Internship: Physics-guided Neural Network (PNN) feedforward control of a convertible delta-wing aircraft

Supervisors: Tudor-Bogdan Airimitoaie (University of Bordeaux), Mircea Lazar (Eindhoven University of Technology).
Keywords: feedforward control, convertible aircraft, physics-guided neural networks, differentially flat systems.

Internship description:

Convertible aircraft combine the advantages of classical airplanes (wing design to reduce fuel consumption and allow for long distance flights) with those of multicopters (hover, manoeuvrability at low speed, take-off and landing without the need of a runway). There are two main convertible aircraft designs:

1. tilt-rotor, where only the rotors tilt, while the aircraft body and the wings are always horizontal;
2. tilt-wing, where the wings and the rotors tilt together, while the body is fixed.

We are interested in a tilt-wing delta-wing convertible aircraft as the one that can be seen in Fig 1. Notice that the body is not represented in this figure. That is because we are considering a single wing design with a minimum dimension body that can be incorporated inside the wing for the transportation of objects such as a a small video camera.

This aircraft is capable of vertical take-off and landing (VTOL) and hover. Its horizontal flight is energy efficient (w.r.t. a conventional multicopter) as its fixed-wing design allows it to harvest wind energy for its own flight.

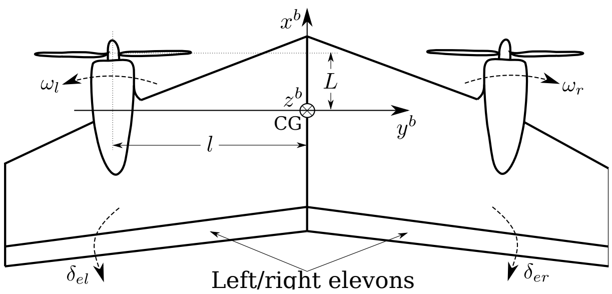

Figure 1: Schematic representation of a delta-wing aircraft capable of VTOL and horizontal flight.

From a control system perspective, we are interested in the transition phase between VTOL/hover and horizontal flight in order to ensure a safe and minimum energy transition.

We propose an architecture combining feedback and feedforward controller components. The main objective of this internship is the design of the feedforward part. Previous work has concluded that the convertible delta-wing aircraft, subject to some assumptions, is flat in hover and also in horizontal flight. However, the flatness analyses are distinct in the two phases. The mentioned assumptions, as well as the differences between the flatness analyses, makes the feedforward control based on the flatness property alone have poor performance in the transition phase. Inspired by recent results in the feedforward precision motion control using Physics-guided Neural Networks (PNN), we aim at enhancing the flatness-based feedforward control with a neural network to improve performance.

The main tasks of this internship are:

- Study the existing delta-wing aircraft modelling, flatness analysis and Matlab/Simulink code (previous internship report).
- Understand the principles of PNN feedforward control and apply them for the delta-wing aircraft.
- If necessary, transfer of the Matlab code to Python to use existing neural networks design and training tools, such as pytorch or tensorflow.

Skills: a good understanding of control systems and knowledge of at least one controller design methodology (such as PID, $\mathcal{H}_\infty$,...), good coding skills in Matlab/Simulink and Python are highly desired. Knowledge of nonlinear systems' analysis (including flat dynamic systems) and neural networks design and training is a plus.
Period: February - July 2024 (6 months).
Grant: approx. 600€/month.
Location: IMS-lab, UMR 5218, 33405 Talence Cedex, France.
How to apply: send CV, motivation letter, and available grade transcripts to tudor-bogdan.airimitoaie@u-bordeaux.fr