Draper Laboratory

Developing an Autonomous John Deere Gator

The Vehicle:

NavCom GPS:
The NavCom GPS provides the vehicle with global position and heading information.

Honda Genset:
The genset provides 2000W of power, enough to supply all of the vehicle's electronics.

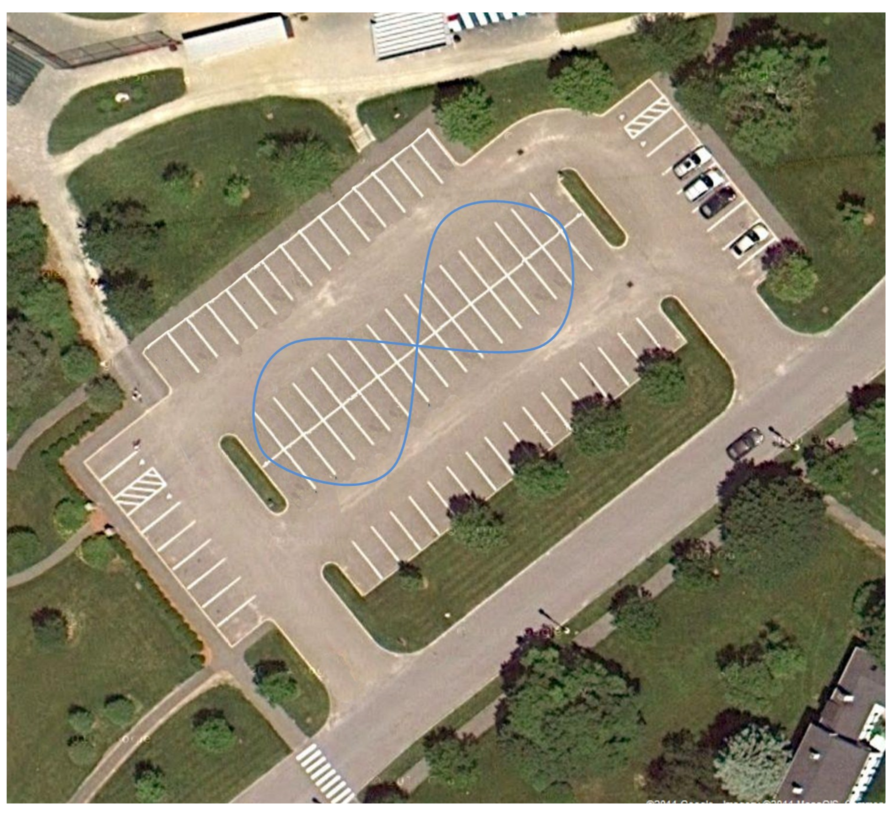
SICK LIDAR:
The SICK LIDARs use rotating lasers to determine the range of objects at ranges up to thirty meters.

Drive By Wire :
The vehicle uses motors and linear actuators to allow the computer to control the steering wheel, gas, and brake.

Electronics Box:
- 8 Core Server
- NI R-Series FPGA
- Motor Controllers

Wheel Encoder:
A quadrature encoder provides the vehicle with wheel odometery information.

The Missions:



Base Mission:

Parking Lot Patrol

Required Vehicle Capabilities
- Navigate to GPS waypoints
- Repeat missions taught by a human driver
- Detect and avoid road barricades

Mission Outcome
Vehicle repeated user-taught figure eights while avoiding various obstacle configurations.


This mission demonstrates the vehicle's ability to detect and avoid obstacles.


The vehicle commits navigate to one side of an obstacle.

