Towards Understanding Visually Guided Locomotion over Complex and Rough Terrain: A Phase-Space Planning Method

Ye Zhao*, Jonathan S. Matthis** (Presenter), Sean L. Barton***, Mary Hayhoe**, and Luis Sentis*

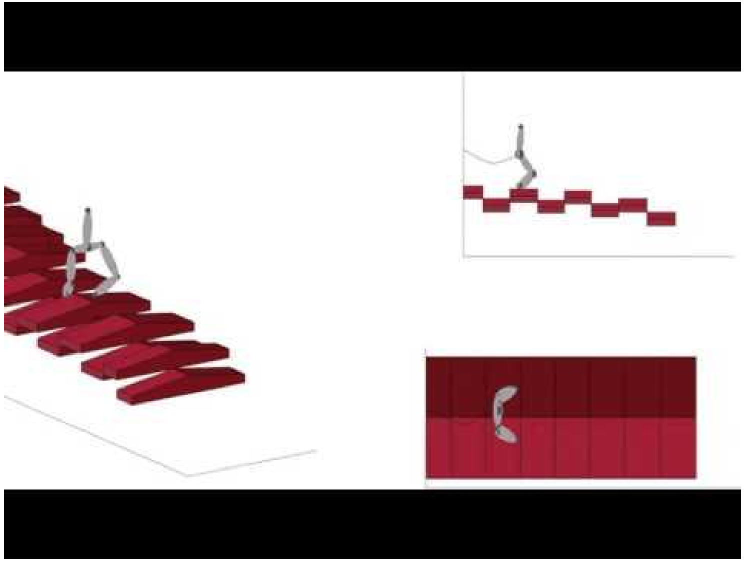
(The first three authors have equally contributed)

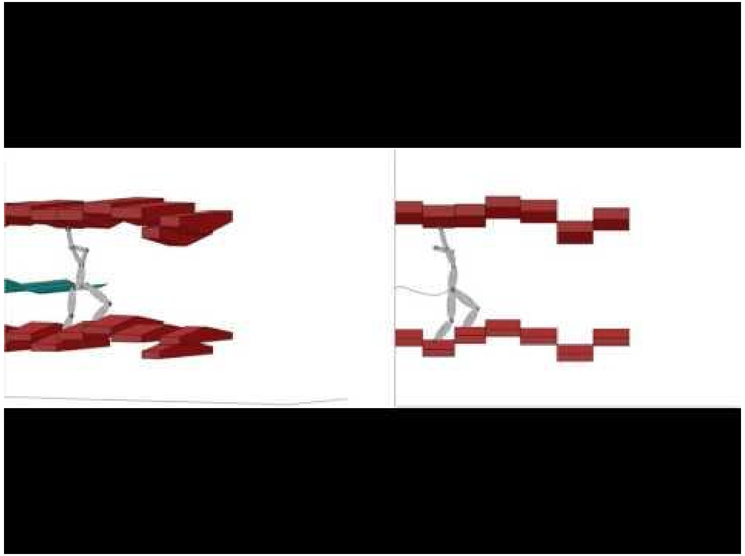
*Human Centered Robotics Laboratory, The University of Texas at Austin,
**Center for Perceptual Systems, The University of Texas at Austin,
***Department of Cognitive Science, Rensselaer Polytechnic Institute.

Dynamic locomotion in Nature

THE UNIVERSITY OF TEXAS AT AUSTIN

Kinodynamic Motion planning over rough terrain

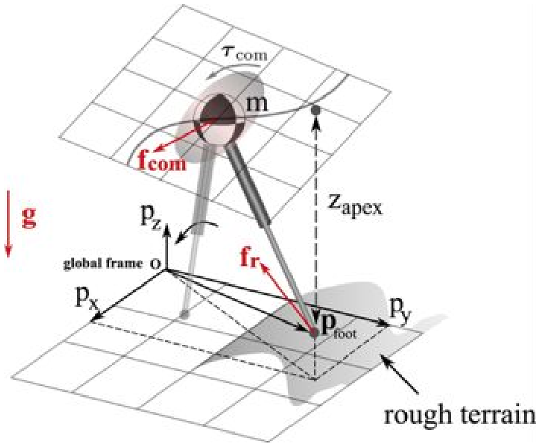




- Keyframe-based kinodynamic hybrid planning
- Applicable to general and constrained environments
- High-level contact decision maker reactive to adversarial environments

