Collocated proportional-integral-derivative (PID) control of acoustic musical instruments

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Education in Acoustics: Tools for Teaching Acoustics
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Special thanks to the Wallenberg Global Learning Network for supporting the REALSIMPLE project

Outline

Overview

Theory

Laboratory Exercise In Pure Data

The RealSimPLE Project

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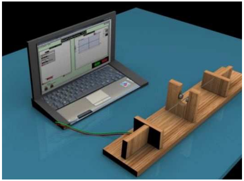

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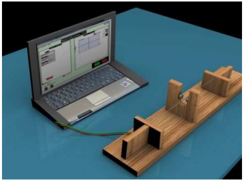

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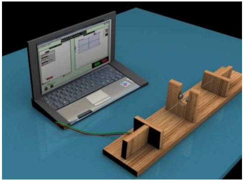

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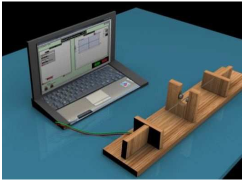

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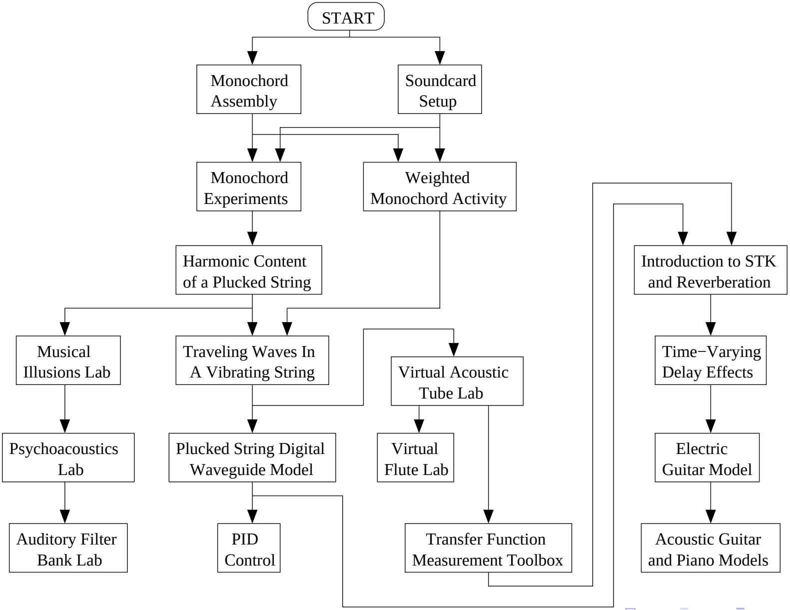
RealSimPLE Laboratory Assignment Dependencies



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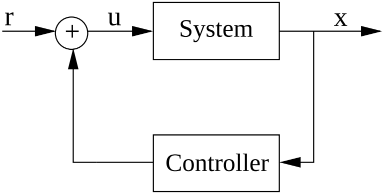
- Experiment with a virtual controlled string using the Pure Data software.
- Gain experience using Pure Data.

Feedback control

Feedback control is the discipline in which system dynamics are studied and altered by creating feedback loops.



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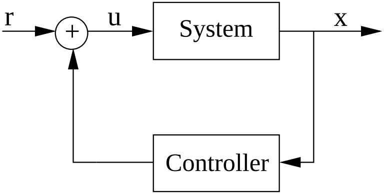

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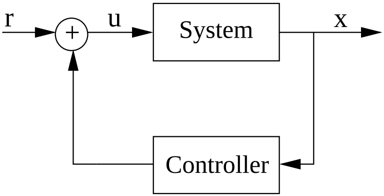

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- Application to a vibrating string

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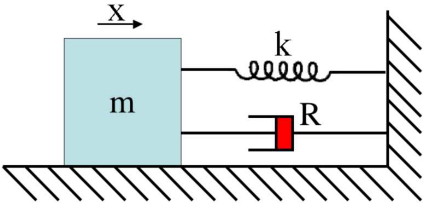
System Model

- If we collocate the sensor and actuator, then we can use the following model of the lowest resonance:



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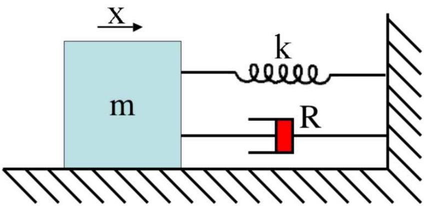

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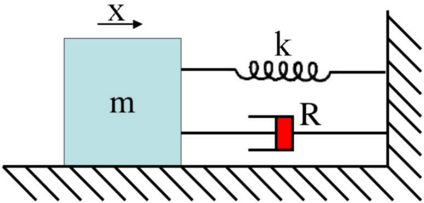

