Adaptive Attitude Control of an Unmanned Helicopter

Giulia Bertolani[1)], Andrea Dan Ryals[2)], Fabrizio Giulietti[1)], Lorenzo Pollini[2)]
[1)]University of Bologna (Forlì Campus)
[2)]University of Pisa

Abstract:

Unmanned Aerial Vehicles (UAV) have become extensively used in a wide range of flight applications, getting a large interest in the scientific and industrial community. In particular, miniature battery-powered fixed and rotary-wings vehicles are suitable for numerous applications, such as load transportation, aerial photography and video shooting, search & rescue, surveillance, tracking etc. Compared to fixed-wing aircrafts, rotorcrafts (multi-rotors and helicopters) have many evident advantages due to their vertical flight and hovering capability. However, these vehicles may operate in potentially obstructed and constrained environments, demanding high capability of the autopilots. For this reason, there is the necessity to design rotorcraft baseline controllers with a considerable high level of robustness against the uncertainties and possible disturbances. The need to improve classical baseline PID-based controllers has contributed to a revived interest in adaptive control techniques. One promising adaptive control technique is $\mathcal{L}_1$ adaptive control, whose main advantage is to decouple robustness from fast adaptation [1]. The adaptation rate can be set as high as the hardware can handle. The separation between adaptation and robustness is achieved by the insertion of a bandwidth-limited filter in the feedback path, which ensures that the control signal stays in the desired frequency range and avoids that adaptative terms oscillations propagate to the controlled system. In figure 1 a general $\mathcal{L}_1$ adaptive control scheme is shown, where u_{bsl} and u_{ad} are baseline controller and adaptive controller input respectively, $\hat{y}$ and y are the predictor estimated output and plant real output, $\tilde{e}$ is the estimation error computed as $\tilde{e} = \hat{y} - y$ and r is the system reference.

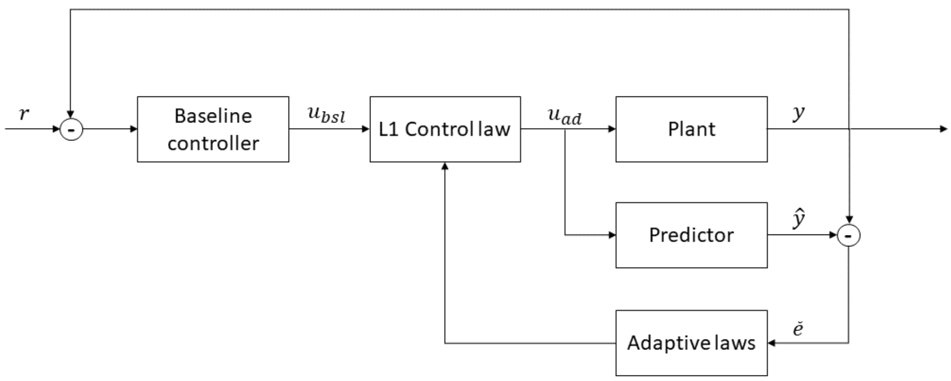

Figure 1: L1 adaptive control general scheme

$\mathcal{L}_1$ adaptive control display great success in enhancing performances and robustness of fixed-wing aircraft [2] [3]. Existing literature on $\mathcal{L}_1$ adaptive control applied to miniature helicopters [4], [5], [6] is mainly focused on numerical simulations.

This paper presents the $\mathcal{L}_1$ adaptive control scheme for a small-scale electrically powered remotely-piloted helicopter. Baseline attitude controller is designed as four linear PID-based controller on longitudinal, lateral, yaw and vertical axes.

To prove $\mathcal{L}_1$ adaptive control performances longitudinal speed control augmentation is implemented and tested in simulation. It consists of an outer loop caring for generating pitch references depending on the longitudinal speed error that an inner attitude loop follows. The inner loop is $\mathcal{L}_1$ augmented. Simulations show robustness towards output and input disturbances, as illustrated in figures 2 and 3 respectively. Both figures use the same color scheme with reference in red(ref), longitudinal speed using $\mathcal{L}_1$ augmentation in green (uad) while speed obtained by baseline controller alone is in blue (ubsl). Output disturbance is applied over measured longitudinal acceleration at time t = 20s and is a step with a magnitude of 2[m/s^2]. Input disturbance is applied over longitudinal cyclic at time t = 20s and is a step with a magnitude of 0.02[rad]. Results clearly show improved performances when $\mathcal{L}_1$ adaptive control augmentation is applied.

