The impact of QoT on feedback control systems

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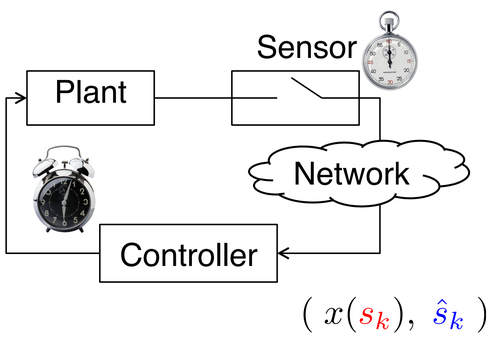
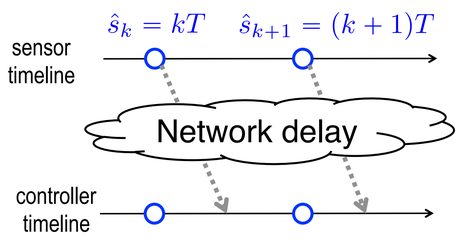
Theoretical Results

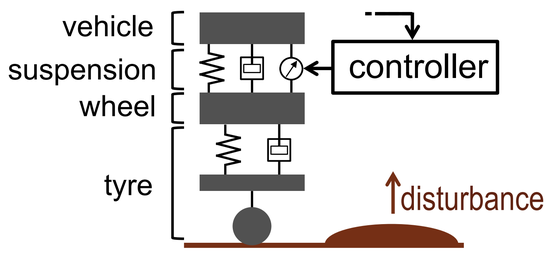
Q: What if sensor/controller clocks are not synchronized?
A: Timing errors effectively introduce distortion and may result in instability





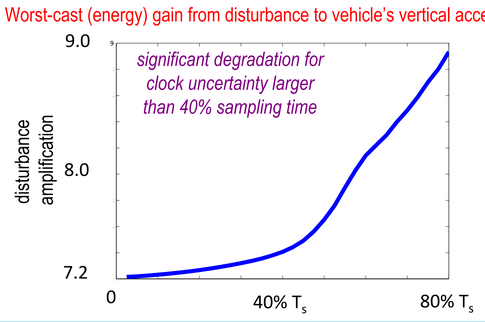
QoT and Disturbance Rejection

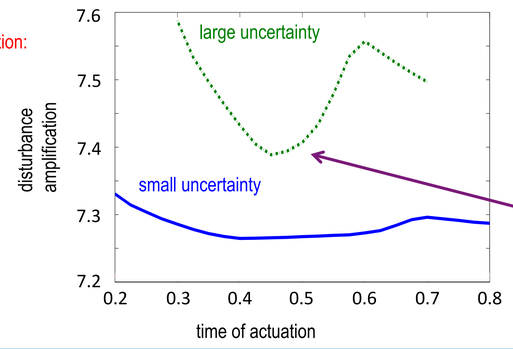
Active suspension system:



x_1 – suspension deflection
x_2 – tire deflection
x_3 – (vertical) vehicle speed
x_4 – (vertical) wheel speed
u – active suspension actuation force
d – vertical ground velocity

Worst-cast (energy) gain from disturbance to vehicle's vertical acceleration:

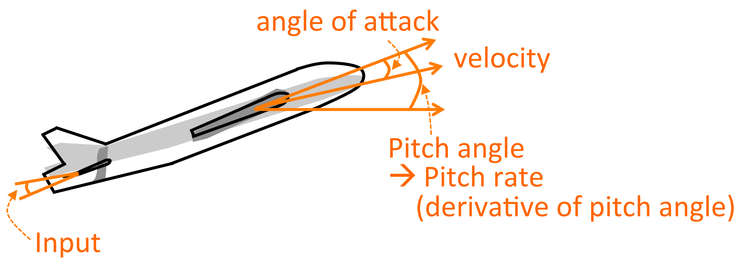




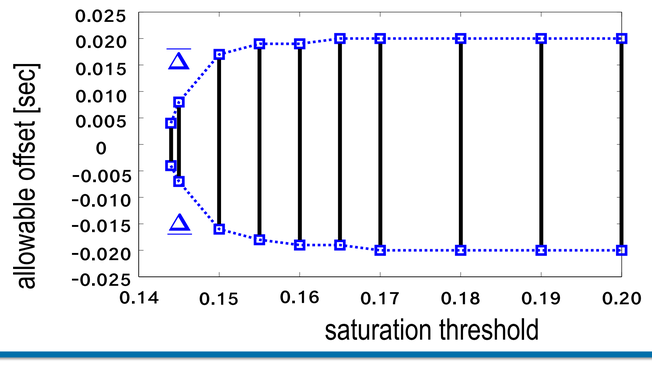
max robustness when actuation is **between** sample times

QoT and Systems with Saturation

TRANS3 longitudinal dynamics (with saturation)



