Multilegged Locomotion: the Friction Dominated Case

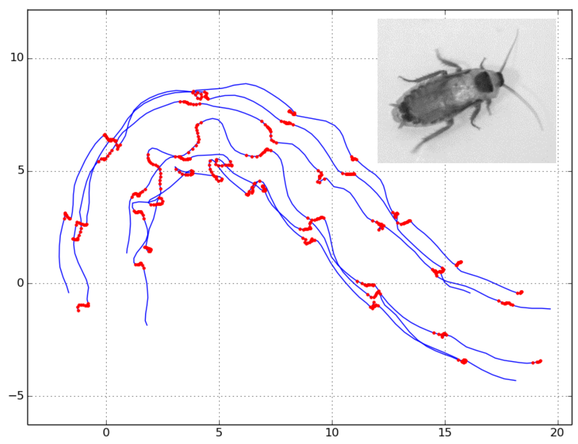
Dan Zhao[1], Shai Revzen[2]

[1]Mechanical Engineering,[2] Electrical Engineering and Computer Science & Ecology and Evolutionary Biology

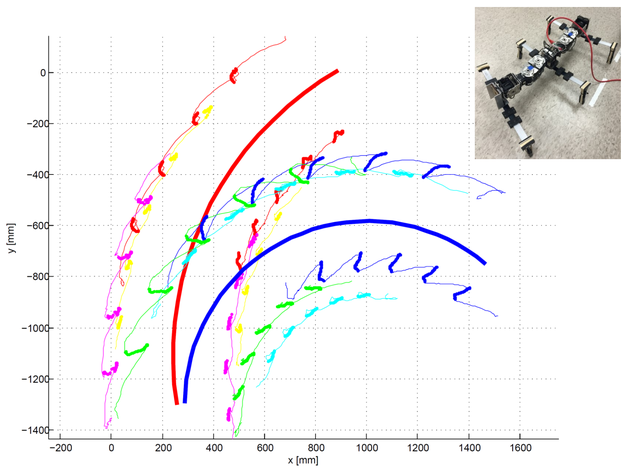
[1]danzhaoy@umich.edu [2]shrevzen@umich.edu

Background

Biologists and engineers often assume non-slip contact for modeling multi-legged locomotion. In our hexapedal robot and cockroach (*Blaberus discoidalis*) experiments, a significant fraction of total foot motion is slipping motion.



Cockroach foot trajectories



Robot foot trajectories

See related poster **Sachdeva, Zhao & Revzen [1319-393458]**[1]for details of cockroach slipping statistics. Slipping plays large role in steering our hexapedal robot [2].

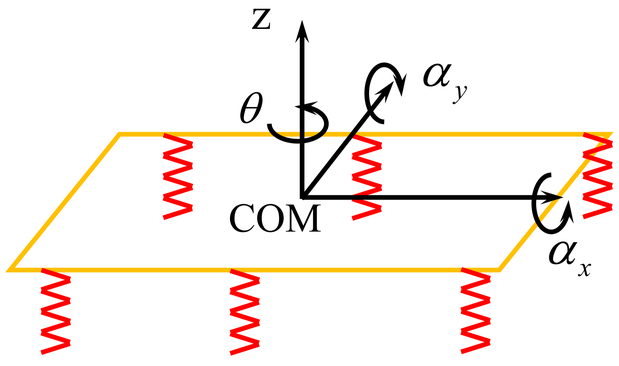
Modeling approach

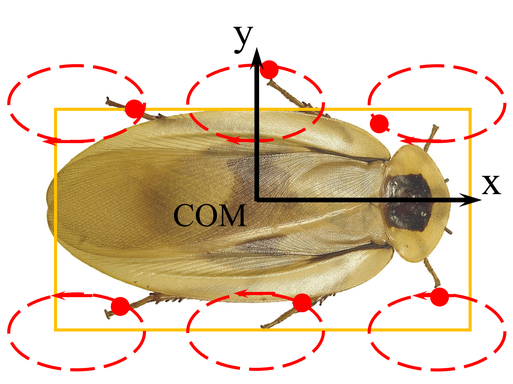
Multi-legged contact with slipping poses a difficulty for modeling due to uncertainty about inter-leg force distribution and consequent foot slipping outcomes.

