Iterative Feedforward Control with Application to a Wafer Stage

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Introduction

Feedforward control enables high performance in industrial motion systems. The key performance enhancement is in general obtained by using feedforward with respect to the reference trajectory. In existing methods, typically a trade-off exists between the attainable performance and the required robustness to changes in the reference. Through new developments in feedforward control it is aimed to attain high performance for a class of reference signals.

Iterative feedforward control with a rational basis

Iterative feedforward control can attain high performance for a class of reference signals [1]. To achieve this, measured data from previous tasks is exploited in conjunction with a suitable parametrization for the feedforward controller $C_{ff}(\theta)$. The need for an approximate model of the system, as is common in ILC [2], is eliminated by formulating the approach as an instrumental variable-based estimation problem as in [3]. The corresponding control configuration is depicted in Fig. 1. The parameters θ^{j+1} in the $(j+1)^{\text{th}}$ task result from an optimization problem based on measured data from the j^{th} task.

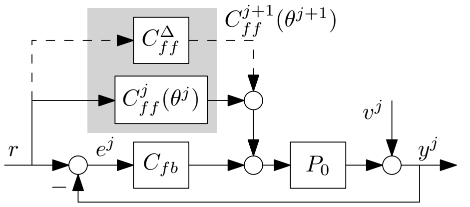

Figure 1: Control configuration for iterative feedforward control.

Existing approaches focus on a polynomial parametrization of C_{ff}, see e.g. [1], [4]. However, in [2] it is shown that for a rational system P_0, a rational parametrization is required for C_{ff} to attain high performance for a class of reference signals. The present research aims to introduce such a parametrization in iterative feedforward control using system identification techniques.

A system identification approach to iterative feedforward control

The present research consists of three main aspects. First, a framework is presented for iterative feedforward control with a rational parametrization. This approach is based on instrumental variables, as in [3], [5]. Second, the limits of accuracy are investigated and an iterative algorithm is proposed that obtains parameter estimates θ^{j+1} with optimal accuracy in terms of variance. Third, an experimental validation of the proposed methodology is presented.

Experimental results

The proposed approach is implemented on a wafer stage. The experimental results in Fig. 2 and 3 illustrate that superior servo performance is achieved with the proposed rational parametrization for C_{ff}.

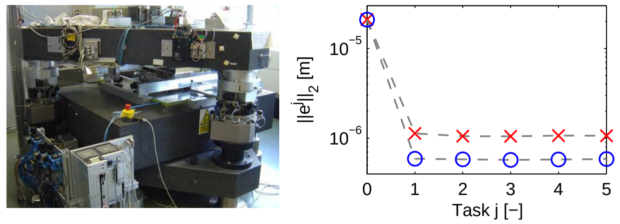

Figure 2: Wafer stage (left) and experimental results (right): superior performance is achieved with a rational parametrization (○) compared to a polynomial parametrization (×).

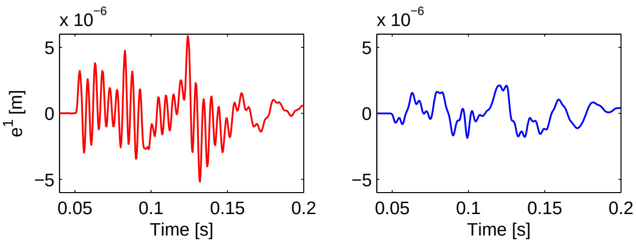

Figure 3: Time domain plot of measured error signal e^1 in the first task. Left: polynomial parametrization, right: rational parametrization.

Ongoing research

Current work is aimed at generalizing the proposed approach to multivariable systems, extensions to position-dependent behavior, and trajectory design.

References

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