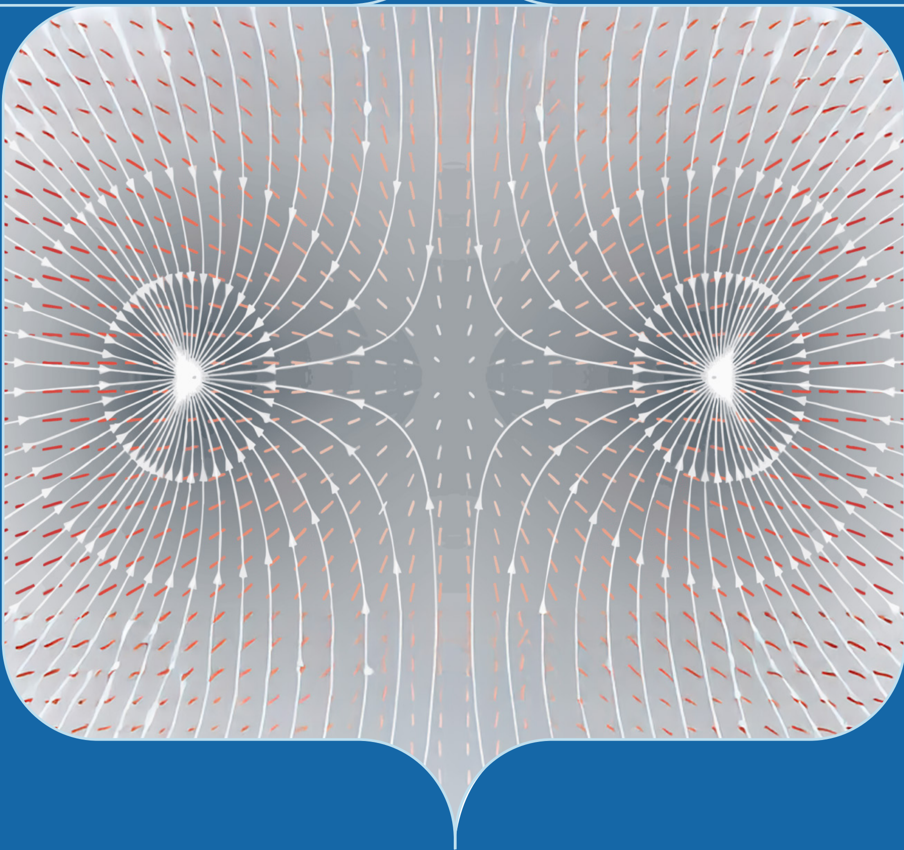


MINES PARIS | PSL

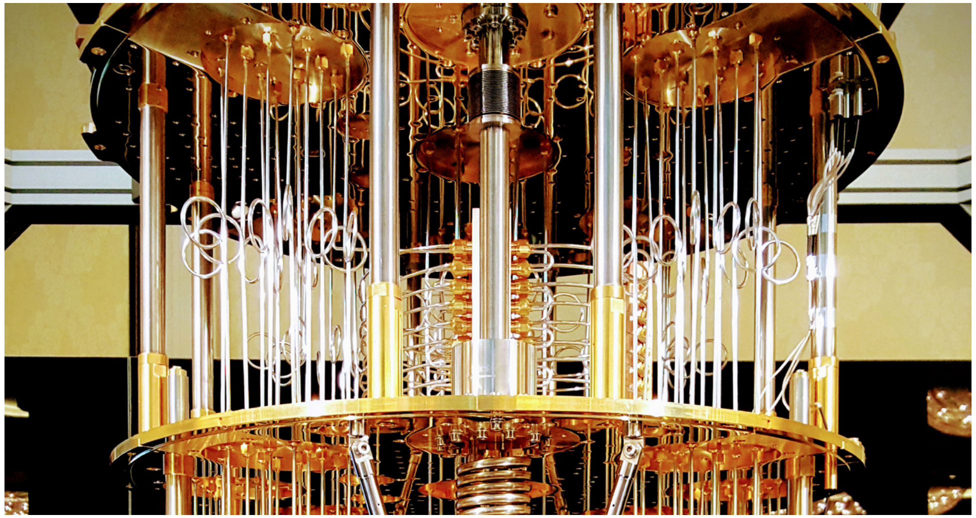
CAS
CENTER FOR SYSTEMS AND CONTROL

CAS : RESEARCH AND EXPERTISE IN THE CONTROL OF DYNAMIC SYSTEMS

The Center for Systems and Control (CAS), *Centre Automatique et Systèmes*, of Mines Paris – PSL specializes in control theory, a field of applied mathematics concerned with the control of dynamic systems.

One of the 18 research centers of Mines Paris – PSL, CAS is part of the Mathematics & Systems Department, one of the School's five departments structured around major scientific themes and future challenges. Committed to a dual-impact research approach, CAS combines academic research with close industrial collaborations.

Within Université PSL, internationally recognized for its openness and excellence, the School provides CAS with an ideal environment in which to integrate theoretical teaching with practical applications.



Short-loop research interactions with stakeholders from other fields – whether scientific, such as quantum physics, microfluidics or optimization, or industrial, including process engineering, robotics, electrical engineering and aerospace – contribute to the advancement of control theory, from its theoretical foundations to the finest details of its implementation in real-time control loops. In this context, CAS has developed major breakthroughs such as differential flatness theory and invariant observer theory, as well as control algorithms deployed in industrial systems, including Fluigent's FlowEZ™ devices and Pryo systems developed by the company Fareco.

CAS IN FIGURES

€1M
per year
in research contracts

11
research staff members

Doctoral level
teaching activities

- *Mathematics and Control* specialization
- ISMME Doctoral School (*Engineering of Systems, Materials, Mechanics and Energy*) of Université PSL

+15
PhD students

+10
industrial partners
involved in direct research collaborations

Master's level
teaching activities

