Direct Sensor Integration for Optimization Fabrics

MSc. Project Proposal at the Autonomous Multi-Robots Lab, Cognitive Robotics, TU Delft

Brief description:

As robotic manipulators are making their way into human shared environments, fast reactive behavior is needed to make sure that obstacles are safely avoided at all time. Trajectory optimization methods, such as Model Predictive Control, are widely used to guarantee collision avoidance during execution. While such methods perform well in slowly changing environments, their computational costs limit the applicability for mobile manipulation. Optimization fabrics offer an alternative to classic trajectory optimization techniques. Based on differential geometry, policies are composed of several components to form a highly reactive and fast behavior. In this project, direct sensor data should be integrated into the framework of optimization fabrics to remove the requirement for formal object detection algorithms.

Collision avoidance is crucial for every robotic application in a human-shared environment. Model Predictive Control is highly valuable to mobile robots as it leverages formal safety guarantees to mobile robots. However, the underlying optimization problem may be highly non-linear and difficult to solve [1]. Control-frequencies higher than 10Hz are generally hard to achieve [1]. For mobile manipulators, it becomes even more difficult to obtain reasonable control-frequencies. On the other hand, optimization fabrics offer a highly reactive motion planning framework for various types of robots [2]. Frequencies above 1kHz are realistic to obtain. However, so far, optimization fabrics depend on precise perception tools to realize safe motions. Specifically, optimization fabrics require a differentiable distance function between robot and obstacle. Sensors, such as Lidar or depth cameras, might directly offer such distance measures.

During this project, we aim at integrating direct sensor measurements into the framework of optimization fabrics. In a first step, the project is limited to mobile robots with lidar sensors. In the second phase, applicability to depths-cameras on mobile manipulators should be explored. It is the goal to extend the theoretical framework of optimization fabrics to dynamic environments using compositions of simple distance functions. The formal method should be evaluated in simulated environments (https://github.com/maxspahn/gym_envs_urdf), as well as the real world.

Desired qualities:

- Motivated and independent
- Good problem solving skills
- Enthusiasm for geometry
- Experience in python programming
- Basic understanding of Linux and git

Start Date: December 2021 (or later)

For further questions or to apply, please contact M.Spahn <m.spahn@tudelft.nl>. When applying, please provide a short motivation, up to date CV, a transcript of your current degree program and intended start date.

Group information: http://www.autonomousrobots.nl/

References:

[1] L. Hewing, M. Wabersich, M. Menner, M.Zeilinger. Learning-Based Model Predictive Control: Toward Safe Learning in Control, 2020

[2] N. Ratliff, K. v. Wyk, M. Xie, A. Li, M. A. Rana. Optimization Fabrics, 2020