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The National University Transportation Center for Promoting Safety

Carnegie Mellon University



Equipment for F1Tenth Autonomous Racing Capstone Course

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FINAL REPORT

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1. Executive Summary

This project enabled the purchase of equipment for an F1Tenth Autonomous Racing Course that was offered for the first time at Carnegie Mellon University in Fall 2023 by the PI Prof. John M. Dolan, then again in Spring 2024. The course was developed by fellow Safety21 UTC member Prof. Rahul Mangharam and team at the University of Pennsylvania, and adapted for CMU by the PI. It gives students a strong foundation in the full autonomous driving software stack and stresses safe maneuvering at high speeds among multiple surrounding vehicles. Participants in and graduates from the course at Penn and other universities have competed in F1Tenth race competitions at major robotics and transportation conferences including ICRA, IROS, and the IEEE Intelligent Vehicles Symposium and gone on to jobs in the intelligent transportation industry. The course therefore has high impact in the area of intelligent transportation workforce development. Furthermore, the technologies and techniques learned for maneuvering safely at high speeds have application to safety at the typically lower speeds of highway and city driving, and to the quick reactions needed to respond safely to emergency situations in conventional driving. This report describes the equipment purchased and other activities supported by the award.

2. Introduction

F1Tenth vehicles (Figure 1) are 1/10-size autonomous cars based on off-the-shelf R/C vehicles available from the company Traxxas or possibly other vendors, but retrofitted for autonomous operation. They have been used for several years now as the basis for university courses on autonomous racing. A popular version of this course was developed by fellow Safety21 UTC member Prof. Rahul Mangharam and team at the University of Pennsylvania, and adapted for CMU by the PI starting in the Fall 2023 semester. It gives students a strong foundation in the full autonomous driving software stack and stresses safe maneuvering at high speeds among multiple surrounding vehicles. Participants in and graduates from the course at Penn and other universities have competed in F1Tenth race competitions at major robotics and transportation conferences including ICRA, IROS, and the IEEE Intelligent Vehicles Symposium and gone on to jobs in the intelligent transportation industry. The course therefore has high impact in the area



Figure 1. F1Tenth Autonomous Vehicle

of intelligent transportation workforce development. Furthermore, the technologies and techniques learned for maneuvering safely at high speeds have application to safety at the typically lower speeds of highway and city driving, and to the quick reactions needed to respond safely to emergency situations in conventional driving.

3. Platform

A suitable Ultimate or Platinum Traxxas chassis (Figure 2) currently costs about \$500. The addition of appropriate computing, sensing, power, and other miscellaneous items brings the total cost of an F1Tenth autonomous vehicle platform to about \$3,000 (see Appendix (BOM)). In the Fall 2023 semester, before funding from the UTC award was available, Prof. Rahul Mangharam at Penn University lent 6 platforms for use in the F1Tenth class being taught at CMU for the first time. For the Spring 2024 semester, the UTC award allowed us to buy 7 platforms of our own.



Figure 2. Traxxas Ultimate R/C Car

Given a desired student team size of 3 or 4, the purchase of seven of our own platforms allowed a class size of between 21 and 28 students. The number of students in both Fall 2023 and Spring 2024 was 22.

4. Results (Supported Activities)

The UTC award funding allowed us to do the following things:

1. Buy initial and replacement parts for seven F1Tenth autonomous car platforms.
2. Offer the 16-663 F1Tenth Autonomous Racing course at Carnegie Mellon University two times during Academic Year 2023-24.
3. Support the participation of a subset of the Spring 2024 16-663 students in a Race Day held at the University of Pennsylvania in late April 2024.

4.1 Purchase of F1Tenth Platforms

We were able to purchase seven F1Tenth cars (see Appendix (BOM)) for use in the Spring 2024 offering of the 16-663 F1Tenth Autonomous Racing course. Students gained experience in mechatronic fabrication and assembly by adding the autonomy retrofit components to the base Traxxas chassis.

4.2 F1Tenth Course

We taught the 16-663 F1Tenth Autonomous Racing course twice during Academic Year 2023-2024 in order to get it firmly established with experienced TAs from the PI's lab. It will subsequently be taught in the spring semester each year. The Fall 2023 instance of the course could not have been taught without a generous loan of six F1Tenth platforms from Prof. Rahul Mangharam at the University of Pennsylvania and the assurance based on receipt of the UTC award that we would have sufficient funding to purchase platforms for future offerings of the course. The latter was true because the six lent platforms from Penn had to be returned for use in

the Spring 2024 offering of the F1Tenth course at Penn. Figure 3 and Figure 4 respectively show the CMU Spring 2024 set-up for Race 2 is a class photo from Race 3.



Figure 3. Track set-up for Race 2 in the Spring 2024 offering of the CMU F1Tenth Autonomous Racing course. Whereas Race 1 required only reactive maneuvering, Race 2 required mapping and localization.



Figure 4. April 2024 class picture at the end of Race 3 in the Spring 2024 offering of the 16-663 F1Tenth Autonomous Racing course at CMU

4.3 Penn Race Day

Prof. Mangharam at Penn suggested that a Race Day be held at the University of Pennsylvania in late April 2024 with participation by students in the F1Tenth Autonomous Racing classes being taught simultaneously at Penn, Lehigh University, and Carnegie Mellon University (CMU). CMU sent about 15 students to participate in the Race Day, and about \$1000 of the UTC funding was used to defray logistics costs for the trip.

