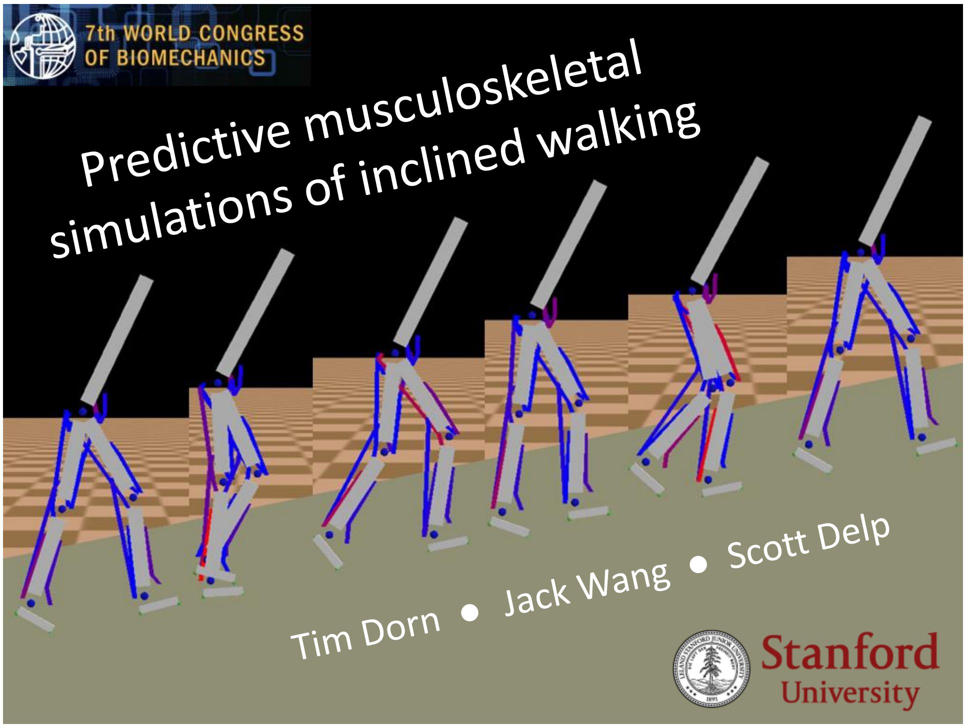
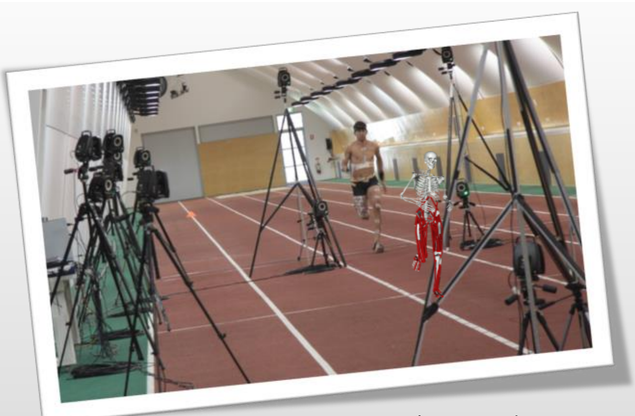




predict
new
motion?

Why predictive simulations?

