Optimization of Bicycle Suspension Tuning

Jeff Robinson | AA222 Final Project Presentation | June 4, 2019

Problem: Bike suspension tuning is more art than science

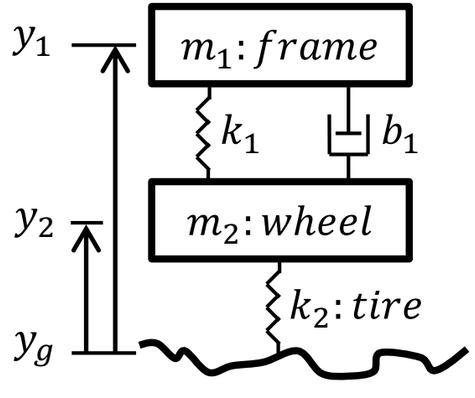
Goal: Applicability of Direct, Stochastic, Population-based algorithms vs. Cyclic Coordinate Descent

Model: 2-DoF Dynamical System

- k_1 & k_2 exponential ramp at displacement limits
- b_1 set by motion rate $(\dot{y}_1 - \dot{y}_2)$, 4 regimes
- Stochastic terrain incline $\dot{y}_g$ (SMA smoothing)

By Steve Bennett - Taken by Steve Bennett, CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=7790524

Design Space: 8D - $\left[k_1 \;\; k_2 \;\; b_{1RH} \;\; b_{1RL} \;\; b_{1CL} \;\; b_{1CH} \;\; \dot{y}_{cross,R} \;\; \dot{y}_{cross,C}\right]$



Objectives: Ground Following – mean distance between tire and ground – corresponds to traction