THE UNIVERSITY OF TEXAS AT AUSTIN

Generalized Prismatic Inverted Pendulum Model



- Center of mass surface manifold

$$\mathcal{S}_{\text{CoM}} = \left\{ (x, y, z) \in \mathbb{R}^3 \;\middle|\; \psi_{\text{CoM}}(x, y, z) = 0 \right\}$$

- Centroidal momentum dynamics

$$\dot{\boldsymbol{l}} = m\ddot{\boldsymbol{p}}_{\text{com}} = \sum^{N_c} \boldsymbol{f}_{r_i} - m\boldsymbol{g}$$

$$\dot{\boldsymbol{k}} = \boldsymbol{\tau}_{\text{com}} = \sum_{i}^{N_c} (\boldsymbol{p}_{\text{foot}_i} - \boldsymbol{p}_{\text{com}}) \times \boldsymbol{f}_{r_i} + \boldsymbol{\tau}_i$$

Output Dynamics of the Center of Mass

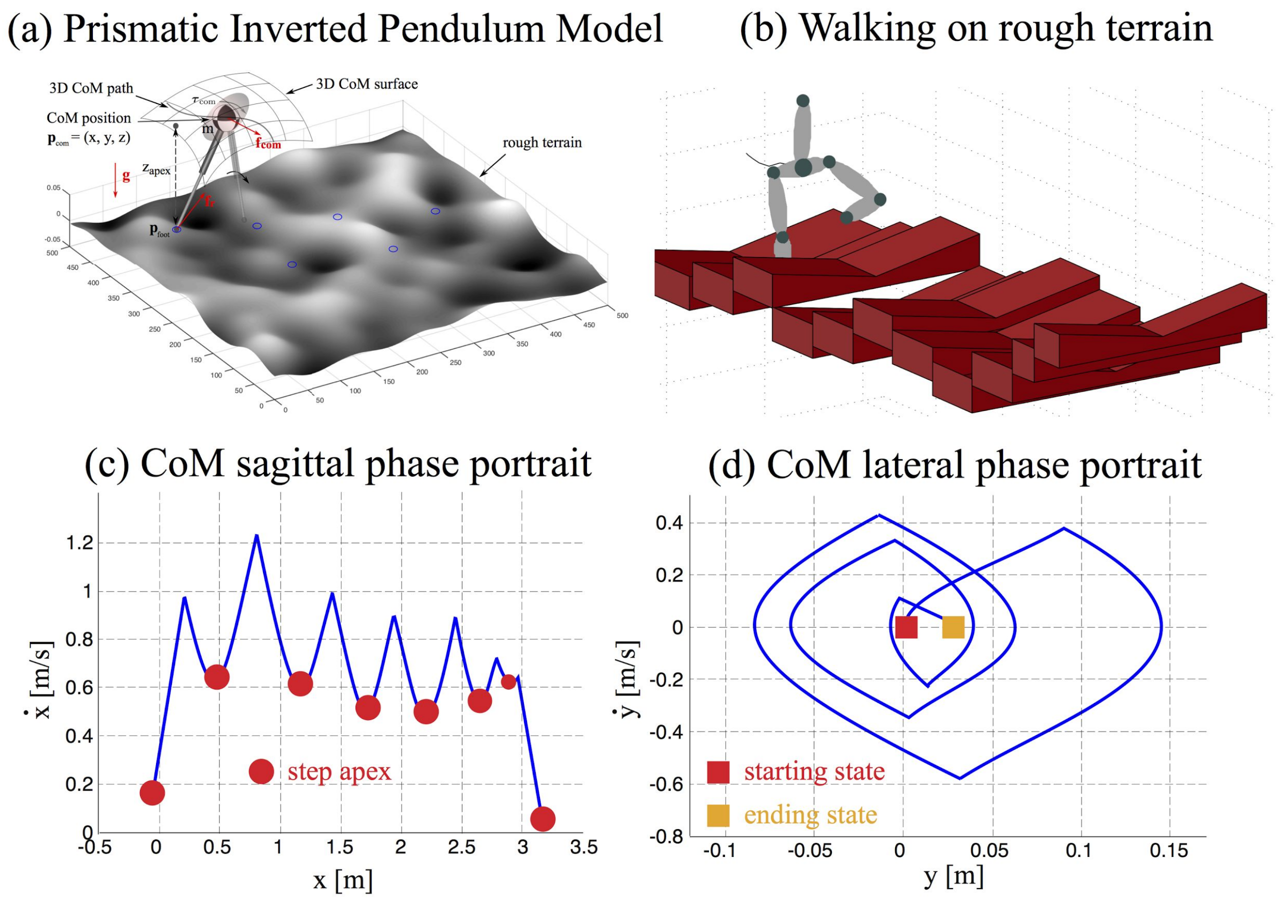
The prismatic inverted pendulum model for a q^{th} walking step, is represented by the following control system,

