Energy-Efficient Trajectory Generation for Battery-Powered Rotary-Wing UAVs

Master Thesis Project (6 months)

Motivation: The last decade has seen a dramatic diffusion of battery-powered rotary-wing micro Unmanned Aerial Vehicles (UAVs, a.k.a. MAVs). Their low price, maneuverability and small launch-and-landing footprint has made them extremely popular, but their aerodynamics have disadvantages, such as the relatively poor energy efficiency, that divides multi-rotor UAVs from conventional helicopters and fixed-wing aircraft. The poor capacity of existing lithium-ion polymer (LiPo) batteries is another issue, typically limiting the flight endurance to 15 to 30 minutes.

Two multi-rotor aerial platforms developed at RIS, LAAS-CNRS

Goal of the Project: In order to address this issue, several works in the literature have tried to improve the mechanical design and the power system of quadrotors, the simplest class of rotary-wing micro UAVs (see e.g. [1]-[3]). Instead of optimizing the physical parameters, in this project low-cost off-the-shelf quadrotor platforms will be considered, and the goal will be to design *intelligent path-planning strategies* to save energy and extend endurance. Indeed, by leveraging the model of the DC motors, Electronic Speed Controller (ESC), and on-board LiPo battery, the objective will be to generate minimum-energy trajectories for a quadrotor UAV. In particular, the student will focus on the following two problems:

- Make the computation of the optimal trajectories generated with the approach recently proposed in [4], amenable to a real-time implementation on a resource-constrained aerial robot.
- Experimentally validate the optimal trajectories on a real quadrotor UAV, and quantify energy saving in different flight conditions.

At the end of the project, the possibility to extend the method in [4] to non-conventional aerial platforms such as fully-actuated rotorcraft [5], [6], will be also explored (see e.g., http://homepages.laas.fr/afranchi/robotics/?q=node/294).

Practical Info: The total duration of the project is around six months. The student will be paid according to the French regulation.

Application: In order to apply, please send an e-mail to antonio.franchi@laas.fr and fabio.morbidi@u-picardie.fr including your: 1) Curriculum Vitae, 2) Bs and Ms transcripts. Please use the tag [mtp-EnergyAerialTraj] in the e-mail subject.

Advisors and Labs: The master thesis project will be supervised by:

- Antonio **Franchi** (Permanent scientist at LAAS-CNRS, Toulouse, France): http://homepages.laas.fr/afranchi/robotics/
- Fabio **Morbidi** (Associate Professor at the Université de Picardie Jules Verne, Amiens France): http://home.mis.u-picardie.fr/~fabio/

The student will work with the:

- "Robotics and Interactions" (RIS) group at LAAS-CNRS, Toulouse, France (https://www.laas.fr/public/en/ris). The RIS group is at the forefront of trajectory generation and planning for aerial robots, being one of the partners of the recent EU FP7 ARCAS (2009-2015) and H2020 AeRoArms (2015-2019) projects. Available platforms in RIS: an indoor flying arena equipped with a motion capture system with up to 30-cameras, 12 custom-built multi-rotor platforms running an in-house software allowing a fine control down to the ESC BLCD motor level.
- "Robotic Perception" group, MIS Laboratory, Université de Picardie Jules Verne, Amiens, France (http://www.mis.u-picardie.fr/equipe-pr). Available quadrotor platforms: DJI Phantom 2 and 4, Emax Nighthawk Pro, and AscTec Pelican.

Required Skills:

- Study in the field of engineering, computer science, physics, or mathematics
- Good knowledge of aerial robotics.
- Expertise in nonlinear and optimal control of dynamical systems.
- Programming skills: Matlab, C/C++ languages, solvers for dynamic optimization (ACADO Toolkit, GPOPS, etc.).
- Good English skills.

References:

[1] "*The Triangular Quadrotor: A More Efficient Quadrotor Configuration*", S. Driessens, P. Pounds, IEEE Trans. Robot., vol. 31, n. 6, pp. 1517-1526, 2015.
[2] "*Energy Management for Indoor Hovering Robots*", J.F. Roberts, J.-C. Zufferey, D. Floreano, in Proc. IEEE/RSJ Int. Conf. Intel. Robots Syst., pp. 1242-1247, 2008.
[3] "*Power and Endurance Modelling of Battery-Powered Rotorcraft*", A. Abdilla, A. Richards, S. Burrow, in Proc. IEEE/RSJ Int. Conf. Intel. Robots Syst., pp. 675-680, 2015.
[4] "*Minimum-Energy Path Generation for a Quadrotor UAV*", F. Morbidi, R. Cano, D. Lara, in Proc. IEEE Int. Conf. Robot. Autom., pp. 1492-1498, 2016.
[5] "*Modeling and Control of FAST-Hex: a Fully–Actuated by Synchronized–Tilting Hexarotor*", M. Ryll, D. Bicego, A. Franchi, in 2016 IEEE/RSJ Int. Conf. Intel. Robots Syst., 2016, pp. 1689-1694, Daejeon, South Korea 2016.
[6] "*A novel overactuated quadrotor unmanned aerial vehicle: modeling, control, and experimental validation*", M. Ryll, H.H. Bülthoff, P. Robuffo Giordano, IEEE Trans. Contr. Syst. Tech. vol. 23, n. 2, pp. 540-556, 2015.