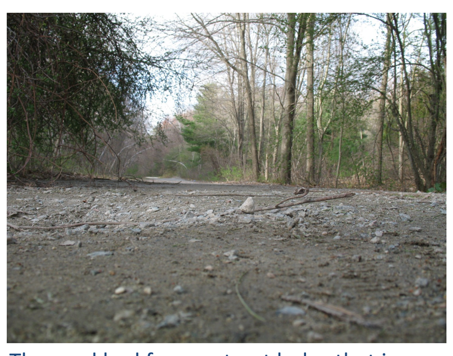
First Option Mission:

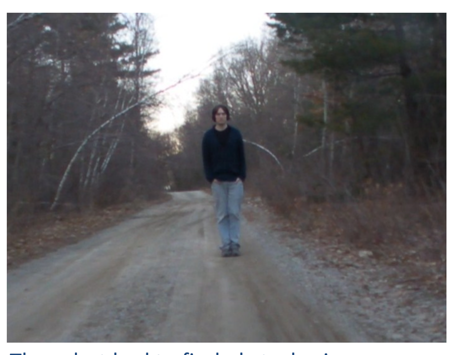
Wooded Road Resupply

Required Vehicle Capabilities
- Detect a drivable road in an environment with complex, organic obstacles.
- Detect obstacles despite data with noise resulting from complex obstacles & rough road terrain.

Mission Outcome
Vehicle navigated a quarter mile of wooded paths. During navigation, the vehicle successfully detected and avoided team members blocking the path.


This mission required the vehicle to navigate dirt roads with heavy vegetation.


The road had frequent pot holes that increased levels of sensor noise.


The robot had to find obstacles in a more complex, noisy environment.

Second Option Mission:

Off Road Patrol

Required Vehicle Capabilities
- Evaluate complex drivability
- Detect sparse obstacles like shrubs & bushes

Mission Outcome
The vehicle was capable of patrolling the loop shown at left indefinitely without human intervention.


Off road navigation required the robot to deal with hills and rough terrain.


The robot had to detect sparse obstacles such as shrubs and bushes.

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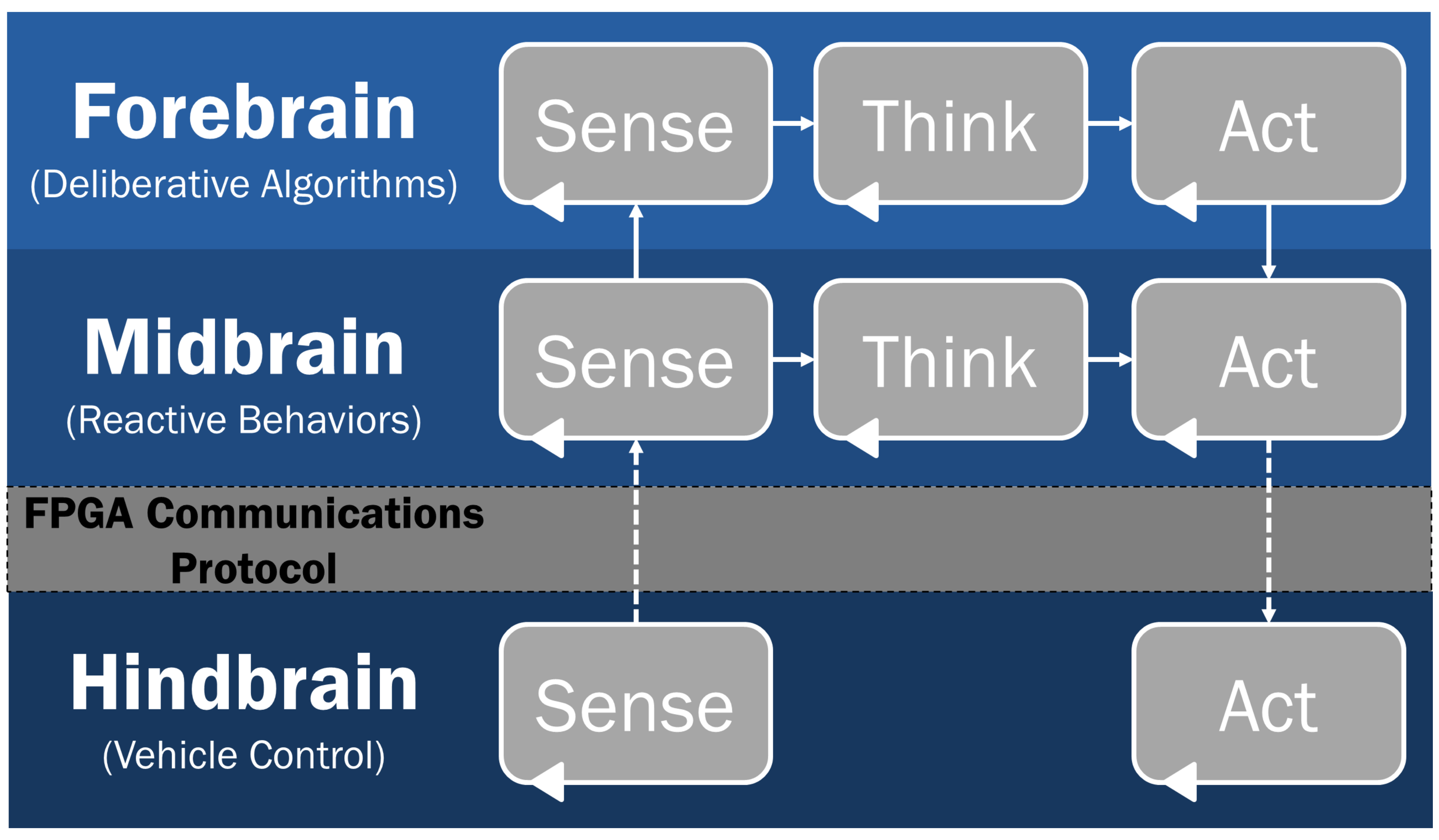
The Software:

