

Abstract

Hierarchical Actor–Critic Approximate Dynamic Programming for Quadrotor UAVs on SE(3)

Optimal control of a quadrotor is complicated by two facts: the vehicle is underactuated, and its attitude evolves on a nonlinear manifold, so the tracking Hamilton–Jacobi–Bellman equation is both time-varying and nonlinear with no closed-form solution. The seminar will present an online, model-based actor–critic architecture that learns approximately optimal policies for both the translational and rotational dynamics while the vehicle flies.

The design is hierarchical. An outer loop learns a policy for the translational dynamics while an inner loop learns a torque policy. Each loop carries its own critic and actor, trained from the Bellman error along the trajectory under a persistence-of-excitation condition.

The central difficulty is that the two loops are not separable. Attitude error contaminates the translational dynamics through the thrust direction, and the angular acceleration commanded by the inner loop is obtained by differentiating the learned outer-loop policy through the extraction map, so the outer loop's learning transients feed back into the inner loop. Rather than assume timescale separation, both coupling channels are retained explicitly. Each loop is shown to be input-to-state stable with respect to the other, and the interconnection is certified by a nonlinear small-gain argument; the required small-gain condition is derived from the boundedness of the extraction gain on the operating set rather than assumed. The result is ultimate boundedness of the closed-loop signals together with approximate optimality of both learned policies.

The framework is validated on aggressive reference manoeuvres currently in high-fidelity simulation engines (IsaacSim), future work entails validations through proper experiments.

Bio

Mohammed is a PhD researcher in Mechanical and Aerospace Engineering at Carleton University in Ottawa, Canada, working with Prof. Hashim on geometric control and reinforcement learning for aerial robotics. His current work develops hierarchical approximate dynamic programming methods for underactuated vehicles evolving on Lie groups, with an emphasis on stability guarantees for learned controllers. He holds a BSc in Computer and Control Systems Engineering and an MSc from Sapienza University of Rome.