsystem

This subsystem is the Sensors. There are three main sensors involved in the project. The Camera receivs light from the environment. The lidar transmitting and receiving waves from the environment to determine distance. Last the GPS receiving data from satellites. All of these sensors send their data to the controller.

Controller Subsystem

The controller subsystem, which is the black computer on the robot, sends the data from the sensors through a program, running in MATLAB, and outputs data to the robotech amplifier.

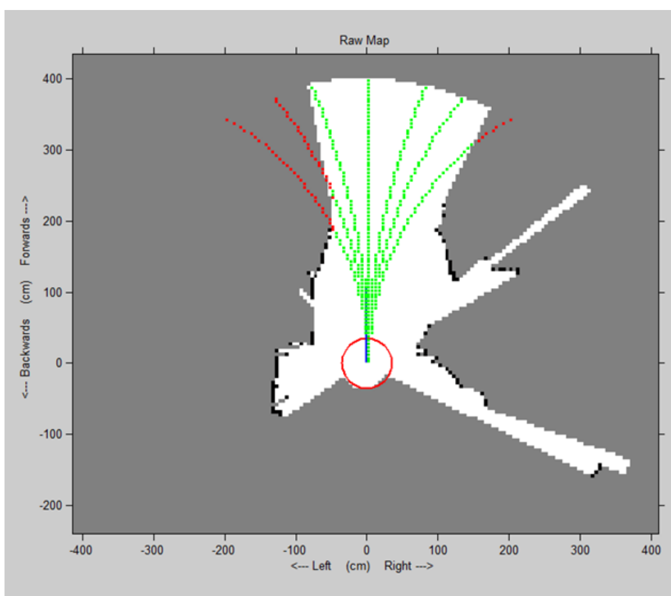
Robotech Amplifier Subsystem

The final subsystem is the Robotech Amplifier. This device receives the voltages sent from the controller or remote control and sends them to each motor. The arduino acts as a switch between the controlling the vehicle autonomously or with the remote.

Results and Analysis

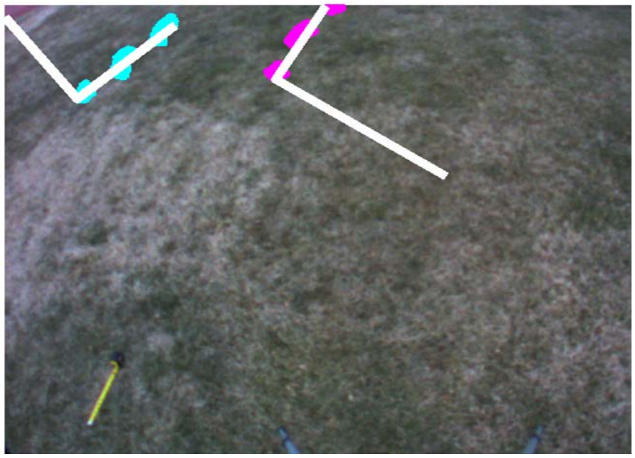
Demonstration

Preferred method of testing would be as follows. Use the remote control to drive the RoboGoat to the desired location for testing. Initialize the LIDAR and test that the Lidar is properly detecting objects and choosing the correct path. After verifying, turn off the LIDAR and turn on the camera. Ensure the camera is calibrated. Test to make sure the camera is properly detecting lines and flags and staying within the desired bounds. After those two steps are complete, uses then together to ensure the system works together. Figures show results of some tests conducted by the LIDAR.

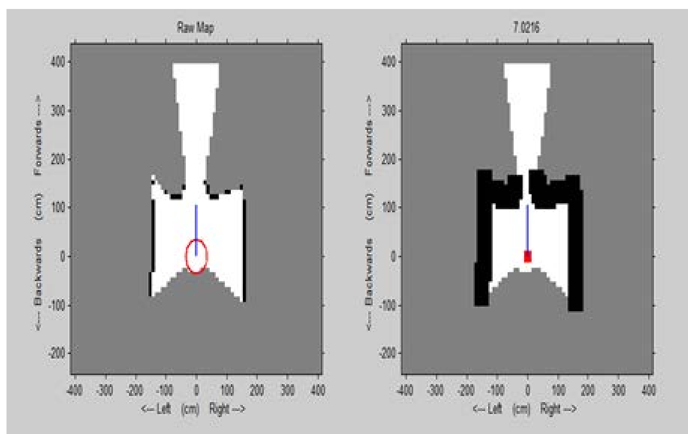


The figure above shows the LIDAR capability alone. All of the white space is no object, the black edges are seen as obstacles and the gray behind the black is unknown to us. The vehicle will then choose the tentacle that has the furthest distance.

The new flag code was incorporated to find the flags, created imaginary points and display them as obstacles on the LIDAR grid system. We created obstacles on the LIDAR grid to block off the entrance to the wrong color pattern and open the entrance to the correct one.



The next two figures below show the actual representation of the idea on the LIDAR grid system.



Project Management

Life Long Learning

The main lesson learned while working on the RoboGoat was the importance of time. One should always account for hardware not working. Additionally, the time is takes for parts to get in should be in the picture from the beginning. Communication is another major aspect when working as a team. Developing a good plan for all these facets is something that was originally overlooked.

Cost analysis and Parts List

Material Costs include a list of technologies that are planned to be used. These include new products along with products that are already implemented in the design. In addition, to the cost of the products is also a labor cost associated with obtaining the technology. Figure shows the information in a tabular form.

Material	Technology	Cost	Labor	Total				
	Solar Panel (2)	$200.00	$50.00	$250.00				
	WeatherProofing	$100.00	$50.00	$150.00				
	Extendable Arm	$72.00	$50.00	$122.00				
	Chassis	$1,700.00	$50.00	$1,750.00				
	Hokuyo UBG-04 LX-F01 Laser	$2,850.00	$50.00	$2,900.00				
	Roboteq Amp	$700.00	$50.00	$750.00				
	AgGPS 132	$1,000.00	$50.00	$1,050.00				
	Emergiency Light	$100.00	$50.00	$150.00				
	Arduino UNO	$30.00	$50.00	$80.00				
	Charge Controller	$60.00	$50.00	$110.00				
	Camera	$670.00	$50.00	$720.00				
	Laptop and Software	$2,200.00	$50.00	$2,250.00				
	Batteries (2)	$100.00	$50.00	$150.00				
	Total	$10,432.00						$10,432.00

Discussion and Conclusion

Overall, this year's RoboGoat team felt strong in what they were able to accomplish. Some major advances were accomplished in helping this project become better in the long run. The goal of implementing what the camera sees onto the LIDAR grid was accomplished. In addition, the tentacle method steers the RoboGoat is a major step that can only improve the overall design in the system. The physical changes make the software changes that much better as well. With that being said, there is always room for improvement. If there was closed loop control implemented on the Roboteq, the overall system would perform much more effectively and efficiently. Also, optimizing the tentacle path method with different speeds will benefit the overall system. Finally, if a camera was bought that had a fixed focal length, it was make the process of setting up the RoboGoat easier. This would ensure calibration is not required every time the camera moves.