Small swimmers at low Reynolds numbers are friction dominated leading to a simplified connection-type model of their motion. When the ratio of inertial to friction forces is small, legged animals could have similar connection-like motions.

Model

Our model takes egocentric leg motions and computes foot slippage and body center of mass motions

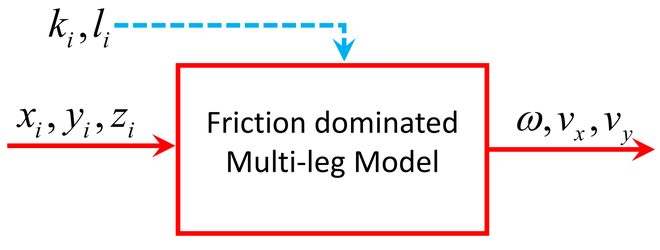




For each leg:

$$F_{Ni} = k_i(z + \alpha_x y_i + \alpha_y x_i - l_i)$$

$$F_{fi} = -F_{Ni}\frac{\mu}{|v_{wi}|}v_{wi}$$



Quasi-statics balance:

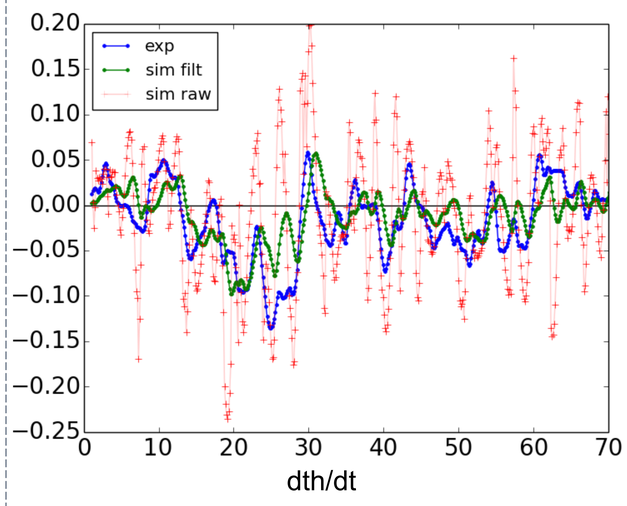
$$\sum F_x = 0 \quad \sum F_y = 0 \quad \sum F_z = 0$$

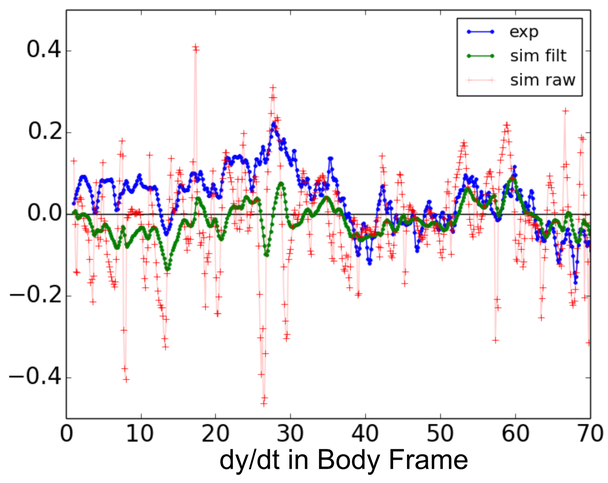
$$\sum M_x = 0 \quad \sum M_y = 0 \quad \sum M_z = 0$$

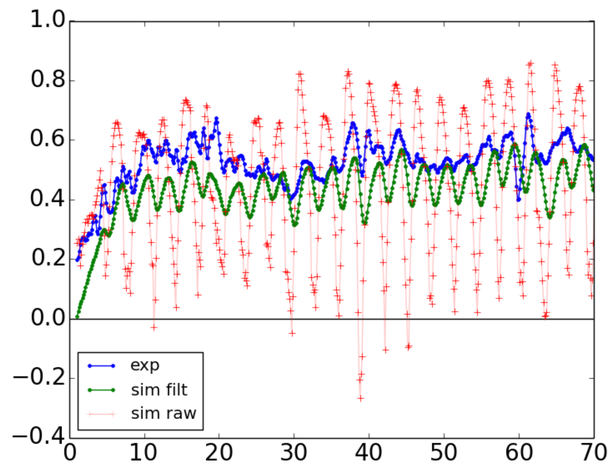
Solve for: $z, \alpha_x, \alpha_y, \omega, v_x, v_y$

