Robustness of PI & PID controllers in the Presence of Sampling Jitter

Wei Yu[1], David I. Wilson[2], Jonathan Currie[2] & Brent R. Young[1]

[1]Chemical and Materials Engineering, The University of Auckland,New Zealand

[2]Electrical & Electronic Engineering, Auckland University of Technology, New Zealand

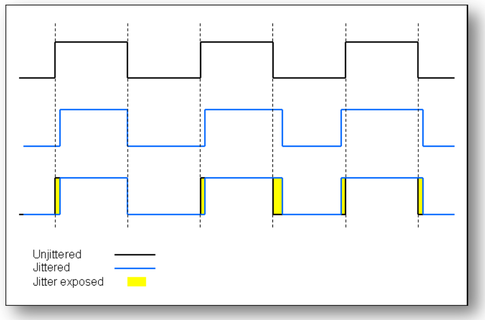
Importance

Sampling jitter is a common industrial control problem adversely affecting the performance of PI and PID controllers.

Using performance benchmarks applied to a wide variety of industrial plant models shows that while the PI control is relatively immune to jitter, the derivative component of the PID controller causes the PID controller to exhibit excessive sensitivity to sampling jitter.

Sampling Jitter

Many real-time control systems are implemented as distributed control systems over a possibly wireless communication network or a field bus. While the controller supposedly works at a fixed nominal period, varying computer load, unexpected delays and other unforeseen issues all contribute to a system that experiences a stochastic sampling rate known as sampling jitter.



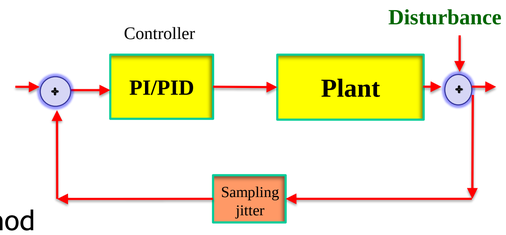
PI & PID Controller Robustness

Process

Output: $$y_{k+1} = \frac{B_k(q^{-1})}{A_k(q^{-1})} q^{-f} u_k + d_k$$

Disturbance: $$d_k = \frac{\theta(q^{-1})}{\phi(q^{-1})\nabla^h} a_k$$

PI/PID controller: SIMC-PID tuning method



Control Performance Assessment

Control performance assessment or CPA is a useful tool to establish the quality of industrial feedback control loops.

Performance index: $$\eta = \frac{\sigma_{MV}^2}{\sigma_y^2}$$

The performance index or Harris index is scaled to lie within [0,1], where values close to 1 mean better control.

References

[1] Huang, B. (2002), Minimum variance control and performance assessment of time-variant processes, *Journal of Process Control*, **12**:707-719.

[2] Harris, T.J. & Yu, W. (2007), Controller assessment of a class of nonlinear systems, *Journal of Process Control,***17**: 607-619.

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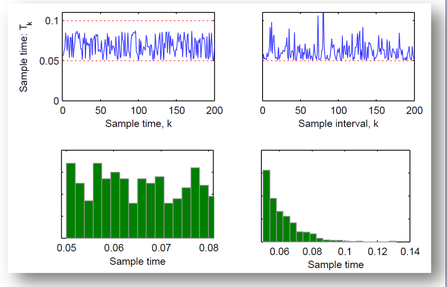
Simulations & Results

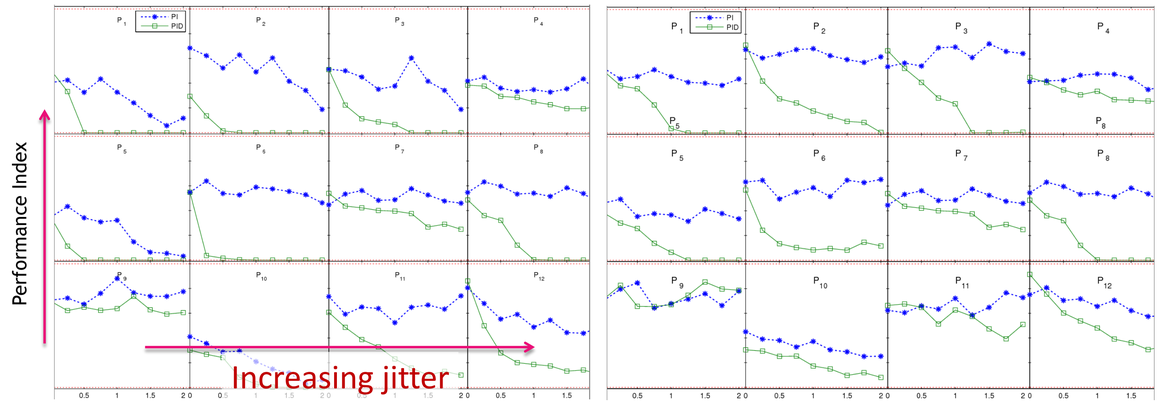
12 processes subjected to 3 disturbance models with 2 sampling jitter distributions

- For the majority of plants, PID is superior to PI if there is no sampling jitter (which is as expected).
- For PI control, the controlled performance deteriorates relatively slowly with increasing sampling jitter. This indicates that PI controllers are relatively immune to fluctuations in sampling time.
- PID control deteriorates rapidly with increasing sampling jitter. Consequently this suggests that PID control is not a good choice when the control loop experiences sampling jitter.



Uniform distribution of sampling jitter

Exponential distribution of sampling jitter



Conclusion

The contribution of this work is to investigate the control performance degradation for systems with sampling jitter. We use a controller performance index to quantify the degradation as a function of jitter magnitude, and we also investigated different plausible probability distributions for the jitter.

Clearly all controllers will be adversely effected by jitter, but those controllers that employ terms involving finite differences in time such as the derivative control in PID controllers, and high-order controllers involving numerator dynamics are likely to be particularly vulnerable to this sort of disturbance.

Acknowledgments

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