F1TENTH MPC

Autonomous Racing with Model Predictive Control

Student

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Introduction: Autonomous racing provides a challenging environment for evaluating perception, planning, and control algorithms at the limits of vehicle performance. Among the available control approaches, Model Predictive Control (MPC) is particularly attractive due to its ability to predict future system behavior while explicitly considering system constraints. This thesis investigates the implementation of a nonlinear MPC controller on an F1TENTH vehicle. The project combines simulation-based development with deployment on a physical RC vehicle equipped with LiDAR sensing, and an NVIDIA Jetson computer. The simulation environment was used as a digital twin for rapid development. An example of the recorded vehicle trajectory within the simulator is shown in Figure 1, while the experimental racetrack used for evaluation is illustrated in Figure 2.

Objective: The main objective of this thesis was the development and realization of a nonlinear MPC controller capable of autonomously navigating a racetrack while operating close to the limits of controllability. This required the derivation of a suitable vehicle model, the design of reactive path-planning and the integration of a real-time optimization solver. The controller was first validated in simulation and subsequently transferred to a physical F1TENTH vehicle. The complete hardware platform used for the experiments is shown in Figure 3. All software components were implemented within the ROS 2 framework to ensure modularity and efficient communication between sensors, actuators, and control algorithms.

Conclusion: The developed nonlinear MPC controller successfully achieved the objectives of this thesis. Both simulation and real-world experiments demonstrated stable autonomous navigation, accurate velocity tracking, and real-time feasibility on the F1TENTH platform. The simulation environment proved effective for development and testing before deployment on the physical vehicle. Although certain limitations remain in state estimation and the purely reactive path-planning approach, the implemented system still provides a strong foundation for future improvements and extensions.

Figure 1: Recording of the car position on the racetrack inside the simulation.
Own presentment

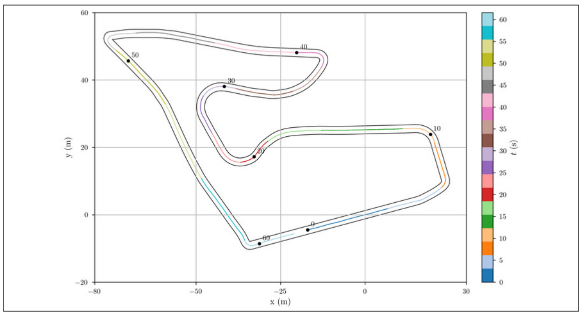


Figure 2: Image of the racetrack with annotations indicating the curve and driving direction.
Own presentment

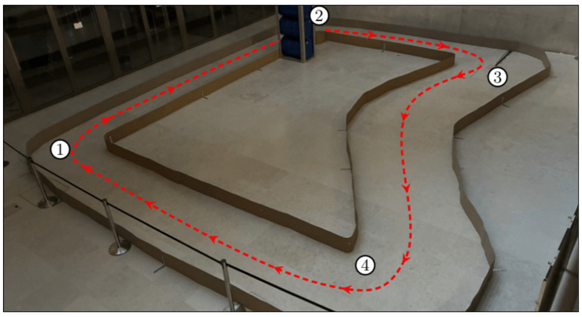
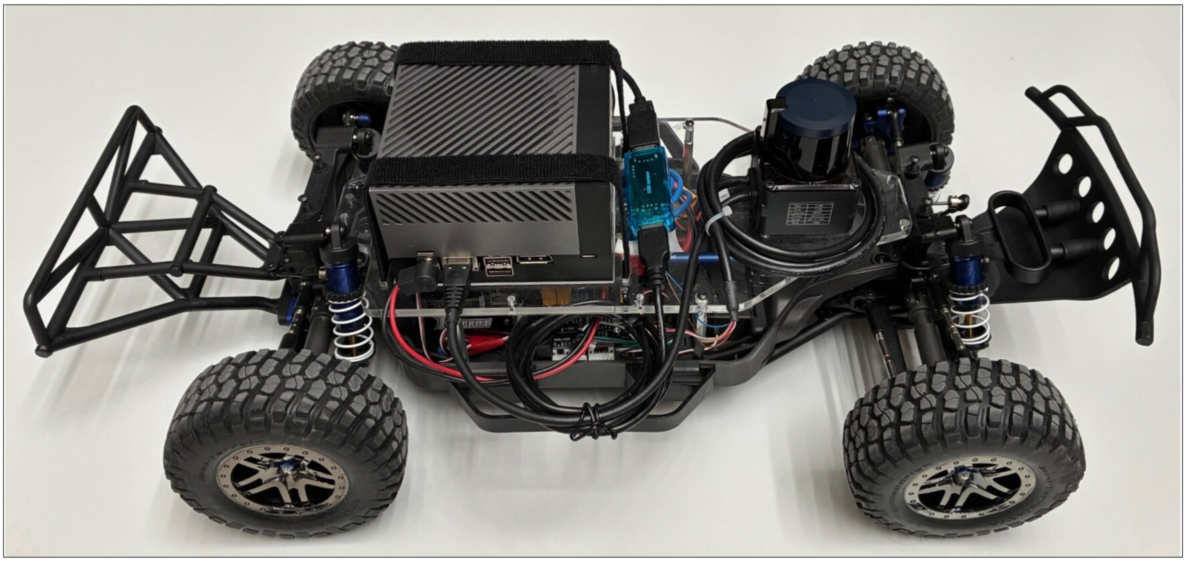


Figure 3: Fully assembled F1TENTH car with all mounted hardware components.
Own presentment



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