Olin Robotics Architecture:

The is one of the first robots to utilize the Olin Robotics Architecture. The architecture was developed in a collaboration between the Draper SCOPE team and research conducted by Professor David Barrett. It decomposes software vertically by representation abstraction and memory duration. It also decomposes software horizontally into a procedural software pipeline.



The forebrain tracks the vehicle's position relative to the defined mission. The warfighter defines the mission either as a series of GPS waypoints or as a route a soldier has driven to teach the robot.

The midbrain uses fast, reactive behaviors to move towards the objective specified by the forebrain. This layer uses a blending arbiter to select determine what heading the vehicle should take.

The FPGA communications protocol passes data between the FPGA hosted hindbrain software and the PC hosted midbrain software..

The hindbrain converts and transforms sensor input before passing it to the midbrain. It is also responsible for performing motor control to maintain the vehicle speed and heading commanded by the midbrain.

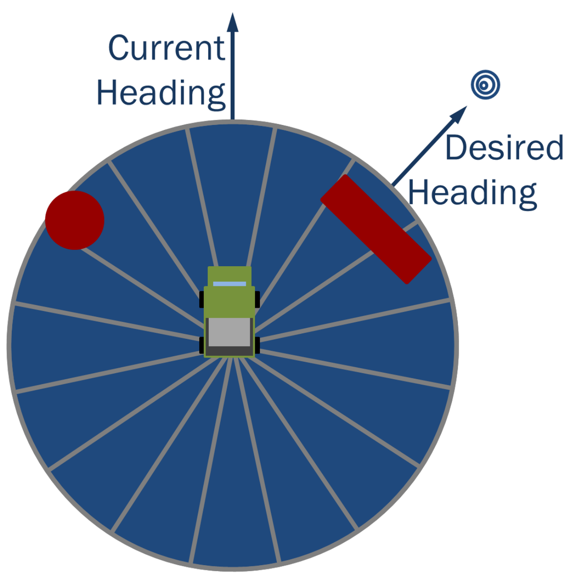
Behavior Arbitration:

