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# Modelling and control of photobioreactors integrated in closed-loop biorefineries

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***Highlights***

- Identification and tuning of black-box dynamic models of the process
- Optimal control strategies for feeding and extraction times

## 1. Summary

This project aims to develop phenomenological control models that can be on-line adjusted to optimize operation of biological processes. The proposed application is on microalgae cultivation, whose economic balance at industrial scale to produce biofuels is currently positive only if some integrated solutions are adopted, as closed-loop waste-to-energy schemes: wastewater in exit from other biowaste-to-biofuels processes and flue gas rich of CO2 are both used as nutrients for microalgae. Scale-up from pilot to industrial usually requires continuous or semi-continuous operation, so feed flowrates to microalgae must be manipulated, by taking into account also light–dark cycles. Moreover, extraction must be operated at controlled time intervals, depending on the dynamics of algae growth.

## 2. Problems /challenges

The development of physically-based dynamic models for the prediction of photobioreactors performance or for defining their optimal control strategies is very difficult, due to both the uncertainty in kinetics of biological systems and to the great number of variables affecting process conditions.
On the other hand, if surrogate models are preferred, on-line measures of the main process variables must be collected. In this latter case, only rapid measurements should be used, this means that direct microalgae concentration measures must be excluded, causing possible errors in models.

**2. Solution**

Different black-box and NN models are tested using only flowrate, pH, T, Conductivity and DOx measures. Interesting results are obtained by NARX; being nonlinear in variables it can describe complex dynamics, while being linear in parameters its identification can be carried out only by a LS algorithm. Different control strategies are proposed to extract microalgae when their lipid content is maximum: the most interesting one is by correlating the actual derivative of pH with the kinetics law (variable in time) of microalgae growth, so to compute the optimal extraction time during operation.

**3. Results / benefits**

A self-made monitoring/control tool (MEMO: www.en2.unige.it/environ-chem-processes-lab/) is adopted at this stage. A 3-months run on two lab-scale reactors is used to build the surrogate models that are compared and validated by different time series. The control strategy is validated by analyzing lipid content post microalgae extraction. Other interesting results emerged, as the possibility to correlate the delay in the oxygen concentration response to feed input with the different microalgae growing phases. These very promising results encourages a commercial development of the project.