ILC Exam Report

Implementation of f-ILC

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Outline

1. Overview
2. What is Iterative Learning Control ?
3. Contributions of the paper
4. Functional ILC
5. Simulations
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Overview

- Brief summary of Iterative Learning Control
- Implementation of “Iterative Learning in Functional Space for Non-Square Linear Systems” by *C. Della Santina* and *F. Angelini*[1].
- Julia[2] Code found at https://github.com/PaioPaio/ILC_exam

What is Iterative Learning Control ?

Iterative Learning Control[3] (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 Iterative Learning Control ?

In a nutshell ILC :

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Contributions of the paper

- Treatment of the case in which **#inputs<#outputs**
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System Set up

LTI Continuous Time System

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

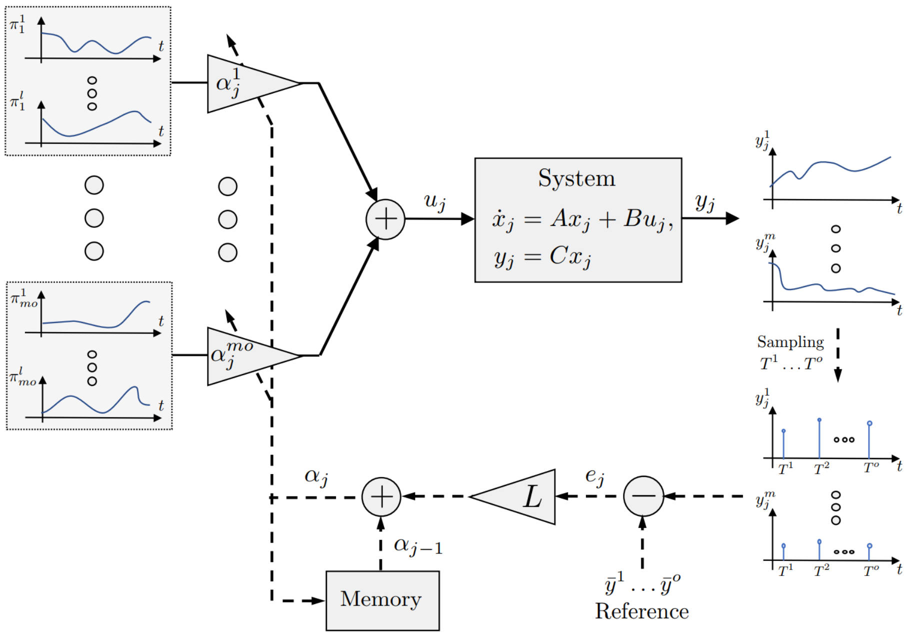
This system is:

- **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 $\{T^1, ..., T^o\}$

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 $\{T^1, ..., T^o\}$, $(T^0 = 0)$
- $L \in \mathbb{R}^{mo \times mo}$ learning matrix s.t. $\rho(I - LH) < 1$



