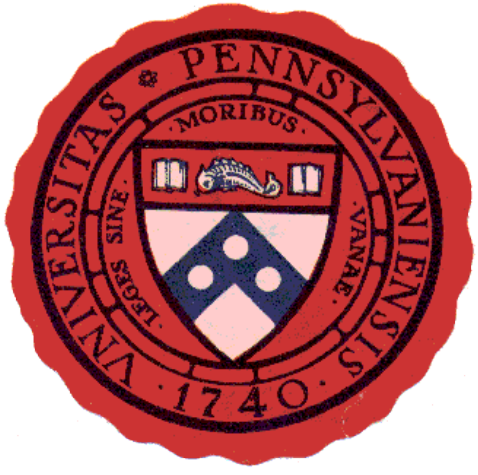
Near–simultaneous footfalls lend stability to multi–legged gaits

Sam Burden, Shankar Sastry,
Dan Koditschek, **Shai Revzen**

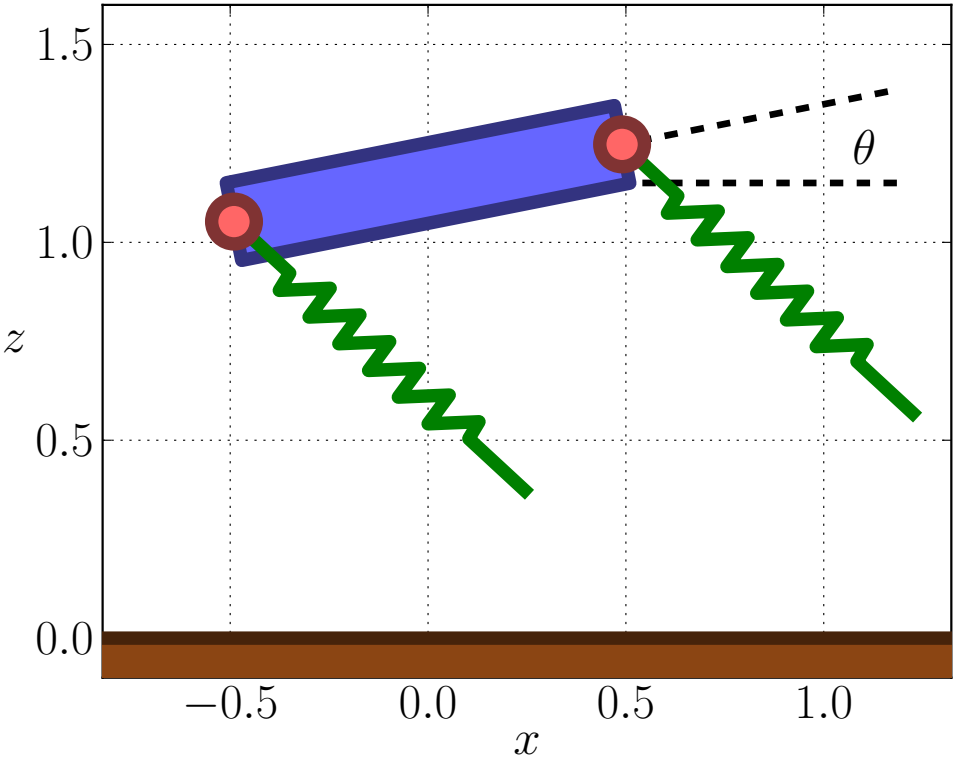


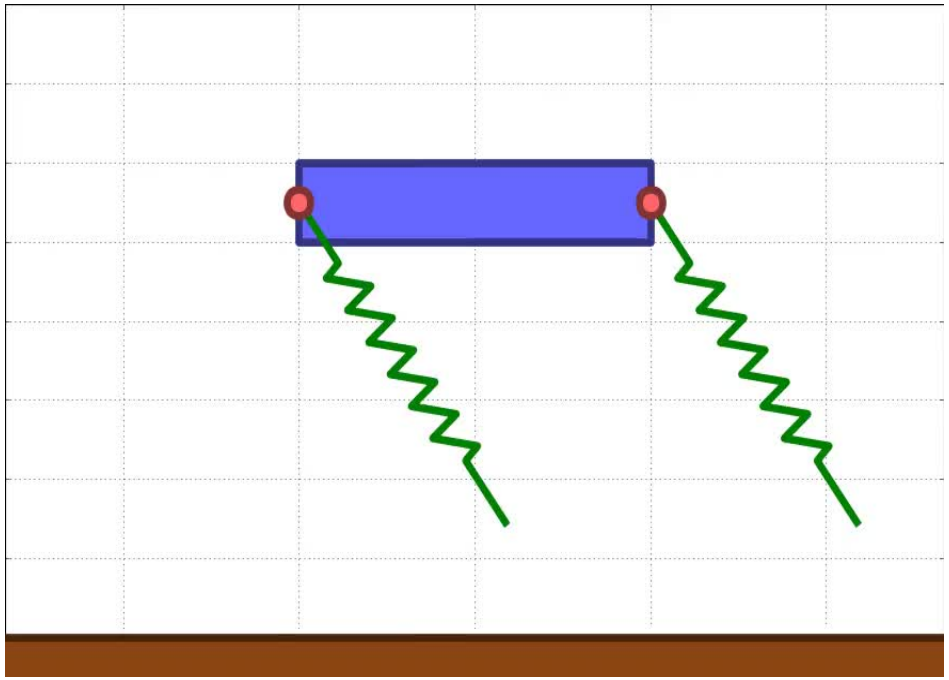
Near–simultaneous footfalls in gaits of animals & robots

MeMyHorseAndI.com

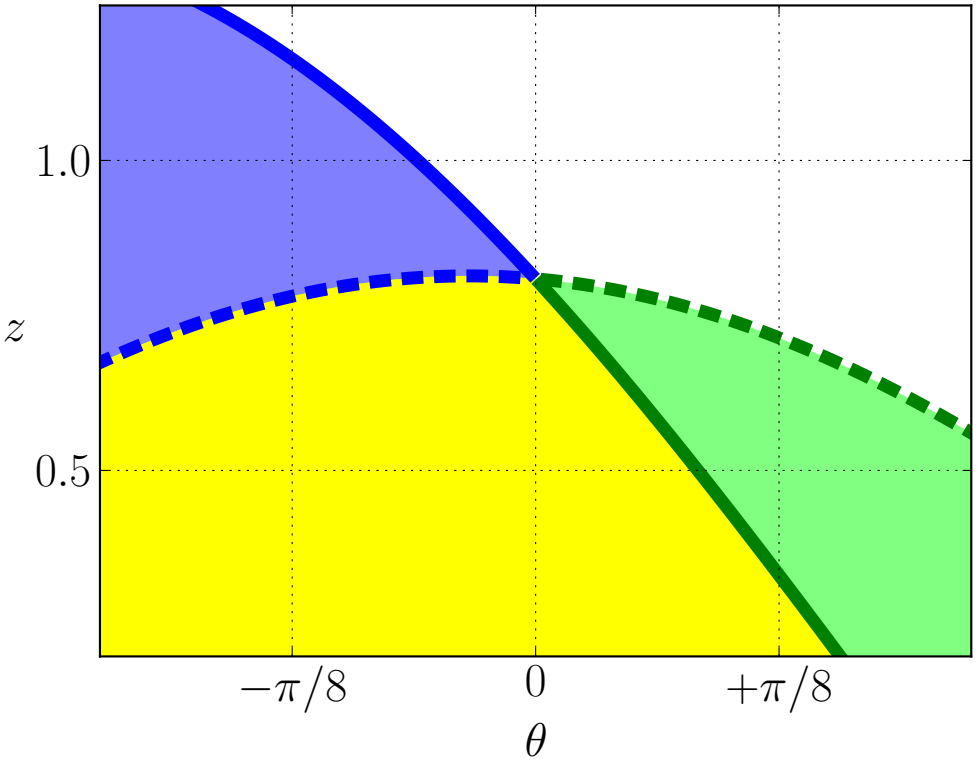
Hyun, Seok, Lee, Kim IJRR 2014

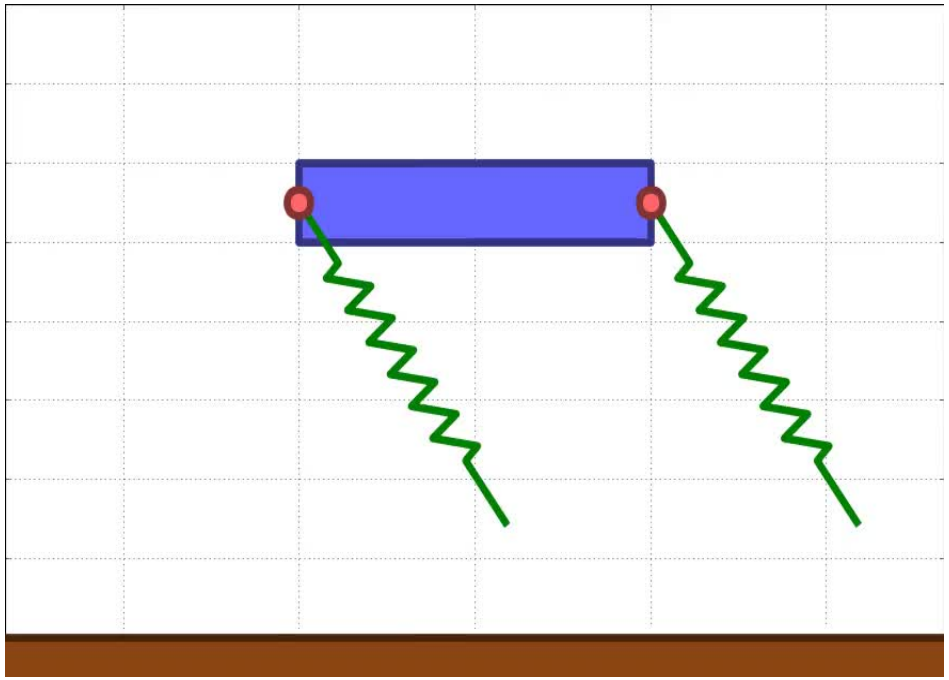
Illustrative model encountering simultaneous footfalls



