Sargent Centre for Process Systems Engineering

Simultaneous Process Design and Control Optimisation using Reinforcement Learning

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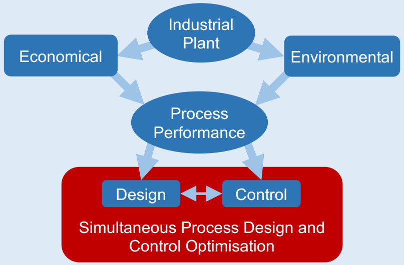
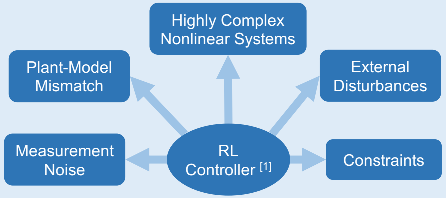
IMPORTANCE





OBJECTIVES

1. Propose a new approach using reinforcement learning (**policy gradient**).

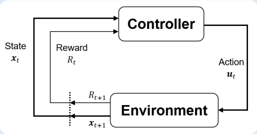
2. Showcase the control performance using two case studies from [2].

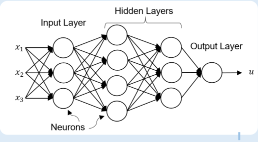
METHODOLOGY

Formulate bi-level problem

$$\begin{aligned}
&\min_{\boldsymbol{p}} C_p(\boldsymbol{p}) + \kappa C_\kappa\big(\boldsymbol{x}(t),\boldsymbol{y}(t),\boldsymbol{u}(t),\boldsymbol{p},\theta^P(t)\big)\\
&s.t.\ f_p\big(\boldsymbol{p},\theta^P(t)\big) = 0\\
&\quad\ \ g_p\big(\boldsymbol{p},\theta^P(t)\big) \le 0\\
&\quad\ \ \min_{\boldsymbol{u}(\tau)} C_u\big(\boldsymbol{x}(t),\boldsymbol{y}(t),\boldsymbol{u}(t),\boldsymbol{p},\theta^P(t)\big)\\
&\quad\ \ s.t.\ \dot{\boldsymbol{x}} = f_u\big(\boldsymbol{x}(t),\boldsymbol{y}(t),\boldsymbol{u}(t),\boldsymbol{p},\theta^P(t)\big)\\
&\quad\ \ \qquad g_u\big(\boldsymbol{x}(t),\boldsymbol{y}(t),\boldsymbol{u}(t),\boldsymbol{p},\theta^P(t)\big) = 0\\
&\quad\ \ \qquad h_u\big(\boldsymbol{x}(t),\boldsymbol{y}(t),\boldsymbol{u}(t),\boldsymbol{p},\theta^P(t)\big) \le 0
\end{aligned}$$

Prepare controller

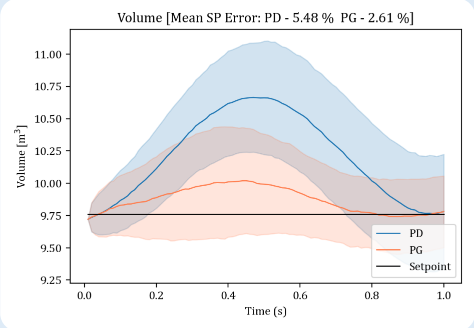




Solve the bi-level problem

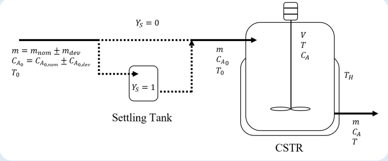
$$\boldsymbol{u}_t = \pi_\theta\big(\boldsymbol{x}_t^{obs}, \boldsymbol{x}_{t-1}^{obs}, \boldsymbol{y}_t^{obs}, \boldsymbol{y}_{t-1}^{obs}, \boldsymbol{p}^{obs}\big)\forall t$$

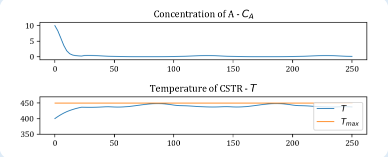
CASE STUDY 1: Tank



- Disturbance on inlet flow.
- **OCP**: Maintain **dynamic** setpoint.
- **Design**: Maximum flow **disturbance**.

CASE STUDY 2: CSTR





- Minimise reactant concentration.
- **OCP**: **Constrained** control.
- **Design**: Cost related optimisation with **binary decision** making.

CONCLUSIONS

Control Performance ✓ | Constraints ✓ | High Non-linearity [2] ✓ | Bi-linear Problem ✓

REFERENCES

[1] Petsagkourakis, P., et al. (2020) *Reinforcement learning for batch bioprocess optimization*. Computers & Chemical Engineering. [Online] 133, 106649. Available from: doi:10.1016/j.compchemeng.2019.106649.

[2] Diangelakis, N.A., et al. (2017) *Process design and control optimization: A simultaneous approach by multi-parametric programming*. AIChE Journal. [Online] 63 (11), 4827–4846. Available from: doi:10.1002/aic.15825.

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