University of Florida

InstiGator

Technical Report

ION Robotic Lawnmower Competition
Beavercreek, Ohio
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1. Introduction

The purpose of this report is to document Team InstiGator's progress for the 8th Annual ION Robotic Lawn Mower Competition. The goal of the competition is for the team to design and build an autonomous robot that is capable of mowing a predetermined area of grass while intelligently navigating around static and dynamic obstacles.

2. Overview

2.1. Team Organization

Team InstiGator is composed of three undergraduate students and one graduate student. The team's background consists of three electrical engineering students and one mechanical engineering student. Mike Franks is the team leader and was responsible for electronic design and robot controls. Andres Vargas is the mechanical lead and was responsible for the chassis design and fabrication. Colin Watson is the software lead and was responsible for the programming of the robot's microcontroller and sensor integration. Camilo Buscaron is on the electrical team and was responsible for designing battery monitoring circuitry.

2.2. System Overview

The robot, named InstiGator, was designed with simplicity in mind. The goal was to build the robot so that it would be able to complete the competition with as few sensors and as little computational power as possible. Therefore it was decided to only use differential GPS for navigation and ultrasonic sonars for obstacle detection.

Using only these two sensor types allowed the team to be able to perform all computations with only an inexpensive ARM7 microcontroller.

In order to achieve longer run times and the ability to cut tall and thick grass, it was decided to use a gas engine to actuate the cutting blade. The team's strategy was to use the four corners of the rectangular field to be mowed to generate a number of paths for the robot to follow. The robot uses these paths to do waypoint following until the entire field has been cut. In the event of an obstacle, the robot will jump to the next path and continue mowing in the opposite direction. Once the last path is reached, the robot will turn 180 degrees and mow back to the starting position to ensure the maximum amount of the field is mowed.

3. Mechanical Design

The original plan was to use an existing push mower frame for the main chassis. However, it was decided that the push mower's structure would lose a great deal of rigidity once the team cut and added new structures to the frame. Therefore, the robot's chassis was completely custom built to ensure a safe and stable platform.

3.1. Main Chassis

The main chassis was constructed from steel sheet and tubing. Steel was chosen for its strength and due to the ease which it could be welded. Subassemblies were designed to be modular and easy to remove using screws and bolts, allowing for future modifications and an easy teardown of the chassis in the event of repairs.

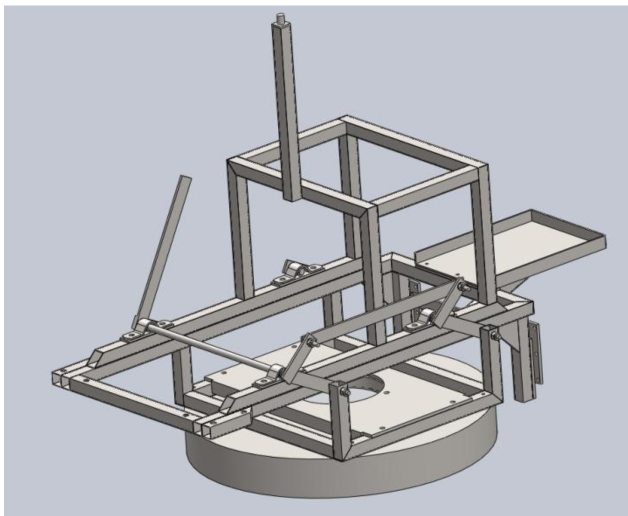

Figure 1. *InstiGator's Main Chassis*

The main chassis is illustrated in figure 1. The engine mount and blade shroud is attached to the main chassis via pitman arms.

This allows the team to adjust the height of the cutting blade for different grass heights. This also helps in isolating engine vibration from the main chassis and the electronics box.

3.2. Engine Kill Mechanism

The team needed a method for killing the gas engine in the event of an emergency shutdown as well as after the field had been mowed. According to the competition rules, the cutting blade had to stop within three seconds of an emergency shutdown. The gas engine that was used had an existing mechanism that disconnected the engine's spark plug, thus killing the engine. There was also a brake mechanism which stopped the flywheel and the cutting blade. However, a great deal of force was required to disengage the existing brake mechanism. Therefore, the team had to design an apparatus that could engage the brake system while overcoming the large force. The implemented design consists of a cocking lever which disengages the brake while simultaneously closes the engine's sparkplug switch. The lever is held in place by a solenoid, which when activated, allows the cocking lever to swing up and engage the brake while also breaking the engine's sparkplug switch. A CAD rendering of the engine kill mechanism is illustrated in figure 2.

