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An Application of Iterative Learning Control in Object Trajectory Tracking

Nguyen Huu Chinh
Thai Nguyen University of technology
Email: chinh_kty@tnut.edu.vn

Abstract
This paper presents an approach to trajectory tracking control using Iterative Learning Control (ILC) without requiring a mathematical model of the controlled system. Traditional control methods depend heavily on system modeling, which may not always be feasible due to system complexity or uncertainty. ILC offers a model-free alternative by utilizing repetition in tasks to iteratively improve control performance. The simulation results demonstrate that trajectory tracking accuracy improves as the number of learning iterations increases.
Keywords: *Iterative Learning Control (ILC), Trajectory Tracking, Model-Free Control*

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I. Introduction

The ultimate goal of any automatic control system is to ensure that the system's output follows a desired reference trajectory. Most modern control strategies rely on an accurate mathematical model of the plant. However, due to external disturbances, non-linearities, or incomplete knowledge, obtaining such a model is not always practical. Iterative Learning Control (ILC) provides a solution by learning from previous executions of a repetitive task, progressively refining the control input to reduce tracking error over iterations.

II. Problem Formulation

2.1. System Description

Consider a discrete-time single-input single-output (SISO) system represented by the transfer function:

$$W(z) = \frac{(z+0.5)}{z^2+0.7z+0.1} \qquad (2.1)$$

The equation is represented a discrete - time transfer function

$$W(z^{-1}) = \frac{z^{-1}+0.5z^{-2}}{1+0.7z^{-1}+0.1z^{-2}} \qquad (2.2)$$

This can be rewritten as the following difference equation:

$$y_k(t) = u_k(t-1)+0.5u_k(t-2)-0.7y_k(t-1)-0.1y_k(t-2) \qquad (2.3)$$

Where $y_k(t)$ and $u_k(t)$ are the output signal and input of the system at time t

2.2. Learning Rule

The ILC algorithm updates the control input in the next iteration based on the error in the current iteration:

$$u_{k+1}(\tau) = u_k(\tau)+K.e_k(\tau+1) \text{ for } 0 \le \tau \le T \qquad (2.4)$$

III. Simulation and Discussion

3.1. Simulation Setup

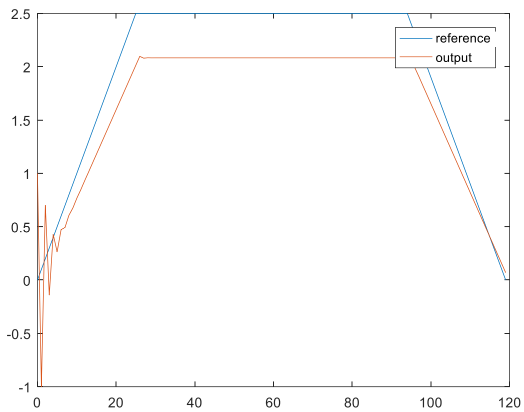
Learning gain: K = 0.5
Initial conditions: y(1) = 1, y(2) = -1
Simulation horizon: T = 60
Reference signal:

$$r(t)=\begin{cases}0.1t & (0\le t\le 25)\\ 2.5 & (25\le t\le 95)\\ -0.1(t-95)+2.5 & (95\le t\le 120)\end{cases} \quad (2.5)$$

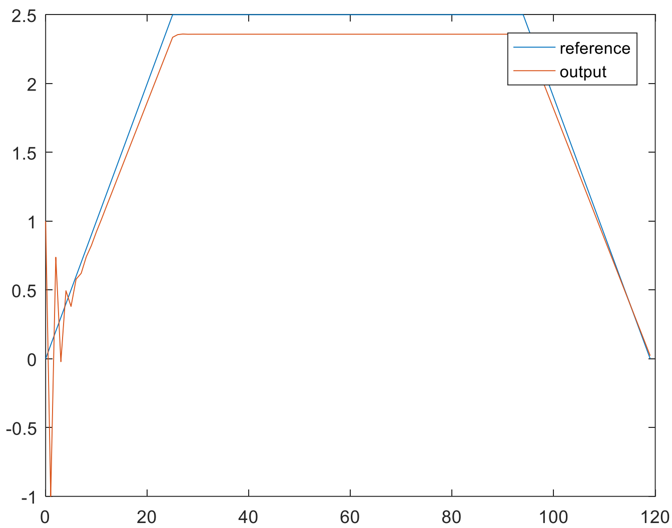
The control and learning algorithm is implemented in MATLAB to simulate multiple earning iterations.

3.2. Results

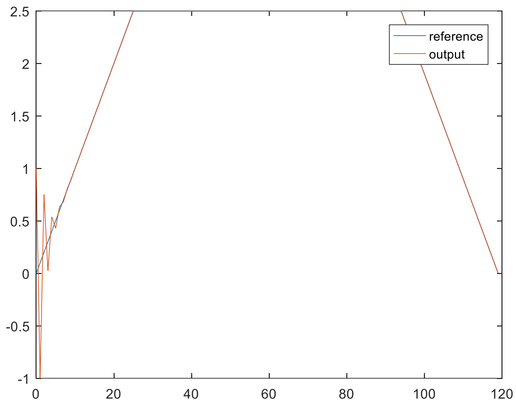
Iteration 1: The output signal begins to approximate the reference trajectory, but significant tracking errors remain.



Iteration 3: The control system shows improved tracking accuracy with reduced error.



Iteration 10: The system output closely follows the reference, indicating successful learning.



These results affirm the effectiveness of the ILC strategy in improving tracking performance over successive iterations.

IV. Conclusion

The study confirms that Iterative Learning Control can significantly enhance trajectory tracking performance in systems with repetitive operations, even in the absence of a precise mathematical model. The choice of learning law and tuning parameters plays a crucial role in convergence and effectiveness. Future work may explore robustness and generalization to nonlinear or time-varying systems.

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