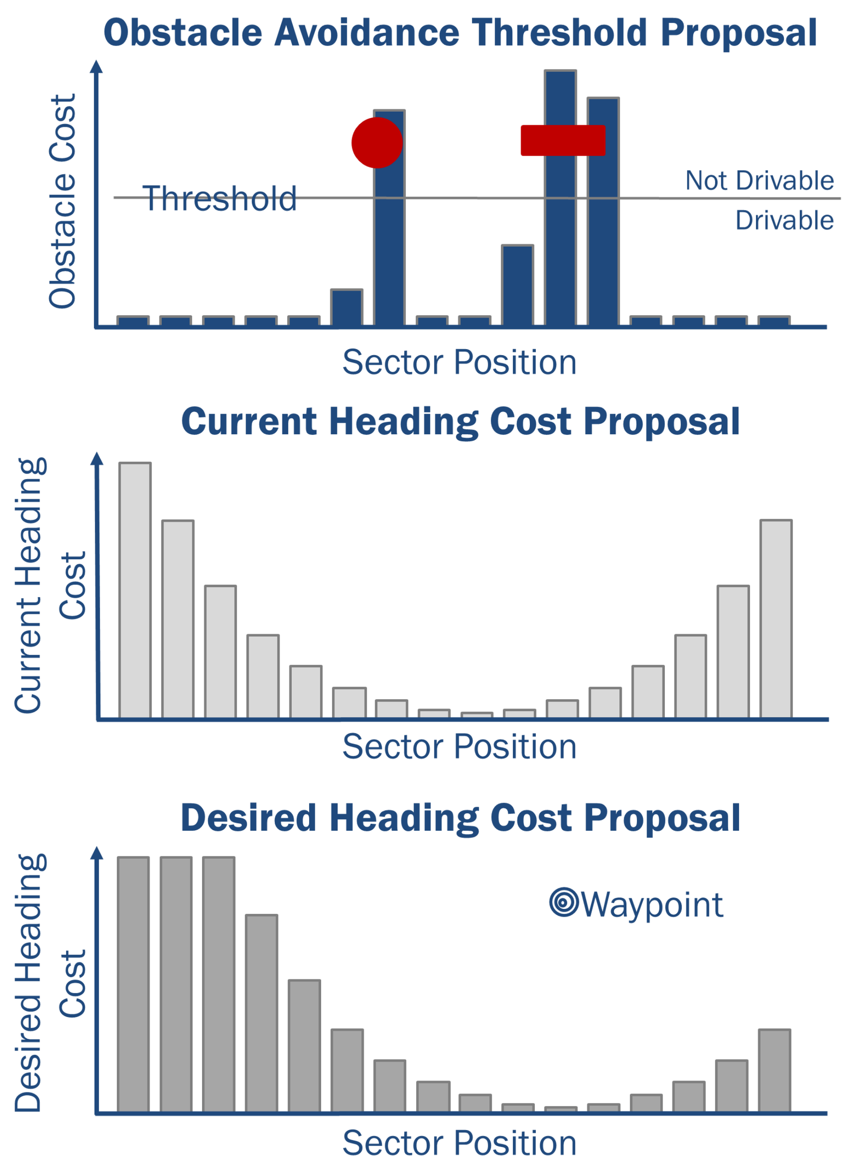
The Gator uses a set of fast reactive behaviors to track its current mission objective. Each of these of these behaviors forms a proposal for what direction they believe the robot should travel. Then an arbiter blends the proposed actions to create a single command.

