Iterative Feedforward Control: Enhanced Accuracy and Efficiency

Frank Boeren[1], Tom Oomen[1], Dennis Bruijnen[2], and Maarten Steinbuch[1]
[1] Control Systems Technology, Dept. of Mechanical Engineering, Eindhoven University of Technology, The Netherlands
[2] Mechatronics Technologies, Philips Innovation Services, Eindhoven, The Netherlands
Email: *f.a.j.boeren@tue.nl*

Introduction

Feedforward control is widely used in control systems to effectively compensate for known disturbances. For positioning systems, feedforward with respect to the reference signal is essential to achieve requirements regarding throughput and positioning accuracy. In view of the ever-increasing requirements for next-generation precision motion systems, advances in feedforward control are required to attain accurate positioning of systems that are subject to aggressive reference trajectories.

Iterative Feedforward Control

Iterative feedforward control can significantly improve the servo performance of a motion system for a class of reference signals, see, e.g., [1]. To this purpose, measured data from previous tasks is exploited in conjunction with a suitable parametrization for the feedforward controller C_{ff}. That is, measured data in the j^{th} task is used to update a fixed structure feedforward controller according to

$$C_{ff}^{j+1} = C_{ff}^{j} + C_{ff}^{\Delta},$$

as depicted in Fig. 1, such that the reference-induced error in the $j+1^{\text{th}}$ task is minimized when C_{ff}^{j+1} is applied to the closed-loop system. The update C_{ff}^{Δ} results from an efficient optimization procedure with an analytic solution.

The contribution of the presented research is threefold. First, it is shown that existing approaches, including [1], may suffer from a closed-loop identification problem, thereby hampering servo performance. To enhance performance, a framework is proposed based on instrumental variables [2]

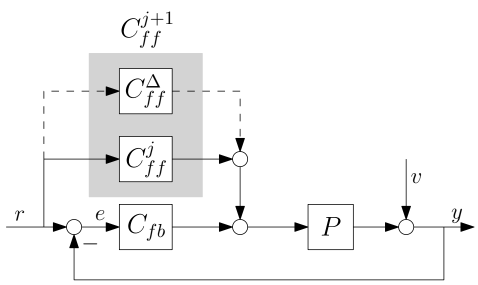

Figure 1: Two degree-of-freedom control configuration for iterative feedforward control.

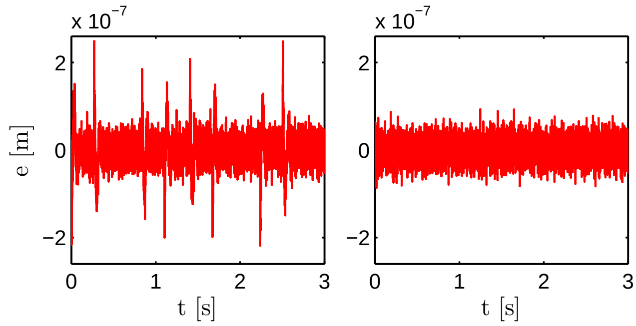

Figure 2: The error signal e contains a significant reference-induced component in existing approaches (left), while for the proposed approach e is dominantly stochastic (right).

to effectively deal with this closed-loop identification problem. Second, limits of accuracy are investigated in an instrumental variable framework [3], [4]. A detailed description of recent work in iterative feedforward control is presented in [5]. The provided analysis of accuracy aspects leads to optimal choices of instrumental variables. Third, closer connections between automated and manual tuning are established. A simulation example as depicted in Fig. 2 illustrates that the reference-induced error is minimized with the proposed approach.

Ongoing research

Current work is aimed at generalizing the parametrization of the feedforward controller and extensions to multivariable systems, input shaping, and trajectory design.

References

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