Ride Comfort (Transmitted Impulse) – RMS of $\dot{y}_1$

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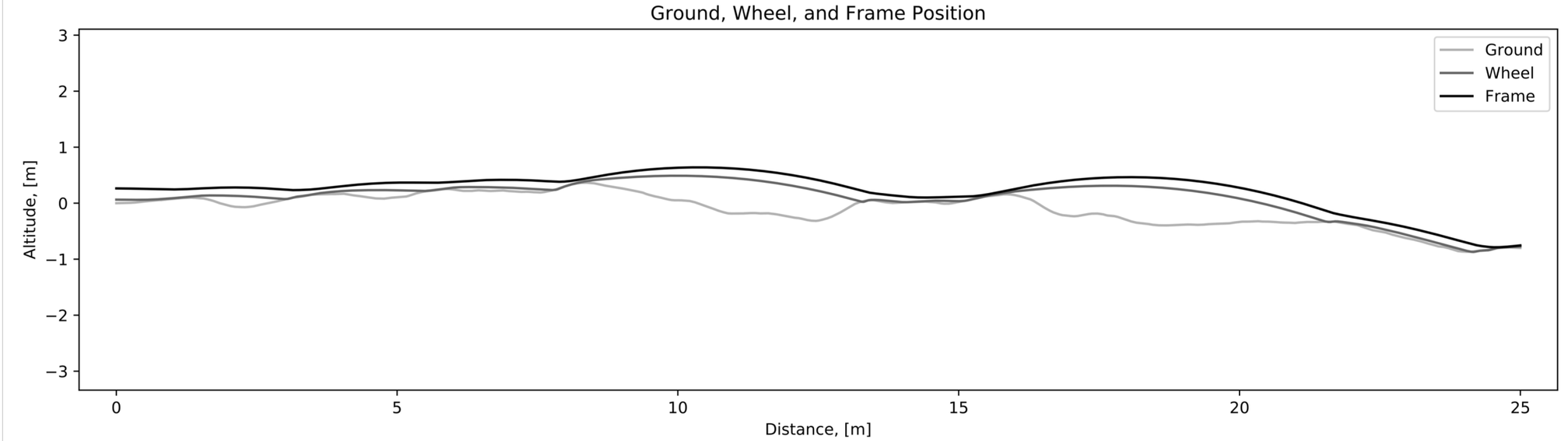
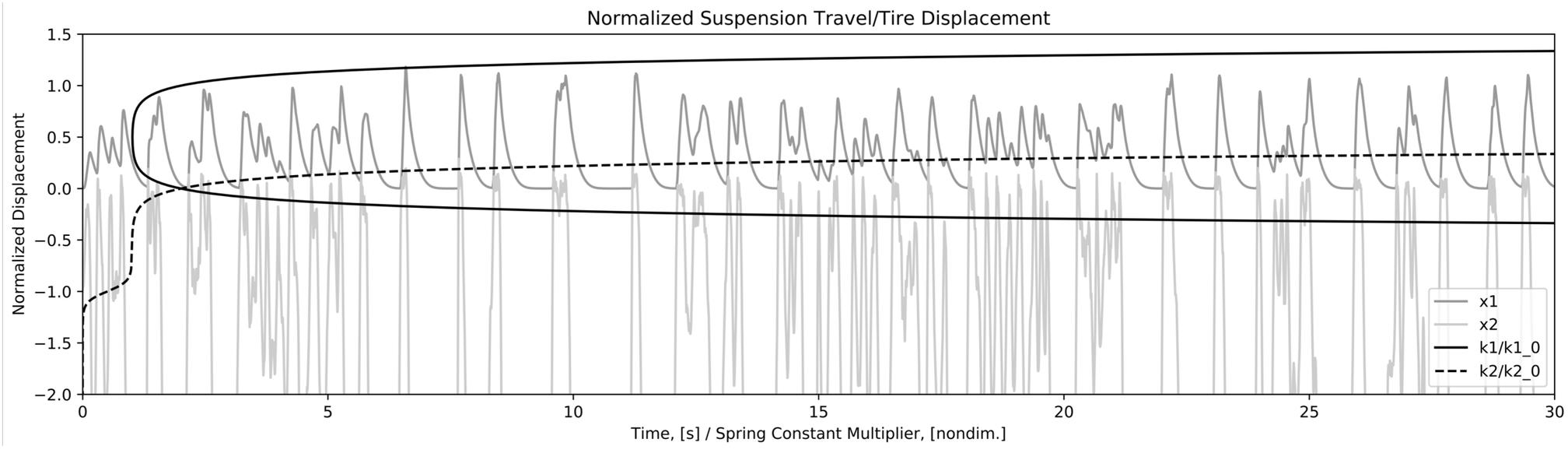
Example Simulation Plots





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Constraints: Damping Ratio $0.2 < \zeta < 1.0$

Positive sign, except $\dot{y}_{cross,C}$ by definition

Quadratic & Count penalties, fixed multiplier

Algorithms: Representatives of each gradient-free type

- Direct: Cyclic Coordinate Descent (CCD), Generalized Pattern Search (GPS) with basis vectors, Nelder-Mead Simplex (NMS)
- Stochastic: Adaptive Simulated Annealing (ASA), Covariance Matrix Adaptation (CMA)
- Population: Particle Swarm Optimization (PSO), Firefly Algorithm

Weights	1.0, 0.0	0.5, 0.5	0.0, 1.0	Mean Rank
CCD	0.0002465 [1]	3.773 [6]	6.057 [3]	3.33
GPS	0.03780 [2]	3.495 [4]	5.781 [1]	2.33
NMS	0.04329 [3]	3.975 [7]	(unstable)	5.66
ASA	0.4126 [6]	3.675 [5]	6.344 [5]	5.33
CMA	0.2389 [5]	3.221 [1]	6.215 [4]	3.33
PSO	0.1137 [4]	3.301 [3]	5.896 [2]	3.00
Firefly	0.1137 [4]	3.277 [2]	5.896 [2]	2.66

Results: Tested with 3 weightings: [GF, RC] = [1.0, 0.0], [0.5, 0.5], [0.0, 1.0], 640 objective evaluations, 1 iteration of each algorithm

CCD is 4th, GPS is 1st, represent commonly used methods

More sophisticated algorithms require more evaluations, less reliable