Iterative Learning Control for Varying Tasks

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1 Background

Iterative Learning Control (ILC) [1] can significantly enhance the performance of systems that perform repeating tasks. However, small variations in the task often lead to a large performance deterioration. This leads to a trade-off between high performance and extrapolation properties, i.e., the ability to cope with reference variations. The goal of this research is to improve this trade-off in ILC.

2 Iterative Learning Control

Consider the control setup in Figure 1 with trial number j. Given old measurement data e_j, f_j, the goal in ILC is to determine f_{j+1} such that $J_{j+1} = \|e_{j+1}\|_2^2$ is minimized.

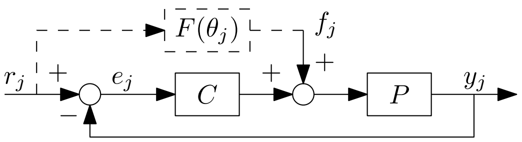

Figure 1: Control setup: the goal is to minimize error e_j by iteratively updating feedforward f_j.

ILC is known to achieve excellent performance for systems operating repetitively ($r_j = r, \forall j$). However, for varying reference signals there is significant performance deterioration.

3 Basis functions

To enhance extrapolation properties, ILC is extended with basis functions by using $f_j = F(\theta_j)r$, with $F(\theta_j)$ a parameterized filter. Examples include polynomial basis functions [2] of the form $F(\theta_j) = A(\theta_j)$ and more recently rational basis functions [4] of the form $F(\theta_j) = \frac{A(\theta_j)}{B(\theta_j)}$, where $A(\theta_j), B(\theta_j)$ are affine.

An analytic solution to the optimization problem is available for polynomial basis functions and rational basis functions with fixed poles. However, this requires a careful selection of poles and typically limits the achievable performance. In this work [3], rational basis functions are proposed where both poles and zeros are not pre-specified but optimized. In pre-existing work [4] an iterative approach based on Steiglitz-McBride identification is presented, which from related system identification algorithms is known to generally yield non-optimal results. The new approach, which has strong connections to instrumental variable system identification, does yield optimal results in the sense that it converges to a minimum [5]. The solution takes the standard ILC form $\theta_{j+1}^{\langle q \rangle *} = Q^{\langle q \rangle} f_j + L^{\langle q \rangle} e_j$, with $Q^{\langle q \rangle}, L^{\langle q \rangle}$ based on approximate models of C and P.

4 Simulations

Simulations with various ILC approaches for the y-direction of the printing system in Figure 2 are executed. The reference signal is varied over the trials: r^a is active at trial $j = 0,1,2$, r^b at $j = 3,4,5$, and r^c at $j = 6,7,8$. The results are shown in Figure 3. The figure indicates that the performance of standard ILC deteriorates significantly after a change in reference signal, whereas the influence on the performance of ILC with basis functions is negligible. The results also indicate the enhanced performance of ILC with rational basis functions using the proposed approach compared to the pre-existing approach.

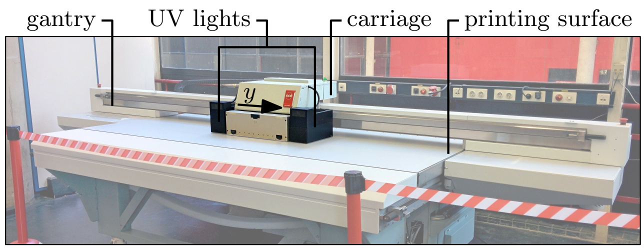

Figure 2: Océ Arizona 550 GT at TU/e CST Motion Lab.

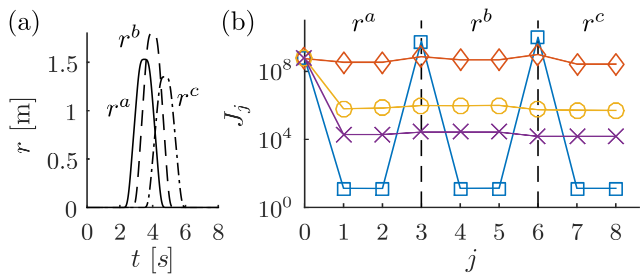

Figure 3: (a) trial varying reference signal; (b) performance criterion J_j for standard ILC (□), polynomial basis functions (◇), and rational basis functions using the pre-existing approach (○) and proposed approach (×).

References

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