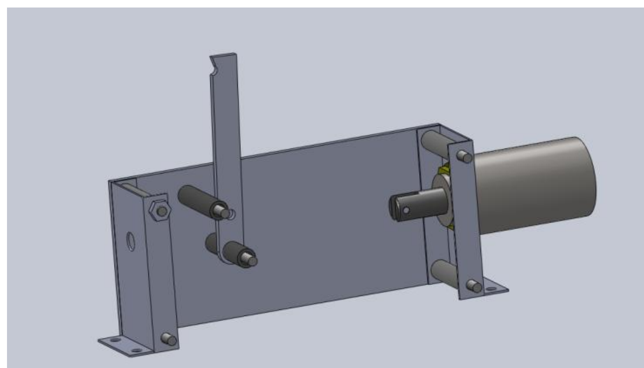

Figure 2. *Engine Kill Mechanism*

4. Electrical Design

The electrical system was designed around a 24V system because the two electric wheel chair motors used for propulsion required this voltage. Two 12V sealed lead acid (SLA) batteries were wired in series in order to obtain the 24 volts. The batteries were center tapped in order to provide 12V required by the GPS unit. A switching regulator was then used to step the 12V down to 5V which powered the onboard electronic controller. An overview of the electrical system design is illustrated in figure 3.

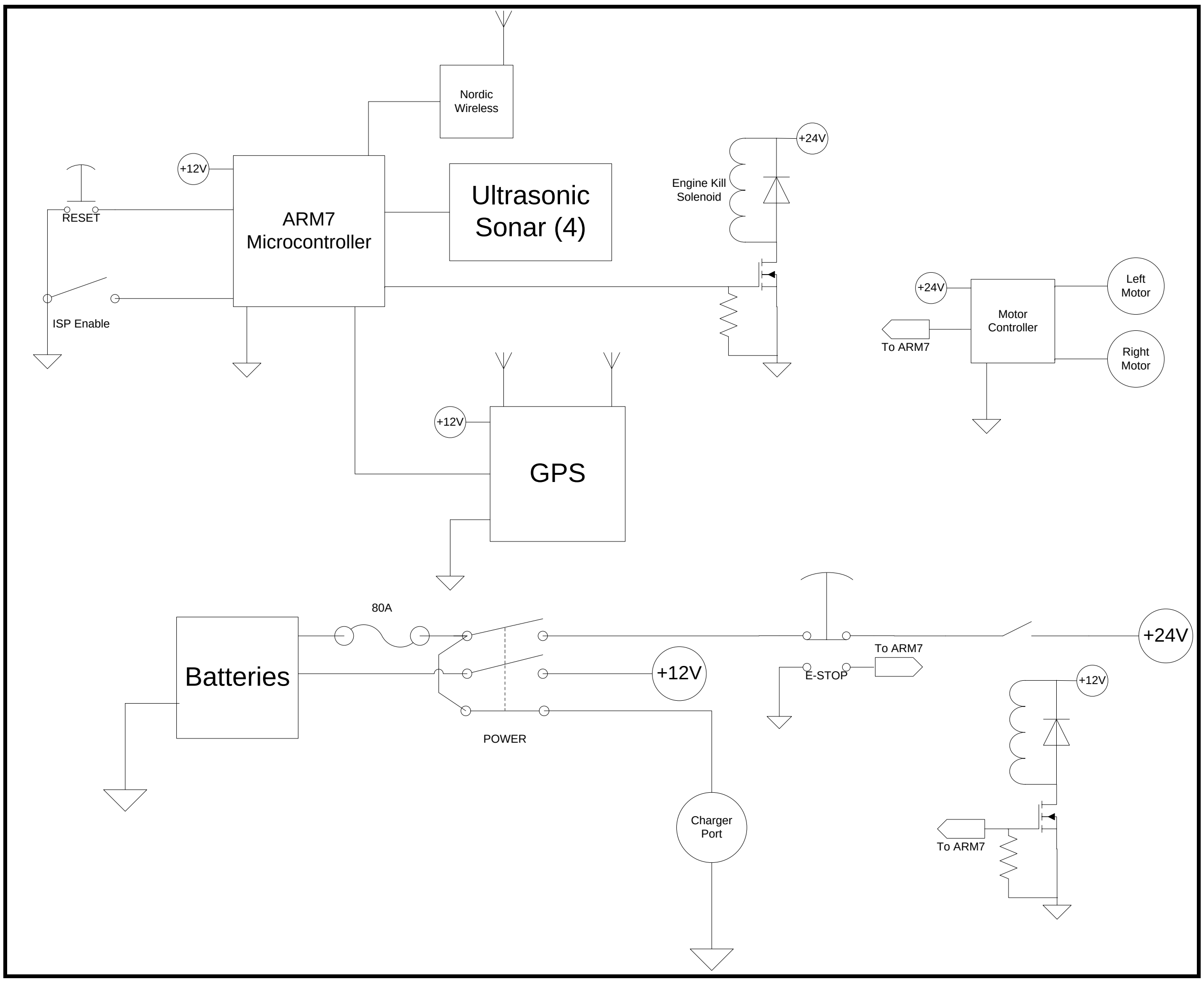

Figure 3. *Overview of the electrical System.*

4.1. Main Control Board

The main control board was designed and populated by the team. The main control board is responsible for receiving data from all the onboard sensors as well as monitoring the wireless E-stop sate. All computations are performed by an embedded 32-bit ARM7 microcontroller. The microcontroller