Geometric control

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Summary

Problem at hand

In a variable pitch quadrotor the rotor thrust is varied by changing its blade pitch angle as opposed to its RPM. However, the control allocation in the actuator for generating the commanded thrust and torque is not a static, linear relation, but is nonlinear and dynamic. Further, transient disturbances are present due to rapid variations in aerodynamic load on the rotor dynamics while varying the blade pitch angle. Control law which is robust and stable globally is difficult to design but is essential.

The Big Idea

The proposed control law consists of a robust attitude controller augmented with a saturated thrust-feedback position controller. The control law is shown to almost-globally stabilize the tracking errors on SE(3) at an exponential rate.

Details about control law

The control law is designed in the following stages. First, an intrinsic geometric control law is designed on SO(3) in order to (almost) globally track a commanded attitude trajectory. The control law is based on back-stepping and is distinct and more efficient than the one presented in (Lee (2013)) where bounds on structural parameters and tracking rates are imposed, which inhibit the system performance. The proposed back-stepping design is then extended to include the first order actuator dynamics whose states are the net thrust and torques about the body axes. Finally, this control law is extended to the translational dynamics by designing a smooth saturated feedback law for the net rotor thrust which ensures (almost) globally stable tracking. Further, the double sided thrust generation capability has been exploited in order to design a control law which ensures that the zero equilibrium of the tracking errors is (almost) globally exponentially attractive, and is exponentially stable within the linear region of the saturation functions governing the thrust feedback. Numerical simulations with the proposed controller have been presented, where in the quadrotor initially recovers from a downward facing pose and tracks an aggressive trajectory.

Takeaway

First,a back-stepping based tracking control law is designed for the dynamics on SO(3) $\times$ R4 for the attitude and actuator dynamics. The control objective is to track a prescribed attitude trajectory Rd(t) and net thrust fd(t). In the second stage, this control law is modified to track a prescribed position trajectory on SE(3) $\times$ R4.