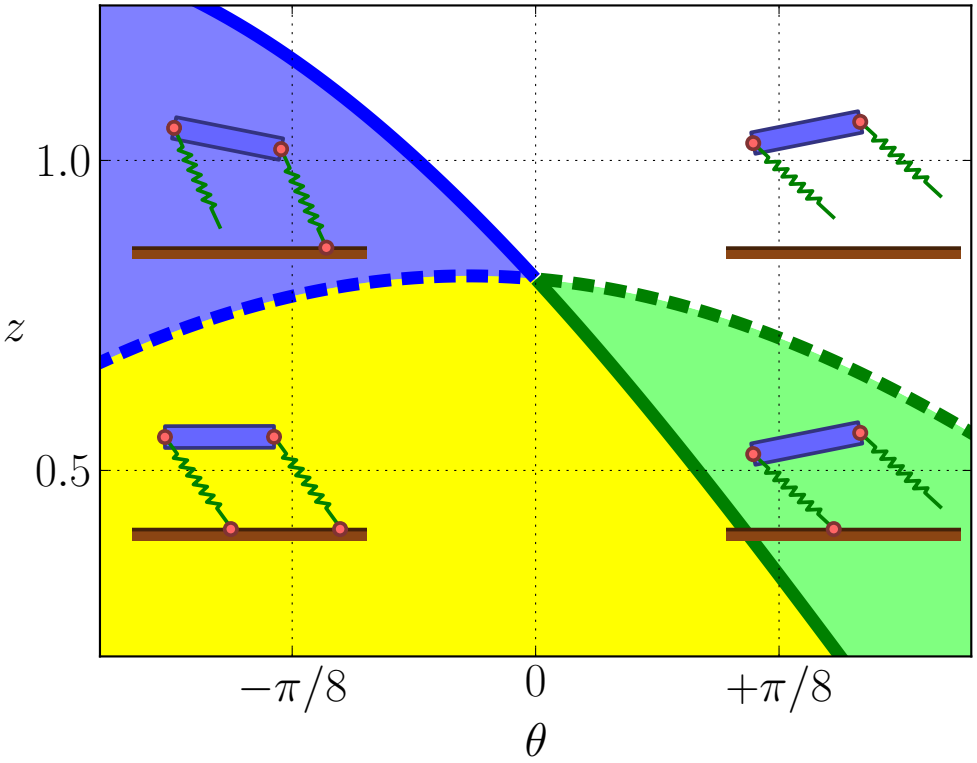


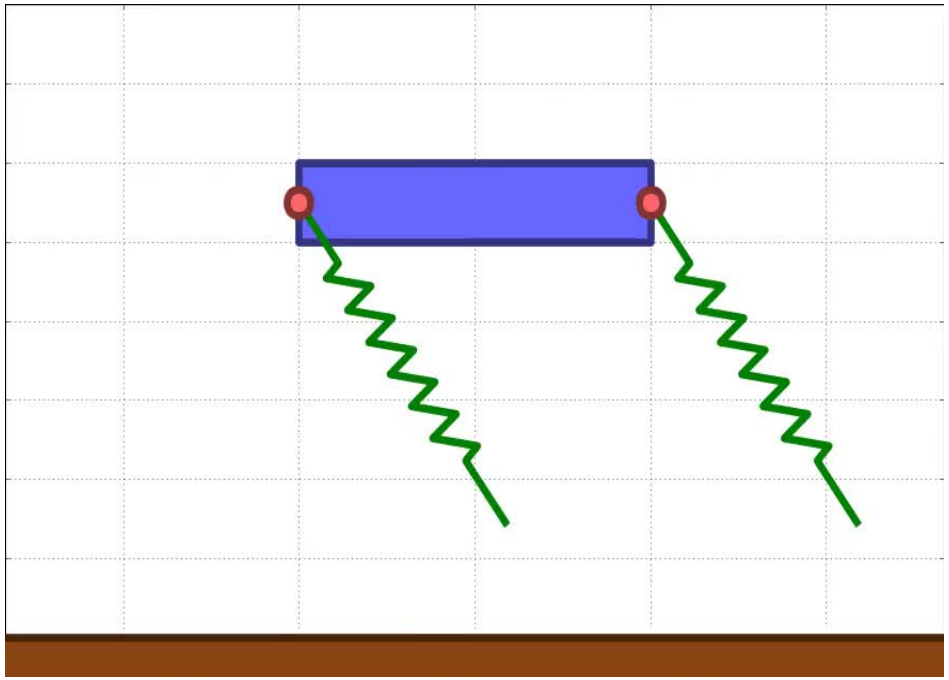
Illustrative model encountering simultaneous footfalls



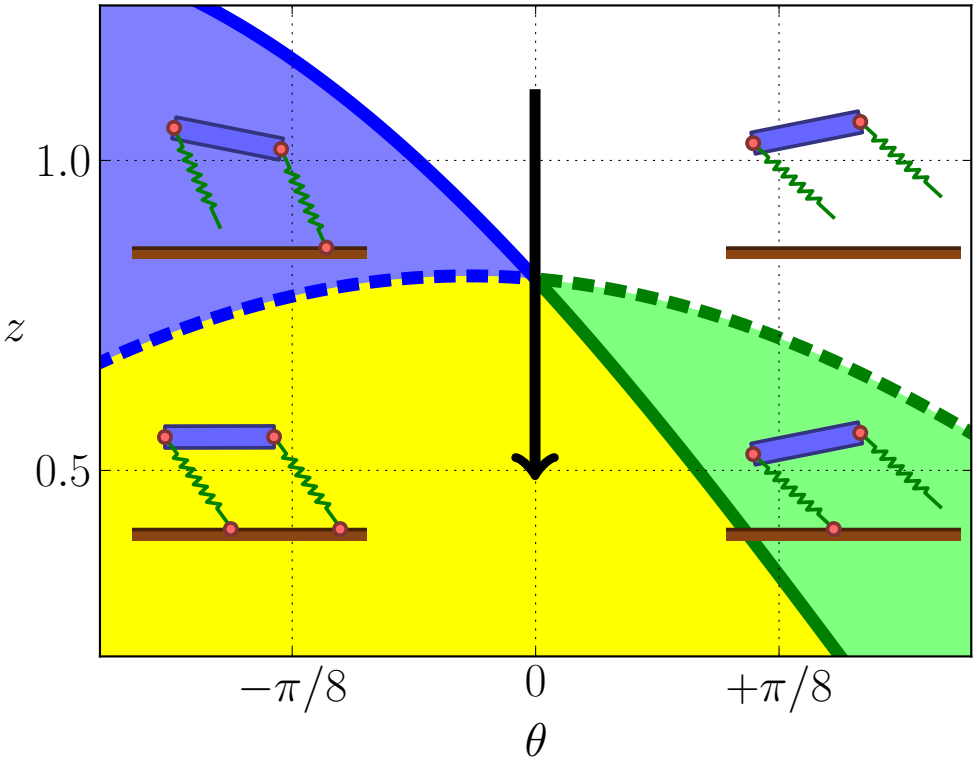


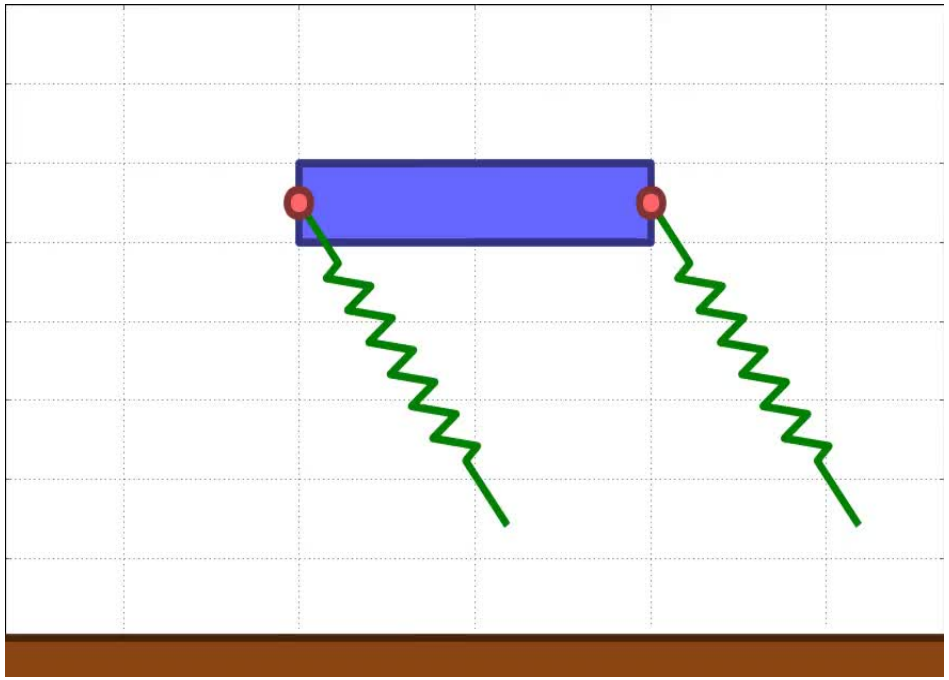
Illustrative model encountering simultaneous footfalls



