Application of Transformed Manipulated Variables to Cascade Control Systems for Disturbance Rejection and Linearization

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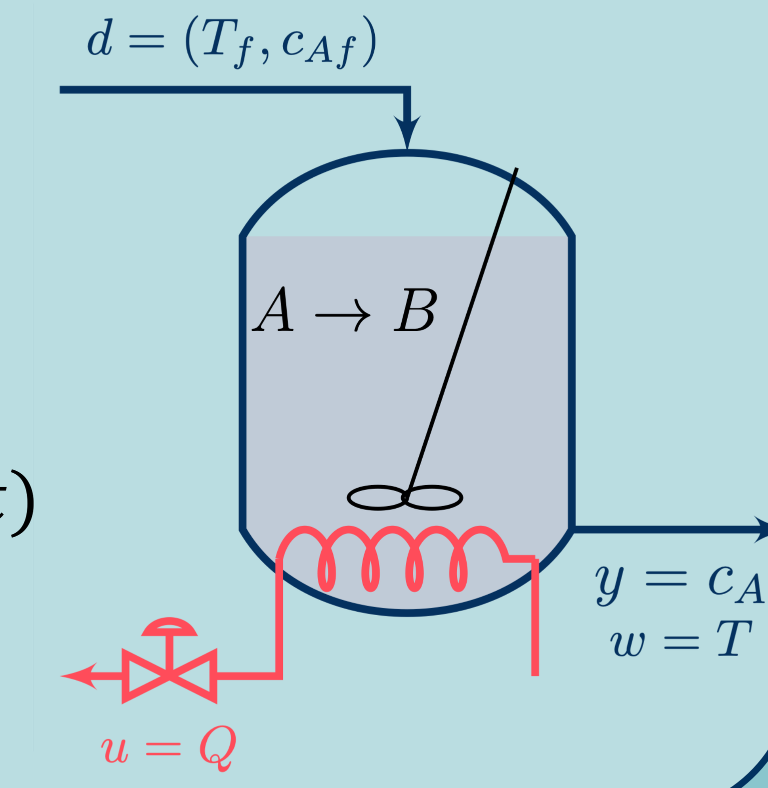
Overview

- What? Powerful, simple method for control of nonlinear systems to achieve decoupling, linearization and disturbance rejection.
- Why? Existing techniques are very complex (e.g. feedback linearization) and not widely used in industrial settings.
- How? Simple manipulated variable (MV) transformations, also for systems with relative order > 1.
- Outcome? Several case studies, including pH control and polymerization. Simple CSTR Case Study is presented here.

CSTR Case Study

- System with relative order 2 (Q to c_A)
- Simple transforms:
  - Input 1 Calc.: $v = f - A_1\, c_A$, where $f = RHS\ of\ mass\ balance\ eqn.\,(dc_A/dt)$
  - Input 2 Calc.: $v_2 = g - A_2\, T$, where $g = RHS\ of\ energy\ balance\ eqn.\,(dT/dt)$
- A_1 and A_2 serve as tuning parameters.
- Transformed system becomes linear.



Disturbance of Feed Temperature

Block diagram below: transformed system = red box.

