PostDoc subject: Estimation and adaptive control for a tethered kite for vessel propelling

This PostDoc is proposed in the context of the KiWin project led by the Beyond the Sea company. The goal of the project is to give sailors the control over the force of the wind to propel all vessels, optimize their energy consumption and reduce their greenhouse gas emissions. A reduction of fuel consumption by 20% for transatlantic trips is targeted.

The KiWin project is a joint project between Beyond the Sea, KleyFrance (company expert in mechatronics systems), University of Bordeaux (IMS-lab, in charge of designing the control and supervision algorithms), University of Montpellier (development of an experimental test-bench), École de l'Air et de l'Espace (specialized in aerodynamic modelling). The project is funded by Bpifrance (Banque Publique d'Investissement) and several PhD thesis will start in September 2023.

The proposed PostDoc will be held at the IMS-lab (Integration from Material to Systems), which brings together fundamental research, engineering and technology, emphasizing an integrative systems approach in the disciplines of Information Technologies. IMS is a joint research unit for the French National Center for Scientific Research (CNRS), University of Bordeaux and Bordeaux INP. The PostDoc researcher will integrate the Automatic control group in the CRONE thematics team. The general subject of thematics research is the (real or complex) non-integer derivative as operator and modelling tool, its synthesis extended to complex field and also its applications in the engineering sciences. More precisely, in reason of the affiliation of this thematics to the Automatic control group, which is constituted of 3 components, one particularly privileged research axis is in applying fractional order derivative in automatic control, notably in system identification through non integer model, and in robust control through the CRONE control (Commande Robuste d'Ordre Non Entier, a French acronym for Robust Control of Non Integer Differentiation).

Previous research related to the KiWin project:

A first PhD thesis carried out at the IMS-lab in collaboration with Beyond the Sea and defended by Baptiste Cadalen in 2018 dealt with the modelling of the kite during its dynamic flight, the definition of acceptable trajectories and the design of robust linear control laws using the CRONE methodology. This study showed results confirming the feasibility of the industrial objective.

More recently, the PhD thesis of Asma Achnib (defended in 2019) and that of Evgeny Shulga (in collaboration with Stellantis company, defended in 2022), considered the addition to a linear robust control design methodology (CRONE) of an optimal/anticipative component, first linear and based on the optimization of FIR filters, then nonlinear and using an optimal trajectory planning inspired by MPC control.

Among the approaches for supervision, we first distinguish those based on knowledge models. In Rim Rammal's PhD thesis (defended in January 2021), we have developed a set of methods based on flatness theory for the diagnosis of nonlinear systems. These methods imply a precise knowledge of the model of the physical system which can be difficult to establish. Machine learning methods make it possible to circumvent this difficulty, but a large amount of data is necessary for learning the models/detectors used. After a first work carried out as part of a Master's internship at the IMS laboratory, Mathias Lecroart's PhD thesis (started in October 2021) focuses on the combination of these two classes of methods in a context of predictive maintenance.

Proposed PostDoc research:

In addition to two PhD thesis starting in fall 2023, we are recruiting one or two PostDoc researchers that should have strong knowledge in one or more of the following areas:

- Sensor data fusion for a numerical twin of the kite system and improving control and supervision algorithms;
- Real-time trajectory optimization based on extremum-seeking;
- Iterative learning control in order to enhance the feedback control algorithms.

Bibliography:

1. B. CADALEN, F. GRIFFON, P. LANUSSE, J. SABATIER and Y. PARLIER : A control solution for a tethered kite trajectory tracking with application to ship propulsion – Journal of Dynamic Systems, Measurement and Control, Vol 42, December 2020.
2. A. ACHNIB, T.B. AIRIMITOAIE, P. LANUSSE, M. AOUN, S. ABRASHOV and M CHETAOUI : Discrete-time robust control with an anticipative action for preview systems – Journal of Dynamic Systems, Measurement and Control of the ASME (JCR), doi: 10.1115/1.4041711, 2018.
3. A. ACHNIB, T.B. AIRIMITOAIE, P. LANUSSE : Robust Design of an Anticipative Feedforward-feedback Controller for MIMO Systems – International Journal of Control, Automation, and Systems, vol. 20, no. 3, pp 924-940, DOI: 10.1007/s12555-021-0034-z, 2022.
4. S. SHULGA, P. LANUSSE, T.B. AIRIMITOAIE, S. MAUREL and A. TRUTET – Model Predictive Control of engine intake manifold pressure with an uncertain model – 7th NonLinear Model Predictive Control (NMPC'2021) – Bratislava, Slovakia, July 11-14, 2021.
5. R. RAMMAL, T-B. AIRIMITOAIE, P. MELCHIOR, F. CAZAURANG. Unimodular Completion for Computation of Fractionally Flat Outputs for Linear Fractionally Flat Systems. 21th World Congress of the International Federation of Automatic Control, July 2020, Berlin, Germany.
6. A. ARIBI, C. FARGES, M. AOUN, P. MELCHIOR, S. NAJAR, M.N. ABDELKRIM, Fault detection based on fractional order models: Application to diagnosis of thermal systems, Communications in Nonlinear Science and Numerical Simulation, numéro 10, volume 9, pages 3679-3693, 2014.
7. R. RAMMAL, T-B. AIRIMITOAIE, F. CAZAURANG, J. LEVINE, P. MELCHIOR. On the Choice of Multiple Flat Outputs for Fault Detection and Isolation of a Flat System. 21th World Congress of the International Federation of Automatic Control, July 2020, Berlin, Germany.

8. M. LECROAT. Étude et mise en œuvre de solutions pour pallier le manque de données, en vue d'entraîner ou de tester des algorithmes d'apprentissage profond dédiés à la maintenance prédictive. Stage de Master de l'Université de Bordeaux, Septembre 2021.

Duration: 12-24 months.

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Application: send CV, letter of motivation, 2 letters of recommendations, copy of one of candidate's own publications that is related to the proposed subject, copy of the PhD defence report (if available) to all three supervisors.