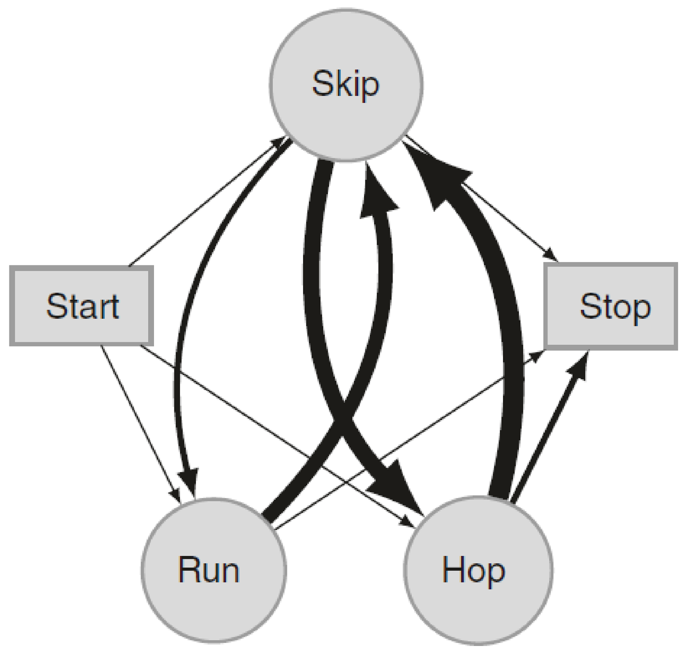
Understand gait transition in Jerboas using a template model

Zhenyu Gan, Mechanical and Aerospace Engineering, Syracuse University, Syracuse, USA, zgan02@syr.edu
Talia Moore, Robotics Institute, Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, USA, taliaym@umich.edu

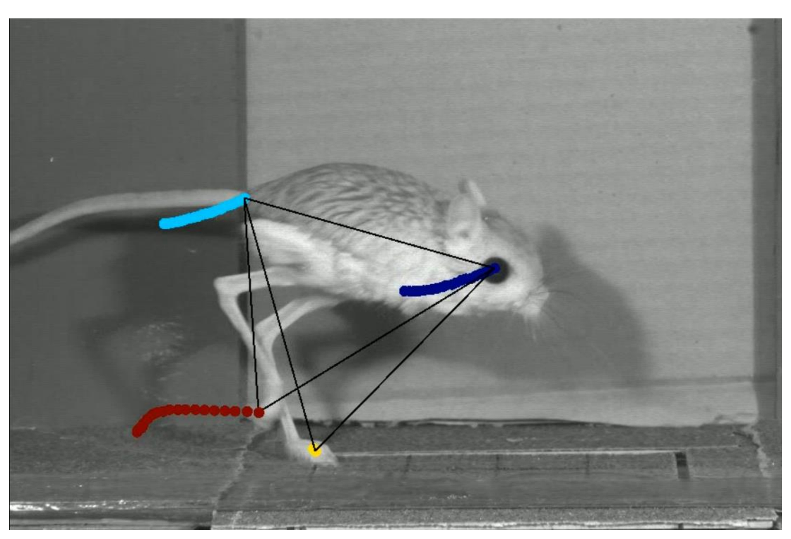
Motivation

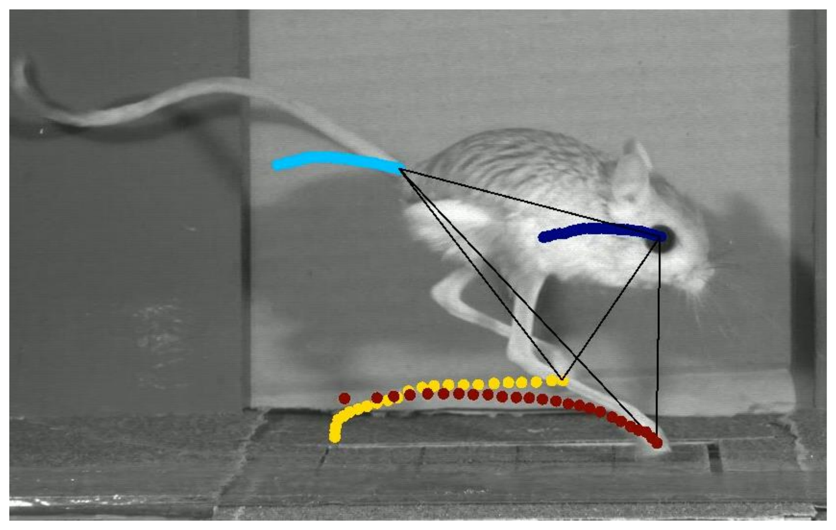
Jerboas quickly switch among many gait patterns that are associated with distinct accelerations, rather than speeds [1]. It has been hypothesized that these bipedal gait transitions are likely to enhance their evasion ability. However, it is difficult to understand the underlying dynamics of these locomotion patterns due to the large number of degrees of freedom expressed by the animals.



