Vibration Suppression in Discrete Elastic Rods Using Model Predictive Control

Rocco Barletta, Aerospace Engineering
Mentor: Dr. Leixin Ma, Assistant Professor
Fulton Schools of Engineering

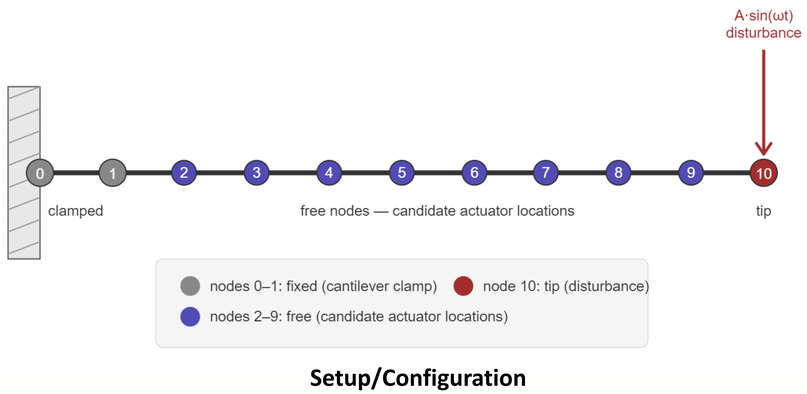
Objective/Research Question:

This work seeks to integrate Discrete Elastic Rods (DER) modeling with nonlinear Model Predictive Control (MPC) and Bayesian Optimization (BO) to identify optimal magnitude and location of control forces to minimize vibration with low computational effort.

Background:

- DER models structures as a system of nodes related through bending/stretching energy equations
- MPC handles nonlinear beam dynamics and solves optimization over time horizon to determine control force and minimize vibration
- Bayesian Optimization uses a Gaussian Process to predict performance at untested nodes and determine the optimal control node(s)

Methodology:



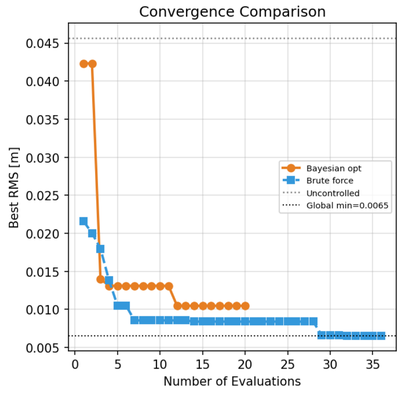
Setup/Configuration

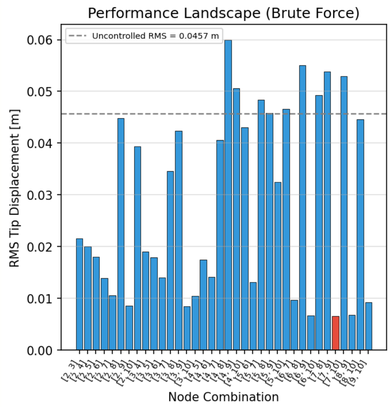
Bayesian Optimization

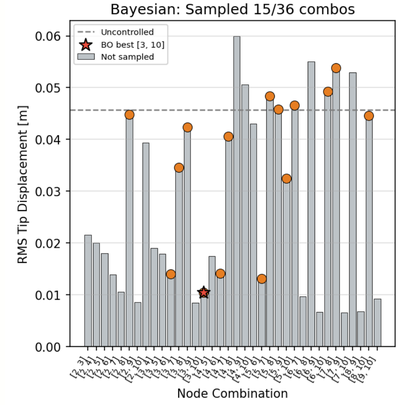
- Nine candidate nodes for control; 36 possible pairs
- 15 evaluations performed

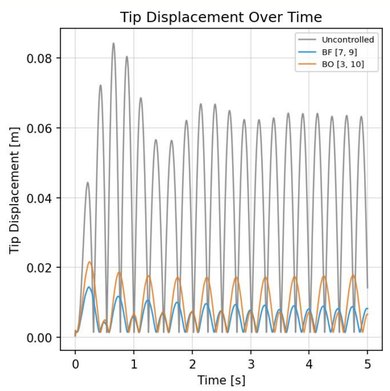
Model Predictive Control

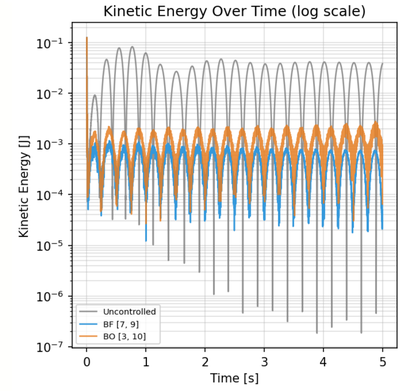
- Horizon: N = 30 steps
- Step size: dt = 0.01s
- Minimizes tip displacement, velocity, and effort











Results/Outcomes:

	Uncontrolled	Brute Force	BO
RMS tip disp. [m]	0.045667	0.006523	0.010479
Peak tip disp. [m]	0.084299	0.014407	0.021608
Mean KE [J]	0.021733	0.000496	0.001146
Vibration reduction [%]	—	85.7%	77.1%
Mean MPC solve time [ms]	—	11.609	12.027
Total time [s]	—	666.5	405.2
# Evaluations	—	36	15
Best nodes	—	[7,9]	[3,10]

Key Takeaways

- DER-MPC optimized with BO is a viable method for computationally efficient vibration reduction
- Brute force will always find the optimal solution, though it will take longer
- BO finds an answer fast without sacrificing too much accuracy
- In theory, performance scales with complexity

Challenges & Future Work:

The challenges with this framework are that:

- BO often wants to select the same node twice
- Each candidate placement requires its own solver, which is very time consuming

In the future, it would be useful to:

- Optimize the number of control inputs, not just the location
- Extend to 3D and implement shape matching/path following framework

FURI

Ira A. Fulton Schools of Engineering
Arizona State University