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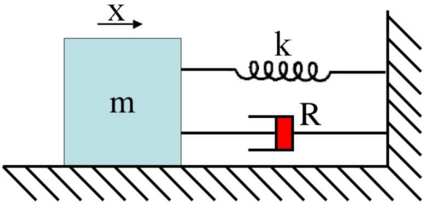

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- Equivalent mass m, spring with constant K, and damping parameter R
- $m\ddot{x} + R\dot{x} + Kx = 0$
- Pitch $f_0 \approx \frac{1}{2\pi}\sqrt{\frac{K}{m}}$, and the decay time constant $\tau = \frac{2m}{R}$

Proportional-Derivative (PD) Control

- If we implement the feedback law $F = P_D\dot{x} + P_P x$, then we arrive at the following differential equation
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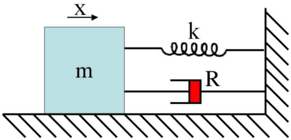

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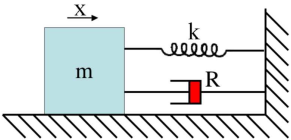

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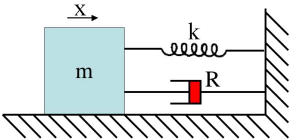

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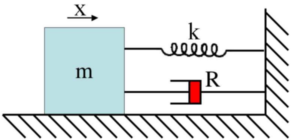

- PID Control:
  - Can control the damping with P_D and P_I
  - Can control the pitch (some) with P_P

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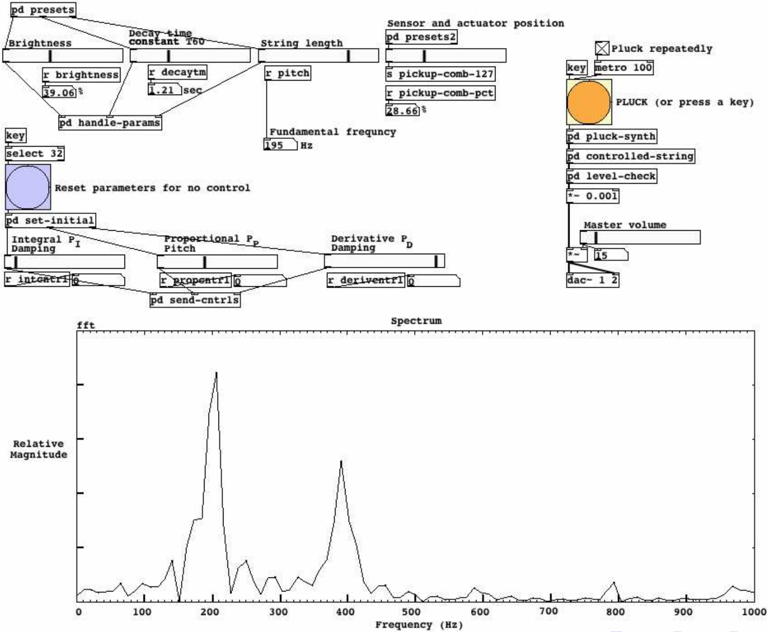
Pure Data



pd presets
Brightness
Decay time constant T60
String length
Sensor and actuator position
pd presets2
r brightness
39.06 %
r decaytm
1.21 sec
r pitch
s pickup-comb-127
r pickup-comb-pct
28.66 %
pd handle-params
Fundamental frequncy
195 Hz
Pluck repeatedly
key
metro 100
PLUCK (or press a key)
pd pluck-synth
pd controlled-string
pd level-check
*~ 0.001
Master volume
15
dac~ 1 2
key
select 32
Reset parameters for no control
pd set-initial
Integral P_I Damping
Proportional P_P Pitch
Derivative P_D Damping
r intcntrl
r propcntrl
r derivcntrl
pd send-cntrls
fft
Spectrum
Relative Magnitude
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)

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- Some combinations of the control parameters result in instability.
- The patch disables sound if the level becomes too large.

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4. This is a weakness of the simplified model.

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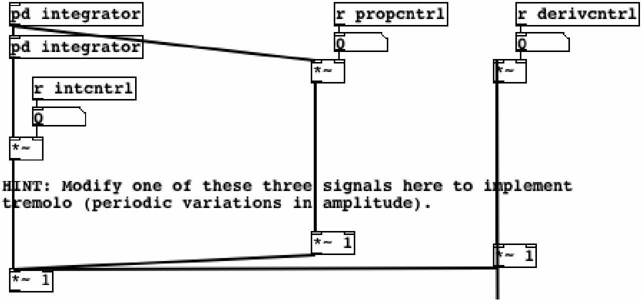

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Thanks

Questions?