Multirate control for high accuracy and low cost: dual-stage experiments

Multirate control for high accuracy and low cost: dual-stage experiments

Jurgen van Zundert[1], Tom Oomen[1], Wouter Aangenent[2], Maurice Heemels[1]
[1]Eindhoven University of Technology, Control Systems Technology group, Eindhoven, The Netherlands
[2]ASML Research Mechatronics, Veldhoven, The Netherlands
j.c.d.v.zundert@tue.nl

Motivation: balancing performance versus cost

Dual-stage systems are commonly used in industry to achieve a high position accuracy over a large range. The different performance requirements of the stages (e.g., μm vs nm: order 10^3) result in different control bandwidths which naturally leads to a multirate design.
Multirate designs balance performance versus cost through use of different sampling frequencies. This enables reduction of implementation cost in terms of hardware, e.g., sensors, actuators, AD/DA converters. This is a clear advantage over traditional single-rate designs in which the sampling frequency for all control loops is determined by the control loop with the most stringent performance requirements.

Contribution: experimental validation of multirate control design framework

Although multirate control has many potential, at present its deployment is hampered by a lack of control design techniques. The main reason is linear periodically time-varying (LPTV) behavior for which well-known control designs based on Bode plots and Nyquist diagrams are not directly applicable.
In this work, the design framework for multirate feedforward control [1] is validated through experiments on a dual-stage system. Recent developments in feedback control for LPTV systems are presented in [2].

Experiments on a dual-stage system

The experimental setup of the dual-stage system is shown in Figure 1. Figure 2 shows the experimental results. The proposed approach *multirate high*, achieves high performance (similar to *single-rate high*) with limited cost since one of the feedback loops is evaluated at low rate.

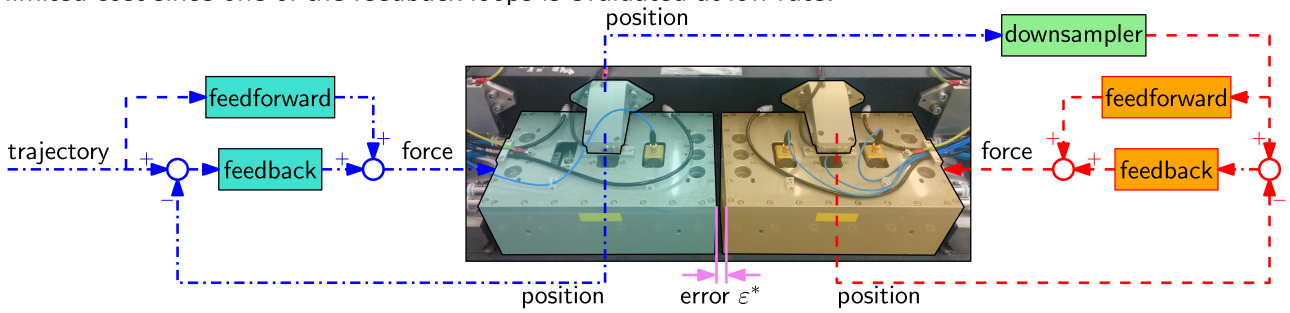

Figure 1 *Experimental multirate dual-stage system with the part in blue at high rate (-·-) and the part in red at low rate (--). The objective it to minimize error ε^* through design of the* feedforward *controller.*

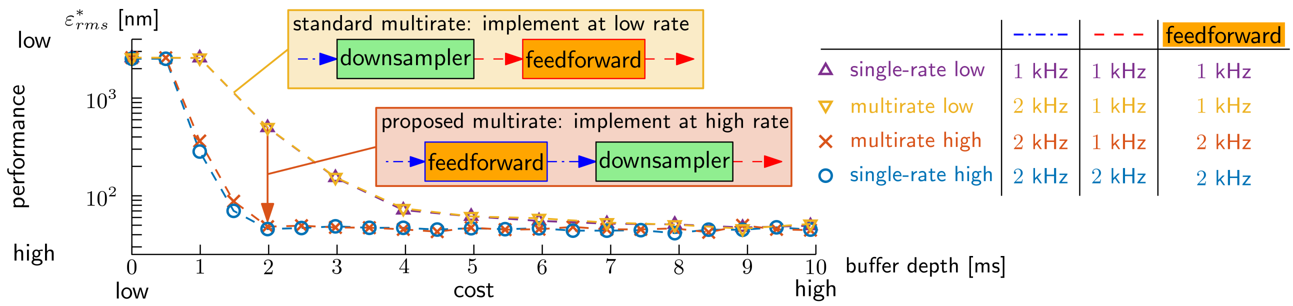

Figure 2 *Experimental results showing performance versus cost and the advantages of multirate control.*

Conclusion

Multirate control may substantially contribute to improved performance and reduced implementation cost for systems with multiple control loops. The presented experimental results confirm this potential.

References

[1] J.C.D. van Zundert, J.L.C. Verhaegh, W.H.T.M. Aangenent, T. Oomen, D. Antunes and W.P.M.H. Heemels, "Feedforward for Multi-Rate Motion Control: Enhanced Performance and Cost-Effectiveness," In *Proceedings of the 2015 American Control Conference*, pp. 2831–2836, Chicago, 2015.
[2] J. van Zundert and T. Oomen. "LPTV Loop-Shaping with Application to Non-Equidistantly Sampled Precision Mechatronics," *15th Int. Workshop on Advanced Motion Control*, pp. 467-472, Tokyo, 2018.