

Flexible learning with prior knowledge

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Flexible learning with prior knowledge: iterative learning control with sampled-data characterized basis functions

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1 Background

Performance and flexibility are typical trade-offs in mechatronic systems. Linearly parameterized feedforward control has both performance and flexibility [1]. The choice of parameterization should be determined by prior knowledge such as sampled-data characteristics.

2 Problem formulation

The controlled system is shown in Figure 1. The goal is to minimize the continuous-time tracking error $e(t)$ using the feedforward signal $f[k] = \Psi[k]\theta$ with parameter θ . For instance, Ψ is parameterized as $\Psi = [r, \xi r, \xi^2 r]$ for a mass-damper-spring system with a differentiator ξ . Typically, n^{th} order backward difference is used as n^{th} order differentiator ξ_{BD}^n to design the feedforward parameterization [2] as

$$\xi_{BD}^n = \left(\frac{1 - z^{-1}}{T_s} \right)^n. \quad (1)$$

This does not explicitly address the zero-order-hold characteristic of the step-like input shape restriction.

3 Approach

The aim is to develop flexible feedforward control with intersample consideration. The approach considers the feedforward parameterization with basis functions for flexibility that are designed with sampled-data characteristics such as zero-order-hold and multirate state tracking [3].

4 Results

The stable inversion of the n^{th} order integrator discretized by zero-order-hold is used as n^{th} order differentiator ξ_{SI}^n to design the feedforward parameterization as

$$\xi_{SI}^n = \left\{ \mathcal{Z} \left(\frac{1 - e^{-sT_s}}{s} \cdot \frac{1}{s^n} \right) z \right\}^{-1}. \quad (2)$$

The experimental result in the single inertia system $G(s) = \frac{1}{Js^2}$ with the acceleration feedforward parameterization is shown in Figure 2. The sampling time is $T_s = 20\text{ms}$. It shows that the feedforward parameterization using stable inversion $\Psi_{SI}[k] = \xi_{SI}^2 r[k+1]$ outperforms that using backward difference $\Psi_{BD}[k] = \xi_{BD}^2 r[k+1]$.

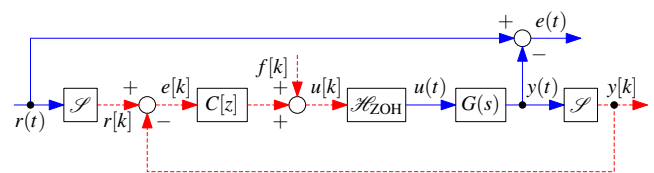


Figure 1: Controlled system discretized by zero-order-hold \mathcal{H}_{ZOH} and sampler \mathcal{S} . The discrete-time signal (---) can be controlled and the continuous-time signal (—) is the performance variable.

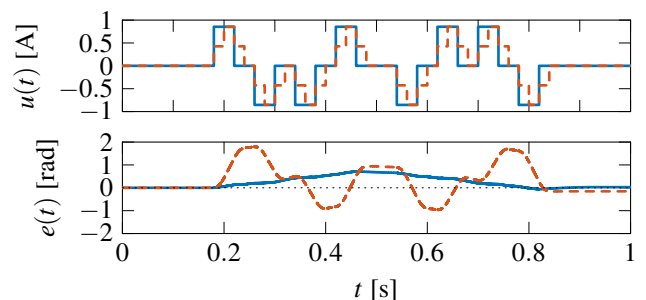


Figure 2: Experimental result of a reference tracking problem, with a parametric feedforward using stable inversion (—), that outperforms backward difference (---), reducing RMS and MAX errors by a factor of two.

5 Ongoing research

The ongoing research focuses on extending the feedforward parameterization that considers higher-order characteristics.

Acknowledgements

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