Towards optimal gait assistance:
human-in-the-loop optimization & neuromechanical simulation

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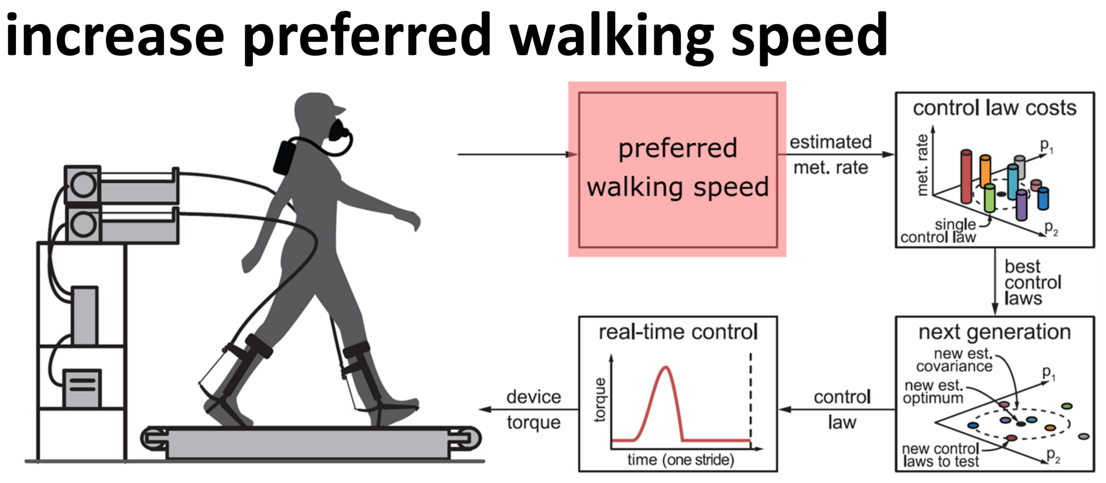
Human-in-the-loop optimization of ankle-exoskeleton assistance for faster walking speed

Question: Can ankle assistance increase walking speed?

Background:

- Human-in-the-loop optimization (HILO) with ankle-exoskeletons successfully reduce metabolic energy cost[1]
- Preferred walking speed can be measured on a self-paced treadmill[2,3]

Our approach: Apply HILO to find ankle assistance torques that increase preferred walking speed

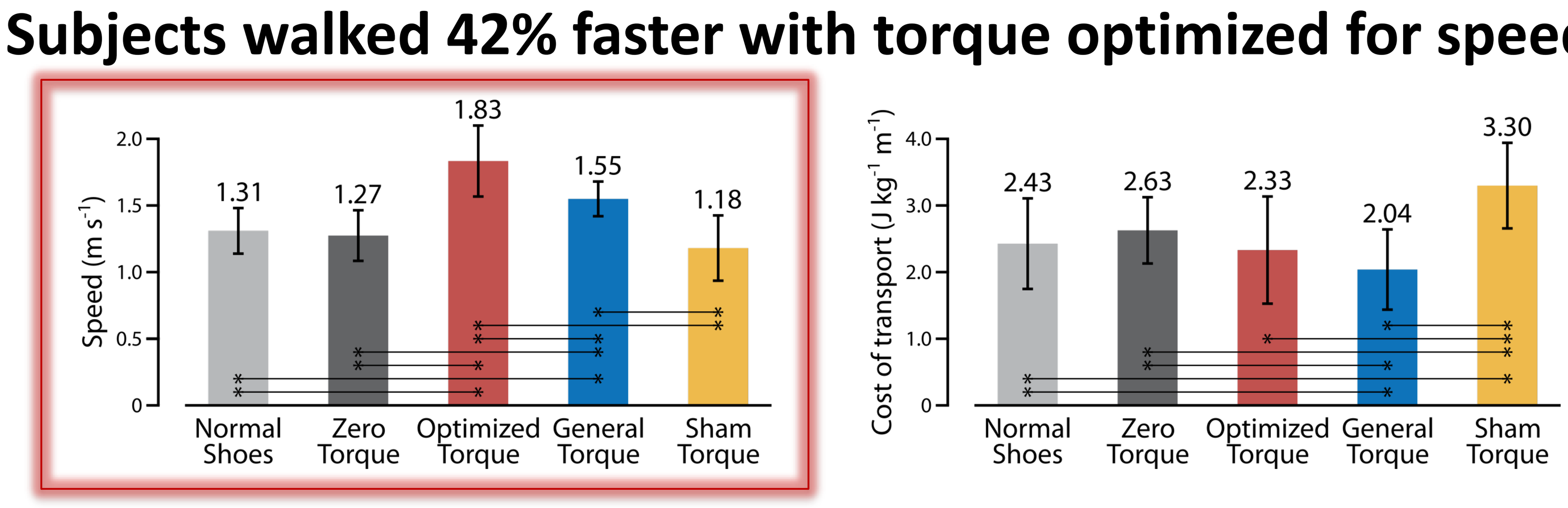


Day 0:
- Familiarization (30 min)

Day 1 & 2:
- Warm up (5 min)
- HILO (70 min)
- Validation (30 min)

Results (N=10)

Subjects walked 42% faster with torque optimized for speed!