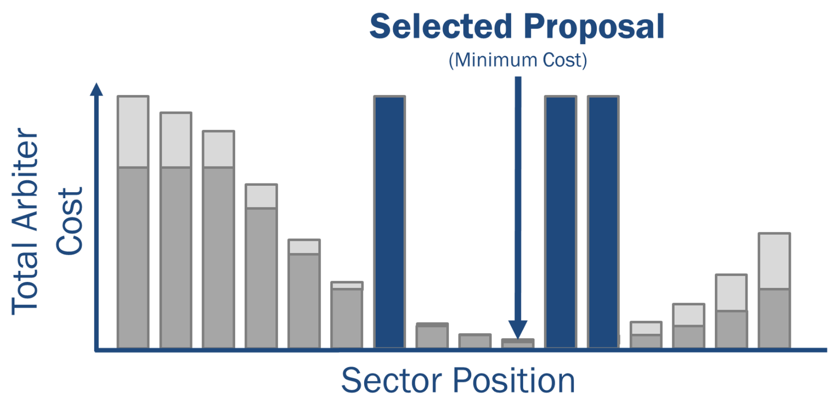
1 Define Action Proposals

2 Behaviors Generate Action Proposals

3 Select Action Proposal







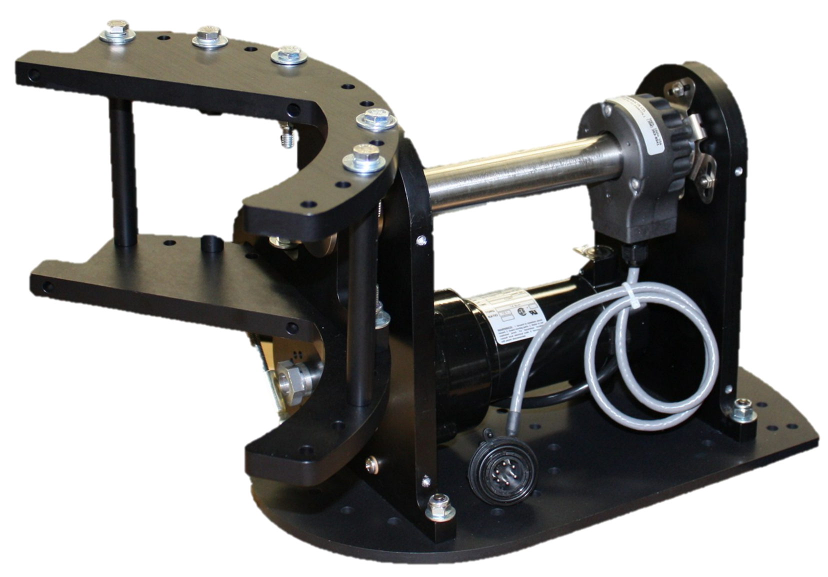
Step 1 — Define Action Proposals:
In order to choose a direction of travel, the robot divides the world into polar sectors, as shown above. In this example, the robot also sees two obstacles (shown in red) and has an objective waypoint it is trying to travel towards.

Step 2 — Behaviors Generate Action Proposals:
Behaviors all Each behavior generates a ranked preference for each possible vector of travel. This ranking takes the form of a cost histogram. The higher the cost of a given sector, the less desirable that vector of travel is. In addition to being able to form cost proposals, a behavior can create a threshold proposal which marks all sectors above a given cost as undrivable.

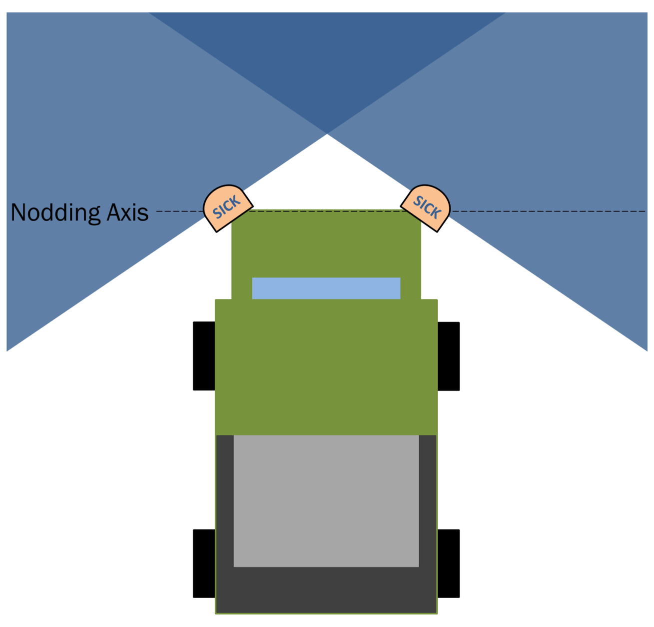
Step 3 — Select an Action Proposal:
Selecting an action to take is a two step process. First, all cost proposals are summed. To limit the influence of less important behaviors, cost proposals are multiplied a gain. In the second step, all sectors marked undrivable by a threshold proposal are assigned a maximum cost. Finally, the arbiter commands the lowest cost proposal.

