1. Motivations

Microalgae cultures have a wide range of applications ranging from waste water treatment to biofuel production. Online measurements are mandatory for advanced control and monitoring purposes, however, in microalgae culture, it is impossible to measure online the internal quota (Q). Software sensors (observers) appear as an appealing solution: they blend partial information available from sensor into a mathematical model of the process in order to reconstruct online the unmeasured process states.

This poster shows the conditions under which even if the model appears theoretically observable, the observer will be unable to reconstruct the process states despite tuning. Furthermore, we study the performances of an Extended Kalman Filter and an Unknown Input Observer for Unknown Input estimation.

3. Nonlinear Observability

To assess global observability, the model can be cast into a canonical observability form [3]:

$$\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} f_1(x_1, \ldots, x_n) \\ f_2(x_1, \ldots, x_n) \\ \vdots \\ f_n(x_1, \ldots, x_n) \end{bmatrix}, \quad y = x^T \cdot A$$

Where: $n \in \{1, \ldots, q\}$, $a^i_j \in \mathbb{R}^{n_q}$, $n_1 \geq n_2 \geq \cdots \geq n_q$ and $\sum_{i=1}^{q} n_i = n_x$. If:

$$\forall j \in \{1, \ldots, q\} \quad : \quad \text{rank} \left( \begin{bmatrix} \partial f_j/a^j_1 \\ \partial f_j/a^j_2 \\ \vdots \\ \partial f_j/a^j_n \end{bmatrix} \right) = n_{i+1}$$

⇒ the system is theoretically globally observable.

5. Results

An EKF is tested with experimental data of microalgae cultures [2] for the estimation of the internal quota Q first using only biomass measurements. A loss of observability occurs when: $Q = Q_i$ which affects the estimation of $S$. Moreover, when $S = 0$, the estimation of $Q_i$ is affected. On the other hand, using both biomass and substrate measurements considerably improves the situation. Those results are in accordance with our prior observability analysis.

Unknown inputs can be estimated by extending the state vector and relying on an extended Kalman filter, or exploiting a dedicated unknown input observer as in [5]. The unknown input here is the incident light intensity. Simulation results (below) illustrate the convergence of both the augmented EKF and the UIO with low (a) and high (b) levels of noise. With this respect, the performance of the UIO deteriorates faster.

References


Acknowledgements

This poster presents research results of the Belgian Network DYSCO (Dynamical Systems, Control, and Optimization), funded by the Interuniversity Attraction Poles Programme initiated by the Belgian Science Policy Office.