Master internship: Optimal control of a filtration system to minimize membrane fouling

MISTEA research unit, Campus La Gaillarde, Montpellier, France

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Filtration processes are an essential step in the treatment of wastewater. Their performances have a significant impact on their running costs. Filtration membranes are constantly being improved, and are now capable of retaining particles as small as pathogens, making it possible to safely reuse treated water in the future, in response to the increasing scarcity of drinking water on earth.

However, membranes may become clogged over time due to the accumulation of a "cake" on their surface, increasing intra-membrane pressure and reducing the flow of filtered water. The membranes therefore need to be washed regularly, which can be achieved by a back-washing which consists in reversing the flow. A compromise needs to be found between the filtration and washing phases in order to maximize the volume of treated water over a given time, or to minimize the energy consumed by the pumps to push the water through the membrane for a given volume of filtered water over a fixed time interval.

These optimization problems have already been tackled using a simple dynamic model of a filtration / back-washing process and applying optimal control theory [3, 1] (see also Chapter 6 of [2]). It has been shown that the solutions are of "bang-bang" type with a singular arc or a switching surface.

The objective of this internship is to consider a more complex (and more realistic) dynamic in which two types of residues are explicitly distinguished - either particulate molecules of large size, which form a cake onto the membrane surface and can be easily removed by backwash or small particulate molecules which rather block the pores of the membrane and are thus much more difficult to remove. The aim of this internship is then to revisit the optimal control problem in order to understand the interplay between these two types of residues and to determine optimal strategies to keep the membrane performances on the long term. The expected approach will be based on optimal control theory, in particular the use of Pontryagin's Maximum Principle, but also on numerical resolutions using the Bocop software developed by Inria (or other dedicated solver). The subject is part of an ongoing research work funded by the "Défi clef Water Occitanie" French program.

The expected profile of the candidate is to prepare a master's degree in applied mathematics or automatic control, or an engineering school with one of these specialties. The prerequisites are a good knowledge of the theory of ordinary differential equations and optimization, and good skills in numerical simulations with software such as Matlab, Scilab, Python, Julia... Depending on the background and the motivations of the candidate, the work can take a more theoretical or more applied direction. The internship can last from 4 to 6 months, with the usual monthly remuneration.

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References

[1] Aichouche, F., Kalboussi, N., Rapaport, A., Harmand, J. *Modeling and optimal control for production-regeneration systems - preliminary results.* European Control Conference ECC'20, May 2020, Saint Petersburg, Russia. pp.564-569.

[2] Harmand, J., Lobry, C., Rapaport, A., Sari, T. *Optimal Control in Bioprocesses: Pontryagin's Maximum Principle in Practice*, Wiley, 2019.

[3] Kalboussi, N., Rapaport, A., Bayen, T., Ben Amar, N., Ellouze, F., et al. *Optimal control of membrane filtration systems.* IEEE Transactions on Automatic Control, 2019, 64 (5), pp.8704-8709