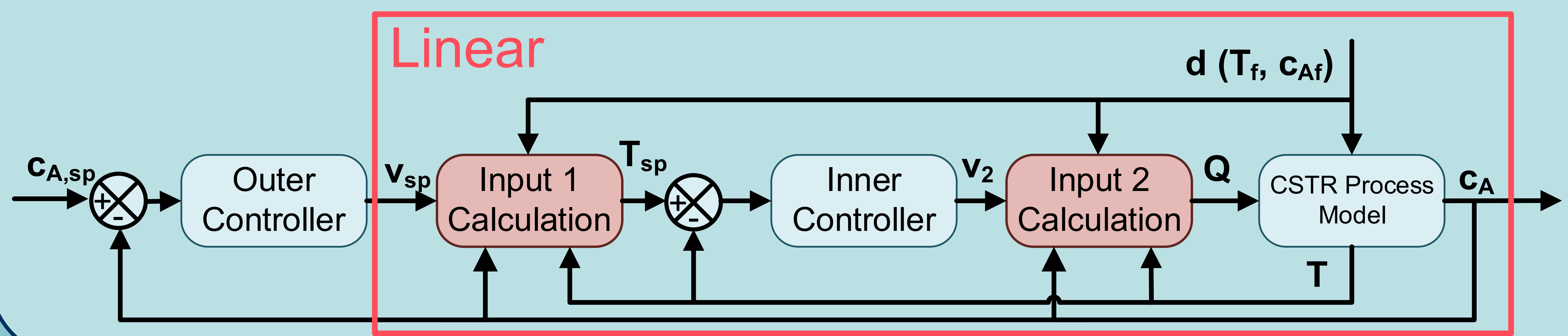
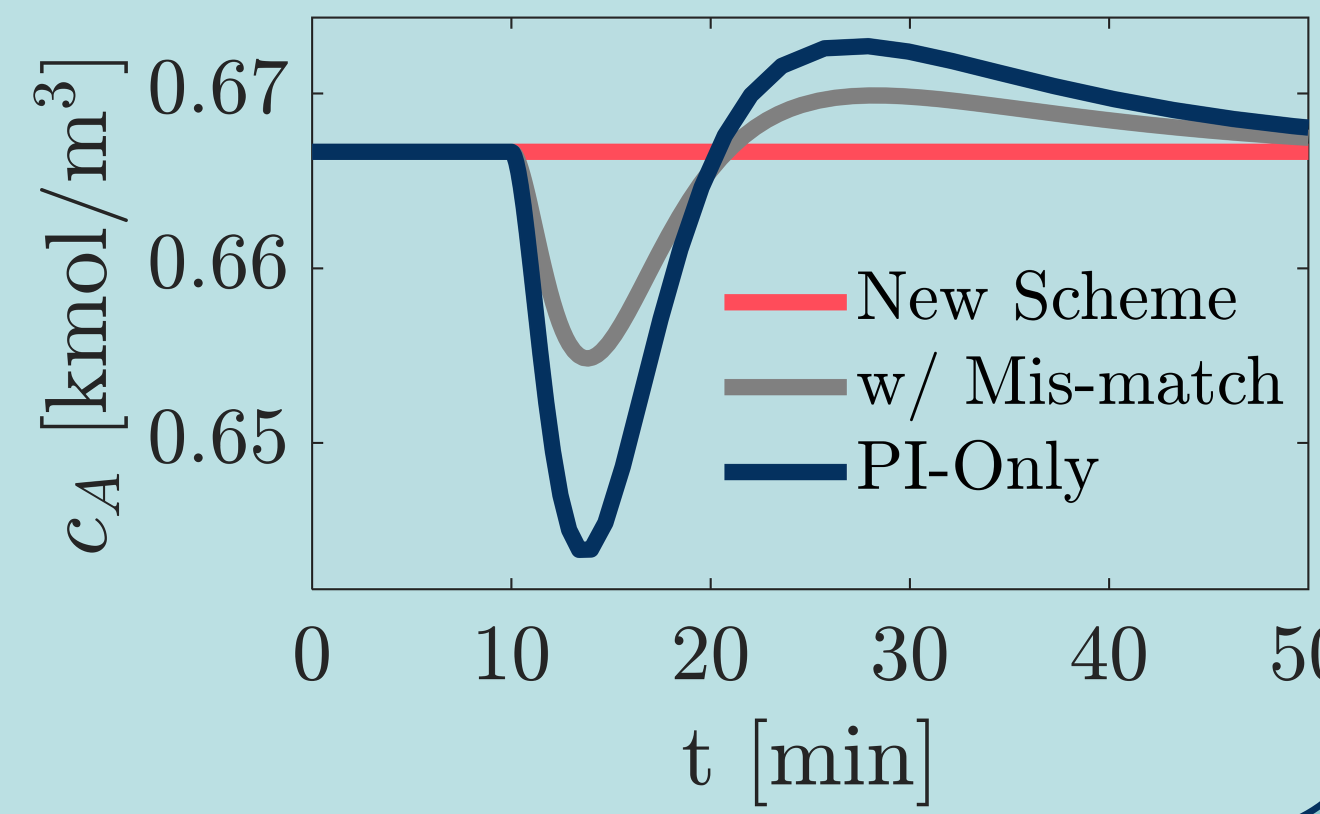


Figure right: Comparison of control schemes for a disturbance of $\Delta T_f = +5\%$ at $t = 10\ min$.