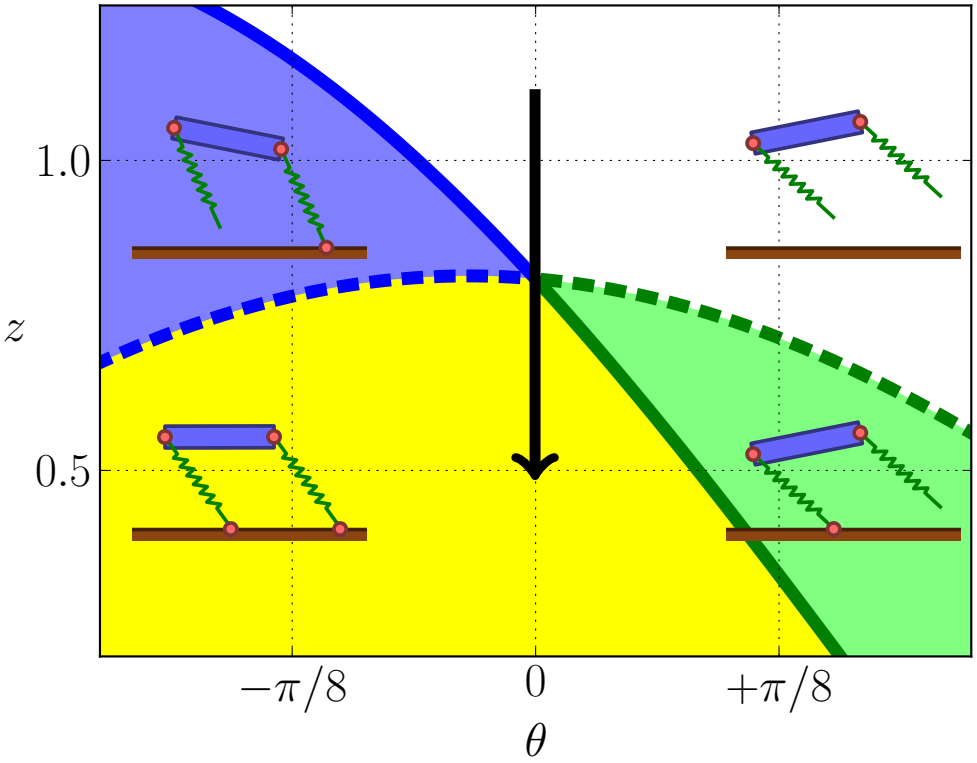


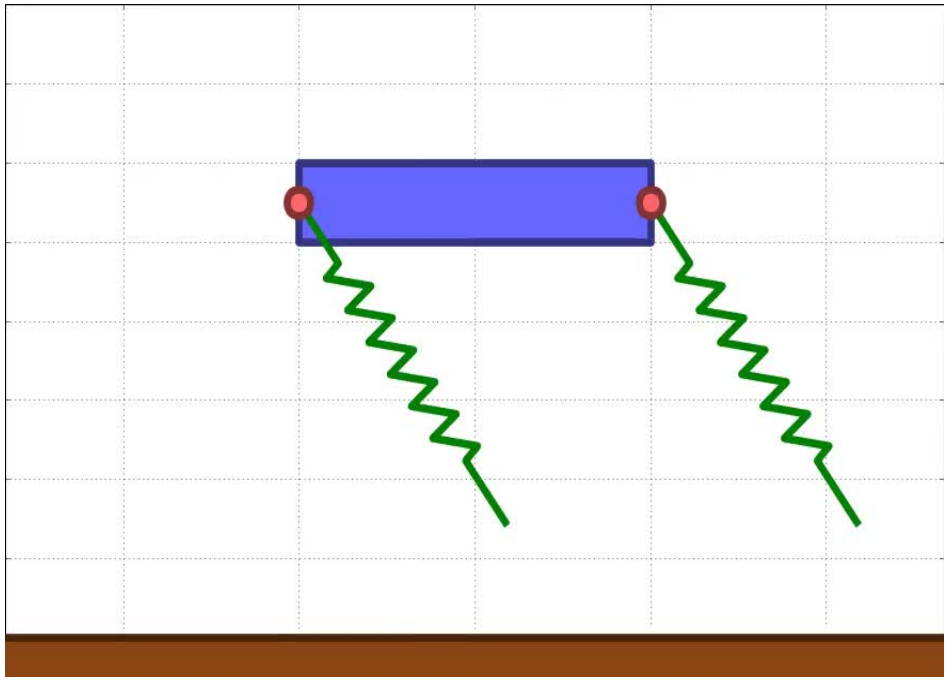
Illustrative model encountering simultaneous footfalls





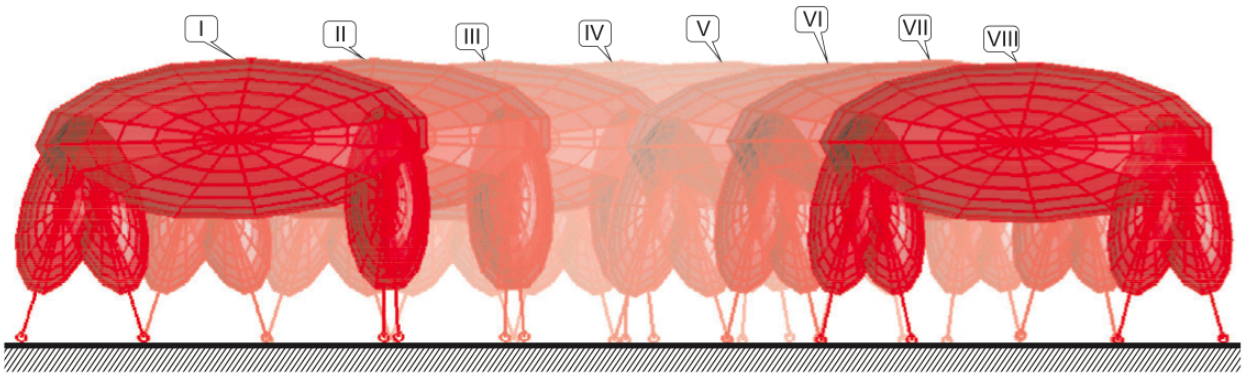
Illustrative model encountering simultaneous footfalls



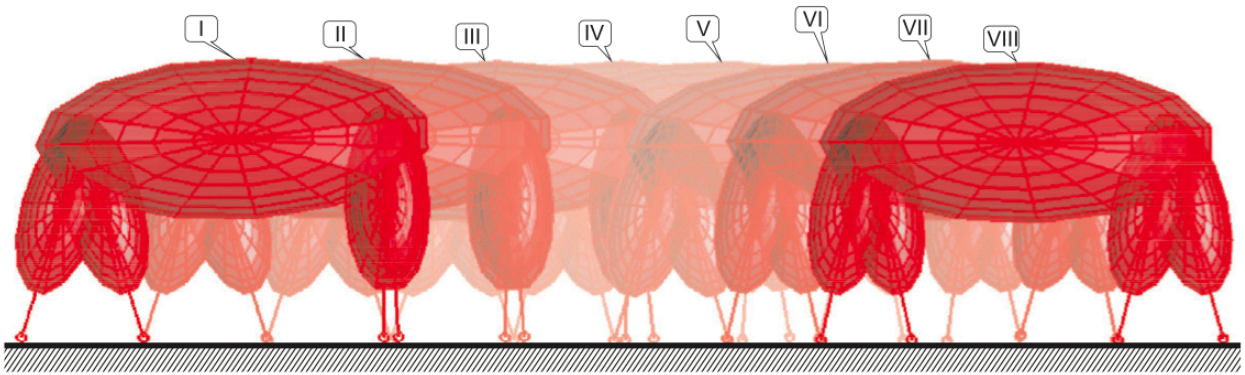


Trot trajectory encounters multiple simultaneous footfalls.

Rigid limbs yield sensitive gaits near multiple impacts



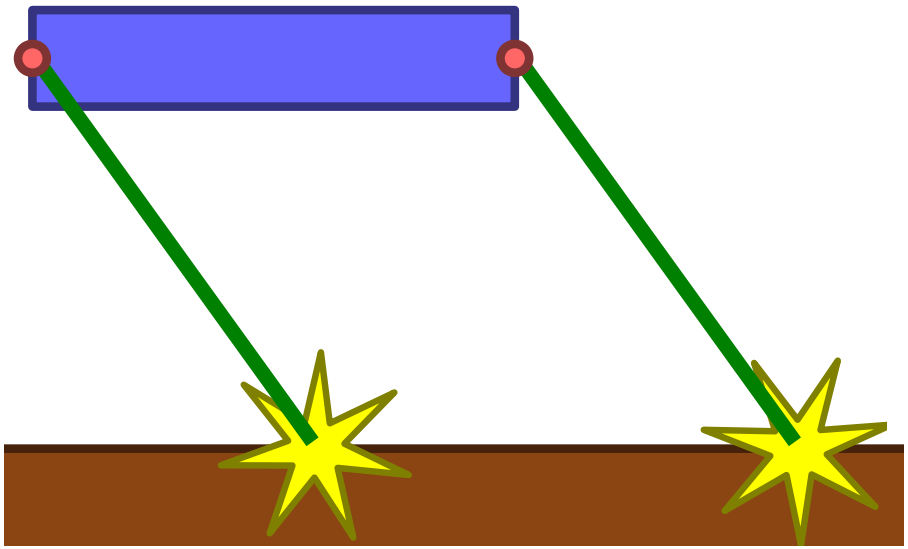
Rigid limbs yield sensitive gaits near multiple impacts



