Model-based Assurance for Autonomous Vehicles

Md. Emazuddin Alif, School of Engineering, Vanderbilt University

https://cps-vo.org/group/sdss-cps

Objective

To create model based safety assurance techniques for Connected and Automated Vehicles (CAVs) in order to provide better safety certification by investigating and evaluating a technology called Goal Structured Notation (GSN) and it's performance with Systems Modeling Language (SysML). The student project was to build a systems engineering model of an autonomous underwater vehicle that would follow a line

Overview

- Unmanned Underwater Vehicles (UUV), a big part of CAV technology was the domain of our simulation. Iver3 standard was selected as the UUV to run the experiment.
- Used simulations to evaluate and test systems, which is a necessary tool for building safety assurance cases.
- Student Project: Building a simulation model for the sensors in the UUV

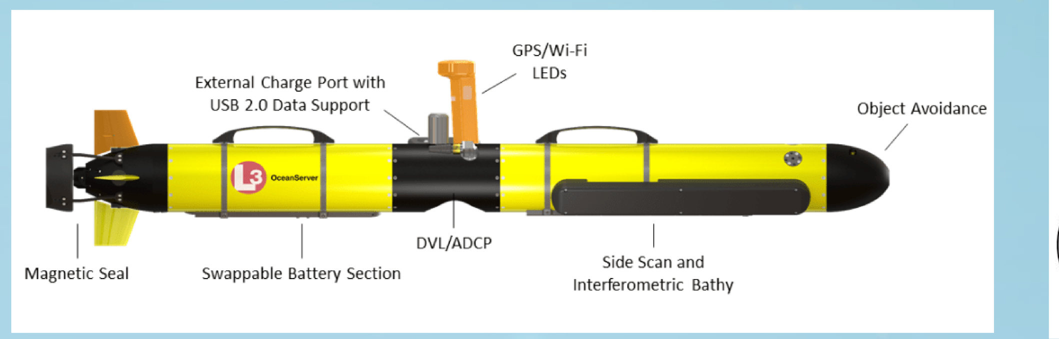

Figure: Iver3 Standard

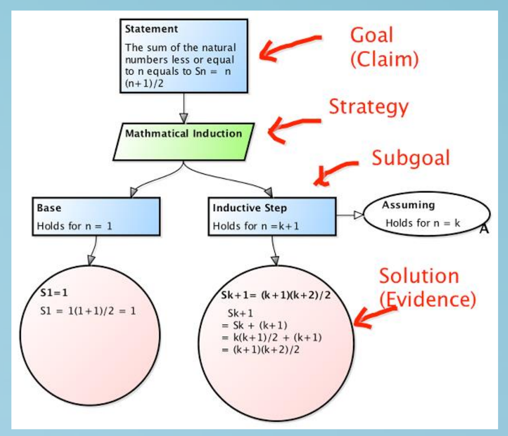

Figure: GSN in mathematics

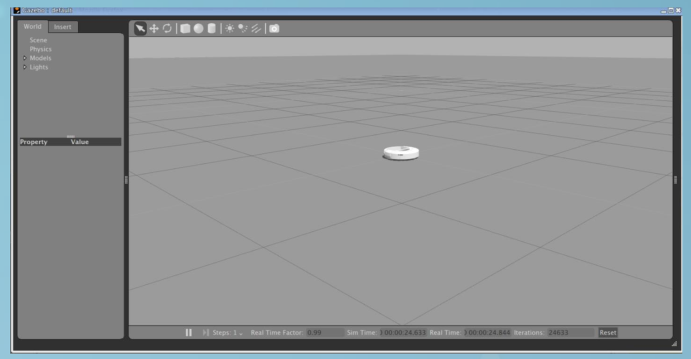

Figure: Roomba in Gazebo

Key Challenges

- The UUV uses sonar to generate the image of the pipe as a line. If the pipe is covered by sand the UUV moves in the last recorded vector until it finds the pipe again. If the pipe bends significantly while under sand, the UUV loses track of the pipe.
- The line following algorithm was tested in a simulation environment called Gazebo. Unfortunately Gazebo's built-in library did not have the necessary models or the sensors to simulate the UUV
- Gazebo models are controlled by Gazebo plugins. Gazebo plugins are very complicated chunks of code, and making new plugins from scratch to provide autonomy to the robot would make the robot very complex and outside the scope of the student expertise.

Iver3 in a nutshell

- Low cost commercial UUV
- Sonar, Conductivity and Temperature sensor, Camera, Locator beacon, handheld remote control, GPS
- Inside compartment has enough space for a second computer

GSN in a nutshell

- Developed at University of York in 1990s
- Graphical argument used to document and prove that safety goals have been met
- Builds its safety case using logic based maps
- Standard format for graphic documentation of safety cases since 2014

Solutions

- The UUV is now being modified to stop and go back to the last known location of the pipe if the pipe cannot be sensed for more than 30 seconds and then search for it in increasingly large circles.
- In simulation, a Roomba model in Gazebo was modified to serve the purpose of the autonomous underwater vehicle. Four sensors were created for the robot, two cliff sensors to detect edge and two color sensor to detect the color of the ground.
- A simple ROS (Robotic Operating System) node was created using Python 2.7, that would use the existing Gazebo plugins to subscribe to the sensor message and publish velocity commands to the model.

CAVs by Numbers

- Study shows 50% CAV penetration in traffic would reduce avg. delay by **6.8%**, **16.9%** for 75%, and **33.8%** for 100%. For urban traffic just 25% would reduce the delay by **12.4%**
- Study shows in most positive scenario CAVs can reduce emission of light-duty vehicles by **83%**
- CAV is a **$35bn** industry in US & safer vehicles and more research means it will keep growing

Societal Impact

- More rigorous safety certification will help in building public trust and commercialization of CAVs and drones
- Introducing CAVs in public transit will cut down traffic time significantly
- Will open a new dimension for people with disabilities in terms of vehicle ownership
- Will cut down demand of parking spaces by a big margin in dense urban areas

This work was supported in part by the US National Science Foundation (NSF) under the Partnerships for International Research and Education (PIRE) award 1743772.