Feedforward Control in the Presence of Input Nonlinearities: A Learning-based Approach

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1 Background

Advanced feedforward control methods often enable mechatronic systems to perform varying motion tasks with extreme accuracy. Many of these developments focus on linear time-invariant systems, either polynomial [1] or rational [2], possibly with friction compensation. In many systems, additional nonlinearities, including actuator saturation, are present that may limit control performance.

2 Problem Formulation

The aim is to achieve low error and high flexibility to varying tasks for motion systems that exhibit dominant linear dynamics, and which contain a static input nonlinearity, i.e., a Hammerstein system. This research aims to learn a parametrized input nonlinearity using data.

3 Approach

A parametrized linear feedforward, i.e., basis functions [1], can compensate the linear component of the described system. In addition, the input nonlinearity can be compensated by inversion in the feedforward, together constituting a Wiener feedforward. The key idea is that norm-optimal iterative learning control (NOILC) is able to compensate nonlinear behavior if it is repetitive. In order to do so, the input nonlinearity is modeled using a parametric model. Then, the NOILC optimization is performed with a repeated reference satisfying persistence of excitation for the nonlinear system. Lastly, the converged NOILC feedforward signal is fitted by the parametrized Wiener feedforward. The fitted parameter values can be used to invert the input nonlinearity.

4 Results

Fig. 1 shows results for positioning of a simulated wire bonder system in one direction, i.e., SISO, with an input nonlinearity. Shown are linear rational basis function (RBF) feedforward [2] and RBF with inversion of the input nonlinearity, obtained using the proposed method. Observe that the proposed method compensates the input nonlinearity,

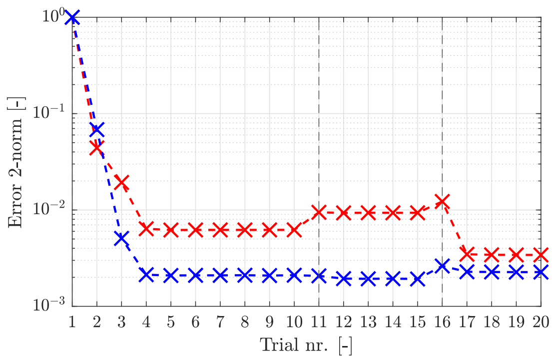

Figure 1: Comparison of the error 2-norm per trial for linear parametrized feedforward (-) and the proposed method (-). In order to show the flexibility of the methods, the motion task is changed at trials 11 and 16. This task change is indicated by vertical dashed lines.

which results in a lower error 2-norm and higher performance directly after a task change compared to strictly linear parametrized feedforward.

5 Conclusion and Outlook

This research introduces a method for identification and compensation of input nonlinearities by exploiting a norm-optimal ILC signal. Results indicate that performance in terms of both tracking error and flexibility to task variations are improved.

References

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