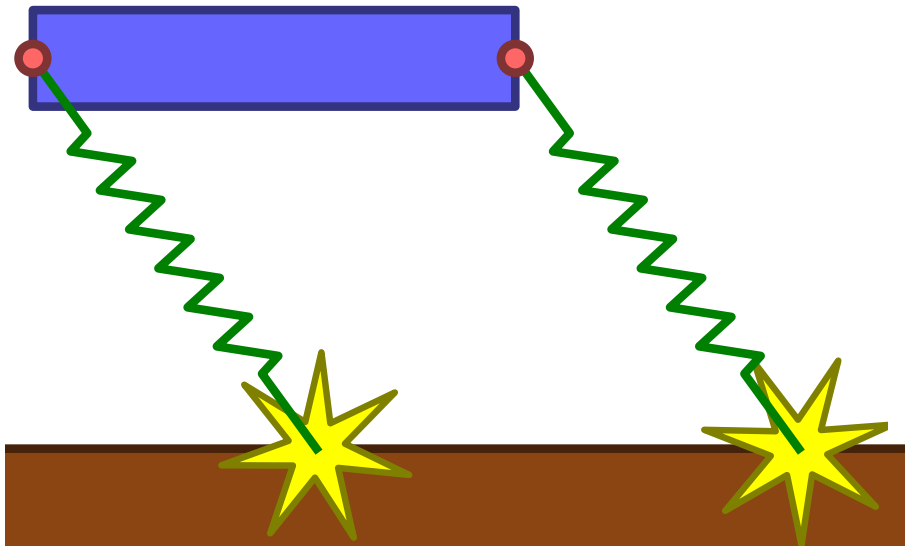
Quadruped with rigid legs possesses three adjacent trot (or trot–like) gaits

Remy, Buffington, Siegwart IJRR 2010

Viscoelastic limbs yield consistent outcomes from impacts



Rigid limbs

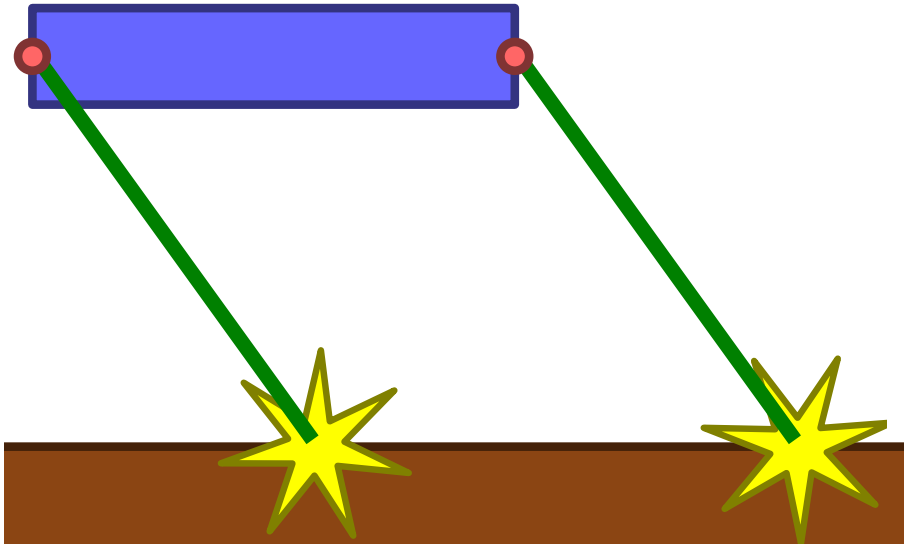


Viscoelastic limbs

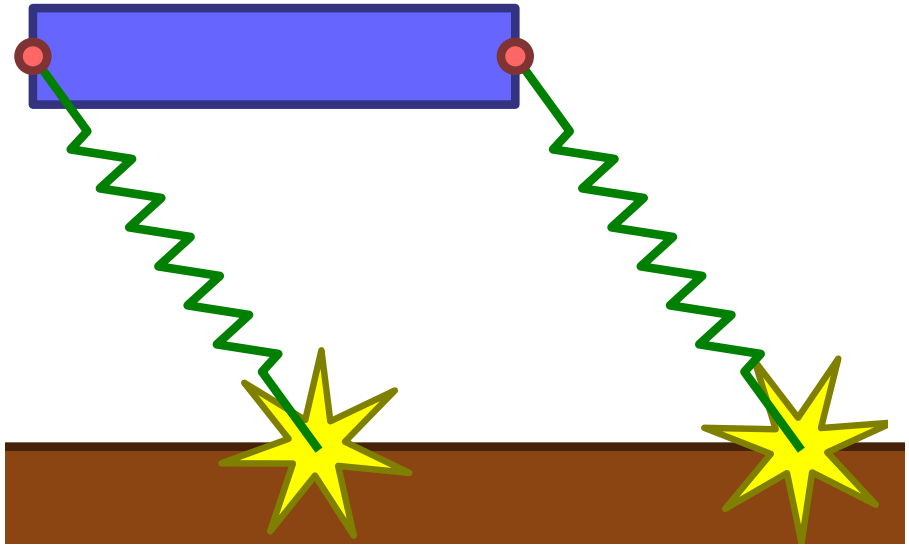
Viscoelastic limbs yield consistent outcomes from impacts

Impact restitution

$$\dot{q}^+ = \Delta \dot{q}^-$$



Rigid limbs

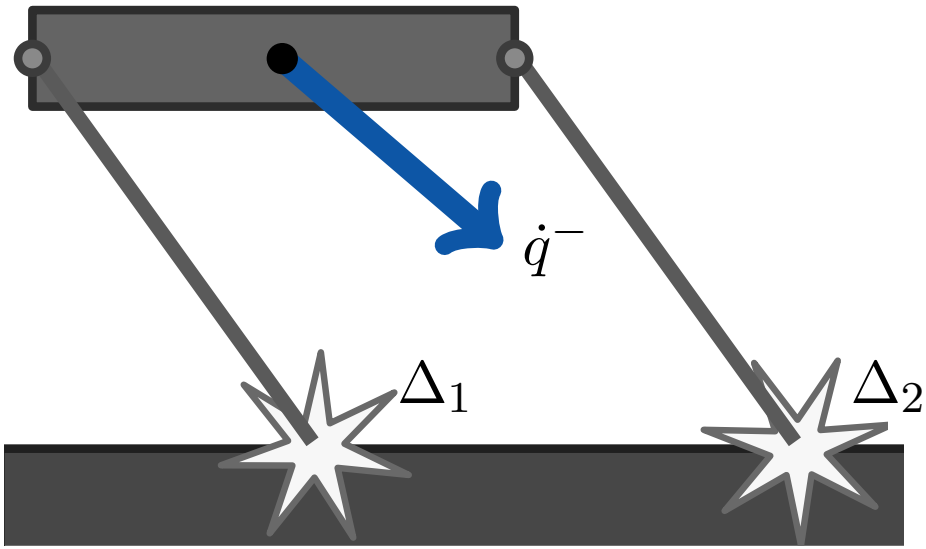


Viscoelastic limbs

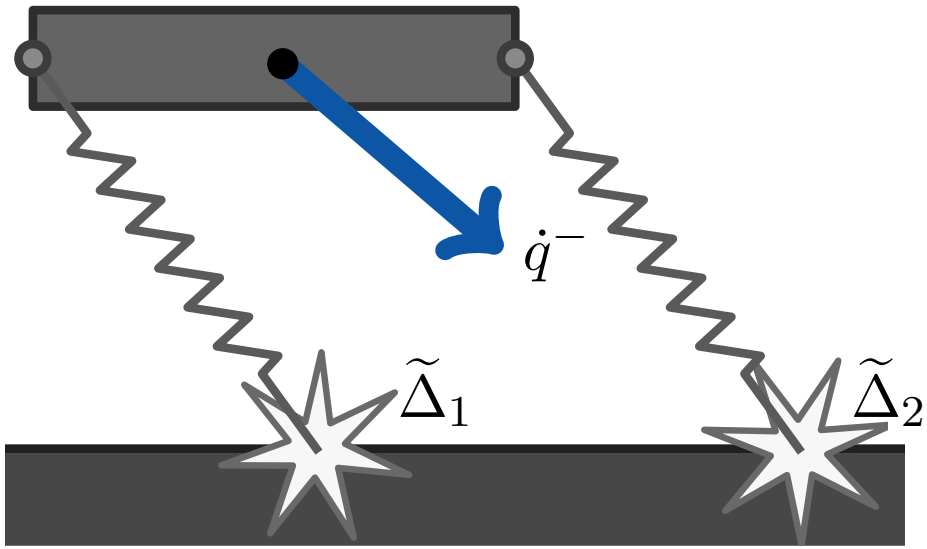
Viscoelastic limbs yield consistent outcomes from impacts