- Signal processing
- Control theory
- Continuous optimization
- Differential equations
- Quantum computing

MAJOR CONTRIBUTIONS BY OUR RESEARCHERS

More than 40 scientific publications per year

- **Lifetime of cat qubits: a breakthrough in quantum computing**

This publication represents a major advance in quantum computing, demonstrating the implementation of quantum operations on a highly stable qubit. The key result lies in the measured bit-flip time of this qubit, which exceeds 10 seconds. This innovation paves the way for more powerful and stable quantum computations, with applications ranging from cryptography to molecular modeling and artificial intelligence.

ENS–INRIA–Mines Quantic team, "Quantum control of a cat qubit with bit-flip times exceeding ten seconds."

- **Differential flatness theory: simplified trajectory planning**

This seminal article establishes the theory of differential flatness, characterizing dynamical systems whose trajectories are parameterized by an output and its derivatives. This property simplifies control design, especially for trajectory planning and tracking, and has since been extended beyond nonlinear systems to frameworks including boundary control of partial differential equations.

Fliess, M., Lévine, J., Martin, P., & Rouchon, P. (1995). Flatness and defect of non-linear systems: introductory theory and examples. *International Journal of Control*, 61(6), 1327–1361.

- **ANAMEL: optimization software for oil refineries**

This publication presents the ANAMEL software, which optimizes crude oil blending in refineries to produce fuels with specified properties. This complex, weakly instrumented, multi-input problem is addressed using an adaptive optimal control approach. The solution has been deployed in numerous TOTAL refineries.

Chebre, M., Creff, Y., & Petit, N. (2010). Feedback control and optimization for the production of commercial fuels by blending. *Journal of Process Control*, 20(4), 441–451.

