CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: Autonomous F1/10 Racing for Everyone	
Sponsor Information: Intelligent Control Systems (ICONS) Laboratory	**Truong X. Nghiem**, Assistant Professor School of Informatics, Computing and Cyber Systems Northern Arizona University Email: truong.nghiem@nau.edu Phone: 928-523-4973 Trong-Doan Nguyen, PhD Student School of Informatics, Computing and Cyber Systems Northern Arizona University Email: dtn57@nau.edu

Project Overview:

WELCOME TO THE WORLD OF SPEED!!! ARE YOU READY TO RACE?

Waymo (Google), Uber, Tesla and hundreds of startups all over the world are putting huge efforts into building autonomous driving software for vehicles. These efforts are expected to enable a future where we can drive much more safety, even completely freed from the driving task, or at least have autonomous delivery robots (which you might have seen on the NAU campus recently). Waymo - the pioneer in the field - has been testing its self-driving cars on Phoenix's roads for some time.

Although cars are becoming smarter and safer to drive, many technical challenges are still left to be solved. Safety guarantee is a major issue that requires breakthrough ideas and solutions, especially for self-driving cars in which a multitude of very complex hardware and software components are involved. To address these challenges, high-fidelity simulations and small-scale autonomous vehicles are widely utilized for research, development, and testing of technical solutions. Right here in SICCS, ICONS Lab is actively pursuing this research and will build four high-speed small-scale autonomous racing cars called F1/10 (pictured above). These racing cars allow us to push the speed to extremes where the safety and autonomy are challenged by very short reaction timelines.

The Problem

FF1RR (Flagstaff's F1/10 Robo-Racing) is a project, funded by IEEE and SICCS, that will offer exciting educational activities to raise the awareness, interest, and knowledge of school and university students about autonomous vehicles and autonomous systems in general. The program is based around the idea that the F1/10 autonomous cars could, in addition to their value as a research platform, serve as a motivating and powerful educational platform as well, allowing students to use them to explore the basics of robotics and autonomous vehicles. The problem is that the current suite of F1/10 software is quite complex, scattered across a variety of tools and modules that require considerable technical expertise to bring together. What is needed is essentially a simplified "wrapper" for this suite of software that, while it might not allow full flexibility in constructing any type of autonomous control systems, does make it fairly simple for high-school students with only moderate technical skills to configure/program the F1/10 cars in some basic exploratory ways, allowing them exciting exposure to the basics of robotics, control and autonomous driving technologies.

Envisioned Solution

The overall goal of this project is to develop a Basic Developers Toolkit (BDK), which can be seen as a simplified version of the Application Developers Toolkits (ADKs) provided for many platforms like Android, iOS, etc. The idea is to provide some function-specific modules (or APIs) that wrap up the complexity of one or more existing F1/10 software tools, to present a clean, simplified usage profile suitable for high-school student developers. The effort can be split into two main tasks (products):

Task 1 (minimum viable product): Development of simplified F1/10 software toolset and APIs.

Develop a set of simplified "wrapper" modules that present a limited, simplified API for student programmers to easily include/access in their small coding projects. It is quite possible that these modules could be literally tailored to support specific programming projects; this is something the team will explore. The FF1RR project is a partner of the F1/10 project (http://f1tenth.org/) and thus has access to all the internal F1/10 code, including most of the main autonomous vehicle modules already developed, e.g., sensing, control, and mapping. This task will extend/refactor the existing F1/10 software in several ways:

- Refactor the current software to make it: a) more user-friendly and accessible to high-school students; b) more modular so that it is easy to enable, disable, and change modules to create different AV configurations with different levels of autonomy. For example, with only a simple configuration parameter change, students can enable or disable the laser-based 3-D mapping module; currently this would require changing code in multiple files.
- Customize and parameterize selected modules so that high-school students can specify parameters and write several lines of code to complete a fully functioning AV software stack.
- Configure multiple levels of autonomy for the driving software (from simple line following to fully autonomous driving) to be used in teaching AV technologies to high-school and university students. These pre-built modules and configurations could be used as sample code, and/or integrated by students into their projects.

Task 2 (a truly usable product): Develop a GUI-based programming prototype

- Even with the simplified building blocks developed in Task1, developing AV programs for F1/10 cars will still require students to have some programming skills; the modules still need to be imported and called in some program written by students. The programs still need to be compiled/built and loaded into remote computer boards. This task explores whether we can make this even easier, allowing even novice programmers to access to F1/10 programming. In particular, we envision a GUI workspace in which junior programmers can select and configure modules developed in Task1 to create simple but viable F1/10 control programs.
- The GUI should make working with AV software more accessible for high-school students, including basic configuration, simulation and visualization, and real deployment. In the configuration step, students can select and configure different modules for sensing, mapping, motion planning and control, etc. Then, they can simulate and visualize the car with the just-configured AV software program, using an existing F1/10 simulation program. Finally, in the deployment step, students can compile the programs for the F1/10 hardware and load them to the car without having to manually compile the code on Linux and transfer it to the on-board computer. Although this is really just a UI layer on top of the newly-developed "Simple" modules, building a seamless and functional interface that streamlines the AV programming process is complex. The aim here is to explore/prove the challenges of building a graphical UI for FF1RR; an acceptable solution here would be a GUI prototype that perhaps only allows programming a limited subset of possible programs.

Project Impact

A summer camp will be held in Summer 2020 in which school students can use the software platform developed in this Capstone project and the F1/10 cars in ICONS Lab to build their own autonomous vehicles and compete with each other in a fun race. Such activities and experiences will help encourage them to pursue STEM in the future.

Knowledge, skills, and expertise required for this project:

- Must have software development skills and programming skills in C/C++ and Python.
- Familiarity with Linux and building programs from source code in Linux.

- Knowledge of Computer Vision, Embedded Programming, Automatic Control, Robotics and/or Robot Operating System (ROS) is an advantage.

Equipment Requirements:

- The sponsor will provide the F1/10 hardware & current software. Students must have personal computers on which Ubuntu Linux can be installed (either directly, on a VM, or on Docker).
- Otherwise, there should be no equipment or software required other than a development platform and software/tools freely available online.

Software and other Deliverables:

- The software applications as described above, deployed and tested successfully with the autonomous racing car platform F1/10. Must include a complete and clear User Manual for configuring and operating the software.
- A strong as-built report detailing the design and implementation of the product in a complete, clear and professional manner. This document should provide a strong basis for future development of the product.
- Complete professionally-documented codebase, delivered both as a repository in GitHub, BitBucket, or some other version control repository; and as a physical archive on a USB drive.