Impact restitution

$$\dot{q}^+ = \Delta \dot{q}^-$$



Rigid limbs

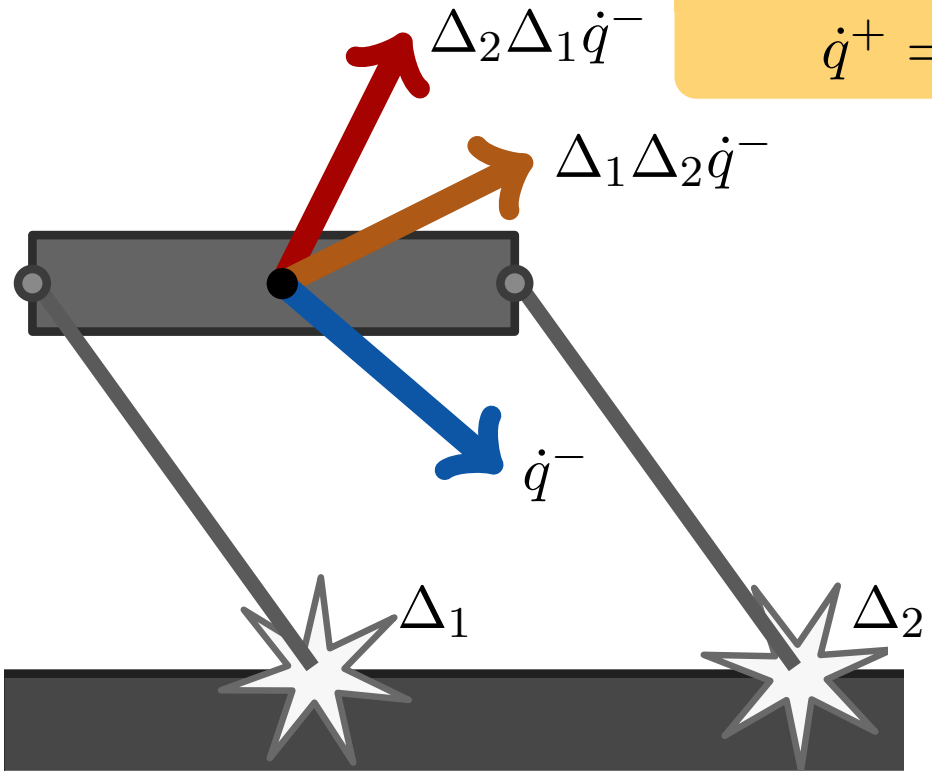


Viscoelastic limbs

Viscoelastic limbs yield consistent outcomes from impacts

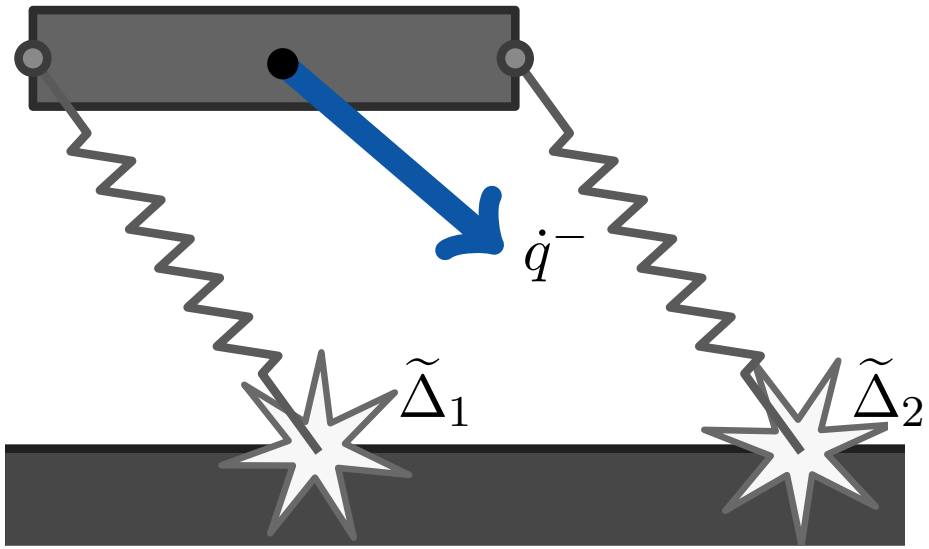
Impact restitution

$$\dot{q}^+ = \Delta \dot{q}^-$$



Rigid limbs

$$\Delta_1\Delta_2\dot{q}^- \neq \Delta_2\Delta_1\dot{q}^-$$

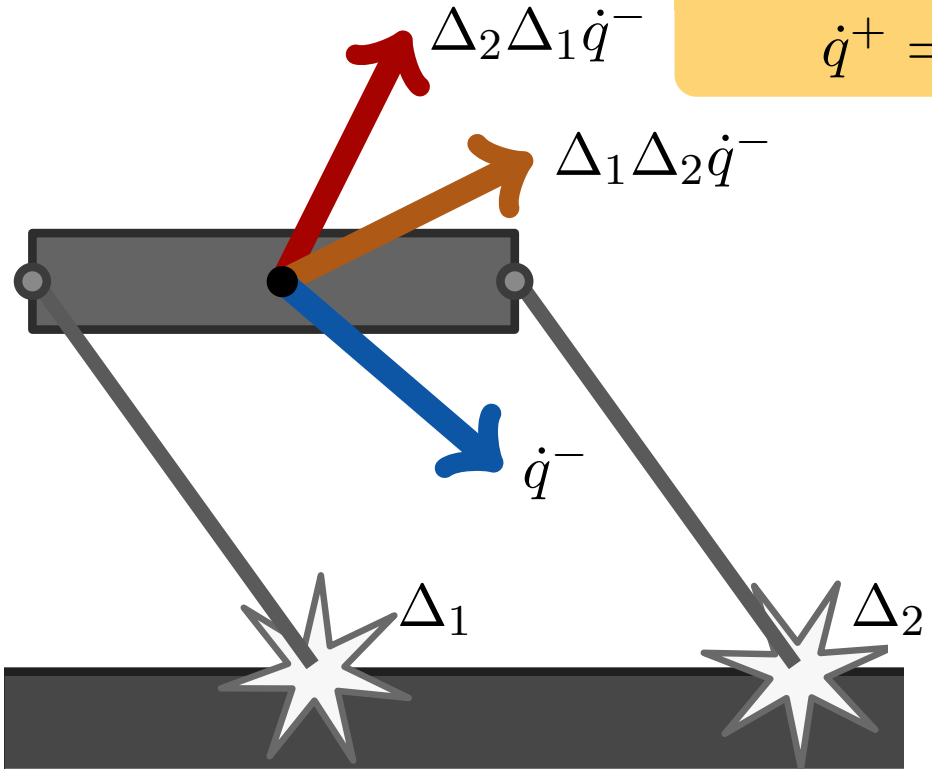


Viscoelastic limbs

Viscoelastic limbs yield consistent outcomes from impacts

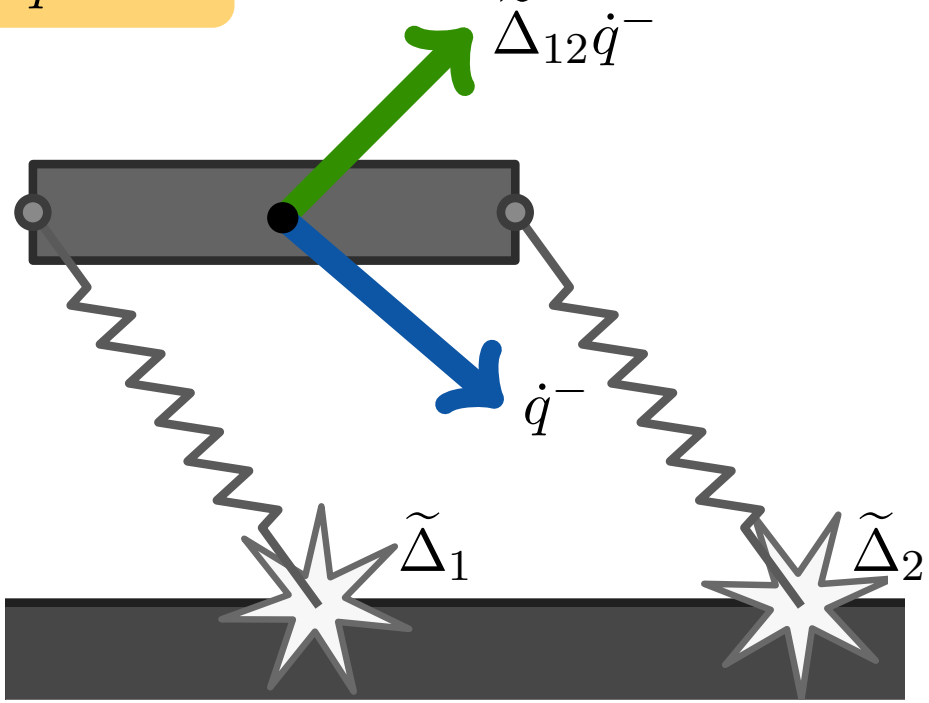
Impact restitution

$$\dot{q}^+ = \Delta \dot{q}^-$$



Rigid limbs

$$\Delta_1\Delta_2\dot{q}^- \neq \Delta_2\Delta_1\dot{q}^-$$