- **Structural frameworks for observing nonlinear systems**

This book proposes a comprehensive analytical framework covering a significant part of the state of the art in state observer design for nonlinear dynamical systems. By defining an observer as the combination of an invertible change of variables and an appropriate (typically stable) dynamics, it explores a set of structures from which the major families of observers emerge, including high-gain and Luenberger observers.

Bernard, P. (2019). *Observer design for nonlinear systems* (Vol. 479). Springer.

Examples of ongoing PhD projects

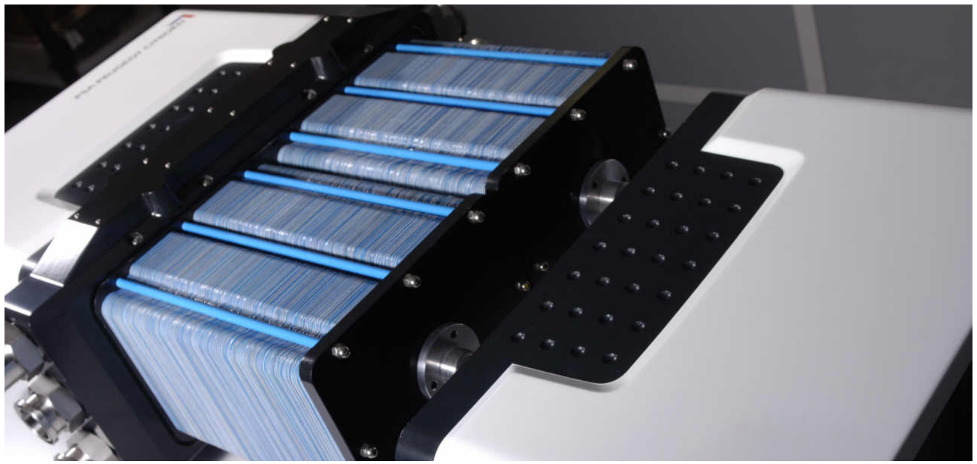
State observers for hydrogen fuel cells to optimize efficiency and durability
Anne-Flor Fontaine, in collaboration with IFP Energies nouvelles (IFPEN)
Supervised by Delphine Bresch-Pietri and Florent Di Meglio

Non-destructive readout schemes for quantum processors based on cat qubits
Adrien Bocquet, in collaboration with Alice & Bob
Supervised by Zaki Leghtas

Observer design for non-regular and hybrid systems
Valentin Alleaume
Supervised by Pauline Bernard and Florent Di Meglio

Control of hydrodynamic filtration processes
Michaël Vincendon
Supervised by Nicolas Petit

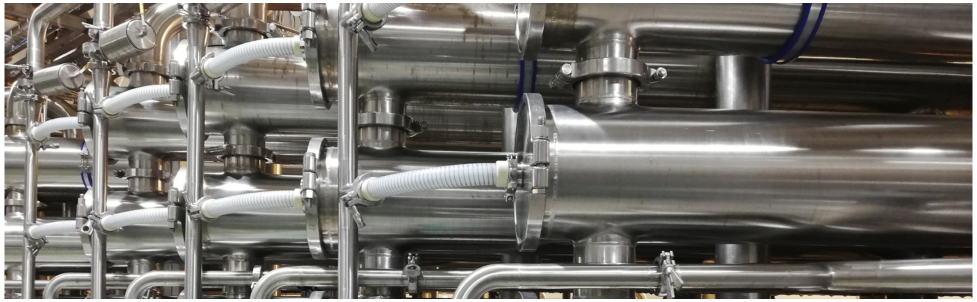
Solving Open Quantum Many-Body Problems Using Semidefinite Relaxation Methods
Gustave Robichon
Supervised by Antoine Tillloy



RESEARCH AREAS

Research conducted at CAS aims to advance control theory. The center publishes in leading international journals and conferences and works in close connection with industrial and experimental challenges.

