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Advanced SUS Model in Mathematica by M. Barton

For Norna Robertson's LSC Talk

LIGO Livingston Observatory

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Motivation

- Want a design model to go beyond the Matlab model of Torrie, Strain et al.
- Need to add:
  - » Full 3D with provision for asymmetries
  - » Proper blade model
  - » Wire bending elasticity
  - » Arbitrary damping and consequent thermal noise
- Similar in scope to the Maple model of Matt Husman but based on a Mathematica framework originally developed for the X-pendulum
- Make best use of tools: export state-space model to Simulink for time-domain and control system analysis.

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Features

- Features
  - A general framework with utilities for specifying different configurations (e.g., quad, triple etc) in a (relatively) user-friendly way
  - 6-DOF rigid bodies for masses (no internal modes)
  - 6-DOF rigid bodies representing blades (slight overkill but simpler than half measures)
  - Massless wires (i.e., no violin modes) but detailed elasticity model from beam equation
  - Arbitrary frequency-dependent damping on all sources of elasticity
  - Symbolic up to the point of minimizing the potential to find the equilibrium position
  - Calculates elasticity and mass matrices semi-numerically (symbolic partial derivatives of functions with mostly numeric coefficients)
  - Eigenfrequncies and eigenmodes calculated numerically
  - Reasonable runtime:
    - 2 minutes with just wire longitudinal elasticity (adequate for most control theory purposes)
    - 2 hours with wire bending elasticity (required for thermal noise estimates)
  - Structured to make version control easy

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Status

- Quad and triple versions released:

  http://www.ligo.caltech.edu/~mbarton/SUSmodels

- Validation against quad and triple Matlab models completed to extent possible:
  - » Four figure agreement in mode frequencies for test cases with blades disabled and no wire bending elasticity
  - » Some minor errors in the quad Matlab model identified and fixed as a spinoff
- Validation against analytical results largely completed:
  - » Wire bending elasticity code is giving correct results
  - » Dissipation dilution is not correctly implemented so there is spurious damping/thermal noise from subsystems that should be lossless - the fix has been identified but not implemented
  - » ETA: another few days
- Choosing correct values for blade parameters largely unfinished:
  - » Apart from elasticity in the working direction, most blade parameters are order-of-magnitude guesstimates
  - » Model is useable for many purposes as-is
  - » ETA to better parameters: a few months