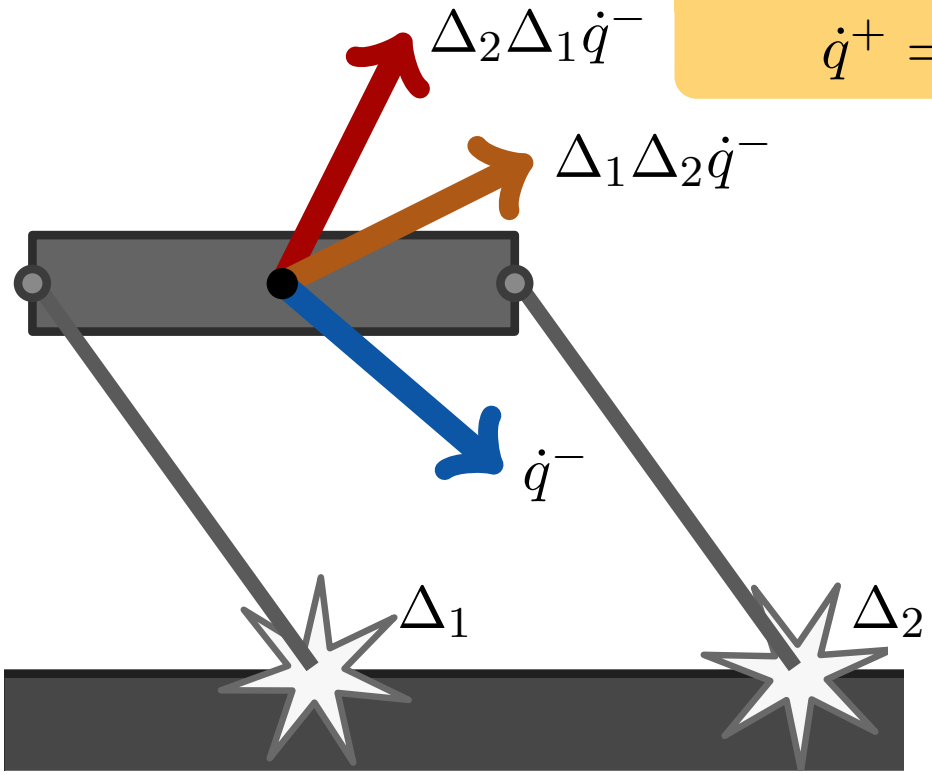
Viscoelastic limbs

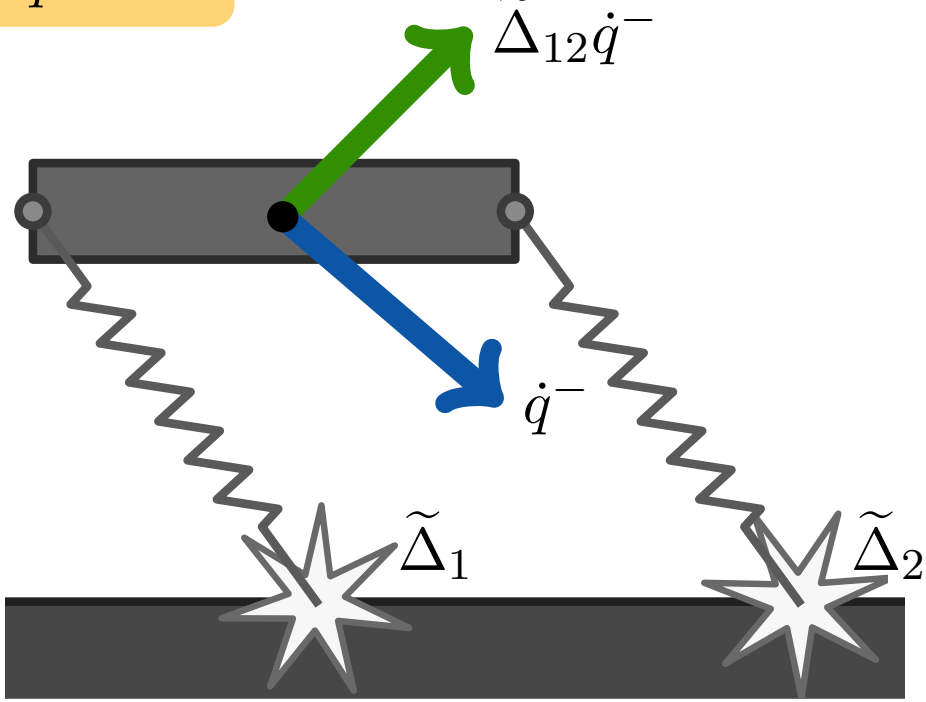
$$\widetilde{\Delta}_1\widetilde{\Delta}_2\dot{q}^- = \widetilde{\Delta}_2\widetilde{\Delta}_1\dot{q}^- =: \widetilde{\Delta}_{12}\dot{q}^-$$

Viscoelastic limbs yield consistent outcomes from impacts

Impact restitution

$$\dot{q}^+ = \Delta \dot{q}^-$$





Rigid limbs

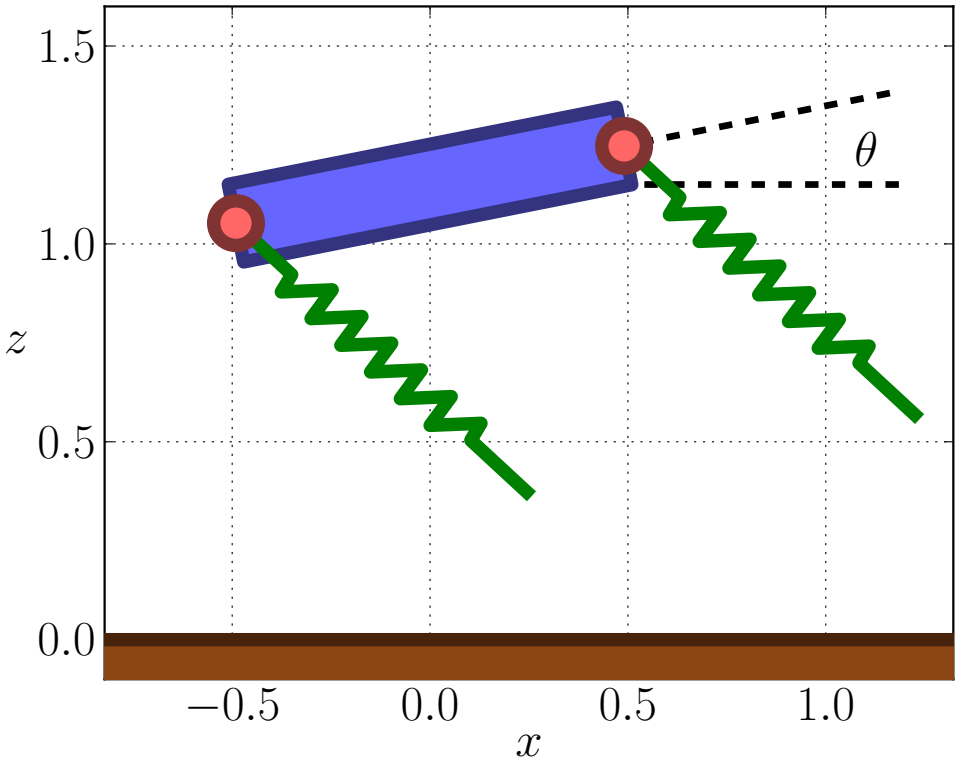
$$\Delta_1\Delta_2\dot{q}^- \neq \Delta_2\Delta_1\dot{q}^-$$

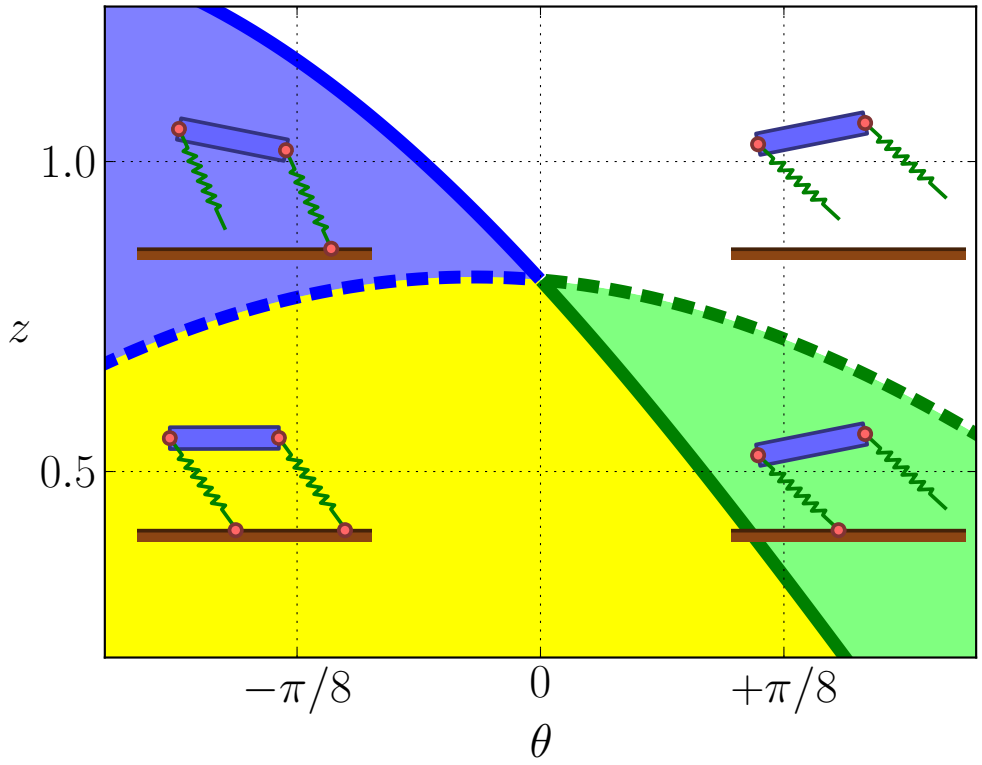
Viscoelastic limbs

$$\widetilde{\Delta}_1\widetilde{\Delta}_2\dot{q}^- = \widetilde{\Delta}_2\widetilde{\Delta}_1\dot{q}^- =: \widetilde{\Delta}_{12}\dot{q}^-$$

