Implementation of an Industrial embedded MPC for a Lab-scale Bioreactor

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1. OBJECTIVE & CHALLENGE

Challenges

- Nonlinear, time-varying fed-batch dynamics.
- Dissolved oxygen (DO) dynamics depend strongly on biomass growth and oxygen transfer.
- Relevant biological states are not directly measurable online.

Objective – Implement an embedded Model Predictive Control (MPC) framework for constrained DO regulation using online state estimation.

Why MPC?

Enables multivariable control while explicitly handling actuator and process constraints

2. MODEL & MPC FORMULATION

Model

$$\dot{x} = f(x, u, p)$$

$$x = [v, C_s, \mu, C_x]^T$$

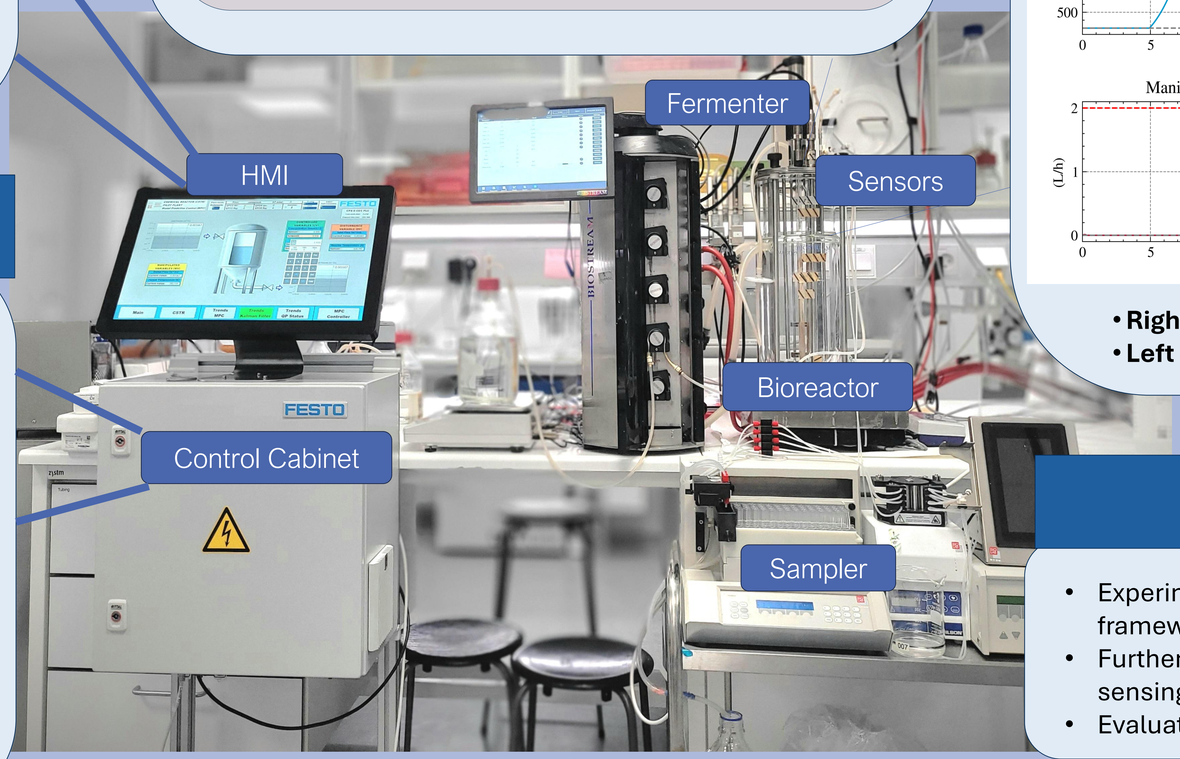
v – Volume of liquid
C_s – Substrate concentration
μ- specific growth rate
C_x – Biomass concentration
x- states, **u**- inputs, **p**- parameters