Permanent staff members gather the needs of economic stakeholders, and research contracts carried by ARMINES and the School give rise to new scientific questions. CAS contributions take concrete form in algorithms executed in real time on industrial or experimental systems developed with its partners. CAS has contributed to major advances across a wide range of sectors, including the oil industry, automotive engineering, electrical engineering, mechatronics, and quantum systems.



Nonlinear control

CAS develops methods for the synthesis of open-loop and closed-loop control laws, state observers, and system identification techniques for nonlinear dynamical systems. Differential flatness and invariant or so-called "KKL" observers are representative examples. This field also encompasses the study of industrial systems in which the handling of nonlinearities is critical and non-standard, such as slugging, stick-slip phenomena, and magnetic saturation in electrical machines. More recently, CAS has focused on non-regular and hybrid systems, using a variety of approaches ranging from extensions of classical control theory to non-smooth optimization and machine learning.

Infinite-dimensional systems

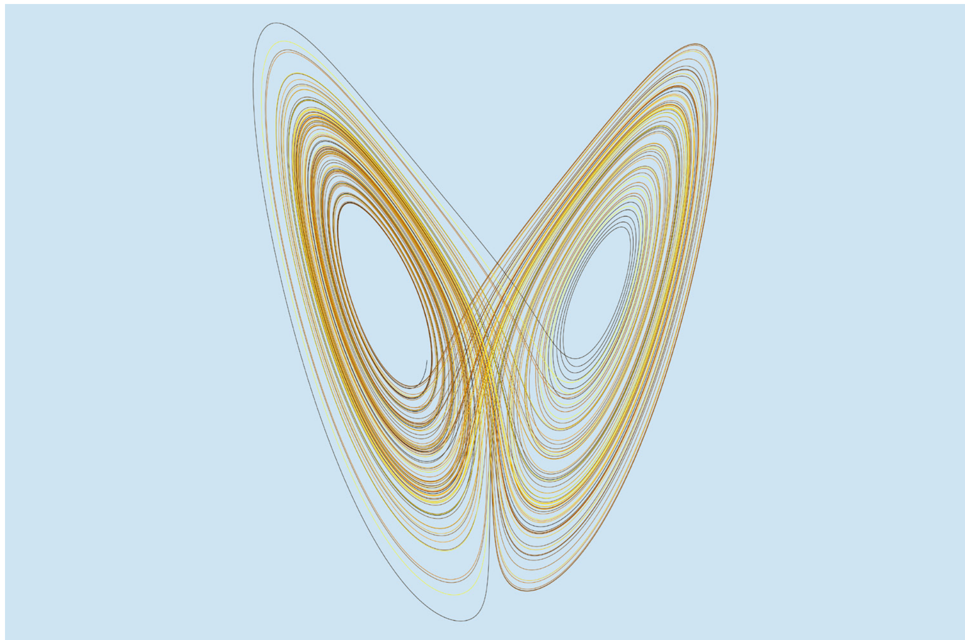
CAS conducts research on the control and estimation of systems with possibly time-varying delays, as well as systems governed by partial differential equations (PDEs). This includes, for example, differential flatness theory, the development of backstepping methods for input-dependent delay systems, and boundary control of hyperbolic PDEs. These works have applications in diverse domains, ranging from drilling operations to the control of internal combustion engines.

Decision mathematics

CAS has strong expertise in large-scale system optimization and optimal control. Its theoretical research addresses the management of state and control constraints, delays, and stochastic phenomena in optimal control problems. In numerical optimization, the center leverages the underlying structure of large-scale problems—such as in optimal power flow—to develop state-of-the-art approaches tailored to modern hardware architectures. CAS also investigates the use of tensor networks to solve very large-scale optimization problems, particularly in fundamental physics, such as open quantum many-body problems.

