

## Data-Driven Control for Multivariable Systems

### Advisors:

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### Context and motivation:

In the rapidly evolving landscape of artificial intelligence (AI), the integration of data-driven control strategies represents a paradigm shift in enhancing system performance and adaptability. The growing interest in data-driven control is motivated by their ability to bypass explicit identification steps, a significant time sink in traditional control design [1, 2, 3]. This approach enables the utilization of data to directly achieve the desired control design objectives. Nevertheless, particularly in the realm of complex systems, the adoption of data-driven design strategies remains unconsolidated. This is attributed to the absence of guarantees and a comprehensive understanding of the closed-loop behavior before deploying the controller. Moreover, the increasing complexity of modern engineering systems, particularly those with multiple interacting variables, poses significant challenges. Multivariable systems exhibit intricate dynamics necessitating innovative strategies for effective control. This research aims to explore and develop advanced data-driven techniques to enhance the control performance of multivariable systems.

The research objectives are as follows. From a methodological point of view, the objective is to investigate how data-driven approaches can capture and exploit the interdependencies among variables to achieve superior control performance compared to traditional methods. Another pivotal aim involves assessing the robustness of data-driven control strategies in the face of uncertainties, control saturations, disturbances, and changes in system [4]. Additionally, the investigation extends to methods to incorporate prior knowledge about the system, if available, into the data-driven control design process. From a practical point of view, the goal is to validate the proposed data-driven control strategies through simulation studies and, if possible, experimental setups on a real-world application. Indeed, the work will be carried out in collaboration with Fives Cryo, a technological leader in the cryogenics market. The objective is the design of a data-based control algorithm for a vacuum brazing furnace. The major difficulties are twofold. The first relates to the very high number of inputs/outputs of the furnace (88 actuators and 49 measurement points), and the second concerns the variability of the load geometries to be considered. The aim is to overcome the controller's dependence on the geometry of the part to be soldered. The thesis work will take advantage of input/output coupling analysis to propose a data-driven control law that enables furnace temperature to be controlled independently of the geometry of the part to be soldered. The results of this thesis will be validated on Fives Cryo's complete digital simulator [5].

### Methodology:

- Conduct a comprehensive review of existing literature on data-driven control and multivariable systems.
- Identify the specificities of the considered real-world application, collect relevant data, and preprocess the data for analysis.
- Design and implement data-driven control algorithms, considering the challenges posed by considering multiple inputs and multiple outputs systems.
- Evaluate the performance of the proposed algorithms through extensive simulations and validate the results with experimental data if possible.
- Compare the proposed data-driven control strategies with traditional control methods, highlighting the advantages and limitations of each approach.

**Master internship:** This research proposition encompasses the possibility of conducting a Master internship before starting a PhD. During the Master internship, the tasks involve identifying the features of the targeted real-world application, gathering pertinent data, and preprocessing the data for subsequent analysis and simulation. The primary goal is to formulate a control strategy through a free model approach, with the intent of validating it using the digital simulator provided by Fives Cryo.

**PhD:** The PhD thesis offers a unique opportunity to contribute to the evolving field of data-driven control while addressing the specific challenges posed by multivariable systems in real-world applications. The main expected contribution is the development of innovative data-driven control algorithms specifically designed for multivariable systems. Furthermore, the project is part of a research consortium where the PhD candidate will interact with a mix of academic and industrial research partners. The candidate will join the research group CID (Control Identification Diagnosis) at CRAN, UMR CNRS – Université de Lorraine in Nancy (<http://www.cran.univ-lorraine.fr/>). The CID group research activities span all facets of systems and control theory, such as linear, nonlinear and hybrid systems theory, modelling and identification and diagnosis. The CID group has a strong interconnection with other academic institutions and industry. For prospective candidates passionate about the intersection of data-driven control methodologies, multivariable systems, and the transformative power of AI, this research offers an exciting opportunity. The collaboration with Fives Cryo ensures that the theoretical advancements contribute not only to the academic understanding of control systems but also make a tangible impact on the forefront of industrial practices within the cryogenics sector.

**Candidate profile:**

- You are a talented and enthusiastic young researcher.
- You have experience or knowledge in the field of dynamic systems and control.
- You have preferably completed studies in systems and control, mechanical or electrical engineering, or (applied) mathematics.
- You work well in a team and are interested in methodological research.
- You have good communication skills and a cooperative attitude to working in a research team.
- You are creative and ambitious, hard-working and persevering.

**Application:** Send an email to the advisors including your CV and your transcripts from your master's degree and previous years.

**References:**

- [1] C. De Persis and P. Tesi, "Formulas for Data- Driven Control: Stabilization, Optimality, and Robustness," in IEEE Transactions on Automatic Control, vol. 65, no. 3, pp. 909- 924, March 2020.
- [2] Fliess, M. and Join, C. "Model-free control", in International Journal of Control 86(12) pp. 2228-2252 2013.
- [3] H. J. van Waarde, J. Eising, H. L. Trentelman, and M. K. Camlibel, "Data informativity: A new perspective on data-driven analysis and control," IEEE Trans. Autom. Control, vol. 65, no. 11, pp. 4753–4768, 2020
- [4] A. Bisoffi, C. De Persis, and P. Tesi, "Trade-offs in learning controllers from noisy data," Systems & Control Letters, vol. 154, p. 104985, 2021
- [5] C. Zacharie, Modélisation des transferts thermiques instationnaires par modèles paramétriques : application à un four industriel de brasage sous vide, Thèse Université de Lorraine.