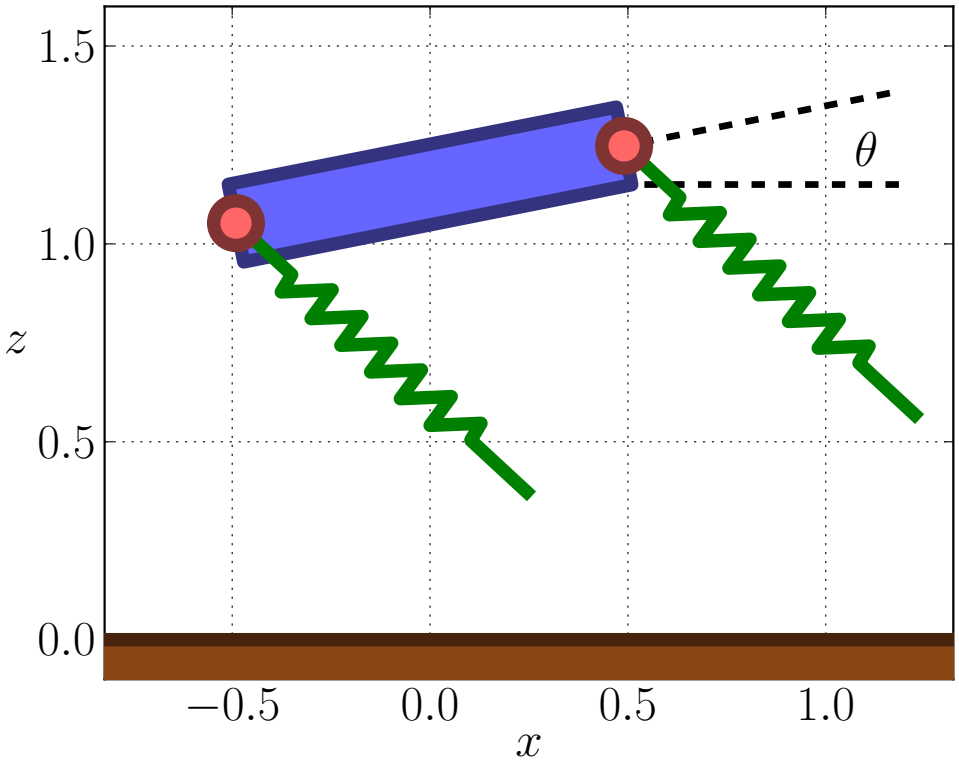
Viscoelastic limbs lead to consistent post–impact velocity.

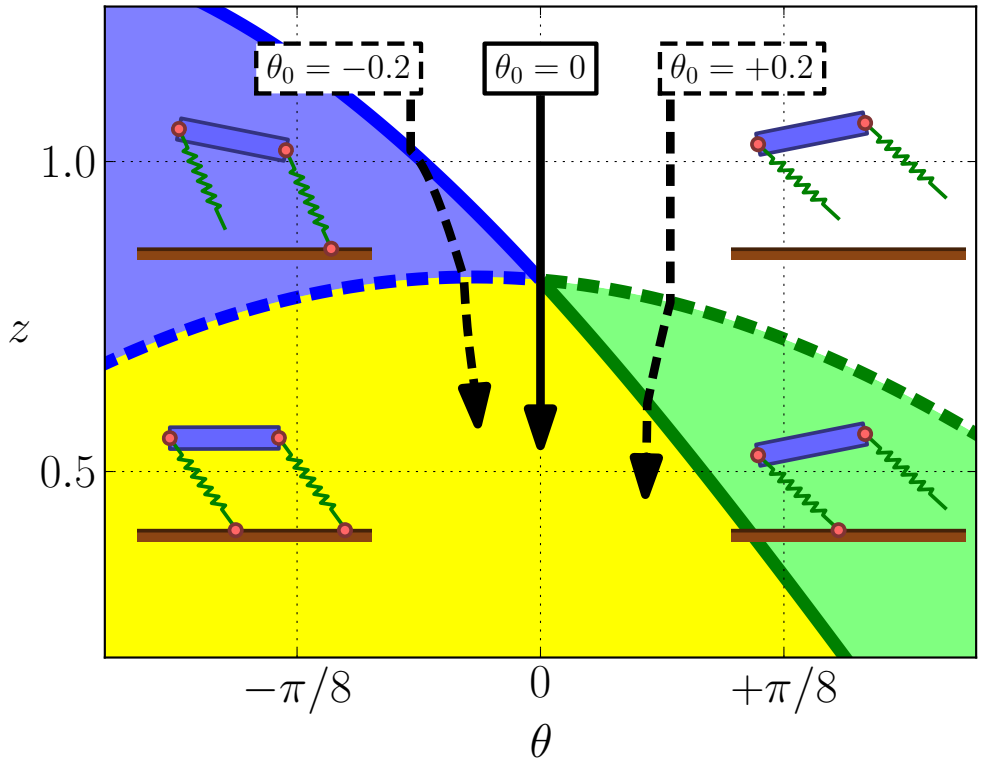
Near–simultaneous footfalls lend stability to pitch



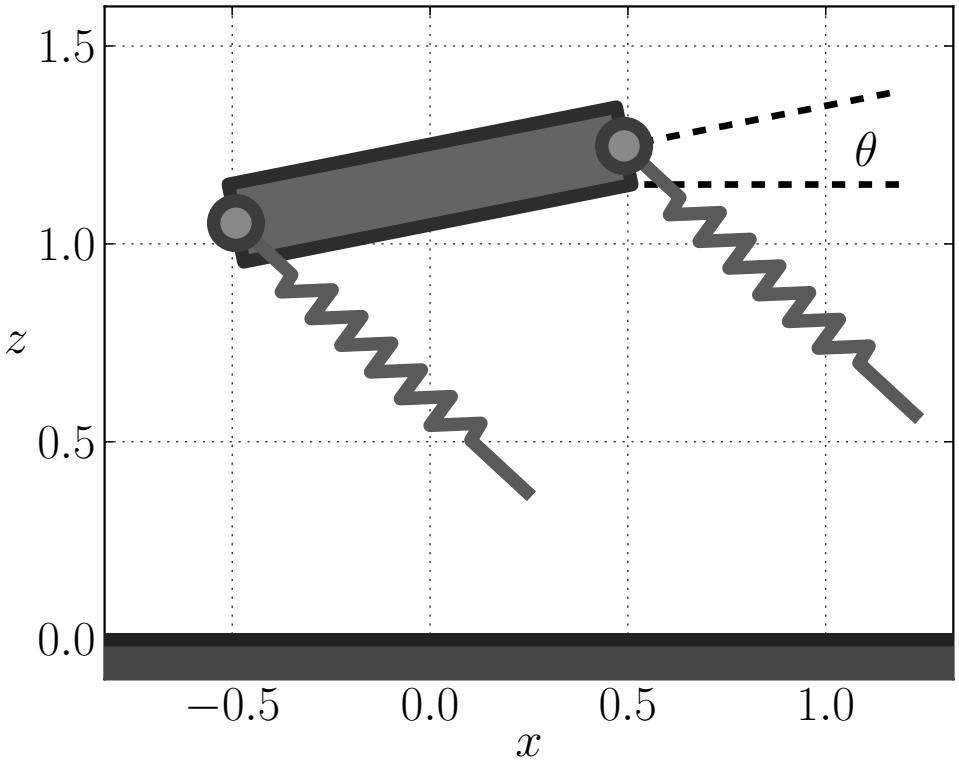


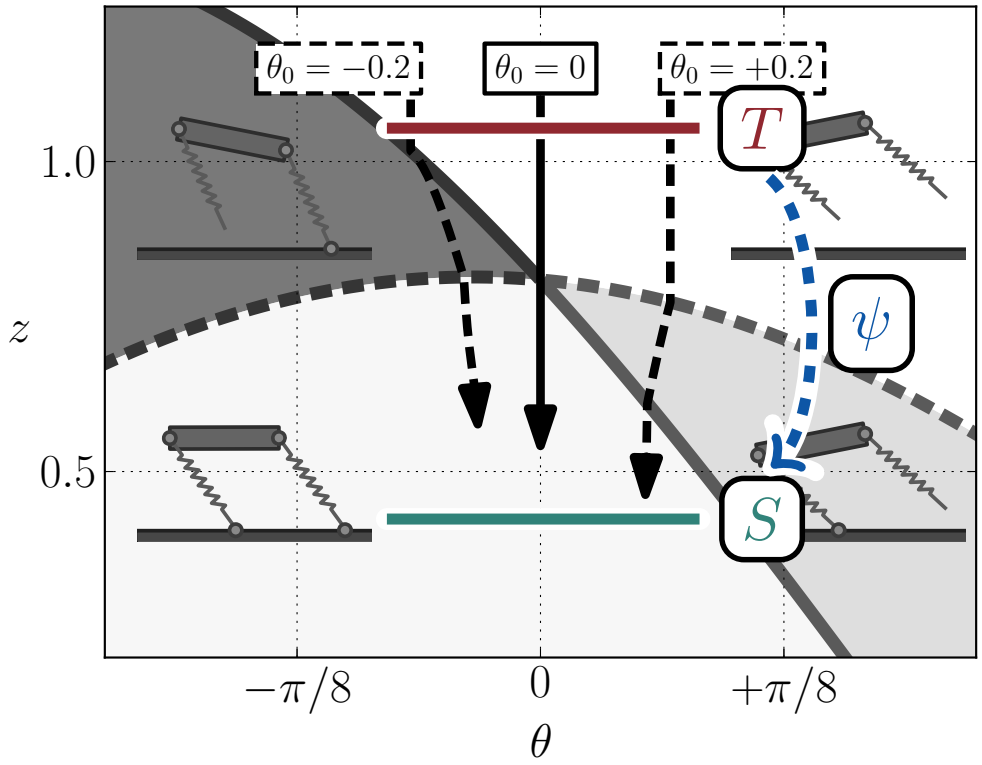
Near–simultaneous footfalls lend stability to pitch



