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Proposal for a Master's Thesis Project

Nonlinear control for a tilting quadrotor

Background

Tilting quadrotors are innovative unmanned aerial vehicles (UAVs) that offer enhanced agility and versatility compared to traditional quadcopters. By integrating tilting mechanisms into their design, these quadrotors can dynamically adjust the orientation of their rotors, enabling rapid shifts in flight direction and improved maneuverability. However, the tilting mechanisms increase the complexity of control algorithms, robustness, and stability analysis as shown in [1]. Despite that there has been comprehensive research on tilting multirotor control systems, the spectrum of hardware/control designs remains fragmented.

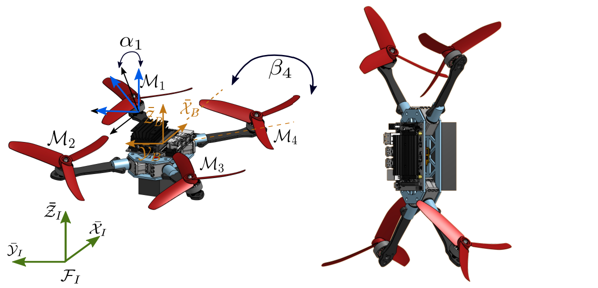

Figure 1: Proof-of-concept of the tilting quadrotor. $\mathscr{M}_i$ stands for the $i-$th rotor and β_4 represents the angle between the $x-$body axis and x axis of the ith propeller and α_1 is the tilt angle of the $\mathscr{M}_1$.

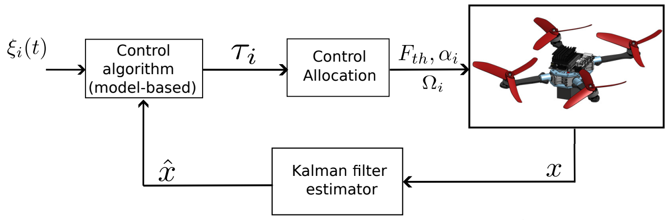

Figure 2: Proposed control architecture of the tilting quadrotor. τ_{th} is the control input and $\hat{x}$ the full estimated state of the system. $F_{th}, \alpha_i, \Omega_i$ denote the total thrust, the tilting angle, and the angular velocity, respectively.

Thesis Goals

This thesis aims to design a non-conventional tilting drone and a framework control architecture capable of achieving enhanced agility, stability, and robustness for agile flight maneuvers and versatile mission capabilities in dynamic environments. Simulation and experimental tests will be carried out to validate the practical stability of the tilting quadrotor. This will be accomplished by enhancing the work developed in [2], with nonlinear controllers that handle input/output constraints and uncertainties and unmodeled dynamics.

Intermediate Goals

- Literature review of tilting quadrotors and their control algorithms [2, 3].
- Design a simulation environment, based on Gazebo, that emulates the tilting quadrotor depicted in Fig. 1.
- Develop the control software architecture, shown in Fig. 2, that stabilizes the aerial vehicle. The control algorithm block represents the nonlinear MPC-like controllers.
- Simulation tests of the overall control architecture in the emulated environment.
- Assembling the designed drone and conducting real-time experiments in the flying arena.

Knowledge

Required:

- System Theory, optimization, and advance control.
- Good programming skills (Python, C++, ROS).
- Experience using Gazebo sim
- Enthusiasm for learning

Not required, but a big +:

- Experience in real-time experiments with drones

References

[1] K. Singh, M. Mehndiratta, and M. Feroskhan, "Quadplus: Design, modeling, and receding-horizon-based control of a hyperdynamic quadrotor," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 58, no. 3, pp. 1766–1779, 2022.

[2] A. Offermann, *Conception et validation d'un robot apte à effectuer des mesures sur ouvrage d'art.* PhD thesis, 2021. Compiègne, France.

[3] A. Offermann, P. Castillo, and J. De Miras, "Nonlinear model and control validation of a tilting quadcopter," in *2020 28th Mediterranean Conference on Control and Automation (MED)*, pp. 50–55, 2020.

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