$$\dot{\boldsymbol{\xi}} = \mathcal{F}(q, \boldsymbol{\xi}, \boldsymbol{u})$$

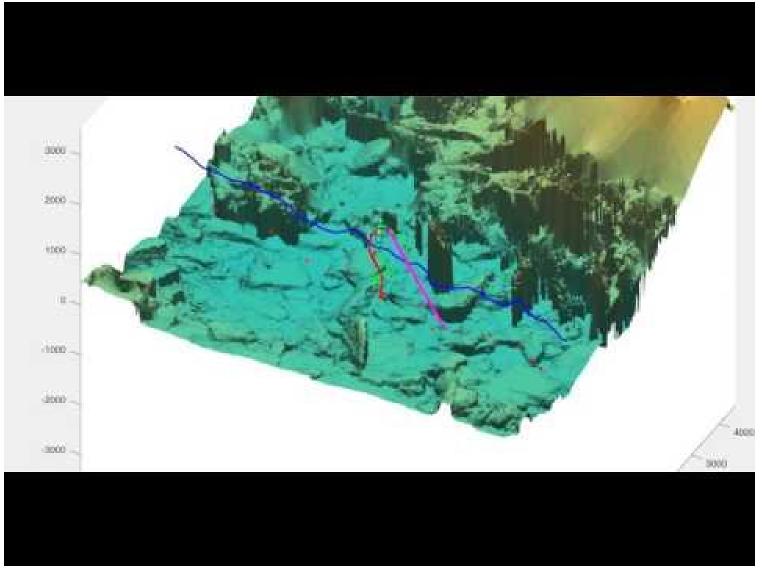
where $\boldsymbol{\xi} = (x, y, z, \dot{x}, \dot{y}, \dot{z})^T, \boldsymbol{u} = (\omega, \boldsymbol{\tau}, \boldsymbol{p}_{\text{foot}})^T$.

THE UNIVERSITY OF TEXAS AT AUSTIN

Dynamic rough terrain locomotion with phase space planner



How human locomotion performs in rocky terrain?

