(F/H) Master 2 / 5$^{\text{TH}}$year Eng. School Internship in Control Theory for Fluid Flow Control

Implementation of data-driven control of an active grid

PRISME Laboratory , UR 4229, Université d'Orléans.

Context.

In most aerodynamic studies conducted to understand and optimise transport systems (cars, aeroplanes, boats, etc.) and electricity generation systems (wind turbines), the flow conditions are set to correspond to some desired physical regimes. Modifying the speed of an aerodynamic facility –a wind tunnel– makes it possible, for example, to change the flow regime, laminar or turbulent, of the experimental configuration under study. Other physical phenomena, such as upstream turbulence or the presence of an incoming turbulent boundary layer, can be reproduced using for instance passive grids or additional roughness on the walls, respectively. However, such technical solutions result in stationary disturbances, which are not representative of unsteady real environmental conditions. For example, the wind arriving at a wind turbine can change in amplitude and direction, either slowly or rapidly. This corresponds to a gust phenomenon, which can significantly alter the aerodynamics and consequently the energy production of the wind farm and induce damages on the structure.

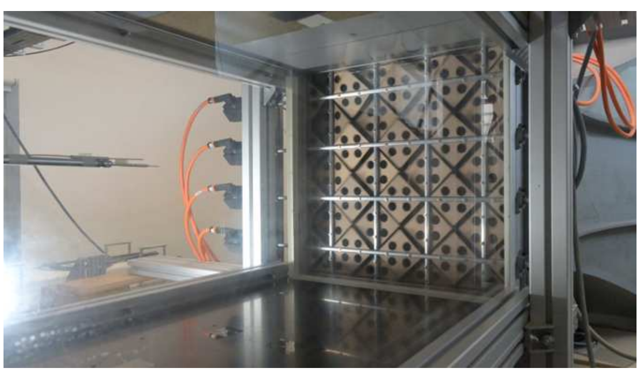

Figure 1: Active grid upstream the wind tunnel test section of the S2 aerodynamic wind tunnel of the Prisme lab.

To meet this objective, the PRISME laboratory designed an active grid that can be placed upstream of the test section in the S2 aerodynamic wind tunnel. Consisting of four vertical and four horizontal motors, controllable in position and speed, this grid generates turbulent conditions upstream thanks to the rotation of flaps fixed to the motor axes (Figure 1). The motors can be controlled using different activation modes. An initial experimental campaign of open-loop tests carried out in 2025 tested three different activation modes: constant rotation, ramp oscillation and hybrid [1]. The properties of steady flow (such as turbulent intensity and integral scale length) and unsteady flow (such as gust amplitude and gust angle) depend on the activation mode parameters (frequency, amplitude, phase, etc.). This campaign was conducted in open-loop to characterise the average flow generated by the grid. However, given the nature of the flow, it is difficult to maintain these upstream conditions along some desired trajectories. These weaknesses of open-loop control can be solved using closed-loop control, namely define control objectives for the flow and use available system outputs to control the grid. However, due to the complexity of both the flow dynamics and the actuation by active grid, this closed-loop control can hardly be implemented in a model-based context.

Data driven control approaches can get around theoretical model based approaches issues such as complexity in applying the fundamental principles of dynamics, particularly in the context of interaction between flaps actuation and fluid mechanics. Basically one can discriminate between direct and indirect data driven control. Indirect control relies on first identification of a model using experimental data, and then synthesis of a control law using standard tools from control theory [2], [3], [4], and benefits from robustness to noise, though can hardly handle complex nonlinear systems with stability guarantees [5]. Direct data driven control relies mainly on the fundamental Willems' lemma [6] to provide Lyapunov stability guarantees through LMIs for control laws synthesized straight using the input-output data for linear systems [7], [8], [9]. These two approaches have been investigated last year [10], [11] and tested on simplified models and on synthetic data.

Internship objectives

The objective of this internship is to implement data-driven control laws using the flow velocity sensors in the wind tunnel. A first step is to address the open-loop implementation in the active grid motors internal environment using Matlab/Simulink. Then, the data-driven indirect and direct control laws developed in [11], [10] will be implemented to perform closed-loop control in the wind tunnel. The choice of the most relevant sensors output information (fluctuating velocity, spectral information, etc...) will be investigated for improving the output feedback control performances. To achieve these goals, the candidate work will follow this canvas:

- Bibliographic work.
- Implementation of a Matlab/Simulink interface for open-loop control of the active grid.
- Definition of the most relevant sensors and their characteristics for further closed-loop control.
- Synthesis of data-driven control using experimental data from the active grid in the wind tunnel.
- Dissemination and exploitation of results.

Environment This internship will benefit from an extremely favourable working environment in terms of resources and expertise, especially in wind turbines wakes [12], [13] and active grid [1]. This study will enjoy the coupling between experimental database at the PRISME lab., existing advanced post-processing analysis codes, and data-driven theoretical framework. The candidate will be part of a pluridisciplinary project of the PRISME laboratory, between the Aerodynamics and Control theory teams, and will receive support from two ongoing theses on wind turbines wakes, and the means of the ANR Young Researcher SONATE.

Profile and required skills: Master 2 or last year Eng. school student in control theory and industrial process control; with good programming skills (Matlab/Simulink). Advanced proficiency in English is also expected, as well as scientific curiosity since this work is on the verge of control theory and fluid mechanics, with good experimental skills for implementation on the Lab experimental facilities).

How to apply?

- Please send us cover letter, CV, grades and ranking for the last two years including a transcript of the current academic records –even if incomplete– as well as any recommendation letter to:
  ✉ **matthieu.fruchard@univ-orleans.fr**, ✉ **cedric.raibaudo@univ-orleans.fr**,
  ✉ **nacim.ramdani@univ-orleans.fr** and ✉ **nicolas.mazellier@univ-orleans.fr**.
- Candidate recruitment is subject to ZRR approval so anticipate a one-to-two months delay between your appliance and your recruitment. Apply preferentially before end of January 2026.
- Duration: 6 months from March 2026. Location: Prisme Lab., Polytech'Orléans (Vinci), 8 rue Léonard de Vinci, Orléans, France. http://www.univ-orleans.fr/fr/prisme

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