TECHNISCHE UNIVERSITÄT WIEN

Autonomous Racing Cars
191.119 (VU 4,0) Semester: 2022S

Lab 1: Race Car & Simulator

2022-03-03

Preface

Read all the instructions below carefully before you start working on the assignment, and before you make a submission. All sources of material and ressources must be properly cited (this also includes datasheets).

- Completeness of solution: A complete solution of a task also includes knowledge about the theory behind.
- This exercise has to be solved individually. Upload your solution in TUWEL until 2022-03-15 23:59.
- For this assignment there is no exercise interview. However if submissions are unclear, students might be invited for exercise interviews.

Learning outcomes

The following fundamentals should be understood by the students upon completion of this lab:

- Know the specification and abilities of the race car hardware.
- Use simulaton models for racing cars and understand the basics and parameters of these models.
- Use ROS and the f1tenth_simulator and be prepared for the further labs.

Deliverables and Submission

Write a exercise report and submit it as PDF file in TUWEL until 2022-03-15 23:59. Submit a video file in TUWEL until the same deadline. Use the provided latex template and do not forget to fill in the parts marked with "TODO". If you do not use the provided template, make sure to include the same information. In any case the report must meet an adequate level for layout and readability that is appropriate for the academic context.
If you are using any program or script (e.g. *Matlab*, *Python*, *C/C++*) to solve an assignment, you must add the full sourcecode in the appendix of your PDF file and reference it in your description of the solution. (But do not add it as separate file in a ZIP-Archive.)

1 Race Car Hardware

This task deals with the basics of our race car hardware. Our hardware is based on the f1tenth racing series (refer to [OKe+22b], [OKe+20]) with some custom modifications. Figure 1 shows the main parts of our race car (some parts were upgraded after this picture). Look into datasheets of the car's components to answer the following questions. The pictures in appendix section *Components* show close-up details of the components (including types and model numbers) s.t. you can find the relevant datasheets on the internet.

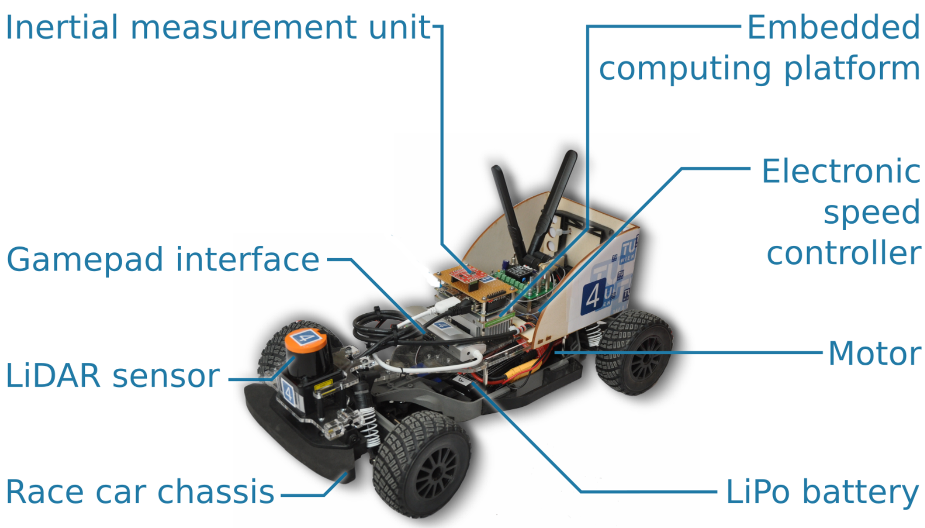

Figure 1: Race car

a.) **LiDAR sensor**
What is the maximum range, minimum range, number of rays, scanning angle, update rate, voltage of the power supply?

b.) **Embedded computing platform**
What hardware interfaces (e.g. ethernet, USB, ...) are there? What is the CPU architecture? How many memory (RAM) and storage (eMMC) is available? What is the allowed voltage of the power supply?

c.) **Electronic speed controller**
What hardware interfaces (e.g. ethernet, USB, ...) are there? What sensor data does it provide?