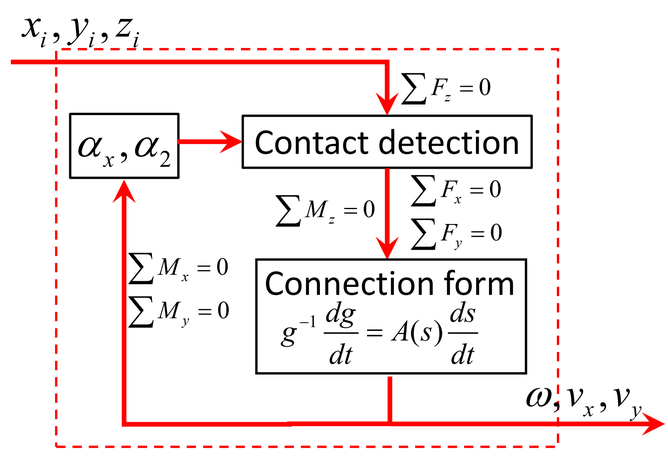
Results

Applying the model to cockroach data, the computed COM velocity in body frame are like figures below. The simulation velocities did catch some of the features of experiment result.



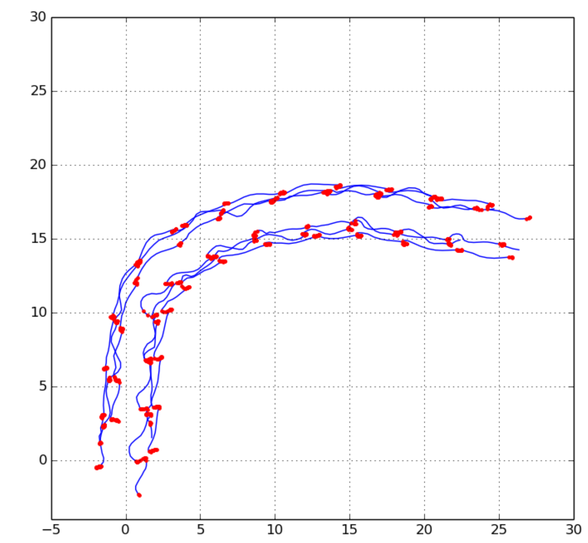




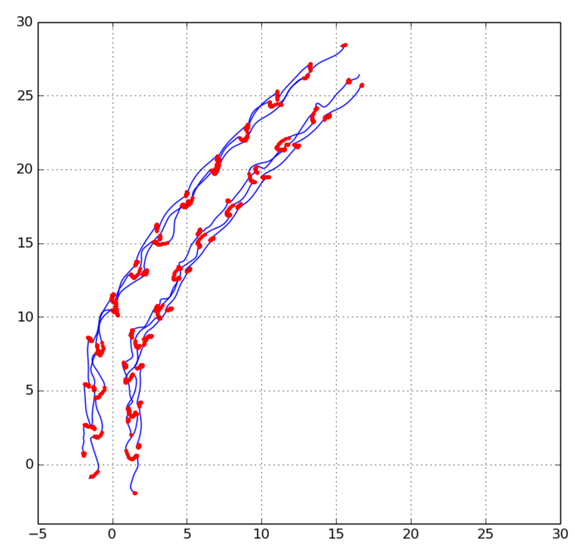


Friction dominated Multi-leg Model

The integrated COM trajectory in world frame are showed below. The simulation can predict turning directions correctly, while the turning radii prediction still needs better parameter fitting and inertia corrections.



Experiment result



Simulation result

This highly simplified model seems worthy of investigation and comparison to more conventional mechanical simulators.

Reference

[1]. Cockroaches Always Slip a Lot. V. Sachdeva, D. Zhao and S. Revzen. SICB 2018.

[2]. Slipping helps steering in a multilegged robot. D. Zhao, S. Revzen, Dynamic Walking 2016.