Chair of Automatic Control

FAU

AuT Team Project (Kickoff in May/June 2025)

Boston Dynamics' Spot: MPC-based Path-Following with Predictive Collision Avoidance

Motivation

Model Predictive Control (MPC) is an advanced control method widely used in academia, particularly in the field of robotics. Specifically, it enables the control of nonlinear systems while accounting for constraints on current and future states. This opens up the possibility of implementing collision avoidance capabilities for robots with simultaneously execution of a desired task such as following a reference path. This greatly enhances the safety of surrounding people and therefore facilitates human-robot co-existence.

Task description

The methodology for MPC-based trajectory tracking and path following with simultaneous collision avoidance has already been developed for wheeled mobile robots at the Chair of Automatic Control [1,2] with implementations in C/C++ and MATLAB. This shall be re-implemented and extended for Boston Dynamics' Spot. Specifically, Spot should be able to follow the position of a person while reliably avoiding static and dynamic obstacles. To facilitate collision avoidance with dynamic obstacles, a prediction of their future movements is required. In more detail, the following tasks and sub-tasks arise

- Development of an MPC-based control algorithm using GRAMPC [3] with
  - collision avoidance
  - path following
  - use of the Python interface "PyGRAMPC"
- Modelling of
  - Spot's system dynamics
  - static and dynamic obstacles with predictions
- Global path planning
- Sensing tasks
  - Global localization using Optitrack Motion Capture
  - Obstacle detection using Spot's depth cameras
- Development of a simulation
- Execution of a real-world experiment

Requirements

Mandatory requirements for each individual group member

- Studies in Autonomy Technologies
- Commitment and the ability to work in a group
- Algorithmic development
- Solid knowledge of Python

Mandatory requirements as a group

- Experience with C/C++
- Knowledge of basic concepts in automatic control

Beneficial knowledge (not mandatory)

- MPC (Lecture: Numerical optimization and model predictive control)
- Path planning & collision detection (Lecture: Robotics 2)

Additional Information

- Inquiries will only be considered if accompanied by a short letter of motivation and a transcript of records.

References

[1] Völz, A. & Graichen, K. (2020). Prädiktive Pfadfolgeregelung für die kollisionsfreie Bewegungsplanung von Robotern. at - Automatisierungstechnik, 68(7), 557-570. https://doi.org/10.1515/auto-2020-0048

[2] A. Völz and K. Graichen, "A Predictive Path-Following Controller for Continuous Replanning With Dynamic Roadmaps," in *IEEE Robotics and Automation Letters*, vol. 4, no. 4, pp. 3963-3970, Oct. 2019, doi: 10.1109/LRA.2019.2929990.

[3] Englert, T., Völz, A., Mesmer, F., Rhein, S., & Graichen, K. (2019). A software framework for embedded nonlinear model predictive control using a gradient-based augmented Lagrangian approach (GRAMPC). Optimization and Engineering, 20(3), 769-809.

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