The Hardware:

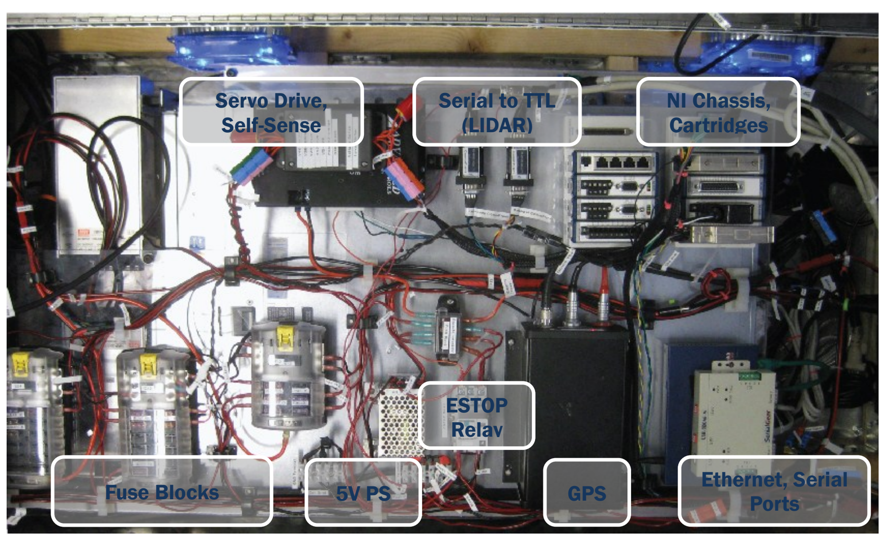
Nodding LIDAR Mechanism:



In order to allow the vehicle to take full advantage of the SICK LIDAR's high data rate, the team designed a nodding mechanism. This nods the LIDAR's beam up and down, allowing the sensor to scan an area and generate a three-dimensional point cloud. Instead of nodding about the laser's scan axis, the LIDARS are rotated on an axis parallel to the front of the vehicle (as shown at right). This allows maximum scanning coverage of the area in front of the vehicle, while still providing data about the area surrounding the Gator.



Redesigned Electronics Box:



The update on the computational fabric of the Gator, including the Dell R5400 workstation, made it necessary for the electronics box layout to be reconfigured. The new layout features a significant larger upper layer; most of the bottom layer is allocated to the workstation, and several components that were on the bottom layer are moved to the top. In addition, the AC UPS, not shown in this diagram, is moved to the side of the container, to allow for more space. The top level is easily removable from the rest of the system for debugging purposes.

The Team:

The Olin College team is composed of five seniors with a wide range of backgrounds.

- Dan Grieneisen (Electrical and Computer Engineering)
- Nick Hobbs (Engineering: Computing)
- Jacob Izraelevitz (Mechanical Engineering)
- Arash Ushani (Electrical and Computer Engineering.)
- Ann Wu (Electrical and Computer Engineering.)

The team has been assisted by Faculty Advisor Professor David Barrett, Corporate Liaison Troy Jones, and junior software developers Matt Alvarado, Varun Mani, Jaime McCandless, and Scott Thomson.

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