MPC-based occlusion avoidance for object monitoring

Abstract: MPC have been used in the context of so-called perception aware applications, where vision-based constraints and objectives are integrated into the underlying optimization problem and solved in a receding horizon fashion. These approaches rely on the existence of a line of sight. However, this assumption is not easily verified in realistic scenarios, in uncontrolled and often cluttered environments. Occlusion avoidance is often tackled with geometric ray-casting to simulate the line of sight. But its evaluation is often computationally heavy, in particular when several occlusion obstacles are considered, and rely on a good knowledge of the environment. Moreover, these approaches rarely consider uncertainties associated with sensor measurements.

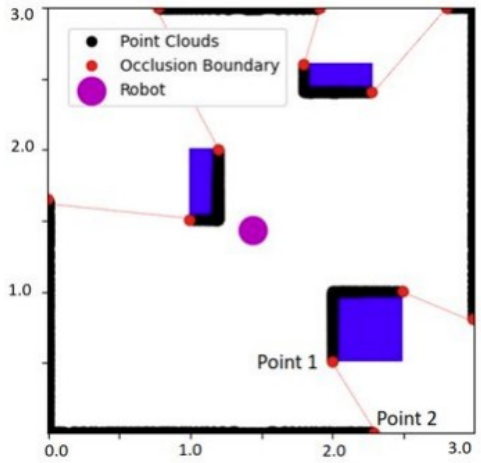

Figure 1: Boundary of occlusion obstacles [7]

On the other hand, chance-constrained MPC are stochastic optimal control technics which have been successfully employed to tackle collision avoidance in receding horizon schemes. This thesis aims to address the problem of real-time occlusion avoidance in object monitoring in cluttered environments, exploiting stochastic constraints.

Tasks:

- Survey existing literature on collision or occlusion avoidance in stochastic MPC schemes
- Investigate relevant mathematical formulation of the problem
- Familiarize with simulation environments and real-time MPC software
- Propose an implementation of the proposed methodology

Literature (indicative):

[1] Bryan Penin, Paolo Robuffo Giordano, and François Chaumette. “Vision-Based Reactive Planning for Aggressive Target Tracking While Avoiding Collisions and Occlusions”. In: IEEE Robotics and Automation Letters 3.4 (2018). https://doi.org/10.1109/LRA.2018.2856526

[2] Hai Zhu, Javier Alonso-Mora. “Chance-Constrained Collision Avoidance for MAVs in Dynamic Environments”. In: IEEE Robotics and Automation Letters 4.2 (2019). https://doi.org/s10.1109/LRA.2019.2893494

[3] Martin Jacquet and Antonio Franchi. “Motor and Perception Constrained NMPC for Torque-Controlled Generic Aerial Vehicles”. In: IEEE Robotics and Automation Letters 6.2 (2021). https://doi.org/10.1109/LRA.2020.3045654

[4] Xiaoxue Zhang, Jun Ma, Zilong Cheng, Sunan Huang, Shuzhi Sam Ge, Tong Heng Lee. “Trajectory Generation by Chance-Constrained Nonlinear MPC With Probabilistic Prediction”. In: IEEE Transactions on Cybernetics 51.7 (2021). https://doi.org/10.1109/TCYB.2020.3032711

[5] Ibrahim Ibrahim, Farbod Farshidian, Jan Preisig, Perry Franklin, Paolo Rocco, Marco Hutter. “Whole-Body MPC and Dynamic Occlusion Avoidance: A Maximum Likelihood Visibility Approach”. In: IEEE Int. Conf. on Robotics and Automation (2022). https://doi.org/10.1109/ICRA46639.2022.9811536

[6] Jacob Higgins and Nicola Bezzo. “A Model Predictive-based Motion Planning Method for Safe and Agile Traversal of Unknown and Occluding Environments”. In: IEEE Int. Conf. on Robotics and Automation (2022). https://doi.org/10.1109/ICRA46639.2022.9811717

[7] Roya Firoozi, Alexandre Mir, Gadi Sznaier Camps, Mac Schwager. “Occlusion-Aware MPC for Guaranteed Safe Robot Navigation with Unseen Dynamic Obstacles”. Online: https://arxiv.org/abs/2211.09156

Relevant Funded Project:

- Digiforest https://digiforest.eu/project/

Main supervisor: Kostas Alexis, Professor, NTNU

Co-supervisor: Martin Jacquet, Postdoctoral researcher, NTNU