5. Future Work

This project has laid the groundwork for, and potential future UTC funding can continue to support, the following activities:

1. Teaching the 16-663 F1Tenth Autonomous Racing course at CMU each spring semester.
2. Participating in an annual multi-university Penn Race Day at the end of the spring semester.
3. Continuing to augment the fleet of F1Tenth vehicles at CMU in order to support greater numbers of students in the 16-663 course.
4. Supporting purchase of back-up/replacement parts and design alterations for the existing F1Tenth vehicles.

6. Appendix (BOM)

	Qty	Cost per unit	Total cost	Link
CHASSIS				
Traxxas Slash 4x4 Ultimate	1	\$499.95	\$499.95	https://www.rcsuperstore.com/traxxas-slash-4x4-ultimate-short-course-truck-w-tqi-telemetry/
COMPUTE MODULE				
Jetson Orin Nano 8GB	1	\$499.00	\$499.00	https://www.amazon.com/dp/B08ZJTCQYP?ref=asc_sw_r_cp_ud_dp_ZRAEPGK1N530KJBL4769F&th=1
Micro SD Card 32 GB	1	\$36.98	\$36.98	https://www.amazon.com/igagstone-2-Pack-Memory-Class10-Adapter/dp/B07HIGZ54Z/?th=1
NVMe SSD Card 500 Gb	1	\$37.99	\$37.99	https://www.amazon.com/Kington-910S-2280-internal-SSV2/dp/B08BRWJHLP9/?th=1
SENSORS				
Hokuyo UST-10LX	1	\$1,050.00	\$1,050.00	https://www.ebay.com/itm/374976607403
Intel RealSense D432i	1	\$99.99	\$99.99	Search on web including ebay
ELECTRONICS				
VESC-related				
VESC 6 MkVI	1	\$258.00	\$258.00	https://trampboards.com/vesc-6-mkvi-in-enc-t6-silicone-sealed-aluminum-box-with-genuine-st90-connectors--vex3
VESC ppm cable	1	\$4.02	\$4.02	https://electrionboardsolutions.com/products/ppm-servo-cable-for-vesc6
TRX to XT90 Adapter	1	\$9.99	\$9.99	https://www.amazon.com/dp/B07C6A8KCE
Bullet Adapter 4mm Male 3.5mm Female	1	\$4.99	\$4.99	https://backbayrc.com/products/no-wires-3-5mm-male-to-3-5mm-female-bullet-plug-adapter-for-esc-motor-wires
Short (1 ft.) A USB-to-microUSB cable	1	\$7.98	\$7.98	https://www.amazon.com/Sabrent-6-Pack-Premium-Cables-CB-LV61/dp/B011xMSPDM
Powerboard-related				
Fenn PCB powerboard	1	\$100.00	\$100.00	https://docs.google.com/spreadsheets/d/3JBTDo5WM0Vsu07Aapp4HdE7v4CPT0kvw0Mrc9W/edit
2.5mm Pitch 4-pin Cable Matching Pair	1	\$0.95	\$0.95	https://www.adafnrl.com/product/4078
12V 5A Power Adapter	1	\$11.99	\$11.99	https://www.amazon.com/Adapter-100-220V-Switching-Security-Accessories/dp/B073105849
FASTENERS				
M2.5 x 0.45mm, 10mm long FF Standoffs	4	\$0.73	\$2.92	https://www.mcmaster.com/35947A005/
6mm hex 14mm M3 standoffs	2	\$4.09	\$8.18	https://www.mcmaster.com/34868A009
6mm hex 25mm M3 standoffs	4	\$5.98	\$23.92	https://www.mcmaster.com/34868A013
6mm hex 45mm M3 standoffs	6	\$4.31	\$25.86	https://www.mcmaster.com/34868A139
M2.5 screw set	1	\$11.12	\$11.12	https://www.mcmaster.com/31296A101/
M3 Socket Head Kit	1	\$14.97	\$14.97	https://www.amazon.com/7INDEJIN-Silver-Socket-Screws-Assortment/dp/B0512MVBMC/?th=1
M5 x 20mm Socket cap screws	1	\$9.49	\$9.49	https://www.amazon.com/Socket-Screws-Grade-Thread-Quantity/dp/B07KWO5PVL
MISCELLANEOUS				
Joystick: DualShock 4 for PS4	1	\$57.99	\$57.99	https://www.amazon.com/DualShock-Wireless-Controller-Playstation-Black-4/dp/B01LWV52R0/?th=1
Traxxas id charge lead adapter	1	\$8.99	\$8.99	https://www.ebay.com/itm/393173294518
Display port emulator	1	\$6.99	\$6.99	https://www.amazon.com/FUERAPU-DP-DisplayPort-emulator-2560x1600/dp/B07LGGCTM7/?th=1
RC Car Work Stand	1	\$11.99	\$11.99	https://www.amazon.com/dp/B08Q35KQ7L
Lowepro DroneGuard CS 400	1	\$45.00	\$45.00	https://www.ebay.com/itm/324056986008
		Total:	\$2,851.25	
ONE-TIME PURCHASES				
Precision screwdriver set	2	\$17.83	\$35.66	https://www.amazon.com/dp/B08ZJTCQYP?ref=asc_sw_r_cp_ud_dp_7624T46357QAP5SD03E

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