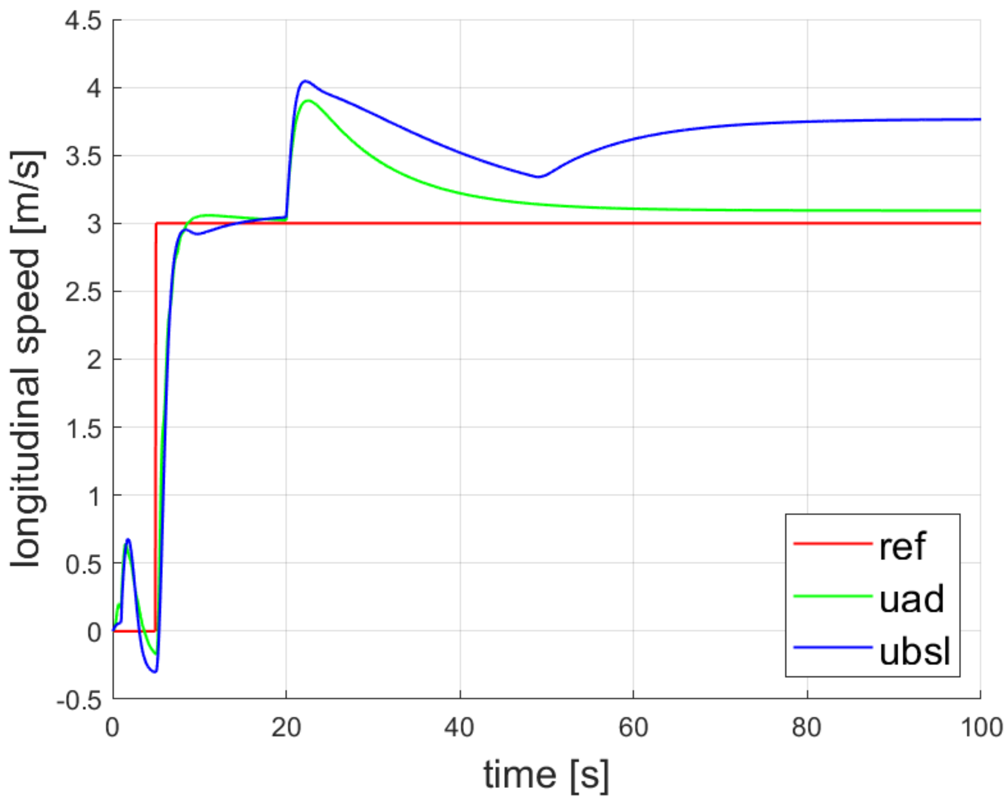

Figure 2: output disturbance

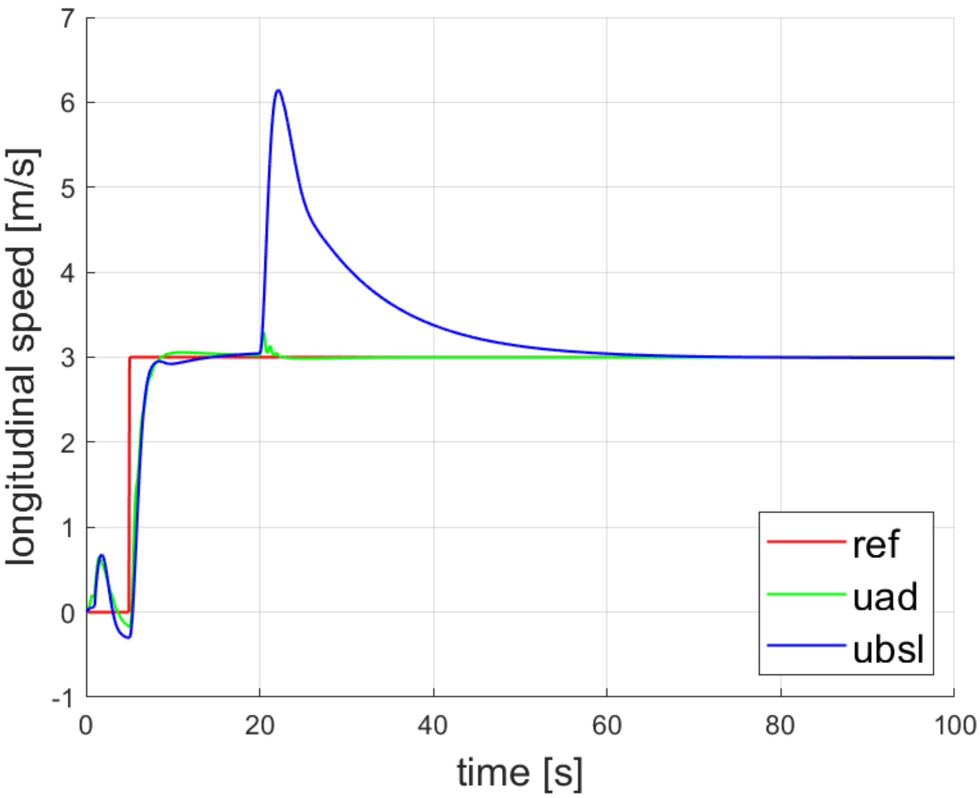

Figure 3: Input disturbance

The final target of this work is to experimentally test during a flight of a small-scale helicopter the robustness and performance augmentation capabilities of the $\mathcal{L}_1$ adaptive control. The original contribution of this work will consist of moving from simulation results to real in-flight applications.

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