SS 2020-2021, SMT, DISAL-MP46 Project Summary

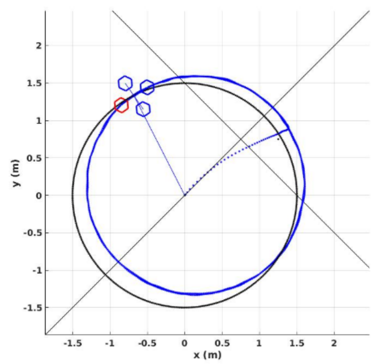
A Robust Model Predictive Control Approach for Trajectory Tracking MAVs under Wind Disturbance

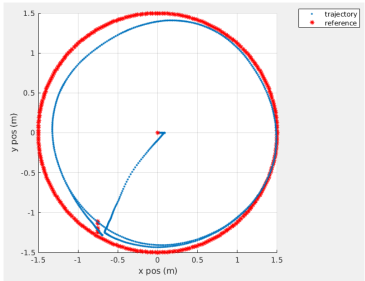
Harsh Jaiswal

Professor : Alcherio Martinoli
Assistant(s) : Kagan Erünsal

Modern Unmanned Ariel Vehicle (UAV) systems are experiencing increased sensing and communication capabilities, while at the same time cost is decreasing. Features such as Vertical Take-off and Landing (VTOL), good maneuverability combined with a simple mechanical design are some reasons why the use of UAVs has become central in many industries and businesses such as farming, construction, delivery, filmmaking, etc. The applications arising with the use of UAVs involve working in environments that have varied obstacles, so it is essential for the quadrotor to be able to follow a predefined trajectory efficiently in the presence of disturbances such as wind etc. A review of different flight control strategies was done, comparing classical control techniques such as PID, and optimal control strategies such as LQR. While they can be sometimes effective, constraints on the system cannot be defined. A common way to handle constraints is to use predictive constrained control techniques such as Model Predictive Control (MPC). Robust MPC techniques have been studied and developed over the years to deal with disturbances acting on the system. A specific formulation, Tube-based MPC was selected and applied for trajectory tracking on a linearized and decoupled system model.

The selected approach was implemented and evaluated in a MATLAB and Webots simulation environment. Three benchmark trajectories for tracking performance were tested. The formulation was done for both the nominal and the robust form of MPC, and a comparative study was carried out. A wind model was selected to represent the disturbance acting on the system and added as a drag force in the X and Y axes. This force was calculated by assuming a wind speed of 7m/s and acting on a cross section of the drone approximated with a bounding box.





The tracking performance was measured in terms of the average root mean squared error (RMSE) between the estimated position and the references. Robust MPC tests showed clear performance improvements over all trajectories in the MATLAB simulation tests for all benchmark trajectories. After validation of approach on MATLAB, the implementation on Webots was done with RobotOS (ROS) framework. This allowed for a more realistic representation of system by simulating different working rates of the systems and a realistic physics simulation engine.

The tracking performance for robust MPC in the Webots simulator showed improvements over the nominal MPC but not significant. This could be attributed to the fact that model mismatch caused the violation in assumed noise bounds. Further the convergence of algorithms used in Tube MPC could not be achieved. This was due to insufficient computational power of the laptop computer used to calculate them. This can introduce conservativeness to the design leading to poor performance.

I proposed improvements that can lead to a better performance in the future by firstly improving the offline computation using better PC. Further wind model can be given to the controller in the design phase and further model mismatch should be modelled as the noise. Finally real experiments on the drone would give better performance evaluation and directions for improvement.

Nonetheless, the MPC framework tested gave promising results in initial simulations and hope for future progress in flight control under disturbance.