Actuator Dynamic Compensator for Incremental Nonlinear Control

Introduction

Multi-rotor drones, known for their agility, still face challenges in following highly maneuverable references or rejecting random wind disturbances due to the dynamics of their actuators. The rotor speed commands generated by the controller cannot be executed instantaneously by the motors. This limitation impacts their accuracy in outdoor windy conditions and reduces their agility in cluttered environments.

Incremental nonlinear control, an adaptive control method, has shown promising results in enabling quadrotors to conduct agile flights and counteract wind disturbances. It leverages instantaneous sensor measurements to compensate for some of the model's knowledge gaps, making it resilient against model uncertainties. Although the incremental linearization technique enhances the robustness of this approach, its potential to mitigate the limitations of actuator dynamics has not been fully explored.

In this research, the student will explore a technique known as "command advancing" within the realm of incremental nonlinear control. Preliminary studies have demonstrated its effectiveness in overcoming the limitations posed by first and second-order dynamic actuators. The student aims to refine and implement this technique on a BLDC (Brushless DC electric) motor and subsequently assess its performance on a quadrotor drone.

Research question

- What strategies can effectively overcome the limitations of actuator dynamics within the incremental nonlinear control framework?
- How can the command advancing technique be effectively implemented in incremental nonlinear control for a BLDC motor?

What we expect from you:

- Highly motivative.

- Strong interest in and knowledge of linear / nonlinear control theories.
- Experience in BLDC motor control, or general hands-on experience with other mechatronic devices.
- Experience with real-world experiments with drones is a bonus.

What you can learn from this project:
- Hands-on experience with the modelling and control of multi-UAV (aerial robot) systems.
- Hands-on experience and knowledge in robotic mechatronics.
- Chance to publish in high-ranking robotic and ML conferences/journals.

Reference
[1] Sun, S., Romero, A., Foehn, P., Kaufmann, E., & Scaramuzza, D. (2022). A comparative study of nonlinear mpc and differential-flatness-based control for quadrotor agile flight. *IEEE Transactions on Robotics*, *38*(6), 3357-3373.
[2]Tal, E., & Karaman, S. (2020). Accurate tracking of aggressive quadrotor trajectories using incremental nonlinear dynamic inversion and differential flatness. *IEEE Transactions on Control Systems Technology*, *29*(3), 1203-1218.
[3]Smeur, E. J., Chu, Q., & De Croon, G. C. (2016). Adaptive incremental nonlinear dynamic inversion for attitude control of micro air vehicles. *Journal of Guidance, Control, and Dynamics*, *39*(3), 450-461.

Contact:
If you are interested in conducting this cool project, please contact Dr. Sihao Sun via s.sun-2@tudelft.nl

When applying, please provide a short motivation, an up-to-date CV, a transcript of your current degree program and an intended start date.

Short bio of the supervisor:
Dr. Sihao Sun is a new member of CoR funded by the NWO talent program “Veni” grant. He has intensive experience in the control, planning, estimation and machine learning of aerial robotic systems by working with Prof. Davide Scaramuzza, Prof. Antonio Franchi, and Prof. Guido de Croon. He’s the winner of the Best Paper Award of Robotics and Automation Letters (RAL) and the NASA Tech Brief award. He has supervised over 20 MSc students, and three of them won CumLaude respectively in TU Delft and ETH / Zurich.