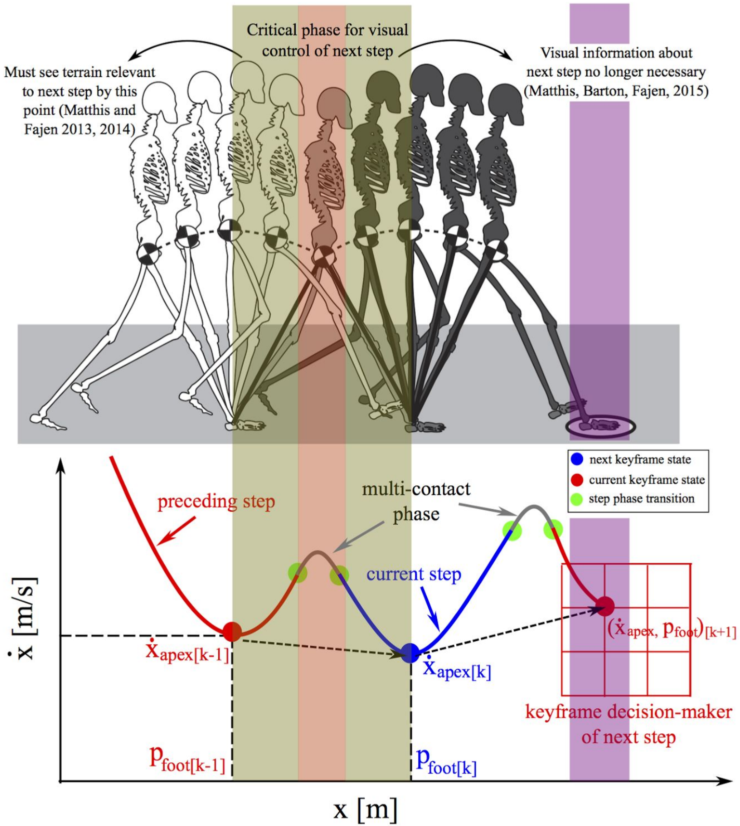


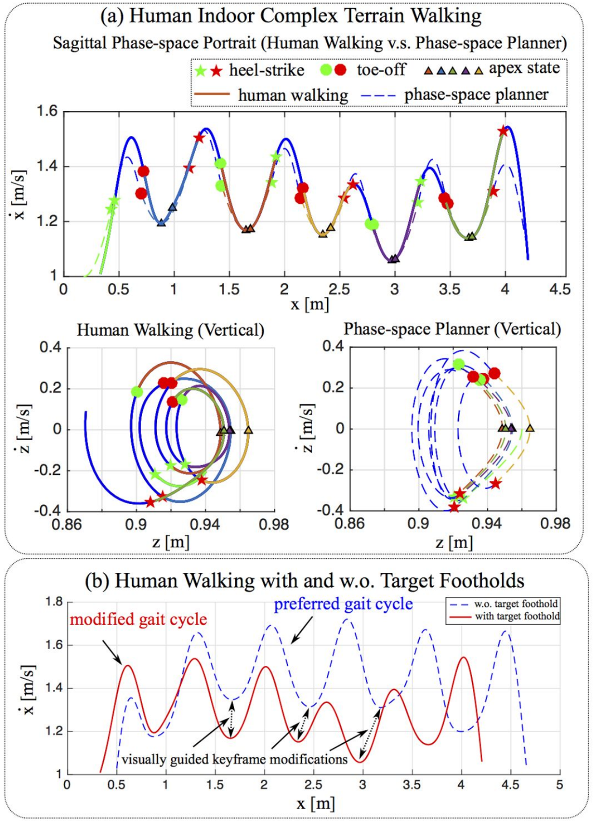
- How vision helps to predict future walking behaviors?
- How to reduce the performance gap between robots and their biological counterparts?

[Matthis, Barton, Fajen, Journal of Vision 2015]

