Stabilizing Controller Design Using an Iterative LMIs Approach for Quadrotors

Oussama Benzinane, Andreas Rauh

Distributed Control in Interconnected Systems
Carl von Ossietzky Universität Oldenburg
26111 Oldenburg, Germany
o.benzinane@gmail.com, andreas.rauh@uol.de

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Introduction

Linear Matrix Inequalities (LMIs) have recently gained a momentum due to the increasing performance of computing hardware. Many current research activities rely on the advantages of this growth in order to design linear state feedback controllers with provable stability and performance guarantees. As an example, the authors of the paper [1] have established an approach based on an iterative LMI solution to obtain the gain matrices of robust controllers and state observers simultaneously in the presence of bounded parameter uncertainty and stochastic noise.

On the basis of the aforementioned work, this presentation discusses possible paths to follow in order to reduce the dependency effect and the wrapping effect that may turn the control and observer synthesis pessimistic.

Control Loop Structure

Consider the cascaded structure of a quadrotor control as it has been proposed in the paper [2]. The state-dependent model for the inner attitude control loop from this paper has firstly been reformulated in terms of a quasi-linear state-space representation by a suitable factorization of the state equations. Defining bounded intervals for the state vector components that are included in the system matrices, a polytopic realization can be constructed. Hence, an observer-based state feedback control approach can be implemented, after temporal discretization of the continuous-time state equations, with the structure depicted in Fig. 1.

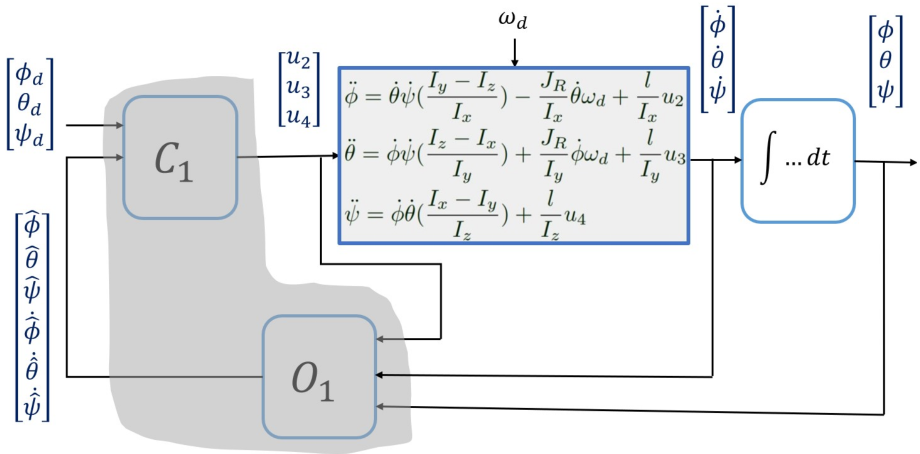

Figure 1: Block diagram of the discrete-time observer-based state feedback control system.

In this graphical representation ϕ, θ, ψ are respectively the roll, pitch, and yaw angles, while ω_d represents disturbances caused by couplings with the outer velocity and position control loops that are not further considered in this contribution; J_R is the rotor inertia while I_x, I_y, I_z are the parameters on the diagonal of the inertia matrix. The blocks C_1 and O_1 are respectively the controller and the state observer. The command signals u_2, u_3, and u_4 are the rolling, pitching, and yawing torque, respectively, which depend on the speed of each rotor.

Preliminary Results and Ongoing Work

Using the proposed approach, it is possible to find controller and observer gains jointly for which stability can be proven despite state and parameter uncertainties with eigenvalue domains strictly included in the interior of the unit circle in the complex z-plane. The response for a desired hovering state is shown in the Fig. 2, where the initial states are fixed at 10°. The resulting control signals are reasonable in their amplitudes and setting times as shown in Fig. 3.

