

# ILC Exam Report

## Implementation of f-ILC

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# Outline

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3. What is missing ?
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6. What is ILC ?
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# Overview

- Implementation of “Iterative Learning in Functional Space for Non-Square Linear Systems” by *C. Della Santina* and *F. Angelini*<sup>1</sup>.
- Julia<sup>2</sup> Code found at [https://github.com/PaioPaio/ILC\\_exam](https://github.com/PaioPaio/ILC_exam)

# What is Iterative Learning Control ?

Iterative Learning Control<sup>3</sup> (ILC) generally concerns the control of a repeated task. It does so by:

- Closing the loop in the **Iteration Domain** rather than directly time
- Learning just the **Feed-Forward Input**

## Remark

ILC assumes that only the initial state is the same at each iteration, no assumptions are made about the terminal state.

# What is missing ?

- No treatment of the case in which **#inputs<#outputs**
-

# System Set up

## LTI Continuous Time System

$$\dot{x}_j = Ax_j + Bu_j, \quad y_j = Cx_j \quad \text{with } x_j \in \mathbb{R}^n, u_j \in \mathbb{R}^l, y_j \in \mathbb{R}^m$$

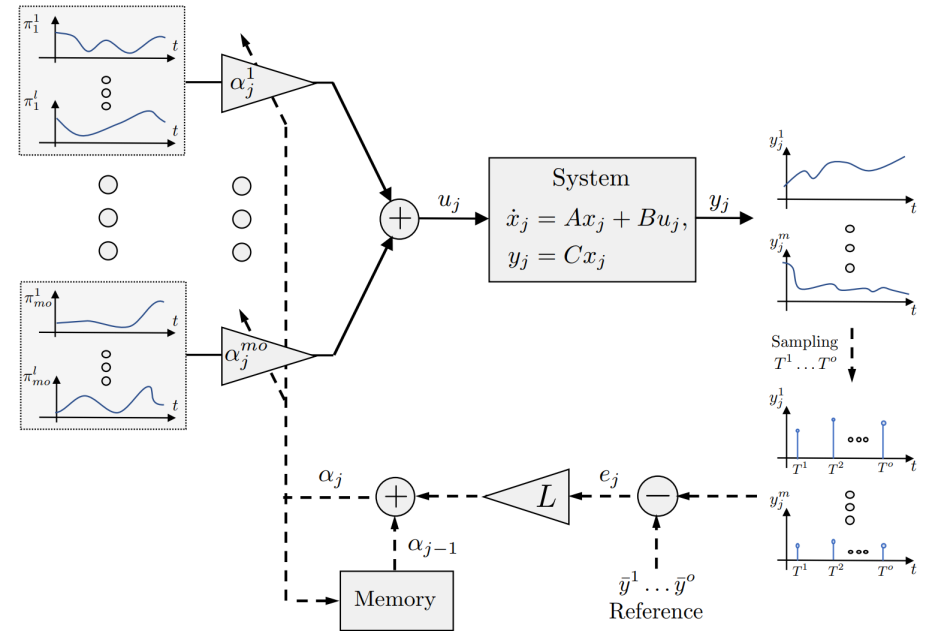
This system is:

- **Iterated** and  $j$  indicates the repetition index
- Usually **non-square**, i.e.  $l \neq m$ , more interesting is the case where the system is underactuated  $l < m$
- **Sampled** only at a finite number of time instants  $\{T^1, \dots, T^o\}$

# Functional ILC

## fILC Structure

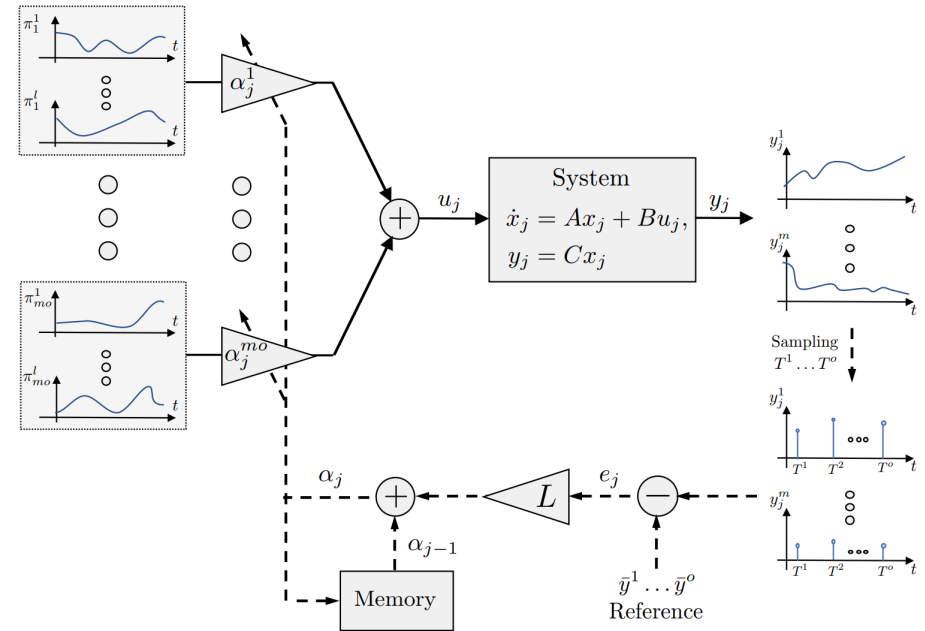
- $\begin{bmatrix} \alpha_j^1 \\ \vdots \\ \alpha_j^{mo} \end{bmatrix}$  vector of weights updated at each iteration  $j$
- $l$  basis functions for each weight
- Reference given at discrete set of sampled times  $\{T^1, \dots, T^o\}$ , ( $T^0 = 0$ )
- $L \in \mathbb{R}^{mo \times mo}$  learning matrix s.t.  $\rho(I - LH) < 1$



# What is functional ILC ?

## fILC Structure

- $\begin{bmatrix} \alpha_j^1 \\ \vdots \\ \alpha_j^{mo} \end{bmatrix}$  vector of weights updated at each iteration  $j$
- $l$  basis functions for each weight
- Reference given only at discrete set of sampled times
- $L \in \mathbb{R}^{mo \times mo}$  learning matrix s.t.  $\rho(I - LH) < 1$





# What is ILC ?

# Bibliography

1. Della Santina, C. & Angelini, F. Iterative Learning in Functional Space for Non-Square Linear Systems. in *2021 60th IEEE Conference on Decision and Control (CDC)* 5858–5863 (IEEE, Austin, TX, USA, 2021). doi:10.1109/CDC45484.2021.9683673
2. Bezanson, J., Edelman, A., Karpinski, S. & Shah, V. B. Julia: A Fresh Approach to Numerical Computing. *SIAM Review* **59**, 65–98 (2017)
3. Bristow, D., Tharayil, M. & Alleyne, A. A Survey of Iterative Learning Control. *IEEE Control Systems* **26**, 96–114 (2006)