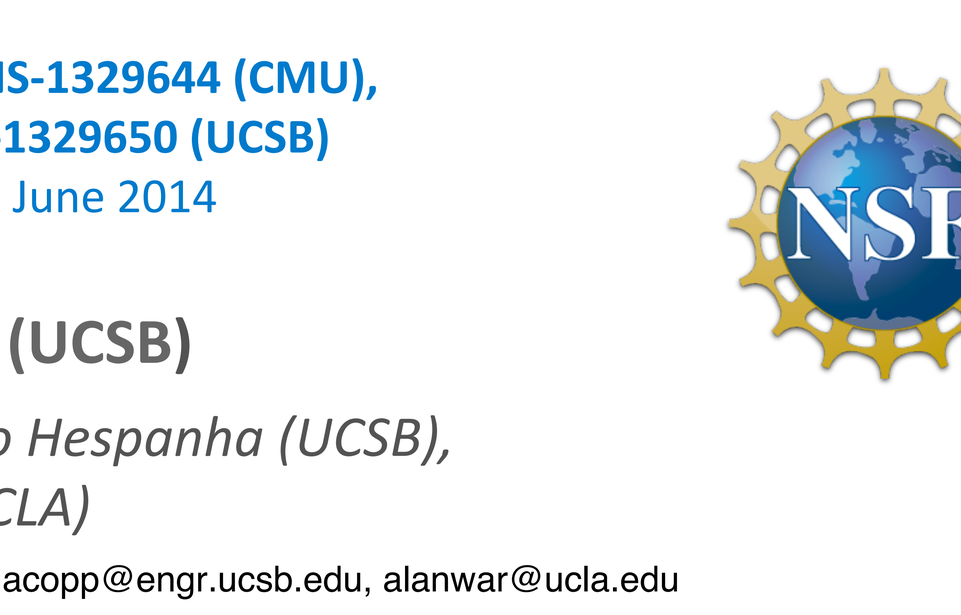
x_1 – velocity
x_2 – angle of attack
x_3 – pitch rate
x_4 – pitch angle
u – elevator input



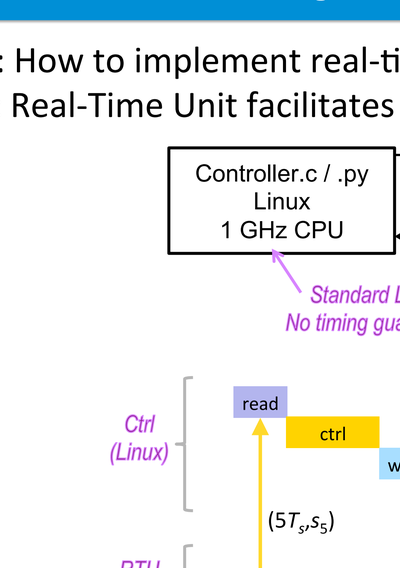
Tight saturation constraints significantly reduce robustness wrt timing errors

Experimental Results

Q: How to implement real-time control on a non-real-time OS?
A: Real-Time Unit facilitates precise timing in a non-RT environment:



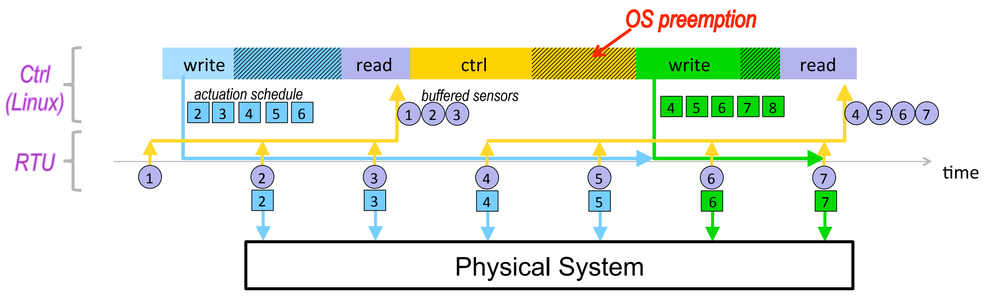
Hardware setup



Timing accuracy: ~10us

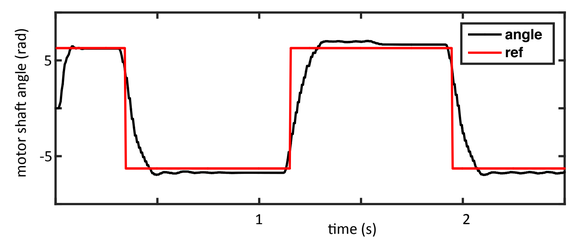
Hardware results

RTU buffers inputs & outputs; a natural use for model-predictive controllers:



Buffered I/O: robust against non-RT OS preemption

Predictive controller uses timestamped sensors & voltages to drive the motor angle as desired



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