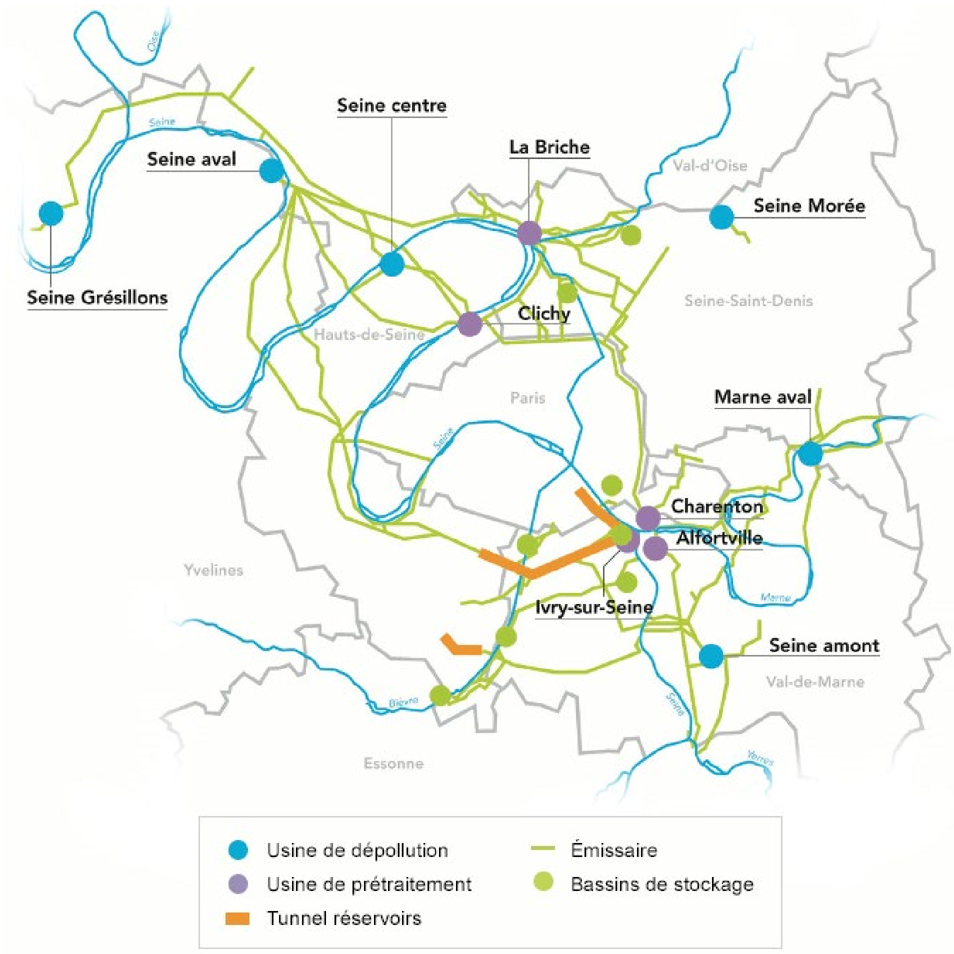
MSc internship:
simulation and optimization of wastewater network management
- application to the Paris network –

Context: During heavy rainfall, sewage networks can become overloaded, no longer ensuring the desired quality of water leaving the system. Some networks have actuators like pumps and detention gates, which can be used to regulate how water reaches the treatment plants. At present, some utilities do so to minimize flooding and combined sewer overflow. It is also possible to use these actuators to improve the treatment efficiency of the plants. This is a difficult computational problem, however, because it is large and nonlinear.

Objectives: The problem of optimal allocation to minimize the impact on the quality of treated water discharges falls within the scope of automatic and optimal control for of non-stationary regimes. Numerous approaches and algorithms exist in the literature, but the most efficient in terms of computation time require specific characteristics of the problem, such as linear dynamics and convex optimization problems, which is not the case for sewage network optimization. Recently, the supervisors of the internship proposed a reformulation of the nonlinear non-convex optimization problem of a network of bioreactor-type treatment units in terms of optimization under second-degree cone constraints [2,4], for which efficient algorithms exist. The aim of the internship is to study this formulation for various concrete objectives and constraints adapted to the waster-water treatments, and to contribute to the development of an efficient code based on existing work [1,3] and the expectations of the SIAPP in charge of managing the Greater Paris network.

Course of the internship: Following a bibliographical phase covering both mathematical models of biochemical processes ("chemostat" type models) [5] and control algorithms used in the water treatment industry, discussions with the supervisors and SIAPP will enable us to define more precisely the assumptions and choices for formulating the relevant control problems, particularly in terms of receding horizon and observers synthesis. In a second phase, the work will involve using existing Python code to produce a generically designed software solution (i.e. adaptable to other networks and/or operating constraints), which will first be tested on simple examples. The final phase will consist of parameter calibration on the network considered by SIAPP and simulations of various scenarios.



Expected candidates: Master's degree or engineering school in mathematics (optimization) or computer science (operations research) with knowledge of dynamical systems (systems of ordinary differential equations), and a strong taste for programming in Python. Knowledge of control and observer theory would be a plus. Particular attention will be paid to candidates motivated by the multi-disciplinary dimension of the subject, able to interact with both control and optimization researchers and engineers specializing in wastewater networks.

References :

[1] Cassandre Tasiaux, Denis Dochain, Joshua Taylor, Alain Rapaport, Peter Vanrolleghem. Optimization of the Paris wastewater treatment plants and sewer network: preliminary results. *3rd Control Conference Africa (CCA24)*, Sep 2024, Balaclava, Mauritania. ⟨hal-04617312⟩

[2] Josh Taylor, Alain Rapaport, Denis Dochain. Convex optimization of bioprocesses. *IEEE Transactions on Automatic Control*, 2022, 67 (9), pp.4932 - 4938. ⟨10.1109/TAC.2022.3167310⟩. ⟨hal-03636799⟩

[3] Josh Taylor, Alain Rapaport, Denis Dochain. A sequential convex moving horizon estimator for bioprocesses. *Journal of Process Control*, 2022, 116, pp.19-24. ⟨10.1016/j.jprocont.2022.05.012⟩. ⟨hal-03681133⟩

[4] Josh A Taylor, Alain Rapaport. Second-order cone optimization of the gradostat. *Computers & Chemical Engineering*, 2021, 151, ⟨10.1016/j.compchemeng.2021.107347⟩. ⟨hal-03206215⟩

[5] Jérome Harmand, Claude Lobry, Alain Rapaport, Tewfik Sari. The Chemostat: Mathematical Theory of Microorganism Cultures. Wiley. John Wiley and Sons, Ltd, 1, 240 p., 2017, Chemical Engineering series / Chemostat and bioprocesses, 978-1-78630-043-0. ⟨hal-01539446⟩

Practical information:

Location: Paris and Montpellier, ideally a few months in Paris then the rest of the internship in Montpellier. Some paid Montpellier-Paris travel will be required, with regular exchanges by Video-conferencing.

Duration: 4 to 6 months

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