Use the Force, Lyapunov! A Novel Quadcopter Motor Controller Using Force Sensor Feedback

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Quadcopter drones are poised to become a widely used technology with important humanitarian, civil and military applications. However, these flying robots face significant and complex aerodynamic disturbances which interrupt controlled, stable flight and impact the quadcopter's reliability, agility, safety, and autonomy. Currently, quadcopter brushless DC motors are run in open loop, and the task of compensating for motor control error lies with the pilot or upper-level, slower control loops. This research presents a novel nonlinear proportional-integral-derivative motor controller incorporating thrust feedback from a custom force sensor installed on the motor mount. It was hypothesized that this quadcopter motor controller would maintain a constant propeller thrust under varying conditions of supply voltage, proximity to surfaces, wind speed, and angle of attack, unlike a traditional quadcopter motor propeller system whose thrust in these conditions was predicted to deviate significantly from the set point. This work included a Lyapunov stability analysis showing the design was globally asymptotically stable. It also included a Matlab/Simulink model with outputs and analysis demonstrating the simulated design's stable and precise setpoint tracking and robustness. Lab experiments tested the physical system's response both with and without the controller, subjecting it to the conditions described above. Experiments supported the hypothesis well by showing the controller's remarkable ability to consistently maintain a desired propeller thrust in the presence of perturbations that caused thrust deviations in the traditional uncontrolled system of over 40%. With the controller enabled, thrust deviated from the desired setpoint by less than 1% in every case.

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Second Award of $2,000