SU 2020-2021, SMT, DISAL-SU33 Project Summary

Comparison of linear and nonlinear model predictive control strategies for trajectory tracking MAVs

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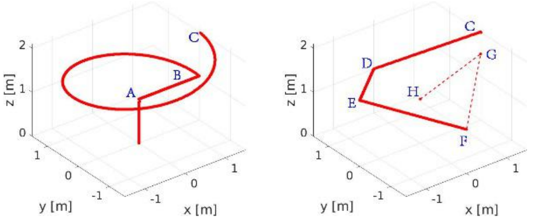
Micro Aerial Vehicles (MAVs) has been increasingly deployed to challenging missions such as surveillance, object delivery and rescue, etc. An essential component in MAV research is how to do trajectory tracking accurately. Model Predictive Control (MPC) is one of the most promising solution as it optimizes the performance over prediction horizon and takes constraint into account. Several literatures show Nonlinear MPC (NMPC) should be preferred for nonlinear systems with fast dynamics such as MAVs, while Linear MPC (LMPC) can be competitive if the trajectory is near the hovering condition. In this project, the aim is to compare LMPC and NMPC strategies on a real MAV engaged in trajectory tracking under as fair as possible conditions.

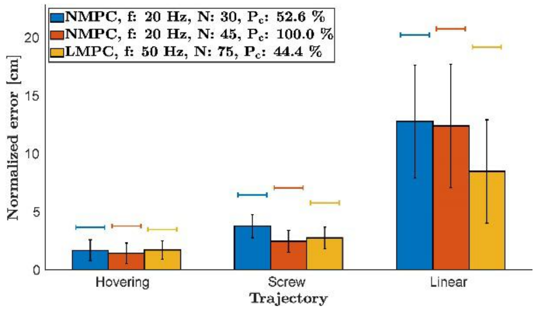


Reference trajectory (Points A to H) depicted in two separate plots for clarity. A: hovering point (10 s), B-C: screw trajectory (0.32 m/s), C-D-E-F: linear trajectory (0.4 m/s), G and H: goal tracking.

To achieve a performance well-tuned to the underlying hardware platform for both strategies, we integrate a disturbance observer based on an Extended Kalman Filter (EKF) to mitigate the issues related to model uncertainty and perturbations. We design various scenarios to cover most-common indoor trajectories in order to validate the results. Furthermore, to secure the objectiveness, we use the same cost penalty parameters and tolerances for both controllers, allocate similar computational budgets, and employ the same low-level QP solver.

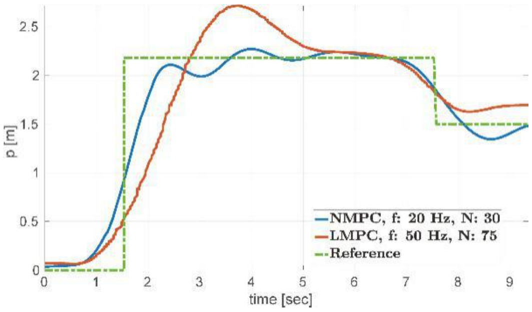
For LMPC, we linearize the dynamic system around hovering condition assuming small attitude angles and discretize the continuous-time model by the Zero Order Hold (ZOH) method. Furthermore, the OCP problem is transformed into a dense QP which can be solved efficiently by qpOASES. For NMPC, We choose the RTI-based SQP approach to obtain the solution.

Since LMPC requires less computation effort, We conducted several experiments to tune both controllers. Then, various trajectory tracking scenarios are designed and physical experiments are carried out with five repetition for LMPC and NMPC respectively with their optimal meta-parameters.



Normalized position error during different trajectories

As can be seen in the figures, for trajectories where the states of MAVs are near the hovering condition, LMPC can outperforms NMPC since its performance can be further improved by increasing the controller frequency and prediction horizon. While in aggressive trajectory such as step response, NMPC have a better performance with smaller rise time and overshoot.



Step response of the goal tracking