parses the packet from the Novatel GPS unit and converts the given latitude and longitude into Universal Transverse Mercator (UTM) points for navigation.

The microcontroller also calculates the distance of objects detected by the ultrasonic sonars. The microcontroller is also responsible for performing position control by updating the left and right motor efforts. The wireless link between the wireless E-stop and the robot is based on the Nordic nRF24L01+ chipset. This was chosen so that data could be sent to and from the robot over the same wireless link, thus reducing the overall part count for the system.

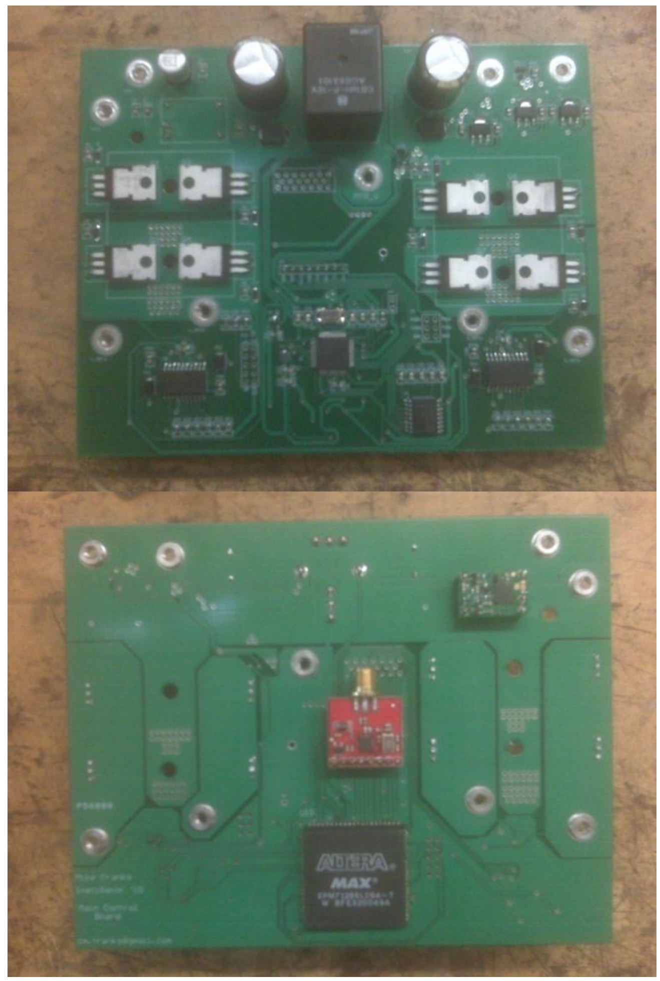

Figure 4. *Main Control Board.*

The motor controller was designed and implemented on the same board as the microcontroller in order to save money for having the circuit boards fabricated. The motor controller is based on two N-Channel MOSFET H-Bridges controlled by two HIP4081 FET controllers. The main board is illustrated in figure 4.