d.) **Motor** and **Race car chassis**
What type of motor is it? What is the maximum rotation speed? What is the total conversion rate from rotations per minute (rpm) to the car speed in meters per second (m/s) for our car? (Give the formula, state values for each variable and calculate the result.) Are there differences for Fiesta and Slash? If yes, elaborate these differences.

e.) **Intertial measurement unit**
What hardware interfaces (e.g. ethernet, USB, ...) are there? What microcontroller (MCU) is used on this module? What sensor data does it provide? What accelerometer, gyrometer and magnetometer chip(s) is/are used on this module?

f.) **Power distribution board**
What is the voltage and amperage rating of the DC/DC converter? What is the minimum input voltage of the DC/DC converter?

g.) **LiPo battery**
What is nominal voltage of the battery? What is minimum cut-off voltage of the battery?

2 Car Simulaton Model

For any simulation of a physical object in a given environment it is required to have a model of the respective object. In the f1tenth_simulator [OKe+22a] the model is based on a vehicle model by Althoff and Würsching [AW20].

a.) Which of the models described by Althoff and Würsching [AW20] is/are used in the f1tenth_simulator [OKe+22a]?
If more then one are used: Which of those is more advanced? How does the simulator determine which model to use in which case?

b.) Lets only consider the more advanced model from previous task (2.a.):
What vehicle parameters are required for this model?

c.) What are the values for the vehicle parameters, as answered in task (2.b.),
in the f1tenth_simulator [OKe+22a]?

d.) How could you determine the actual values for the vehicle parameters, as answered in task (2.b.),
for our race car (the actual hardware)?

e.) What are the constraints for maximum speed v_{max}, maximum acceleration a_{max}, maximum deceleration a_{brake}, maximum steering angle δ_{max} and maximum steering velocity $v_{\delta_{max}}$ in the f1tenth_simulator [OKe+22a]?

f.) How could you determine the actual values for the constraints, as answered in task (2.e.),
for our race car (the actual hardware)?

3 Simulator: f1tenth_simulator

The race car software as well as the simulator are based on ROS [Sta22]. You can either install it directly on your own PC or use a virtual machine [1]. For all further Labs you will need to have ROS and the simulator working on your machine. This task deals with the setup of these parts.

- Install ROS base system as described here: http://wiki.ros.org/noetic/Installation/Ubuntu
  (In section 1.4 of these instructions it is enough to install `ros-noetic-desktop`, you do not require `ros-noetic-desktop-full`. Section 1.6 of these instructions is not needed for now.)

- Install ROS dependencies and needed software:
  ```
  sudo apt-get install ros-noetic-tf2-geometry-msgs ros-noetic-ackermann-msgs ros-noetic-joy
  ↪ ros-noetic-map-server git g++
  ```

- To install the simulator [2] package, clone the repo into your catkin workspace:
  ```
  mkdir -p ~/catkin_ws/src
  cd ~/catkin_ws/src
  git clone https://github.com/CPS-TUWien/f1tenth_simulator.git
  ```

- Then build it:
  ```
  cd ~/catkin_ws
  catkin_make
  ```

- Source workspace settings:
  ```
  source devel/setup.bash
  ```

- Start simulator and visualisation:
  ```
  roslaunch f1tenth_simulator simulator.launch
  ```

a.) Make a video of your screen while you are driving manually around the track and upload this video to the separate submission item in TUWEL.
To enable the keyboard control press `k` in the terminal and then use `w`, `a`, `s`, `d` to control the car. (You can change the speed of the car for keyboard operation in file `params.yaml`. You may also cut your video after 30 seconds even if you did not yet complete the track.)

[1] If you want to use a virtual machine, we suggest *VirtualBox* (available for free at https://www.virtualbox.org/). We tested it with at least 4096 MiB of RAM and 24 GiB disk space inside the virtual machine. As operating system we heavily suggest *Ubuntu 20.04* (available for free at https://ubuntu.com/download/desktop).

[2] This simulator is based on [OKe+22a] with some minor modifications for our lecture.

