CAT Vehicle Program/ECE REU

PI: K. Larry Head, PhD and Tamal Bose, PhD
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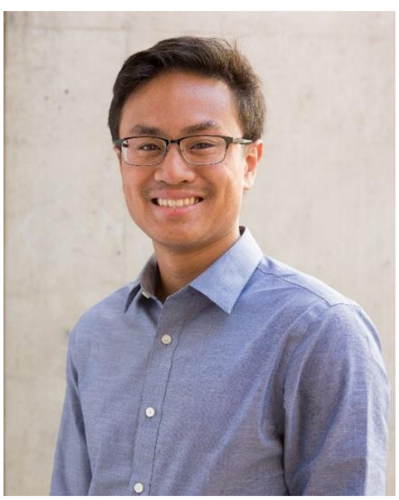
CAT VEHICLE PROGRAM/ECE REU	
	**Jill Alexander** Domain Specific Modeling Language for Test World Generation (Partner: Alex Pyryt) Boise State University, Mechanical Engineering Mentor: Dr. Tamal Bose and Matt Bunting – Electrical and Computer Engineering **Abstract** It is often necessary to use a 3D physics simulator in order to model and test complex robotic systems. Verifying certain behaviors of systems in the real world can be costly, time-consuming, and even dangerous, while simulations are relatively cheap and fast. However, creating simulated environments to test robotic behaviors can take up quite a lot of time and processing power. In order for behaviors to be tested in a variety of scenario, multiple environments must be created, causing verification time to increase. This paper presents a domain-specific modeling language that can be used to speed up this process. This modeling language can be used in WebGME to generate multiple world and launch files in Gazebo, a 3D dynamics simulator. These world files can then be used to test various behaviors of complex robots such as the CAT Vehicle (Cognitive and Autonomous Test Vehicle) in a variety of simulated environments. This model language can save valuable testing time by quickly creating usable test files for complex physics based models such as the CAT Vehicle.
	**Eric Av** Learned Path and Collision Prevention (Partners: Hoang Huynh and John Nguyen) Gonzaga University, Computer Science Mentor: Dr. Tamal Bose and Rahul Bhadani – Electrical and Computer Engineering **Abstract** Autonomous driving has captured academic and public imaginations for years. This project attempts to implicitly teach a car to follow the best optimized route to a destination while avoiding obstacles. The car is taught the optimized route based on a reward/penalty system via reinforcement learning. Using only the distance away from the nearest object and the angle of said object, the car avoids collisions and learns the optimized route in computer simulated worlds. Our goal is to demonstrate the utility of reinforcement learning models designed via simulation for training self-driving cars.

Alex Day
Verification and Creation of Autonomous Vehicle Trajectories for Non-Experts with Reactive Design-Time Feedback and Sensor-Based Response
(Partners: Samuel Hum and Riley Wagner)
Clarion University of Pennsylvania, Computer Science
Mentor: Dr. Tamal Bose and Matt Bunting – Electrical and Computer Engineering

Abstract

An increase in the demand of cyber-physical systems (CPS) has brought about an increase in the complexity of such systems. As their complexity increases, CPS are becoming increasingly inaccessible to those who do not have knowledge in this specific domain. Thus, there exists a need for a language that combines CPS with an interface that is accessible to non-experts. To offset this problem we propose the use of a domain-specific modeling language (DSML) designed in WebGME — a server-based generic modeling environment. The language mirrors the curriculum of non-expert programmers and incorporates the use of sensor data, which is to be deployed on both the Cognitive and Autonomous Test Vehicle (CATVehicle) and Lego EV3 robots. However, maintaining safety within these DSML-designed CPS can be an issue. We aim to address this by coupling the language with assorted verification techniques such as reachability analysis at design time, compile time, and run time. One of these techniques involves the implementation of an off-the-shelf verification tool as a method of providing error messages at both design and compile-time. This paper concerns itself with providing a simple interface to allow non-experts to program safe paths without the need for expert review.

Brandon Dominique
Simulation of a Cognitive Radio using Energy Detection & Reinforcement Learning
New Jersey Institute of Technology, Computer Engineering
Mentor: Dr. Tamal Bose and Noel Teku – Electrical and computer Engineering

Abstract

In this paper, the concept, simulation and implementation of a Cognitive Radio (CR) is discussed. Because of the limited amount of space in the spectrum there needs to be a system in place that can efficiently allocate users to open parts of the spectrum, so that electronic messages of all types can be relayed successfully. As autonomous vehicles (AV) increase in usage, the spectrum will become more crowded due to their different communication methods (i.e. vehicle to vehicle, vehicle to infrastructure). To resolve this, CRs can aid in the allocation of spectrum for AVs by detecting the presence of Primary Users (i.e. having priority access to a channel) on a given set of channels and avoiding any interference by selecting unused channels. Simulation of a CR is accomplished in this paper using Energy Detection and Reinforcement