MPC Formulation

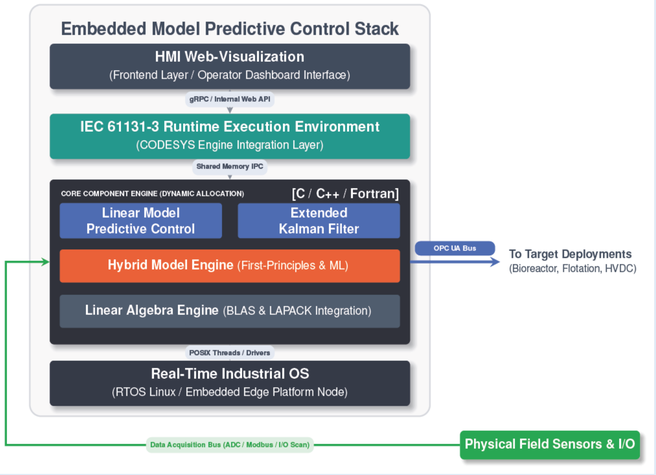
$$\textbf{min } J = \Sigma_{i=1}^{Np} (y_{k+i|k} - r_{k+i})^T Q (y_{k+i|k} - r_{k+i}) + \Sigma_{i=0}^{Nc-1} \Delta u_{k+i|k}^T R \Delta u_{k+i|k}$$

- **y:** $[\ DO, \mu\ ]^T$
- **u:** $[F_{air}, F_{in}, N_{st}\ ]^T$
- **Constraints** : $u_{min} \le u_k \le u_{max}$ & $\Delta u_{min} \le \Delta u_k \le \Delta u_{max}$

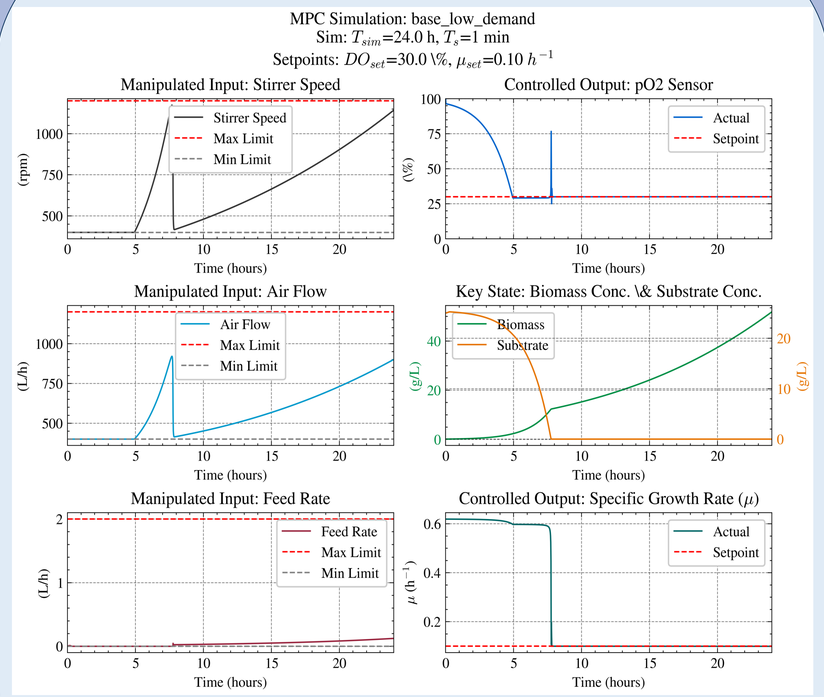
- **Np** - prediction horizon
- **Nc** - control horizon
- **r** - reference
- **Q** - tracking weight
- **R** - control effort weight
- **y** - controlled variable
- **u** - manipulated variable



3. EMBEDDED CONTROL ARCHITECTURE



4. CONTROL PERFORMANCE



- **Right -** Controlled-variable tracking performance.
- **Left -** Corresponding manipulated variable trajectories

5.OUTLOOK

- Experimental validation of the complete embedded MPC framework.
- Further tuning & validation of state estimation and soft sensing.
- Evaluation under fed/batch operating conditions.

IMPACT

Real-time constrained control for improved DO regulation and robust bioprocess operation.

APPLICATIONS

Biotechnology, fermentation, pharmaceutical manufacturing and related bioprocess industries.

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