Appendix

Grading

The following points can be achieved for each task of this exercise sheet:

Exercise	Points
1.a.	6
1.b.	4
1.c.	2
1.d.	7
1.e.	3
1.f.	2
1.g.	2
Subtotal	26
2.a.	3
2.b.	6
2.c.	6
2.d.	8
2.e.	5
2.f.	6
Subtotal	34
3.a.	40
Subtotal	40
Grand Total	100

Components

Figure 2: Inertial measurement unit

Figure 3: LiDAR sensor

Figure 4: Race car chassis (Fiesta)

Figure 5: Race car chassis (Slash)

Figure 6: Embedded computing platform

Figure 7: Electronic speed controller

Figure 8: Motor

Figure 9: LiPo battery

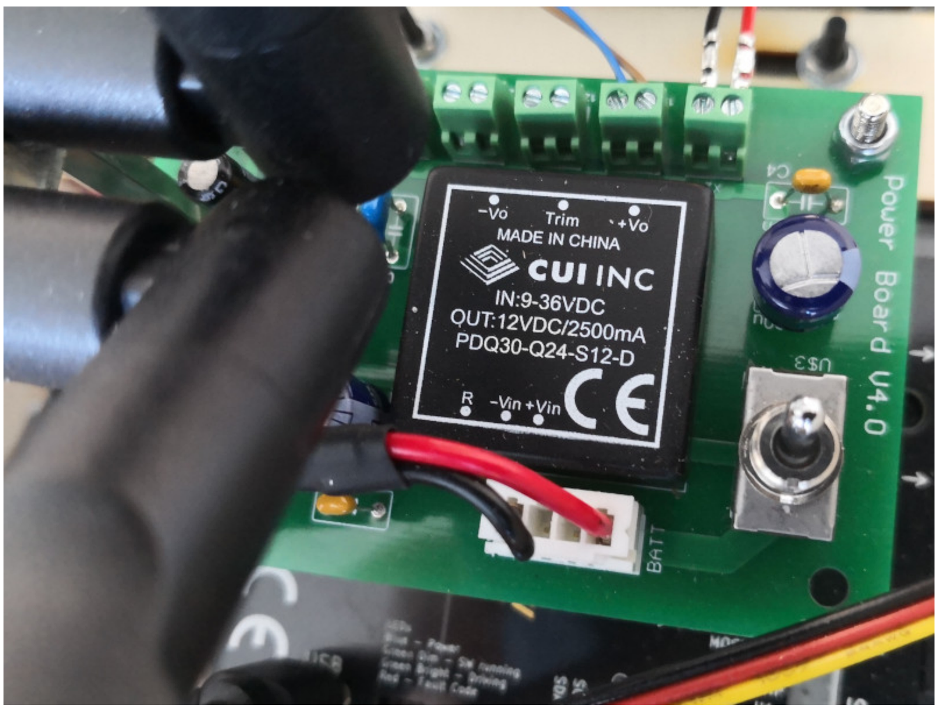

Figure 10: Power distribution board

References

[AW20] Matthias Althoff and Gerald Würsching. *CommonRoad: Vehicle Models*. 2020. URL: https://gitlab.lrz.de/tum-cps/commonroad-vehicle-models/blob/master/vehicleModels_commonRoad.pdf.

[OKe+20] Matthew O'Kelly, Hongrui Zheng, Achin Jain, Joseph Auckley, Kim Luong, and Rahul Mangharam. "TUNERCAR: A Superoptimization Toolchain for Autonomous Racing". In: *2020 IEEE International Conference on Robotics and Automation (ICRA)*. IEEE. 2020, pp. 5356–5362.

[OKe+22a] Matthew O'Kelly, Hongrui Zheng, Achin Jain, Joseph Auckley, Kim Luong, and Rahul Mangharam. *Code repository: f1tenth_simulator*. 2022. URL: https://github.com/f1tenth/f1tenth_simulator.

[OKe+22b] Matthew O'Kelly, Hongrui Zheng, Achin Jain, Joseph Auckley, Kim Luong, and Rahul Mangharam. *F1TENTH Autonomous Racing*. 2022. URL: https://f1tenth.org/.

[Sta22] Stanford Artificial Intelligence Laboratory et al. *Robotic Operating System*. 2022. URL: https://www.ros.org.

Acknowledgments

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