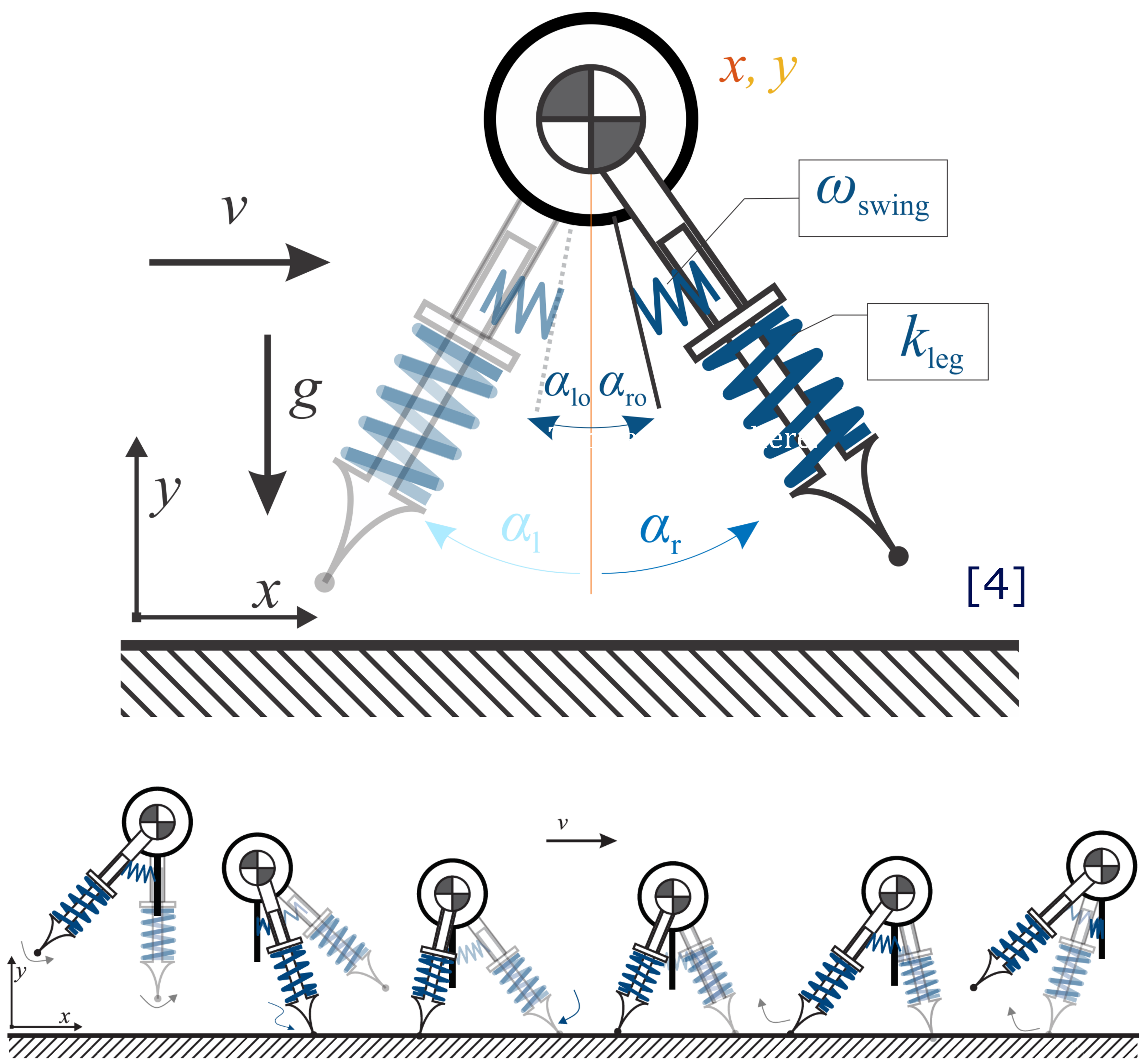
Experiments

- Video recordings were taken at 250 fps using high-speed cameras. Ground reaction forces were simultaneously recorded with an instrumented 2-axis force platform [1].
- Center of mass was estimated by the center between the eye and tail base.
- The pose of the jerboa as well as the foot locations were extracted from the recordings using a learned deep neutral network framework using DeepLabCut [3].