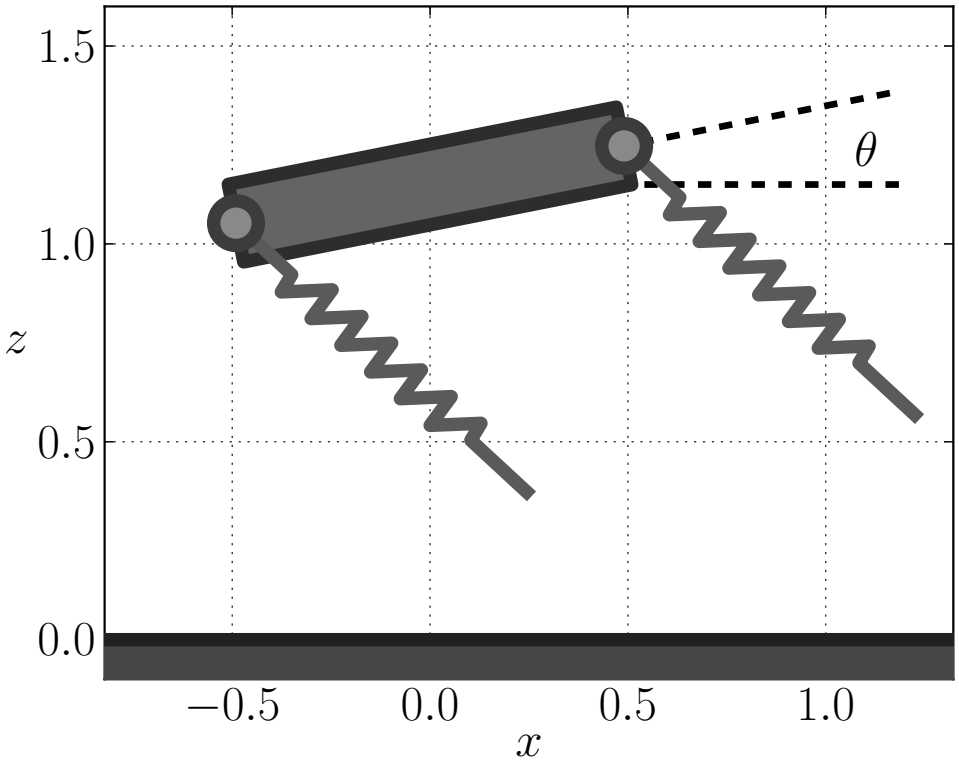


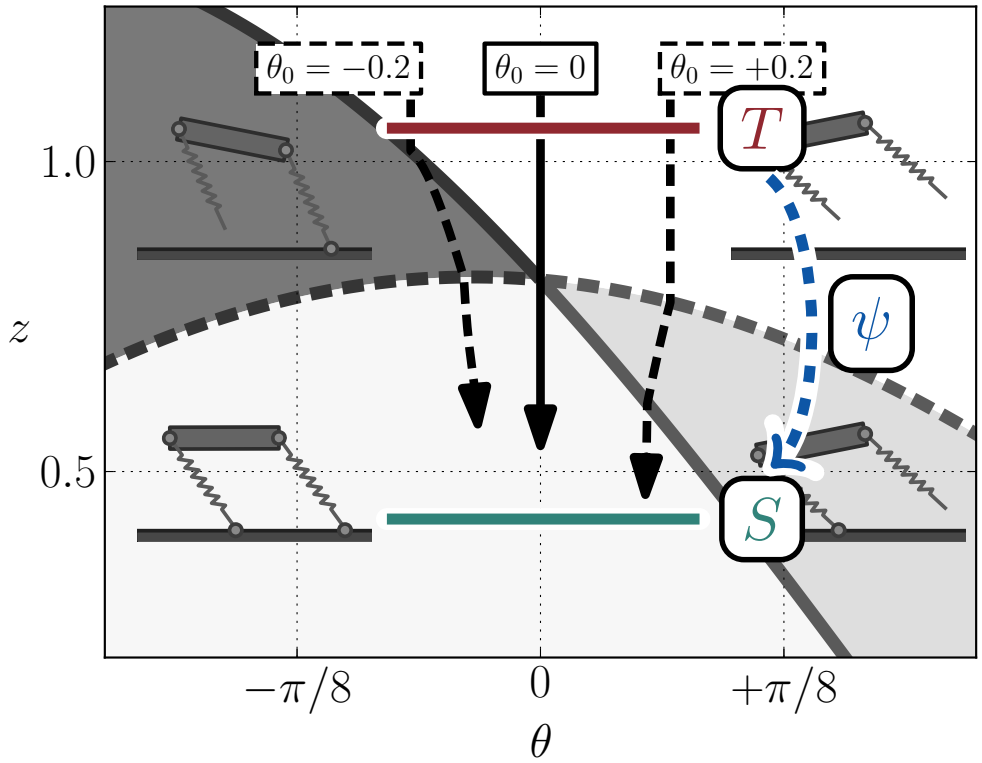
Near–simultaneous footfalls lend stability to pitch





Near–simultaneous footfalls lend stability to pitch

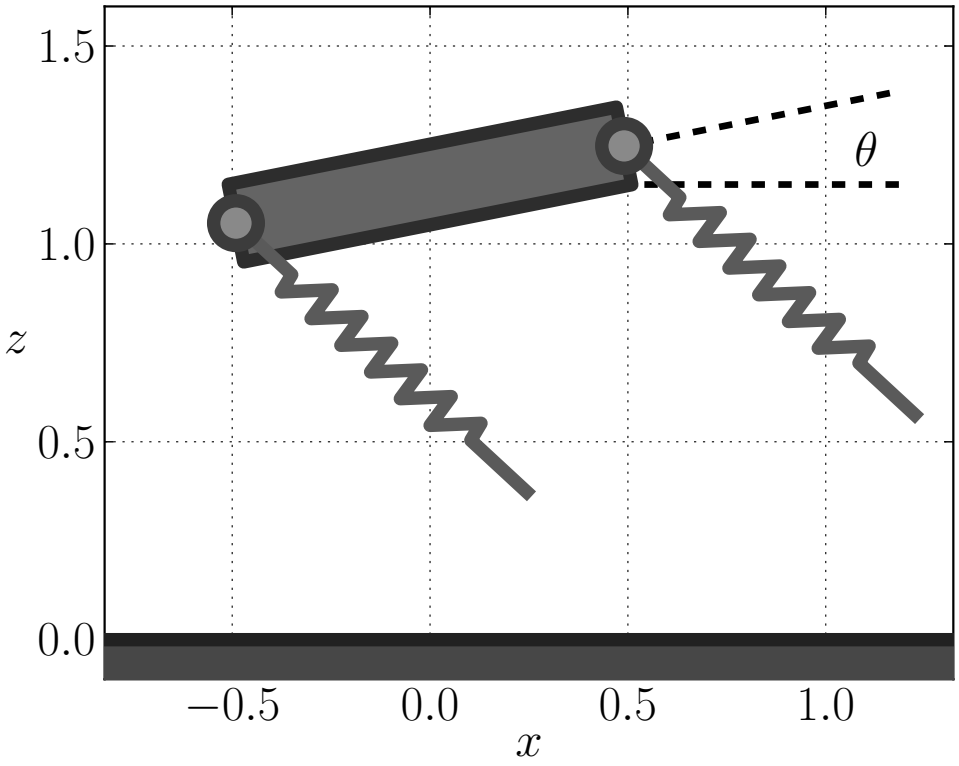


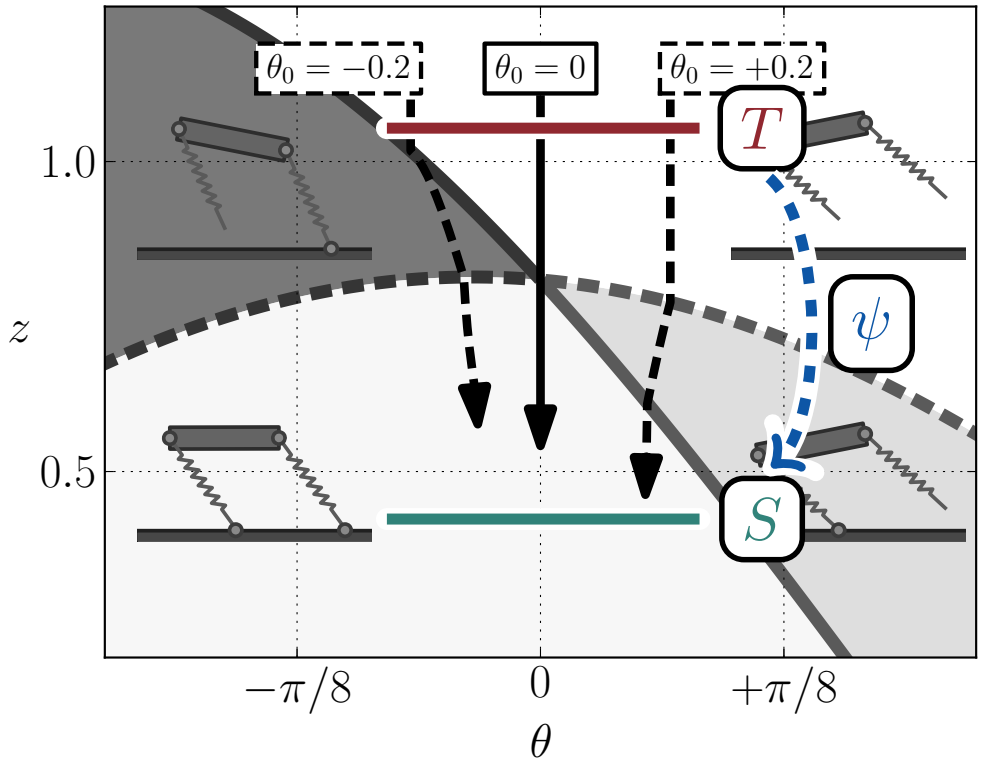


Viscoelastic limbs imply $\psi : T \to S$ contracts pitch

Contraction rate depends on sign of θ_0.

Near–simultaneous footfalls lend stability to pitch





Viscoelastic limbs imply $\psi : T \to S$ contracts pitch

Contraction rate depends on sign of θ_0.

Similar mechanism lends synchrony to limb groupings

See arXiv:1407.1775 and Shai's talk for details.