THE UNIVERSITY OF TEXAS AT AUSTIN

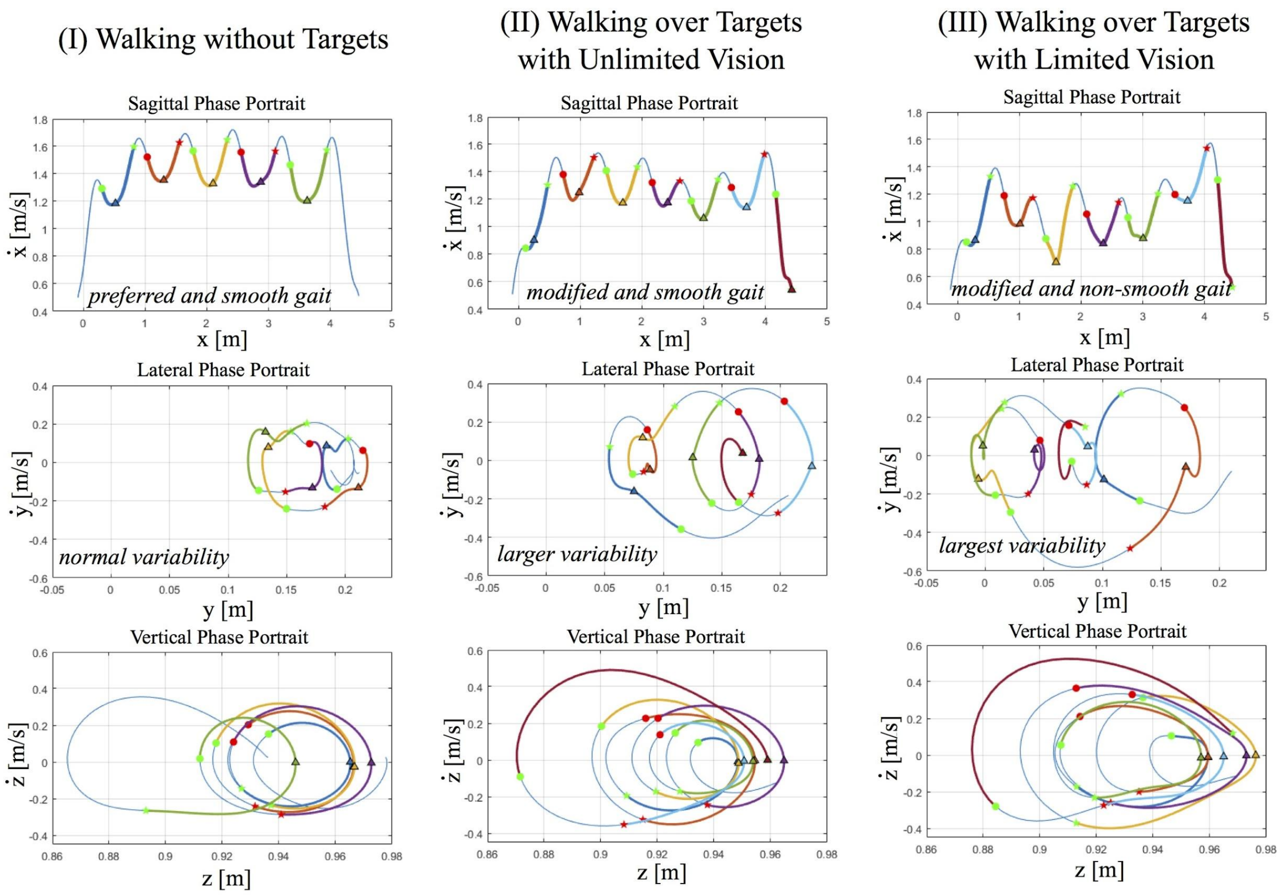
Interpretation via phase space planner





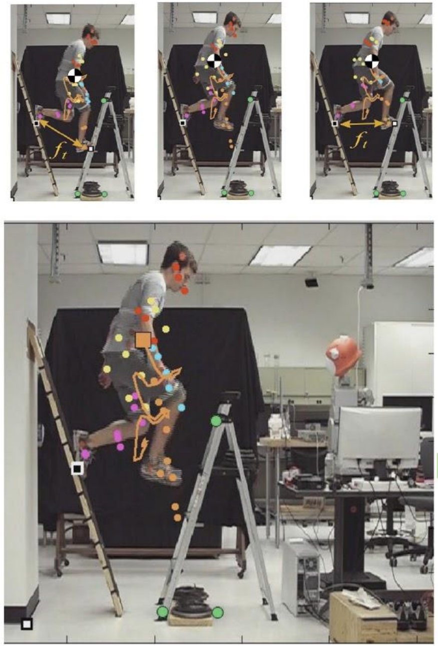
THE UNIVERSITY OF TEXAS AT AUSTIN

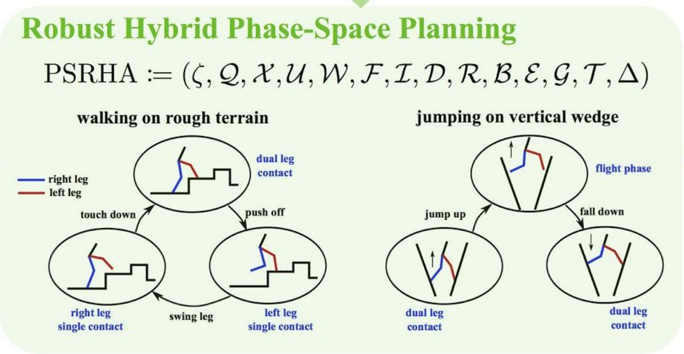
Various test trials under different visual conditions

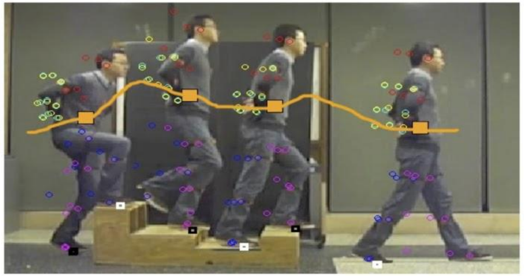


THE UNIVERSITY OF TEXAS AT AUSTIN

Generalizations to extreme locomotion







To be continued ...

Thank you for your Time!