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Proposal for a Master's Thesis Project

Safe control of aerial robots based on robust control barrier functions for wind turbine inspection

Background

Safety-critical control systems must satisfy stability/tracking objectives and safety constraints, where the safety constraints are prioritized. The safety of dynamical systems can be related to a set invariance. Any trajectory starting inside an invariant set will never reach the complement of the set. This can be assured by applying a control framework that unifies stability/tracking objectives, represented by a control Lyapunov function (CLF) or a nominal control law, and safety constraints, represented by control barrier functions (CBFs), through quadratic programming (QP).

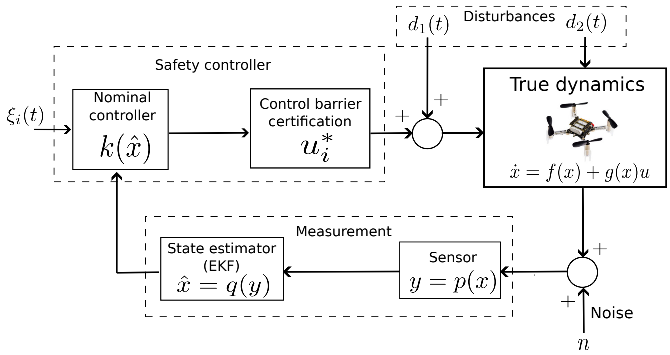

Figure 1: Control framework architecture. d_1 and d_2 represent the internal perturbations in the actuators of the aerial robot and external perturbations, respectively. The measurement block deals with the estimation of the states $\mathbf{x}$ that are not available in the system. This is usually done using the EKF. $\xi_i(t)$ states for the desired trajectories to be tracked.

Thesis Goals

The goal of this thesis is to design and develop an alternative CBF-based control structure, Fig. 1, that considers the whole dynamics of the aerial robot and satisfies different safety constraints. This will be achieved by modifying the nominal controller to optimally track a reference trajectory while dealing with uncertainties of the model and external disturbances.

Intermediate Goals

- Literature review of CBFs algorithms and CLFs control approaches [1, 2].
- Develop and design a safety controller based on CBFs and CLFs as follows: i) nominal controller that stabilizes the aerial robot and ii) CBFs certificates that consider model uncertainties and external disturbances.
- Design and implementation of the extended Kalman filter (EKF) for estimating the states of the drone.
- Implementation of the control framework architecture, depicted in Fig. 1, in Gazebo.
- Real-time test of the proposed architecture in the flying arena, emulating a wind turbine inspection.

Knowledge

Required:

- System theory, control theory, basics of optimization.
- Good programming skills (Python, C++, ROS).
- Experience using Gazebo sim
- Enthusiasm for learning

Not required, but a big +:

- Experience in real-time experiments with drones

References

[1] A. D. Ames, S. Coogan, M. Egerstedt, G. Notomista, K. Sreenath, and P. Tabuada. Control barrier functions: Theory and applications. In *2019 18th European Control Conference (ECC)*, pages 3420–3431, 2019.

[2] W. Xiao, C. G. Cassandras, and C. Belta. *Control Barrier Functions*, pages 7–18. Springer International Publishing, Cham, 2023.

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