Disturbance of Feed Concentration & Set-point Change

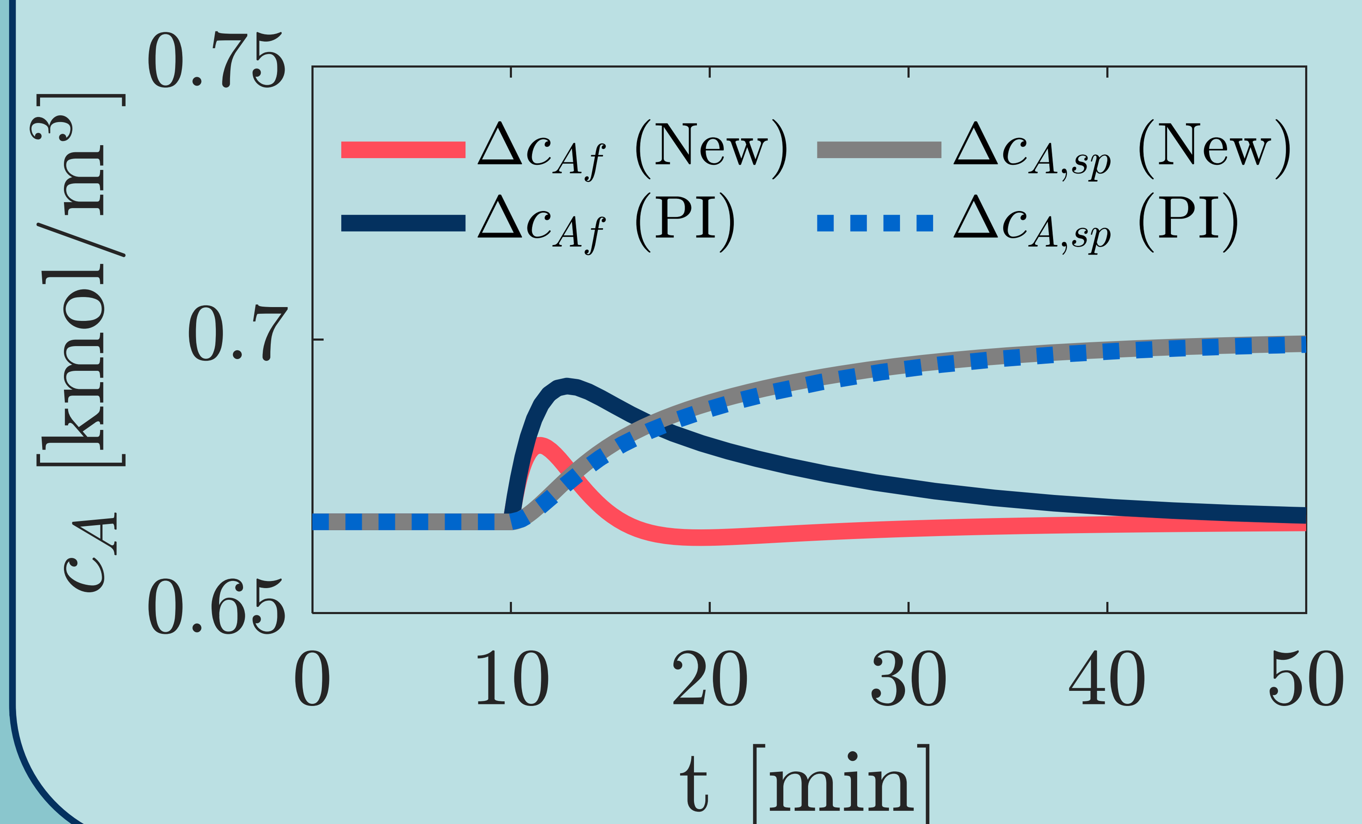


Figure left: comparison of control schemes for disturbance of $\Delta c_{Af} = +0.1\ kmol/m^3$ or set-point change at $t = 10\ min$.

Conclusion & Further Work

- Superior performance than PI-only control for all disturbances.
- Set-point tracking as-good-as PI-only control.
- Performance is enhanced in a very simple, powerful change to the system and proven to work without an exact process model.

- Further work: Work on multiple-input multiple-output (MIMO) systems with relative order > 1.

Reference: Zotica, C., Alsop, N., and Skogestad, S. (2020). "Transformed Manipulated Variables for Linearization, Decoupling and Perfect Disturbance Rejection." In: IFACPapersOnLine.