Simulations

Carts

Basketball in the wind

5 Carts

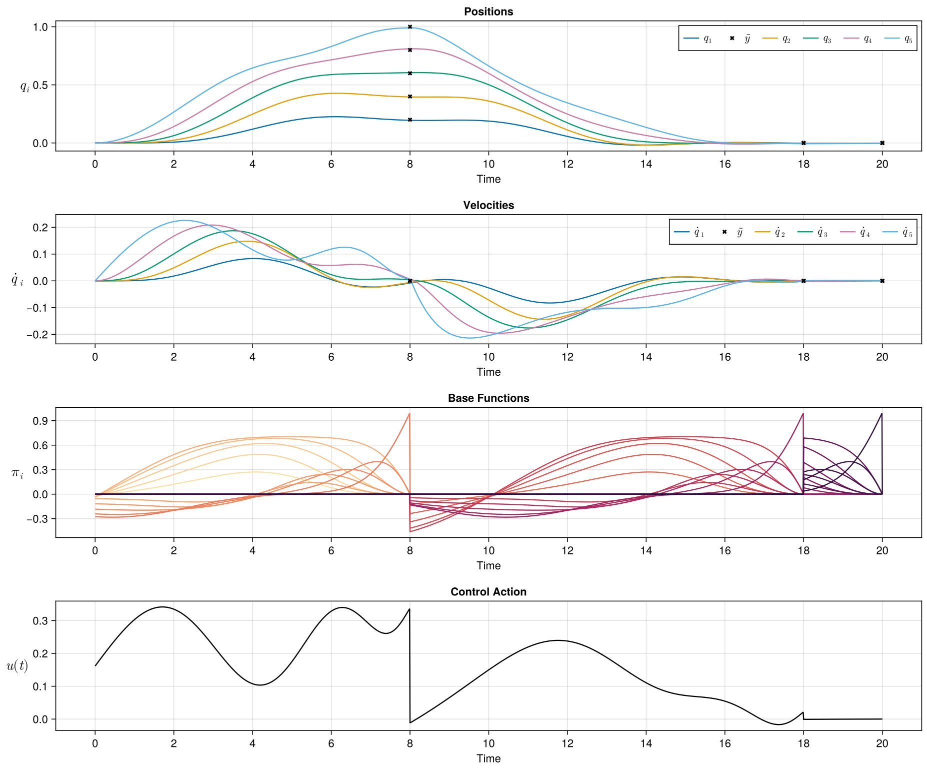


Figure 1: 30 Iterations

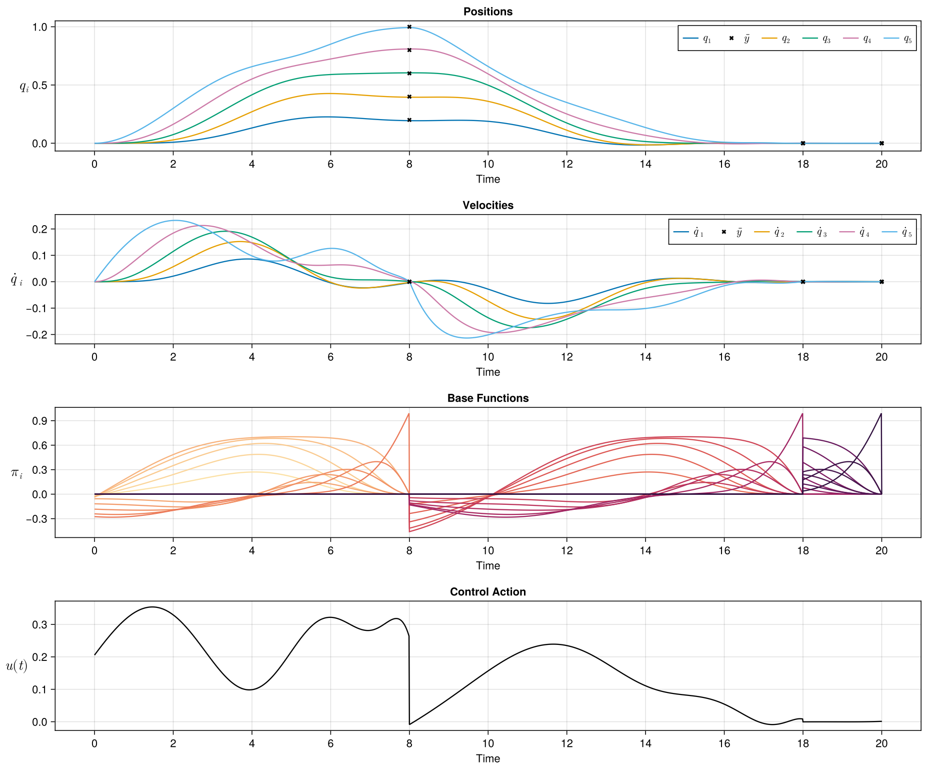


Figure 2: 300 Iterations - Not much changes

8 Carts

