Advanced input shaping filter 3D virtual laboratory

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Virtual laboratories
3-platforms idea
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Virtual laboratories

Advantages

- Low cost maintenance
- High efficiency in training
- Making mass of experiments simultaneously
- Often more demonstrative than real experiment

Commonly used approaches

Matlab engine + GUI in LabView
- Internet connection is needed
- Non-monolithic application

Models in Easy Java Simulations
- Described only by equations
- Not compatible with Matlab/Simulink

Drawback

- The build-in algorithm cannot be usually directly used for controlling real plant or machine
  - In our lab solved with 3-platforms idea
3-platforms idea

- Simulation and development platform
- Real-time platform
- Java applet platform

The control schemes are fully compatible with block algorithms, inputs, outputs and parameters.
Input shaping filter

Process model

\[ P(s) = \frac{\omega_n^2}{s^2 + 2\xi \omega_n + \omega_n^2}; \quad \xi < 1, \quad \omega_d = \omega_n \sqrt{1 - \xi^2}, \]

- \( \omega_n \) – natural frequency
- \( \xi \) – damping coefficient
- \( \omega_d \) – damped frequency

Weighted sum of time delays
Main advantages of IS filters

- Finite impulse response
- Guaranteed stability
- Monotone step response
- Completely parameterized by $\omega_n$ and $\xi$

Main types of IS filters

- ZV (Zero Vibration)
- ZVD (Zero Vibration Derivative)
- ZVDD
- UEI (Extra Insensitive)
- UTHEI
Mathematical model of controlled system

- $x_1, y_1$ – cart coordinates
- $x_1, y_1, z_1$ – load coordinates
- $\alpha$ – viscous friction
- $m$ – mass of the pendulum
- $l$ – length of the pendulum
- $g$ – gravitational acceleration
- $\lambda$ – Lagrange multiplier

Differential equations

\[
\ddot{x}_2 = \frac{-\alpha \dot{x}_2 + 2\lambda x_2}{m} - \ddot{x}_1, \\
\ddot{y}_2 = \frac{-\alpha \dot{y}_2 + 2\lambda y_2}{m} - \ddot{y}_1, \\
\ddot{z}_2 = \frac{-\alpha \dot{z}_2 + 2\lambda z_2}{m} - g, \\
\lambda = \frac{-m(\dot{x}_2^2 + \dot{y}_2^2 + \dot{z}_2^2 - \ddot{x}_1 x_2 - \ddot{y}_1 y_2 - g z_2 - i^2 - \ddot{l}^2) + \alpha(x_2 \ddot{x}_2 + y_2 \ddot{y}_2 + z_2 \ddot{z}_2)}{2(x_2^2 + y_2^2 + z_2^2)}. 
\]
The laboratory development cycle

- Mathematical model deriving
- Control scheme designing
  - Export mdl → java
- 3D model creating
  - CAD with VRML output
- Construction of labs GUI
Figure: 1 – SP with the filtration, 2 – motion control, 3 – pendulum model
The final laboratory

Figure: 1 – control, 2 – interactive scheme, 3 – 3D model, 4 – trends
Conclusion

- Proposed a novel approach for creating virtual labs
- Presented vibration damping with the input shaping filter
- Assembled virtual lab for presenting advanced input shaping filter
- All shaping filter features may be evaluated on 3D gantry crane model
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Available

This laboratory can be tested at www.contlab.eu.

Thank you for attention.