4.2. Wireless E-Stop

The wireless E-Stop uses a Nordic nRF24L01+ chipset to wirelessly transmit the state of the E-stop at a rate of 100Hz. The Nordic chipset was used because it is highly configurable and handles error checking between the transmitter and receiver automatically. The wireless E-stop was built around an ARM7 microcontroller which would monitor the E-stop switch, control the Nordic chipset, as well as utilize its UART to communicate with a laptop for debug data.

The wireless E-stop was also used to upload the mission data to the robot. This allowed for quick testing of different mowing areas without the need to re-flash the main control board's microcontroller. The ARM7 was used so that the team only needed to use one microcontroller Integrated Development Environment (IDE) and allowed the reuse of circuit designs, which aided in a speedy development cycle. The wireless E-stop can be seen in figure 5.

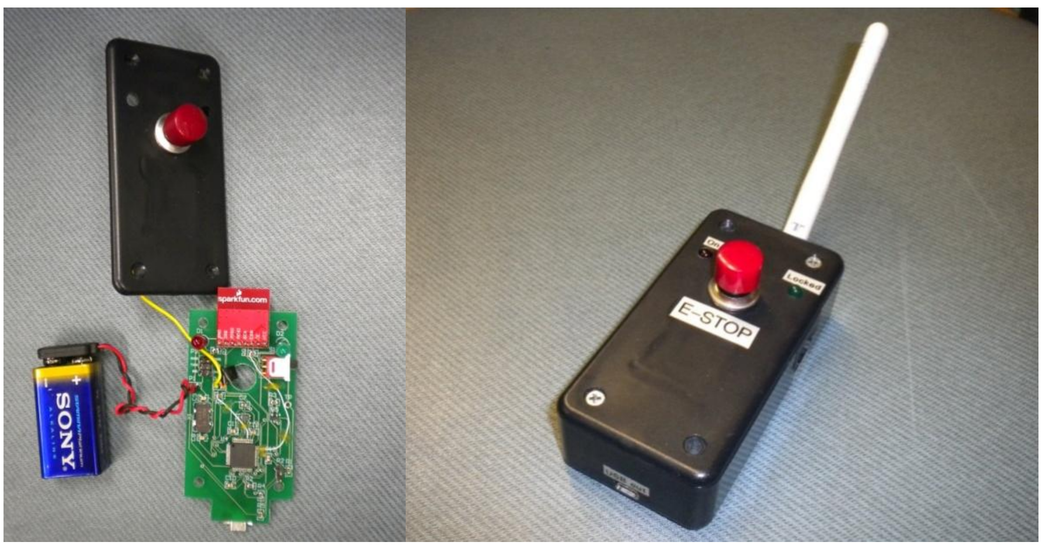

Figure 5. *Custom Built Wireless E-Stop.*

5. Software Design

5.1. Path Planning

Due to the fact that the distance covered by degrees of latitude changes with longitude it was realized that this was not a good system to use for navigation. Therefore, the team decided to treat the Earth as relatively flat for a small region, like that of the area to be mowed, and converted the latitude and longitude values into UTM coordinates. In UTM an increase in the Y values relates to traveling from south to north. In increase in the X value relates to an increase from west to east. However, the area to be cut may be in any orientation with respect to north.

Therefore, a MATLAB script was written that finds the angle that the area to be cut is from true north and then uses that angle to perform a rotation of the field by the angle. By doing this, we only need to give the robot an array of X values representing each path the mower should follow. Two Y values are also given to the robot to signify the start and stop points for each of the paths. The angle that was previously found is uploaded to the robot as well, so that the robot may rotate its current UTM coordinates. By doing this, the robot only needs to check to see if it is too far to the left or too far to the right of the current path's X value. This MATLAB code was later ported to Python and used directly in the Graphical User Interface (GUI). An example of a rotated filed with generated paths is illustrated in figure 6. It was found that a translation was not needed to implement the desired result, so only a rotation was performed, thus saving computation time on the microcontroller.