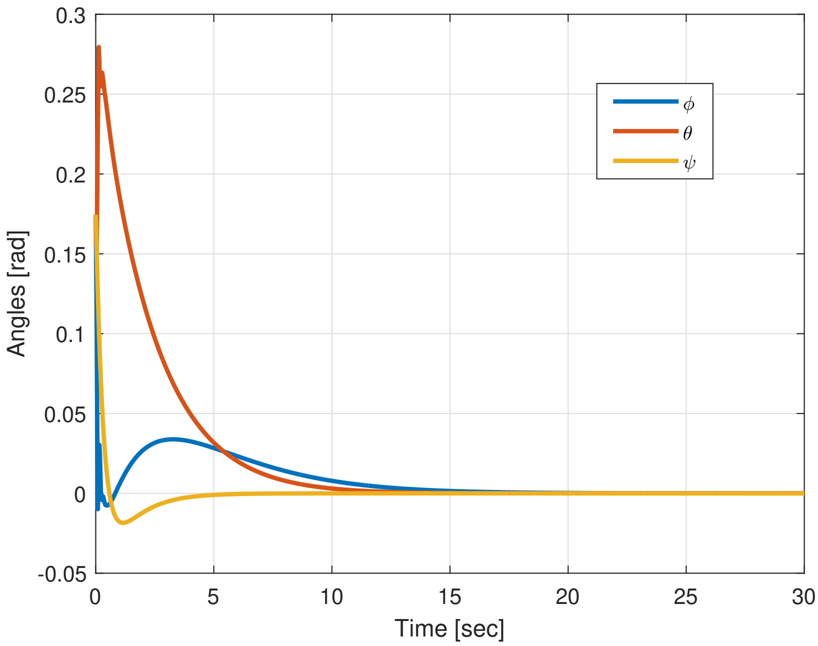

Figure 2: Regulation of the quadrotor's attitude.

So far, the decay rates of the state vector components towards the equilibrium state are restricted by the use of the polytopic uncertainty model in combination with a parameter-independent Lyapunov function approach. In such cases, infeasibility of the LMIs may occur if excessively large distances of the eigenvalues from the boundary of the unit circle are desired.

To overcome this problem, the authors in the cited paper [3] have provided a tool, on the basis of the theorem of Ehlich and Zeller, that provides the possibility to balance between conservatism and the calculation effort. Therefore, ongoing research focuses on combining this method with the algorithm presented in [1] to obtain the gain

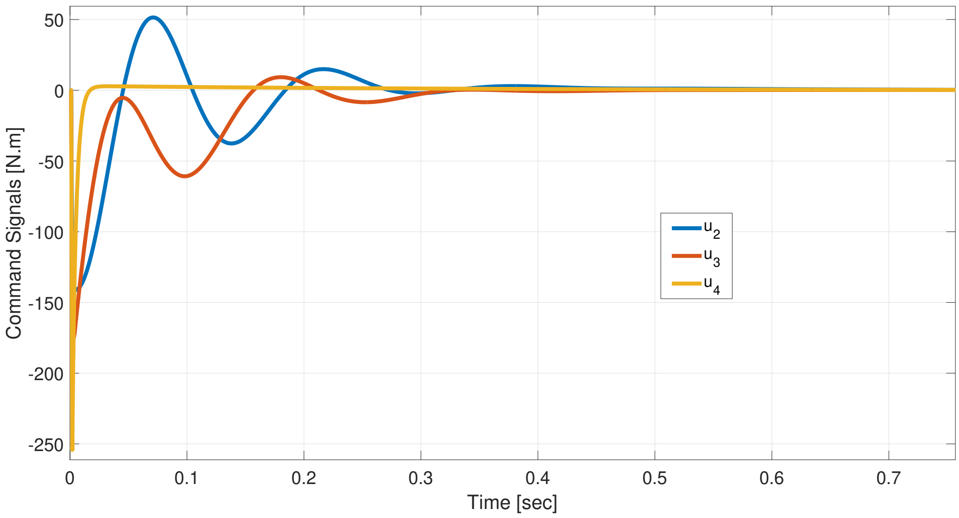

Figure 3: Command Signals applied to the attitude model.

matrices of the controller and the observer with less conservatism and a moderate computational effort.

References

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