

# Intermittent sampling in iterative learning control

**Citation for published version (APA):**

Strijbosch, N. W. A., & Oomen, T. A. E. (2020). Intermittent sampling in iterative learning control: A monotonically-convergent gradient-descent approach with application to time stamping. In R. Carloni, B. Jayawardhana, & E. Lefeber (Eds.), *39th Benelux Meeting on Systems and Control: Book of Abstracts* (pp. 109). Universiteit Groningen. <https://www.beneluxmeeting.nl/2020/uploads/papers/boa.pdf>

**Document status and date:**

Published: 01/01/2020

**Document Version:**

Accepted manuscript including changes made at the peer-review stage

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

**Take down policy**

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

# Intermittent Sampling in Iterative Learning Control: a Monotonically-Convergent Gradient-Descent Approach with Application to Time Stamping

Nard Strijbosch  
Eindhoven University of Technology  
Control Systems Technology  
Email: n.w.a.strijbosch@tue.nl  
P.O. Box 513, 5600 MB Eindhoven  
The Netherlands

Tom Oomen  
Eindhoven University of Technology  
Control Systems Technology  
Email: t.a.e.oomen@tue.nl  
P.O. Box 513, 5600 MB Eindhoven  
The Netherlands

## 1 Background: Iterative Learning Control

Iterative learning control (ILC) can significantly improve the performance in control applications by learning from past experiments. A mature framework has been developed in the past decades for disturbances that are iteration-invariant acting on LTI dynamical systems [1].

## 2 Problem Formulation

The standard assumption that a measurement signal is available at each sample in iterative learning control (ILC) is not always justified, e.g., in systems with data dropouts or when exploiting time-stamped data from incremental encoders [2]. When designing an ILC algorithm for this type of systems, where only intermittent data is available to the ILC algorithm, a few challenges arise:

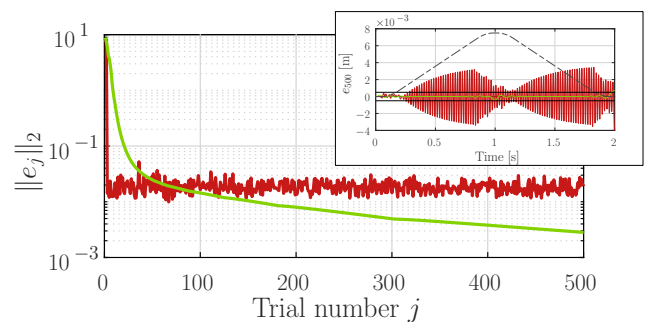
- monotonic convergence is not defined due to varying lengths of error signals,
- computation time for an explicit ILC update explodes due to exponentially growing number of possible data points.

## 3 Decentralized Intermittent ILC

To address this, a new notion of monotonic convergence is defined and a decentralized ILC approach is developed where both theoretical and design aspects are fully commenced, in addition to its application on state-of-the-art applications [3]. The developed ILC framework guarantees monotonic convergence of the sequence of control input signals for all possible time-stamp sequences. Moreover, a decentralized design approach is developed that consists of designing a single diagonal matrix that should only suffice a single LMI. This approach is computationally efficient due to its independence of the number of time-stamp sequences. Moreover, this approach delicately connects to existing gradient-descent based ILC algorithms.

## 4 Results

When applying the decentralized ILC controller to a mass-spring-damper system from which exact time-stamped data is available the results presented in Figure 1 are obtained. It



**Figure 1:** Error norm  $\|e_j^h\|_2$  when applying traditional quantized ILC (—) and when applying the decentralized ILC controller (—). Error  $e_{500}$  at trial 500 after applying traditional quantized ILC (—) and after applying the decentralized ILC controller (—).

can be observed that each iteration the time instances of the available data are varying. Nonetheless, the ILC algorithm is capable of reducing the error significantly, and monotonic convergence of the input signal is guaranteed.

## 5 Ongoing research

Future research focuses on extending the ILC framework to a wider range of systems and applying the developed framework to experimental setups.

## Acknowledgements

This work is part of the research programme VIDI with project number 15698, which is (partly) financed by the Netherlands Organisation for Scientific Research (NWO).

## References

- [1] D. A. Bristow, M. Tharayil, and A. G. Alleyne, “A survey of iterative learning control,” *IEEE Control Systems Magazine*, vol. 26, pp. 96–114, June 2006.
- [2] N. Strijbosch and T. Oomen, “Beyond quantization in iterative learning control: Exploiting time-varying time-stamps,” in *American Control Conference 2019, Philadelphia, USA*, 2019.
- [3] N. Strijbosch and T. Oomen, “Intermittent Sampling in Iterative Learning Control: a Monotonically-Convergent Gradient-Descent Approach with Application to Time Stamping,” in *Conference on Decision and Control 2019, Nice, France*, 2019.