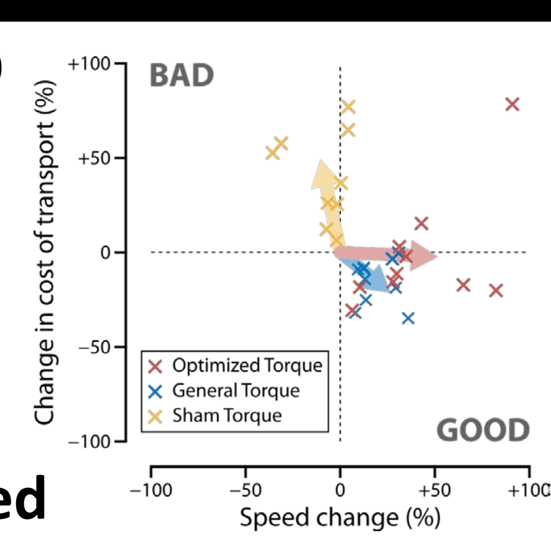
Future direction

Include expert and prior knowledge in HILO

Multi-objective HILO

- Metabolic COT
- Speed
- Stability[4]

Apply to older adults with low walking speed



Broader Impact

Quality of life in population with slow gait

- Older adults, post-stroke, etc.

Understanding human gait adaptation to assistive devices

Neuromechanical simulation to predict gait adaptation

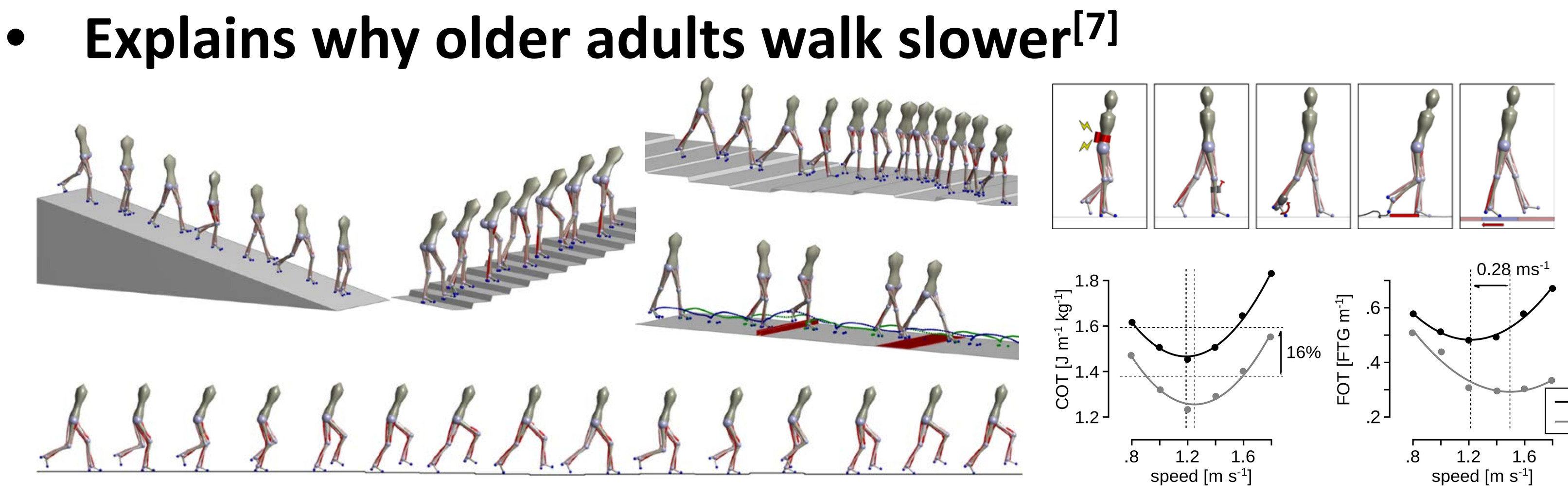
Goal: Model neuro-musculo-skeletal dynamics of locomotion & predict gait behavior in novel environment

