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# PROPOSITION DE SUJET DE THESE

**Intitulé : Joint optimization of actuator/sensor/compensator for closed-loop control of fluid flows**

Référence : **MFE-DAAA-2026-09**
*(à rappeler dans toute correspondance)*

| **Début de la thèse : 10/2026** | **Date limite de candidature : 06/2026** |
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**Mots clés**

**Closed-loop flow control, non-smooth non-convex optimization**

**Profil et compétences recherchées**

**Master in aerospace/mechanical engineering, control science or applied mathematics**

**Présentation du projet, contexte et objectif**

With ever-increasing constraints on the environmental impact of aviation, active flow control appears as a key enabling technology. Closed-loop control may be used to reduce jet noise emission, skin-friction drag or avoid flow separation for instance. Designing optimal closed-loop setups is a challenging task because of the high-dimensionality of fluid systems. Indeed, state-of-the-art methods for controller synthesis (optimal $H_2$ or robust $H_\infty$) cannot easily manage systems of order greater than O(100). As a result, the most common approach is to first form a reduced-order model (ROM) of the flow, optimally capturing its input-output behavior [1]. The ROM is associated with an arbitrarily chosen set of actuators and sensors, inevitably resulting in suboptimal control setups. Ideally, we would like to jointly optimize the actuators, the sensors and the compensator [2], but achieving this goal in high-dimension requires a new methodology.

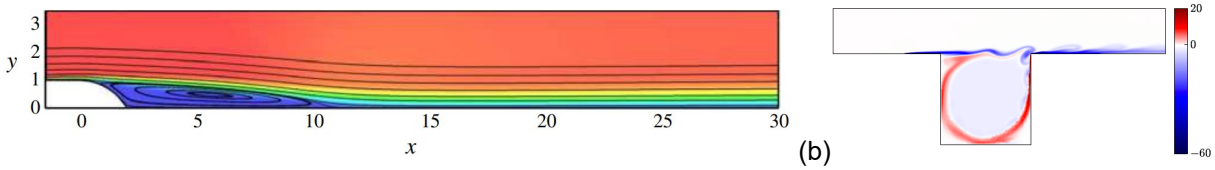


*Figure 1: Canonical benchmark cases for the co-design problem : (a) noise-amplifier flow (backward facing step [6]) and (b) oscillator flow (open-cavity [7]).*

In this thesis, we wish to explore novel approaches to solve the co-design problem. We aim to work directly with the full-order model, or resolvent operator, connecting all possible inputs to all possible outputs. The key idea is that the performance index that we seek to optimize, for instance the $H_2$ or the $H_\infty$ norm of the closed-loop resolvent operator, is related to eigenvalues of large-scale sparse matrices. Therefore, Krylov subspace techniques may be used to efficiently evaluate the objective functional. Similarly, the gradients of the functional with respect to the free parameters (of the actuators/sensors/compensator) may be quickly computed [3]. In essence, Krylov subspace techniques may be used to perform model reduction on-the-fly, during the optimization procedure, without preselecting any actuator or sensor. The optimization problem is however non-convex, and also non-smooth because a) the greatest eigenvalue is not always the same when free parameters are varied, b) closed-loop stability must be enforced. However, this class of problems can now be efficiently addressed using a recently developed BFGS-SQP algorithm [4]. The sparse linear algebra and eigenvalue problems will be solved using the libraries PETSc/SLEPc, while the library pyGRANSO [5] will be used for optimization.

The new approach will be investigated on two canonical 2D incompressible flows (see figure 1): the backward-facing step (a noise amplifier) and the open cavity (an oscillator); using the finite-element code FEniCS. Several parametrizations of the actuators and sensors will be investigated, with various constraints (sparsity, volume-force versus boundary condition). With access to the full input-output dynamics, great attention will be paid to the choice of the system norm to be optimized ($H_2$ / $H_\infty$ norm [8], numerical abscissa, maximum linear transient growth [9]).

**Références :**


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[3] Werner, S. W., Overton, M. L., & Peherstorfer, B. (2023). Multifidelity Robust Controller Design with Gradient Sampling. *SIAM Journal on Scientific Computing*, *45*(2), A933-A957.

[4] Curtis, F. E., Mitchell, T., & Overton, M. L. (2017). A BFGS-SQP method for nonsmooth, nonconvex, constrained optimization and its evaluation using relative minimization profiles. *Optimization Methods and Software*, *32*(1), 148-181.

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[7] Leclercq, C., Demourant, F., Poussot-Vassal, C., & Sipp, D. (2019). Linear iterative method for closed-loop control of quasiperiodic flows. *Journal of Fluid Mechanics*, *868*, 26-65.

[8] Benner, P., & Mitchell, T. (2018). Faster and more accurate computation of the H∞ norm via optimization. *SIAM Journal on Scientific Computing*, *40*(5), A3609-A3635.

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**Collaborations envisagées**

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