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Advanced Feedforward Control for Motion Systems

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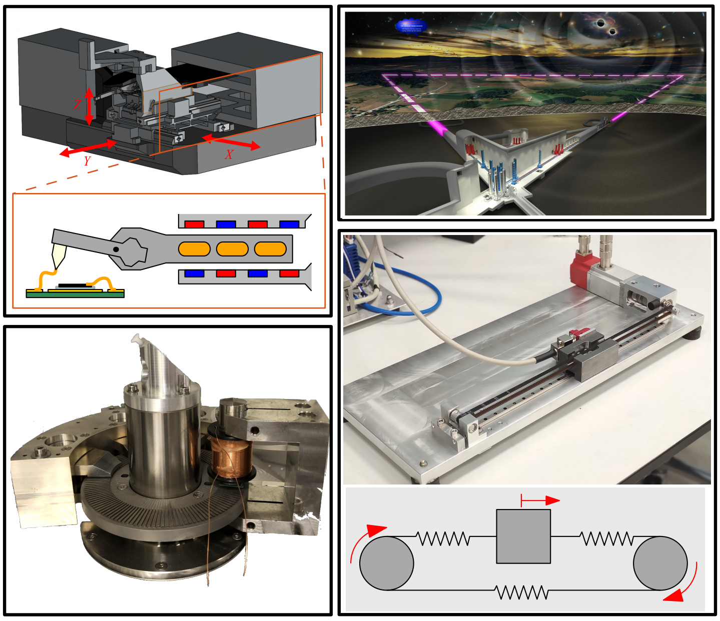
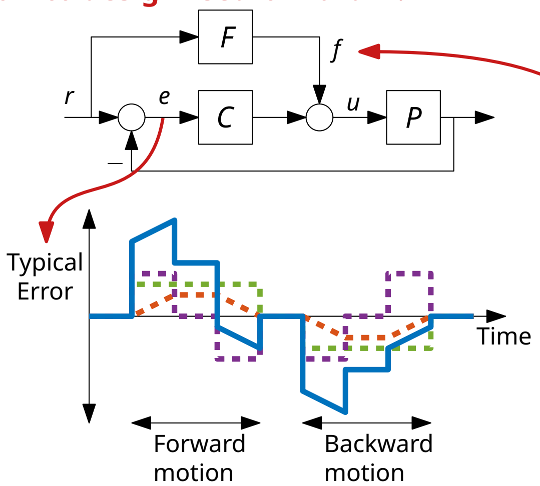
Background and Challenges



How to design feedforward F ?



Employ first-principles-based feedforward [1]:

- ▷ Mass (—)
- ▷ Static friction (—)
- ▷ Viscous friction (—)
- ▷ Compliance

Parasitic effects:

- ▷ Flexible dynamics
- ▷ Non-linear dynamics
- ▷ Position-dependent dynamics

} **High modeling effort!**

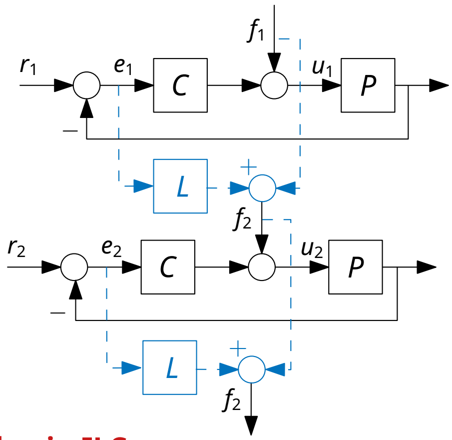
Solution in this poster:

Data-driven feedforward using Iterative Learning Control (ILC)

Iterative Learning Control

Iterative learning control enables [1]:

- ▷ Learning feedforward signal iteratively
- ▷ Compensating reproducible errors



Key idea in ILC:

- ▷ Assume same motion task ($r_1 = r_2 = \dots$)
- ▷ Use approximate model of dynamics in L

Demo: Desktop A3 printer controlled by Matlab with Raspberry Pi!

How to achieve task flexibility?

Parameterize feedforward using 1st-principles feedforward:

$$f(t) = \dot{r}(t)\,\hat{v} + \ddot{r}(t)\,\hat{m} = \underbrace{\begin{bmatrix}\dot{r}(t) & \ddot{r}(t)\end{bmatrix}}_{\Psi(r(t))} \underbrace{\begin{bmatrix}\hat{v} \\ \hat{m}\end{bmatrix}}_{\theta}$$

- ▷ Automated learning of θ instead of $f(t)$

Challenge:

- ▷ How to select $\Psi(r(t))$?

Beyond Iterative Learning Control

Feedforward for next-generation machines:

- ▷ Extend feedforward with neural network [2]
- ▷ Basis functions for position-dependency [3]
- ▷ Model nonlinear dynamics with Gaussian process [4]

References → toomen.eu

[1] T. Oomen, ”Learning in machines”, Mikroniek, 2018.
[2] J. Kon, D. Bruijnen, J. van de Wijdeven, M. Heertjes and T. Oomen, ”Physics-Guided Neural Networks for Feedforward Control: An Orthogonal Projection-Based Approach,” 2022 American Control Conference, 2022.
[3] M. van Haren, L. Blanken, and T. Oomen, ”Basis Function feedforward for Position-Dependent Systems,” Second euspen SIG on Precision Motion Systems & Control, 2022.
[4] M. Poot, J. Portegies, N. Mooren, M. van Haren, M. van Meer, and T. Oomen, ”Gaussian Processes for Advanced Motion Control”, IEEJ Journal of Industry Applications, vol. 11, no. 3, pp. 396–407, 2022.

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