	Learning algorithms such as Q-Learning and Upper Confidence Bound.
	**Daniel Fishbein** Safety and Stability Analysis of FollowerStopper (Partner: Christopher Kreienkamp) Missouri State University, Physics Mentor: Dr. Tamal Bose and Rahul Bhadani – Electrical and Computer Engineering **Abstract** In this paper we prove that the velocity controller, FollowerStopper, is safe and string stable. FollowerStopper is a controller that is meant to be implemented on an autonomous vehicle or in an adaptive cruise control (ACC) system. It takes as inputs the autonomous vehicle's velocity, relative distance to the car in front, relative velocity to the car in front, and a desired velocity. It then commands a new velocity for the autonomous vehicle which will either be the desired velocity or some lower velocity if that is necessary to maintain a safe distance to the car in front. Through mathematical proof, simulation in Simulink, and hardware in the loop implementation on a real autonomous vehicle through Robot Operating System (ROS) and Gazebo, several results are achieved. It is found that, given a maximum LiDAR range of 81 m, there is a maximum permissible safe speed of the car based on its maximum deceleration, and the car is programmed so that it will never be less than 1 m from the vehicle in front. It is shown that a vehicle with FollowerStopper in a singular lane without merges will not crash and that it will be string stable, effectively dissipating human-caused traffic waves if enough vehicles are deployed in the traffic flow.
	**Hoang Huynh** Learned Path and Collision Prevention (Partners: Eric Av and John Nguyen) GSU-Perimeter College, Computer Science Mentor: Dr. Tamal Bose and Rahul Bhadani – Electrical and Computer Engineering **Abstract** Autonomous driving has captured academic and public imaginations for years. This project attempts to implicitly teach a car to follow the best optimized route to a destination while avoiding obstacles. The car is taught the optimized route based on a reward/penalty system via reinforcement learning. Using only the distance away from the nearest object and the angle of said object, the car avoids collisions and learns the optimized route in computer simulated worlds. Our goal is to demonstrate the utility of reinforcement learning models designed via simulation for training self-driving cars.

Samuel Hum
Verification and Creation of Autonomous Vehicle Trajectories for Non-Experts with Reactive Design-Time Feedback and Sensor-Based Response
(Partners: Alex Day and Riley Wagner)
Colorado College, Computer Science
Mentor: Dr. Tamal Bose and Matt Bunting – Electrical and Computer Engineering

Abstract

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Christopher Kreienkamp
Safety and Stability Analysis of FollowerStopper
(Partner: Daniel Fishbein)
University of Notre Dame, Mechanical Engineering
Mentor: Dr. Tamal Bose and Rahul Bhadani – Electrical and Computer Engineering

Abstract

In this paper we prove that the velocity controller, FollowerStopper, is safe and string stable. FollowerStopper is a controller that is meant to be implemented on an autonomous vehicle or in an adaptive cruise control (ACC) system. It takes as inputs the autonomous vehicle's velocity, relative distance to the car in front, relative velocity to the car in front, and a desired velocity. It then commands a new velocity for the autonomous vehicle which will either be the desired velocity or some lower velocity if that is necessary to maintain a safe distance to the car in front. Through mathematical proof, simulation in Simulink, and hardware in the loop implementation on a real autonomous vehicle through Robot Operating System (ROS) and Gazebo, several

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John Nguyen
Learned Path and Collision Prevention
(Partners: Eric Av and Hoang Huynh)
University of Minnesota, Twin Cities, Computer Science and Mathematics
Mentor: Dr. Tamal Bose and Matt Bunting – Electrical and Computer Engineering

Abstract

Autonomous driving has captured academic and public imaginations for years. This project attempts to implicitly teach a car to follow the best optimized route to a destination while avoiding obstacles. The car is taught the optimized route based on a reward/penalty system via reinforcement learning. Using only the distance away from the nearest object and the angle of said object, the car avoids collisions and learns the optimized route in computer simulated worlds. Our goal is to demonstrate the utility of reinforcement learning models designed via simulation for training self-driving cars.

Alex Pyryt
Domain Specific Modeling Language for Test World Generation
(Partner: Jill Alexander)
University of Maryland Baltimore County, Computer Science
Mentor: Dr. Tamal Bose and Matt Bunting – Electrical and Computer Engineering

Abstract

It is often necessary to use a 3D physics simulator in order to model and test complex robotic systems. Verifying certain behaviors of systems in the real world can be costly, time-consuming, and even dangerous, while simulations are relatively cheap and fast. However, creating simulated environments to test robotic behaviors can take up quite a lot of time and processing power. In order for behaviors to be tested in a variety of scenarios, multiple environments must be created, causing verification time to increase. This paper presents a domain-specific modeling language that can be used to speed up this process. This modeling language can be used in WebGME to generate multiple world and launch files in Gazebo, a 3D dynamics simulator. These world files can then be used to test various behaviors of complex robots such as the CAT Vehicle (Cognitive and Autonomous Test Vehicle) in a variety of simulated environments. This model language

	can save valuable testing time by quickly creating usable test files for complex physics based models such as the CAT Vehicle.
	**Riley Wagner** Verification and Creation of Autonomous Vehicle Trajectories for Non-Experts with Reactive Design-Time Feedback and Sensor-Based Response (Partners: Alex Day and Samuel Hum) University of Arizona, Systems Engineering Mentor: Dr. Tamal Bose and Rahul Bhadani – Electrical and Computer Engineering **Abstract** An increase in the demand of cyber-physical systems (CPS) has brought about an increase in the complexity of such systems. As their complexity increases, CPS are becoming increasingly inaccessible to those who do not have knowledge in this specific domain. Thus, there exists a need for a language that combines CPS with an interface that is accessible to non-experts. To offset this problem we propose the use of a domain-specific modeling language (DSML) designed in WebGME — a server-based generic modeling environment. The language mirrors the curriculum of non-expert programmers and incorporates the use of sensor data, which is to be deployed on both the Cognitive and Autonomous Test Vehicle (CATVehicle) and Lego EV3 robots. However, maintaining safety within these DSML-designed CPS can be an issue. We aim to address this by coupling the language with assorted verification techniques such as reachability analysis at design time, compile time, and run time. One of these techniques involves the implementation of an off-the-shelf verification tool as a method of providing error messages at both design and compile-time. This paper concerns itself with providing a simple interface to allow non-experts to program safe paths without the need for expert review.