Quantum systems

Within the Quantic team, CAS is a pioneer in the development of cat qubits and their use toward the realization of a quantum computer. This objective, pursued in close collaboration with the start-up Alice & Bob, structures a significant part of the center's research in this area, including quantum state preparation, quantum error-correcting codes, perturbative methods, and numerical schemes for solving the Lindblad equation. In parallel, CAS explores the potential of new types of qubits, such as GKP qubits, which can partially circumvent the need for error-correcting codes through decoherence engineering based on Josephson circuits controlled by microwave drives.



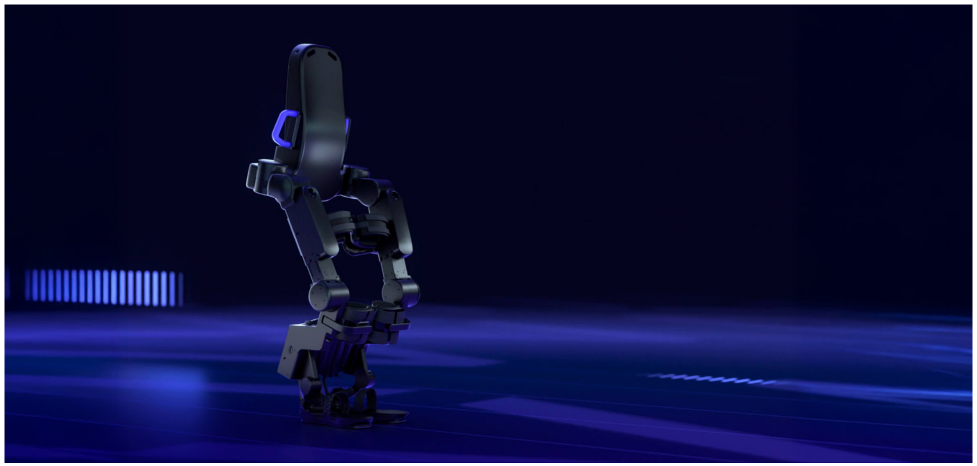
A COLLABORATIVE NETWORK DRIVING INNOVATION

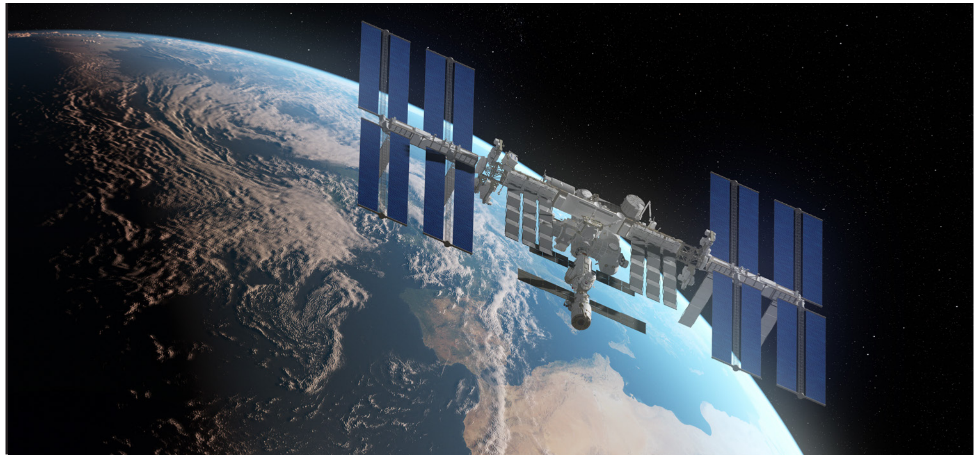
CAS relies on a strong and diverse network of partners from academia, industry, and institutional organizations. These collaborations enrich its research activities, open up new scientific perspectives, and strengthen the link between fundamental science and practical applications.

Drillscan	**Alice & Bob**	**Lithosquare**
K-Ryole	**IFPEN**	**Wandercraft**
Whitewater	**Schneider Electric**	**Safran**
Fairmat		**ANSYS France**

Sensorless control of industrial motors with Schneider Electric

CAS has collaborated with Schneider Electric for over 30 years, notably on the sensorless control of electrical machines. The center contributes to the design of variable frequency drives, which regulate the speed of industrial motors through electrical voltage using current measurements only. Research topics have included state estimation, constraint management at high speeds, and motor parameter identification.





