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Title

Safe Attitude Controller Design for Multicopter via High-order Control Barrier Function

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Abstract

Safety is to make the output of interest confined in a prescribed safety set, and guaranteeing safety is one of the main objectives in control along with concerning stability. This property has attracted a lot of attention from many research fields due to its inherent importance in safety-critical systems. To guarantee safety, the control barrier function (CBF) approach has been extensively studied [1]. Variants of the CBF approach have been discussed for high-order relative degree systems, for example, exponential CBF (ECBF) and its generalization, high-order CBF [2].

Multicopter dynamics can be viewed as a cascade system with an inner-loop of rotational dynamics and an outer-loop of translational dynamics. Existing methods of safe control for multicopter mostly considered position and velocity safeties considering translational dynamics [3]. On the other hand, safe controller design for the safety criteria in the inner-loop of rotational dynamics has received relatively less attention, although the violation of attitude safety may cause severe degradation of the overall system's safety and stability because the response of the inner-loop system is typically much faster than that of the outer-loop.

In this study, a safe controller design method is proposed for the attitude dynamics of the multicopter based on high-order CBF approach. The proposed method considers two attitude safety criteria: i) total thrust force direction and ii) the magnitude of angular velocity constraints. These safety criteria are suggested to intentionally avoid unexpected flip maneuvers, such as inverted flying of multicopter, and too fast rotational maneuvers, respectively, to improve the overall system's safety during non-harsh missions. In particular, the high-order CBF approach is adopted to consider the total thrust force direction constraint because the total thrust force direction's relative degree is two. Numerical simulation is performed to demonstrate the performance of the proposed method in terms of the suggested safety criteria imposed for multicopter attitude dynamics.

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