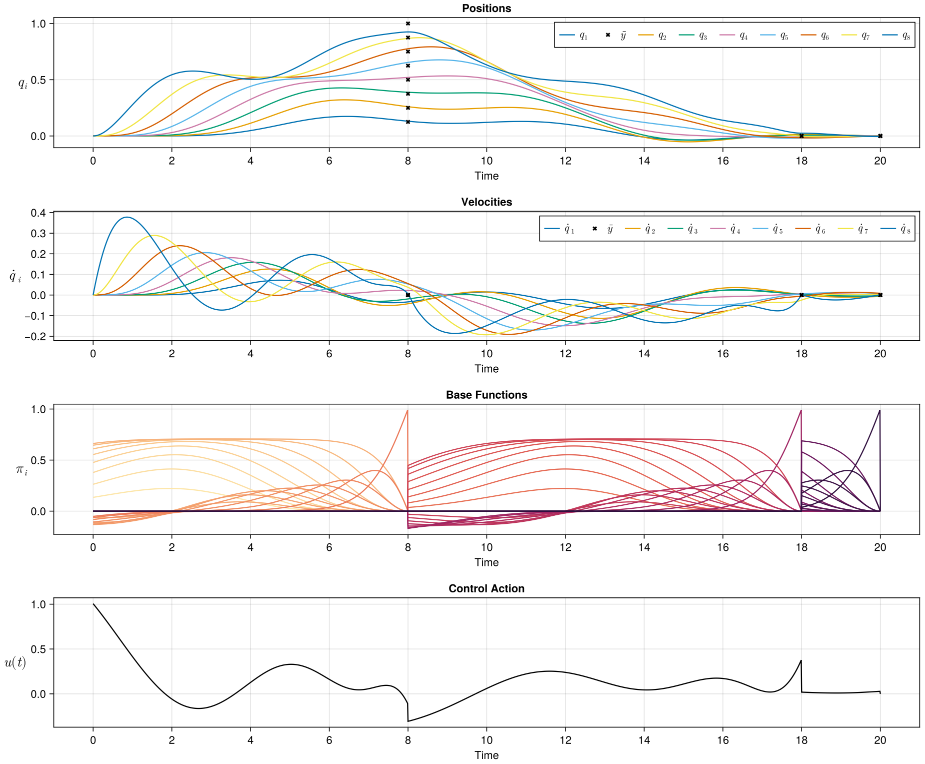


Figure 3: 30 Iterations - Can't perform to specification

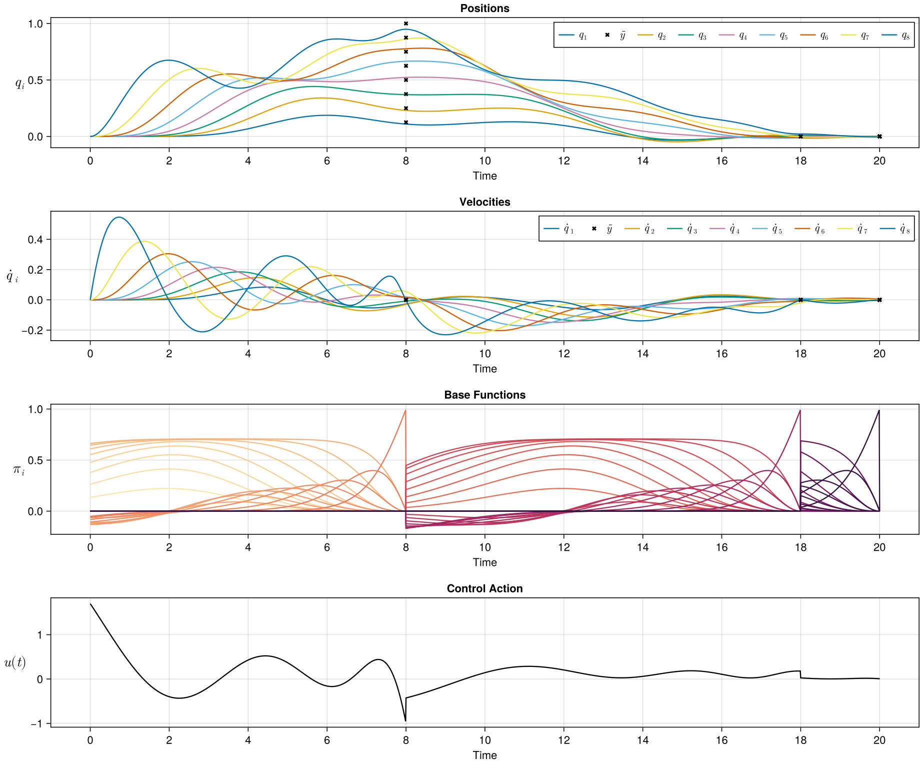


Figure 4: 300 Iterations - Better, still not perfect

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)