IFP Energies nouvelles: control of energy and industrial systems

CAS works with IFPEN on several projects, including the control of offshore wind turbines, engines, and fuel cells. This collaboration, ongoing for more than 20 years, has also addressed emission reduction in internal combustion engines and combustion simulation using machine learning approaches.

CNES: optimal control of space trajectories

CAS collaborates with CNES on optimal control projects for space missions, including the control of landings, ascent trajectories, and vehicle re-entry. These efforts aim to optimize trajectories while ensuring the safety and precision of operations in the context of space missions.

Alice & Bob: toward a quantum computer

Founded following a PhD thesis supervised by Zaki Leghtas, the company Alice & Bob focuses on the design and fabrication of a quantum computer based on "cat qubits" as its fundamental building block. CAS now supports the start-up across a wide range of topics, from the development of core cat-qubit technologies to experiment calibration and the simulation of open quantum systems.

Wandercraft: an exoskeleton for paraplegic patients

Since its founding ten years ago, CAS has supported Wandercraft in the design and development of the world's only self-stabilizing leg exoskeleton. Used in clinical settings, it enables paraplegic and hemiplegic patients to reproduce walking movements while keeping their hands free. CAS has supervised three PhD projects in this context, focusing on gait stabilization, estimation of mechanical deformations using inertial sensors, and online trajectory generation for rehabilitation.

FUNDED RESEARCH: INSTITUTIONAL SUPPORT AND INNOVATIVE PROJECTS

Partner institutions

French National Centre for Scientific Research (CNRS)

French Minister for the Armed Forces and Veterans

French National Research Agency (ANR)

European Commission

Université PSL

Our key collaborative funded projects

HORIZON-JU-CLEANH2-2025 MARINER Partnership – Validation and Demonstration of a Reliable, Efficient, Scalable, and Low-Cost PEM Fuel Cell System

This project aims to design and assemble a 1 MW proton exchange membrane (PEM) fuel cell, together with a roadmap toward a 10 MW system. Such high power levels are required for marine propulsion. CAS contributes to the design of control laws and to the estimation of the fuel cell's state of health.

European Research Council (ERC) grants

"Quantum Feedback Engineering" (Q-Feedback), led by Pierre Rouchon

This project develops control methods to protect key resources of quantum systems, such as coherence and entanglement, from external disturbances. The objective is to make qubits more robust, thereby strengthening quantum technologies for computing, communication, and sensing.

"ECLIPSE", led by Zaki Leghtas, funded by an ERC Starting Grant

This project aims to increase qubit reliability by using superconducting circuits and Schrödinger "cat" states to protect them from perturbations, with the ultimate goal of creating more powerful and secure quantum computers.

"QFT.zip", led by Antoine Tilloy

This project leverages tensor networks to model complex quantum systems by compressing their essential information. It seeks to improve simulations in quantum physics, with potential applications in quantum chemistry and quantum computing.

SUPPORT FOR INNOVATIVE PROJECTS

Mines Paris – PSL leverages the expertise of its research teams and specialists to establish collaborations that enable:

- Accelerated development of products and services
- Exploration of new markets
- Strengthening of teams through the integration of specialized skills (e.g. CIFRE PhD positions)
- Access to funding and grants for collaborative projects
- Expansion of professional networks and increased visibility
- Support for initiatives with strong societal impact

DID YOU KNOW?

Pierre Rouchon elected to the French Academy of Sciences in 2025

Pierre Rouchon is a specialist in control theory and quantum technologies. He has contributed to major advances, particularly in the real-time control of quantum systems, paving the way for innovative applications in this cutting-edge field.

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