# Contract-Based Hierarchical Control of a mobile Ground Robot

TECHNISCHE UNIVERSITÄT DARMSTADT

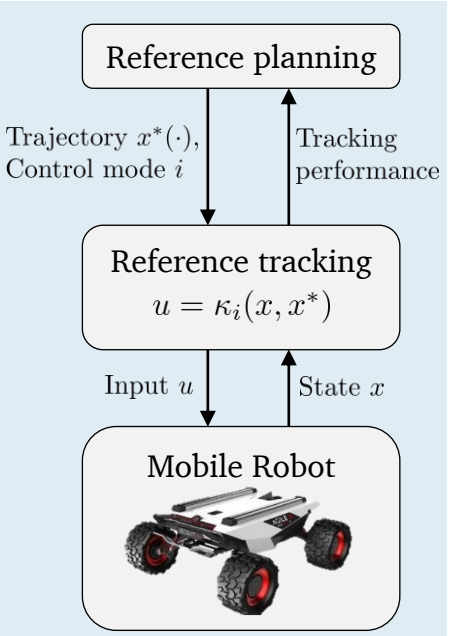
## Project seminar (3 - 4 students)

Complex control tasks, such as the navigation of a robot in environments with obstacles, are often structurally separated into a planning and a tracking task. This has the advantage that the stabilizing tracking controller can run at a higher rate than the computationally expensive planning. However, if e.g., the obstacle avoidance is only considered on the planning level, it also needs to account for possible tracking deviations that can occur.

In contract-based hierarchical control, the planner will consider the tracking accuracy provided by the low-level controllers. Additionally, we allow the planner to dynamically select between multiple low-level controllers, that might be better suited for different scenarios. The planner is formulated as a receding-horizon optimal control problem. In addition to computing the reference trajectory, it will include discrete decision variables, corresponding to the choice of tracking controller, making it a Mixed-Integer Problem.

- A suitable set of tracking controllers need to be selected/designed and their tracking performance needs to be analyzed.
- The planning stage needs to be formulated as an OCP. The task is to reach a target position while avoiding obstacles.
- After successful evaluation in simulation, the developed control scheme shall be applied to a mobile ground robot. Ideally, obstacles should be detected and considered online.

Programming skills (preferably in Python) and prior knowledge of optimal control are required. Experience with ROS is helpful.



Proposed control architecture


[1] B. Elsayed, M. Ibrahim and R. Findeisen, "Moving Horizon Planning and Control Under Uncertainties with Guarantees – Combining Operational Choices and Motion Primitives," *2023 9th International Conference on Control, Decision and Information Technologies (CoDIT)*, Rome, Italy, 2023, doi: 10.1109/CoDIT58514.2023.10284501.

[2] M. Ibrahim, M. K¨ogel, C. Kallies, and R. Findeisen, “Contract-based hierarchical model predictive control and planning for autonomous vehicle,” IFAC-PapersOnLine, vol. 53, no. 2, 2020, 21st IFAC World Congress. doi: 10.1016/j.ifacol.2020.12.058



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CCPS Control and Cyber-Physical Systems