Combined learning for TASK-FLEXIBLE and HIGH PERFORMANCE ILC

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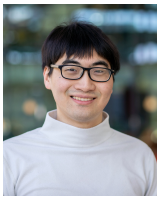


Introduction

Requirements for high-precision mechatronics systems

- High speed and accuracy
  → Data-driven learning (e.g., iterative learning control)
- High reliability
  → Physics-based insight (e.g., mass, spring, damper)

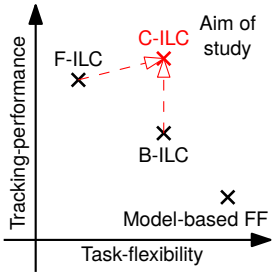
Lithography systems [Nikon]

Chip mounter [Panasonic]

ILC: Iterative Learning Control

pre-existing frameworks

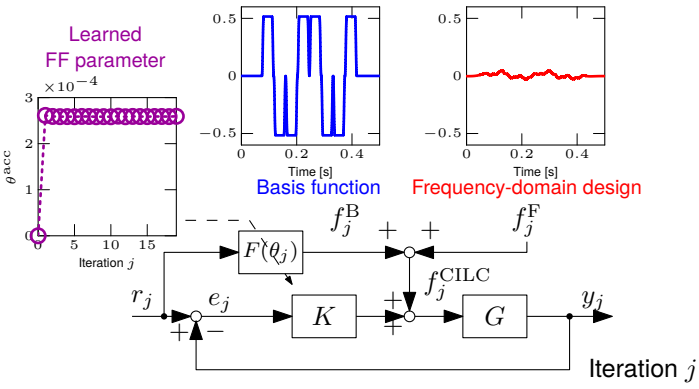
- Frequency-domain ILC (F-ILC)
  → ☺ Peak performance, ☹ Task-flexibility
- Basis function ILC (B-ILC)
  → ☺ Physics-based learning, 😐 Performance



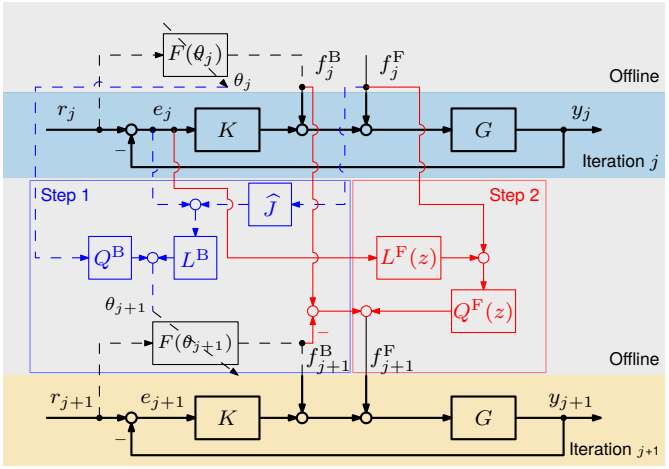
This study [1]

Combine learning of both **Frequency-domain** and **Basis function design**

Combined ILC (C-ILC)



Conceptual C-ILC framework



Detailed C-ILC update procedure

Step 0: Execute iteration j

Step 1: Calculate $f_{j+1}^{\mathrm{B}} = F(\theta_{j+1})r_{j+1}$

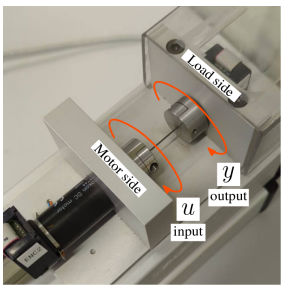
$$\theta_{j+1} = Q^{\mathrm{B}}\theta_j + L^{\mathrm{B}}(e_j + \hat{J}f_j^{\mathrm{F}}), \quad \text{(e.g., } F(\theta) = \theta^{\mathrm{acc}}s^2\text{)}$$

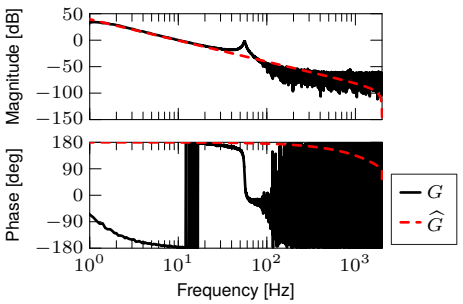
Step 2: Calculate $f_{j+1}^{\mathrm{F}} = Q^{\mathrm{F}}(f_j^{\mathrm{F}} + L^{\mathrm{F}}e_j) + f_j^{\mathrm{B}} - f_{j+1}^{\mathrm{B}}$

(Step 2': If $r_{j+1} \neq r_j$, reset $f_{j+1}^{\mathrm{F}} = 0$)

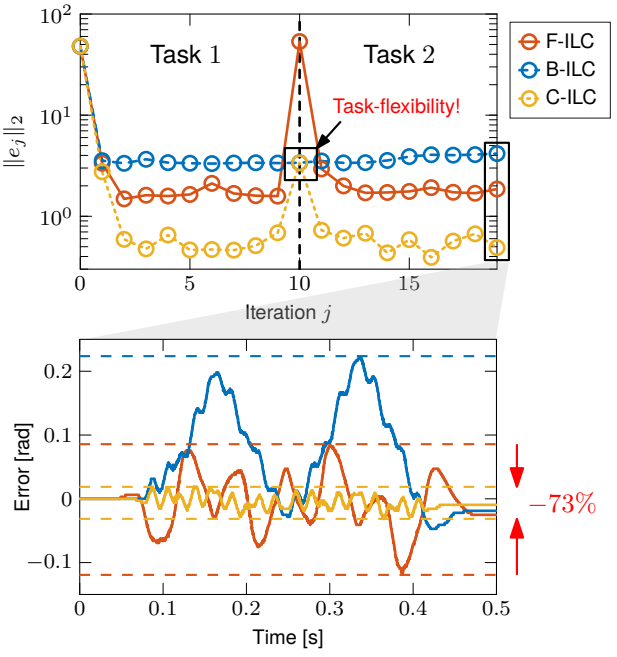
Step 3: Increment j and return to Step 0

Experimental results





Experimental setup



High task-flexibility and tracking-performance of C-ILC

Reference

[1] K. Tsurumoto, W. Ohnishi, T. Koseki, M. van Haren and T. Oomen, "Integrated Rational Feedforward in Frequency-Domain Iterative Learning Control for Highly Task-Flexible Motion Control," *IEEE/ASME Transactions on Mechatronics*, 2024