Model



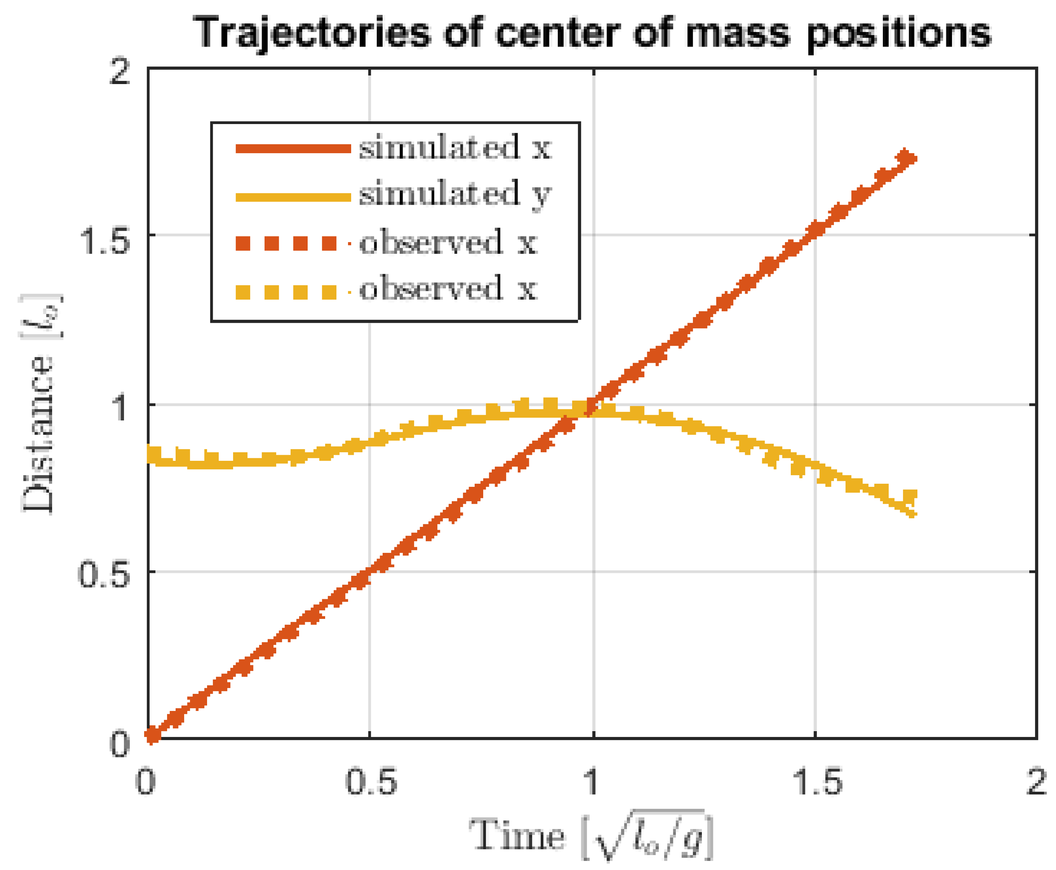
Method

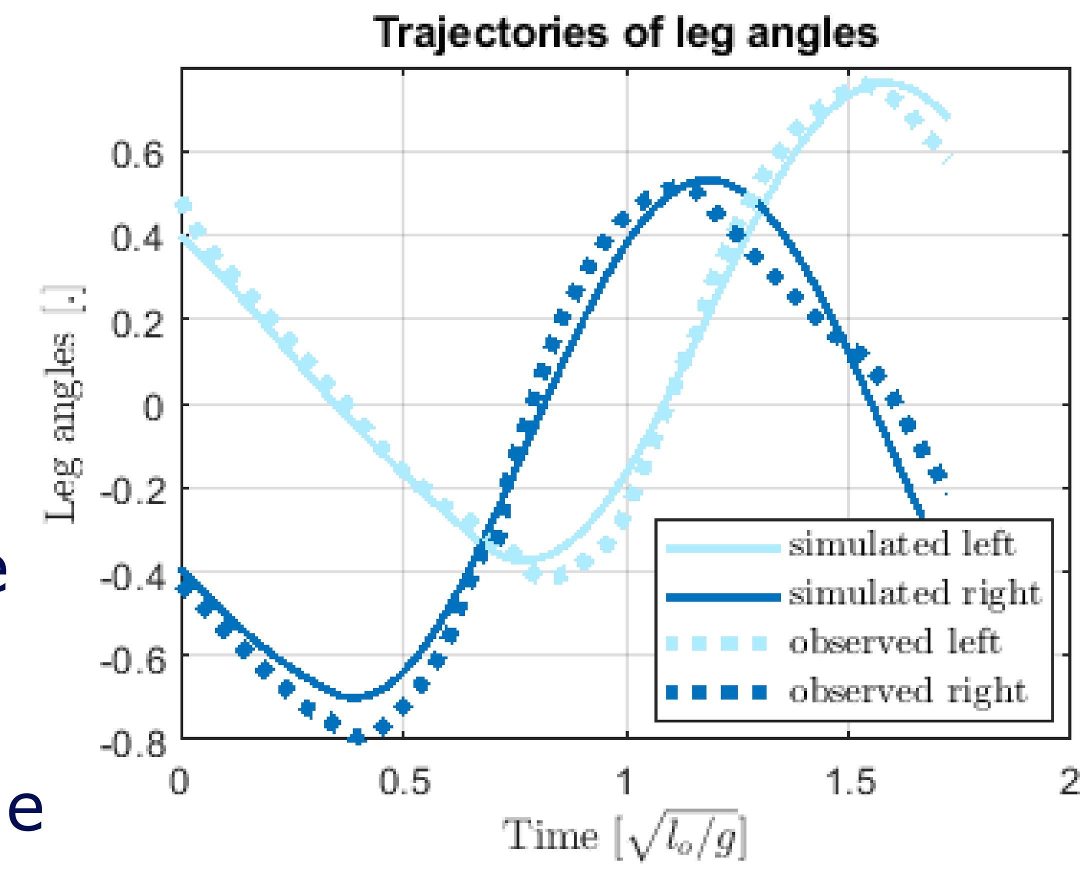
The parameter identification problem can be formulated as a nonlinear optimization problem where the cost function is defined as the summation of the residuals in a total of n trails and the value of this cost function is minimized as an unconstrained optimization problem with a single set of parameters p [2]:

$$C_{opt} = \min \left\{ \sum_{i=1}^{i=n} c_i \left(\mathbf{X}_i, \ \mathbf{p} \right) \right\}$$

$$c_i \left(\mathbf{X}_i, \mathbf{p} \right) = \int_0^{T_i} \left\| X_{sim,i} \left(t, \mathbf{p} \right) - \hat{\mathbf{X}}_i \left(t \right) \right\|^2 + \left\| F_{sim,i} \left(t, \mathbf{p} \right) - \hat{F}_i \left(t \right) \right\|^2 dt.$$

Preliminary results





Fitting results showed our model closely matches the jerboa's center of mass motion and leg angles during a single stride of the skipping gait.

[1] Moore, Talia Y., et al. "Unpredictability of escape trajectory explains predator evasion ability and microhabitat preference of desert rodents." *Nature communications* 8.1 (2017): 1-9.
[2] Gan, Zhenyu, et al. "Passive dynamics explain quadrupedal walking, trotting, and tölting." *Journal of computational and nonlinear dynamics* 11.2 (2016).
[3] Mathis, Alexander, and Richard A. Warren. "On the inference speed and video-compression robustness of DeepLabCut." *BioRxiv* (2018): 457242.
[4] Gan, Zhenyu, et al. "All common bipedal gaits emerge from a single passive model." *Journal of The Royal Society Interface* 15.146 (2018): 20180455.

Syracuse University
UNIVERSITY OF MICHIGAN