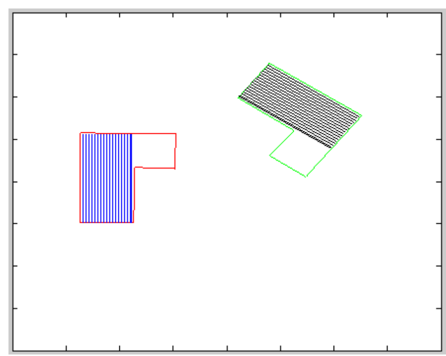

Figure 6. *True and Rotated Field*

5.2. InstiGator GUI

In order to effectively troubleshoot the robot's behavioral code, some method of checking the robot's state was needed. As stated earlier, the Nordic chipsets allowed for bi-directional communication between the robot and a computer. Therefore a GUI was created in Python to allow the team to check sensor values and upload mission data to the robot. The GUI is used to ensure the data from the GPS has become stable. Once the GPS is stable and the latitude and longitude standard deviations have dropped below 10cm, the robot is moved to the four outer points of the area to be cut. Each point is loaded into the GUI and the path data is then calculated. The robot is then set at the starting point and the GUI is used to upload the calculated mission plan to the robot.

At this time the wireless remote used to communicate to the GUI can be disconnected and used only as a wireless E-stop. After an initial pause, the robot then begins the mission. A screen shot of the GUI can be seen in figure 7.

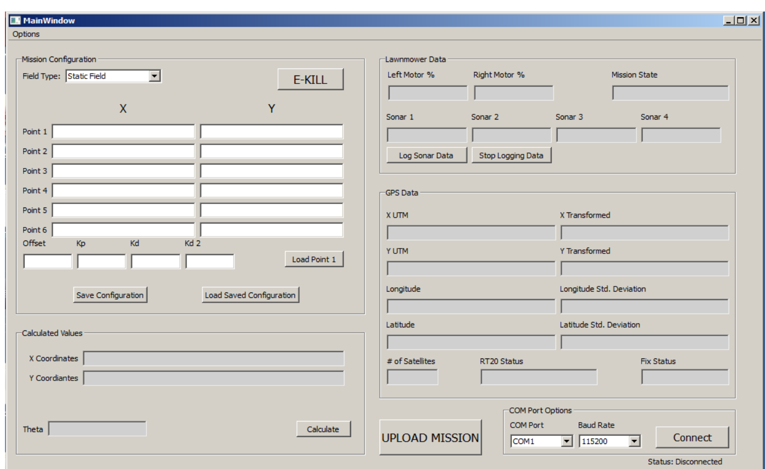

Figure 7. *Screenshot of the InstiGator GUI.*

6. Safety and Reliability

The robot has been equipped with several safety features. First, an E-stop switch has been placed on the top of the electronics box so that it can be easily pressed by anyone standing near the robot in case of an emergency. The E-stop was designed to directly control the power feeding the motors as well as sending a signal to the ARM7 to inform the program that the E-Stop was pressed. The ARM7 controls a relay that also can cut power to the motors when it detects that either the onboard E-Stop was pressed of in the event of a wireless E-Stop press. A wireless E-stop is also incorporated into the design, so an operator may stop the mower from a distance. The wireless E-stop has an indicator which lights up so long as the wireless E-stop is successfully sending E-stop status packets to the robot. This allows the operator to have full confidence that if the E-stop is pressed the robot will receive the command to stop. The microcontroller has also been programmed so that if at any time an exception happens inside the microcontroller, then the robot is shut down.

7. System Specifications

7.1. Physical Characteristics

Dimensions	
Length	1.12m
Width	.61m
Height	.94m
Cutting Width	.5334m

Speed	
Max Speed	~9km/hr
Operating Speed	~2 km/hr

Operating Time		
Electric System	(2) 12V SLA	~6 hrs
Gas Engine	1.89L Tank	~1.5 hrs

7.2. Cost

Item	Qty	Price, EA(New)	Price Paid
Push Mower	1	$149.15	$149.15
Metal/Hardware	4	$35.55	$142.21
Battery, 12V SLA	2	$64.16	$128.32
Motor, 24V w/ Wheel	2	$125.00	$50.00
Charger	1	$129.19	$129.19
NovAtel GPS, RT-20	2	Unknown	$0.00
Electronic Parts	NA	$481.69	$481.69
CCA Fabrication	2	$33.00	$66.00
Electronic Enclosure	1	$36.72	$36.72
Caster Wheels	2	$15.25	$30.50
Solenoid	1	$31.14	$31.14
Wireless Serial Link	2	$31.89	$63.78
Nordic Chipset	2	$19.75	$39.50
Sonar Module	4	$29.50	$118.00
	TOTAL		$1,466.20