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

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Dual stage systems

High position accuracy over a large range
- example: long stroke – short stroke in wafer stages
- different performance requirements for different control loops (e.g., µm vs nm)
- performance requirements determine sampling rate

Multirate approach: high accuracy at low cost

Different sampling rates in different loops
- balance performance and hardware cost (sensors, actuators, AD/DA converters)

Control of multirate systems

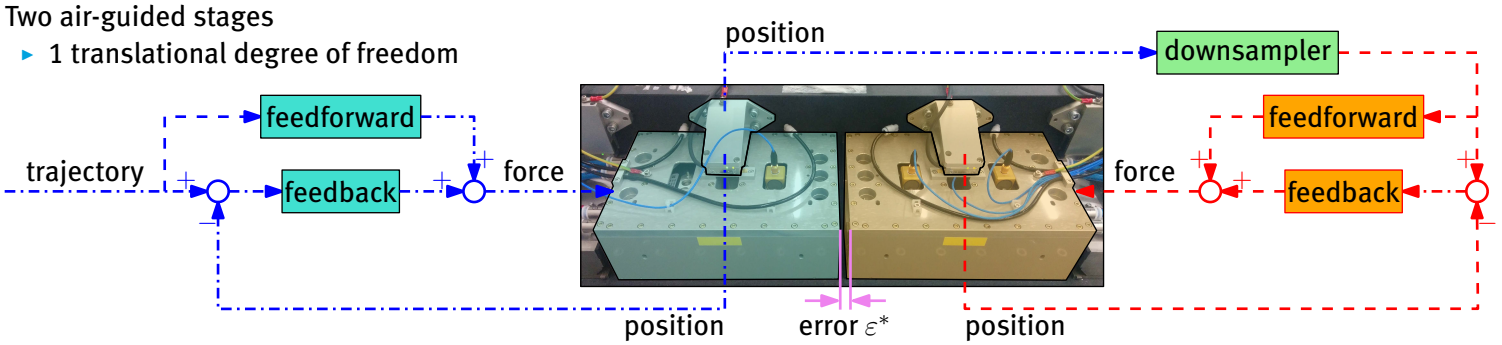
- Aim: systematic control design approach
- Challenge: linear periodically time-varying (LPTV)
  → frequency-domain approaches not applicable

Contribution: multirate feedforward control

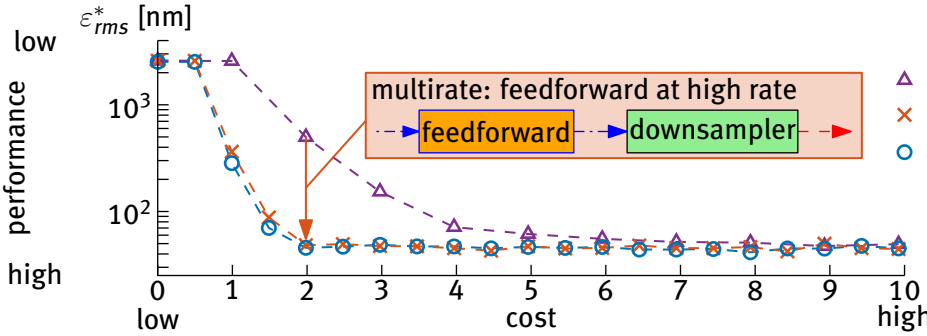
- Focus of this work: feedforward control
  - dominant in control performance
- Multirate feedforward for slow control loop
  - key aspect: feedforward at high rate for same price (no extra sensors or actuators needed)

Experimental dual-stage system

Two air-guided stages
- 1 translational degree of freedom



Experimental results: high accuracy at low cost with multirate control



	loop 1	loop 2	feedforward
△ single-rate low	1 kHz	1 kHz	1 kHz
× multirate high	2 kHz	1 kHz	2 kHz
○ single-rate high	2 kHz	2 kHz	2 kHz

Conclusion

Multirate control: high performance at low cost
- Experimental validation multirate control approach

Related work:
- Feedback control of LPTV systems [2]
- More resource-aware control design [3]

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. ACC 2015, pp. 2831-2836.
[2] Jurgen van Zundert and Tom Oomen. LPTV Loop-Shaping with Application to Non-Equidistantly Sampled Precision Mechatronics. AMC 2018, pp. 467-472.
[3] Jurgen van Zundert. Resource-Aware Motion Control: Feedforward, Learning and Feedback, PhD thesis, November 2018.