Background: Testing exoskeleton assistance involves extensive human experiments (e.g. weeks of training for adaptation)

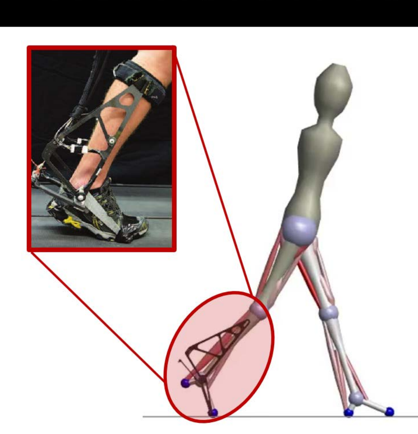
Our approach: Develop predictive simulation framework

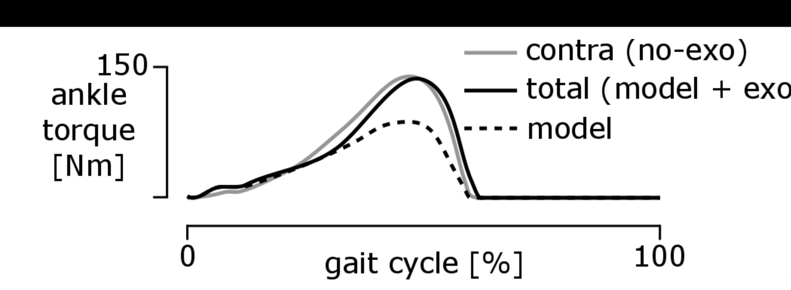
Our current neuromechanical model:

- Generates human-like diverse locomotion behaviors[5]
- Reacts to a range of perturbations similarly to humans[6]
- Explains why older adults walk slower[7]



Extension for ankle-exoskeleton assistance

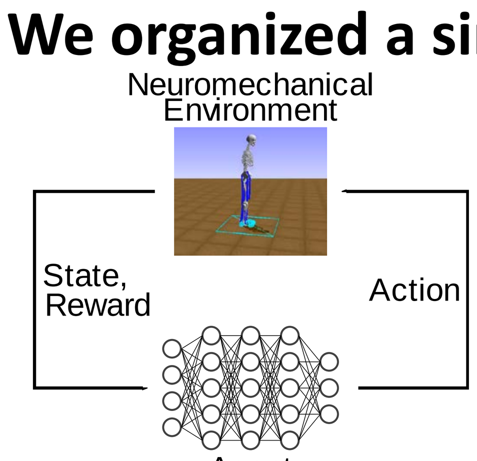




	human COT	model COT
Zhang et al.[1]	-24%	-14%
No ankle trq.	-	+42%

Learn to Move[8,9]: Reinforcement learning + neuromechanical simulation

We organized a simulation competition @ NeurIPS 2019



- Task: Control a 3D musculoskeletal human model to follow velocity commands with minimum effort
- **302** teams**: 1448** solution and **5** paper submissions
- Top **3** succeeded in following target velocities

Mission: Bridge **neuroscience**, **biomechanics**, **robotics**, and **machine learning**

Broader Impact

Simulation tool for developing optimal gait training and assistive devices

Educational platform for human biomechanics and reinforcement learning

[1] Zhang, Fiers, Witte, Jackson, Poggensee, Atkeson & Collins. Human-in-the-loop optimization of exoskeleton assistance during walking. *Science*. 2017.
[2] Song, Choi & Collins. Using force data to self-pace an instrumented treadmill and measure self-selected walking speed. *submitted*.
[3] https://github.com/smsong/self-paced-treadmill
[4] Kim, & Collins. Once-per-step control of ankle push-off work improves balance in a three-dimensional simulation of bipedal walking. *IEEE Transactions on Robotics*. 2017.
[5] Song & Geyer. A neural circuitry that emphasizes spinal feedback generates diverse behaviours of human locomotion. *The Journal of physiology*. 2015.
[6] Song & Geyer. Evaluation of a neuromechanical walking control model using disturbance experiments. *Frontiers in computational neuroscience*. 2017.
[7] Song & Geyer. Predictive neuromechanical simulations indicate why walking performance declines with ageing. *The Journal of physiology*. 2018.
[8] Song, Kidzinski, Peng, Ong, Hicks, Levine & Delp. Learn to Move: deep reinforcement learning in neuromechanical simulations. *in preparation*.
[9] https://www.aicrowd.com/challenges/neurips-2019-learn-to-move-walk-around

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