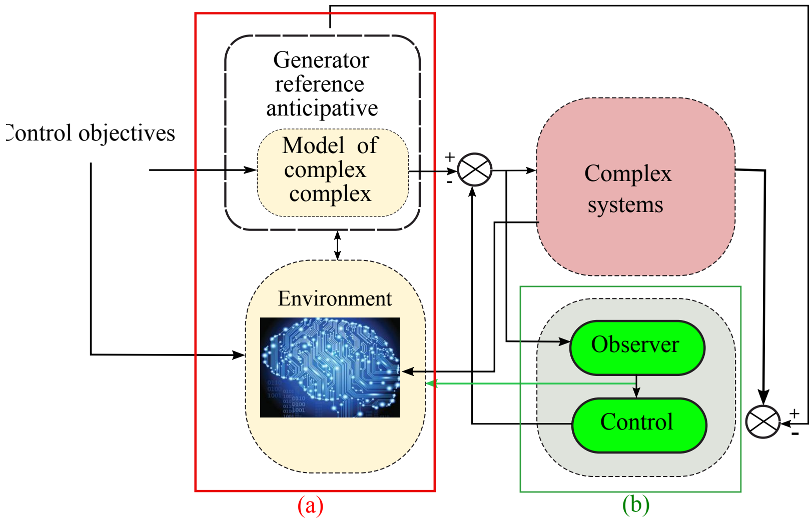
Ph.D Position offer

Supervision:
- Moussa LABBADI
- Emmanuel DELALEAU

Institution:
- Bretagne INP / ENIB (Plouzané, FRANCE)
- *IRDL: Institut de recherche Dupuy de Lôme*
- UMR CNRS 6027

Starting: Sep./Oct. 2026

Subject: *"Safe and Robust Learning-Based Control and Estimation for Dynamic Tasks on Large-Scale Systems with Applications to Soft Robots in a Handful of Trial"*



I. Scientific context

Modern engineering systems, including autonomous robotic platforms, cyber-physical systems, intelligent transportation networks, and large-scale interconnected infrastructures, are becoming increasingly complex, nonlinear, uncertain, and data-intensive. While classical control methodologies have achieved remarkable success in guaranteeing stability, robustness, and performance through model-based approaches, their effectiveness strongly depends on the availability of accurate mathematical models. However, for many large-scale complex systems (LSCS), deriving such models is often difficult or even impossible due to high dimensionality, strong coupling effects, uncertainties, and evolving operating conditions. In parallel, machine learning and data-driven techniques such as reinforcement learning, Gaussian process regression, neural networks, and Koopman operator methods have demonstrated significant potential for learning system dynamics and control policies directly from data. Despite these advances, purely learning-based approaches generally lack rigorous guarantees regarding safety, stability, robustness, and real-time applicability, particularly in safety-critical applications

II. Project objectives

The objective is to develop a new generation of safe, robust, and data-efficient learning-based control and estimation frameworks for large-scale complex systems operating under uncertainty and constraint conditions. The central scientific question is: *How can one mathematically guarantee safety, robustness, stability, and real-time performance for learning-based control and estimation while enabling autonomous learning in a handful of trials?* To address this challenge, the thesis will establish a methodological bridge between modern machine learning techniques and rigorous nonlinear control theory.

A first part of the thesis will provide a comprehensive state-of-the-art analysis of learning-based control and estimation approaches with a focus on their theoretical guarantees. The study will investigate model-free control, neural-network-based adaptive learning methods, Koopman operator approaches, and recent developments in safe learning based on Control Barrier Functions. Special emphasis will be placed on comparing these approaches in terms of mathematical guarantees, safety-critical applicability, robustness properties, scalability to large-scale systems, sample efficiency, and implementation complexity for embedded real-time systems. Furthermore, the thesis will examine the role of Nagumo's invariance conditions and barrier-based techniques as fundamental tools for ensuring safety during both learning and control execution.

Building upon these foundations, the research will develop novel architectures that combine data-driven learning, robust estimation, and safety-critical control. The proposed framework will integrate learning modules for modeling unknown dynamics and disturbances, estimation algorithms for state and uncertainty reconstruction, and robust control layers that preserve closed-loop stability and constraint satisfaction despite approximation errors and external perturbations. Particular attention will be devoted to designing learning algorithms that require only a limited number of experiments, leveraging techniques such as Gaussian-process-based learning, model-based reinforcement learning, meta-learning, transfer learning, and physics-informed machine learning.

The developed methodologies will be validated on soft robotic systems, which constitute an ideal benchmark due to their highly nonlinear, compliant, and distributed nature. Soft robots exhibit infinite-dimensional behavior, large deformations, strong uncertainties, and complex interactions with the environment, making them particularly challenging for conventional model-based control approaches. The objective will be to design safe and robust learning-based controllers enabling soft robots to perform dynamic tasks such as manipulation, locomotion, and physical interaction while learning efficiently in a handful of trials. Through this application framework, the thesis aims to establish a rigorous theoretical and experimental foundation for trustworthy learning-enabled control systems capable of combining autonomy, safety, robustness, and data efficiency in next-generation intelligent autonomous systems.

III. Ideal applicant

The candidate must have a strong background in *Control theory and its applications* to mechatronics and intelligent systems (model-based and model-free methods). Knowledges in Soft robotics and artificial intelligence, and estimation are welcome.

We are looking for a candidate with strong analytical and programming skills, capable of understanding, analyzing, and comparing theoretical proofs published in leading journals in control theory, as well as developing simulations and capable of implementing real-time control to validate theoretical and algorithmic results reported in the soft robotics.

IV. Administrative information

- Institution:
  - **Institut de recherche Dupuy de Lôme (IRDL, www.irdl.fr)**
  - located in "Bretagne INP" (network of engineering school), near Brest-FRANCE
- Salary: Three year work-contract under French regulation for PhD
- Starting in September or October 2026 (or at a mutually agreed date)
- The laboratory is a restricted access area and final acceptation rely on a security ministry procedure

V. Candidacy procedure

Prepare a **zip archive** with at least the following documents (**only pdf**):

- Cover motivation letter describing your interest in the project, and adequation with the required skills
- Detailed CV
- Title and abstract of Master's thesis or internship report
- Transcript of master's or engineering school grades
- Syllabus of the last two years of study
- If possible reference contacts or letters of recommendation
- Copy of ID

Send email to the three supervisors:

- moussa.labbadi@enib.fr
- emmanuel.delaleau@enib.fr

- Subject of the email *must be formatted exactly as*:

  [PhD position] LAST NAME / First name
- Either:
  - zip file attached
  - zip file downloadable from an IRL given inside the email

Applications submitted without the required documents will not be considered. Applications are reviewed as they are received.