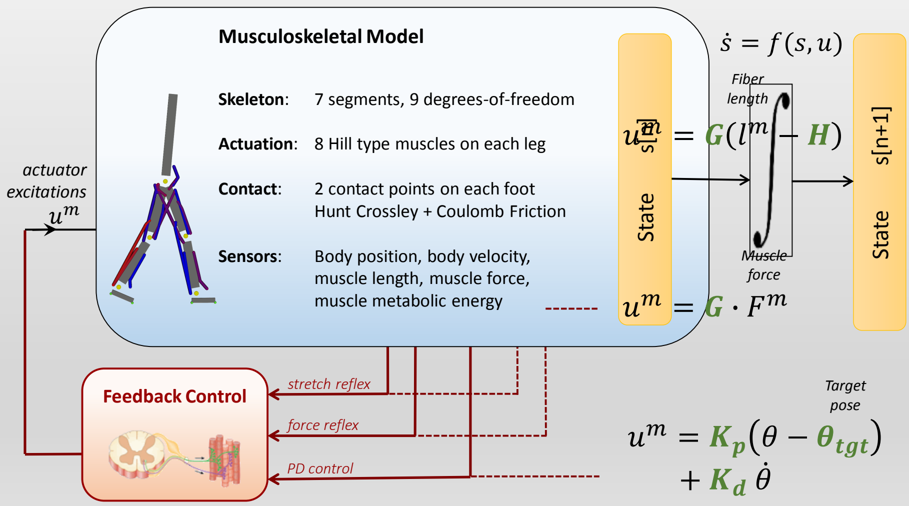
Predict the **human response** to

- wearing an assistive device
- gait after a muscle-tendon surgery

Aim: Synthesize human inclined walking without experimental data

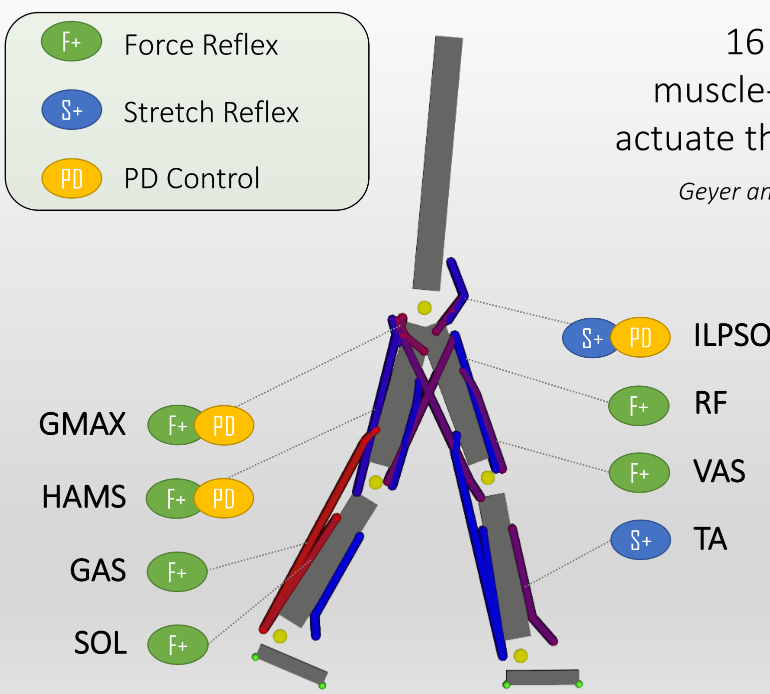
Strategy: Optimal control framework that predicts both motion and muscle recruitment

OpenSim



16 Hill-type muscle-tendons actuate the model

Geyer and Herr (2010)



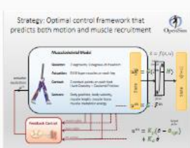
Objective Function to Minimize

$$w_{muscle} \int_0^{t_f} \left(\sum_{m=1}^{nMusc} MetabolicEnergy_m \right) dt$$

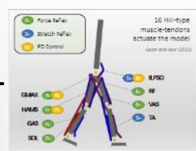
EFFORT TERMS (per stride)
Physiological cost of transport for muscles

$$+ \quad w_{task} \int_0^{t_f} \left(\sum_{i=1}^{nTask} RewardTerm_i \right)^2 dt$$

REWARD TERMS (per stride)
No falling
Target speed of 1.45 m/s
Reduce passive joint torques



+



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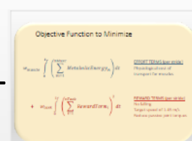


→ Optimization

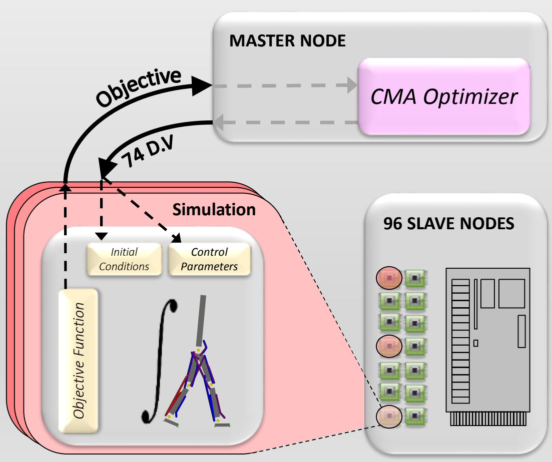
Model

21
initial
conditions

Controllers

53
control
parameters

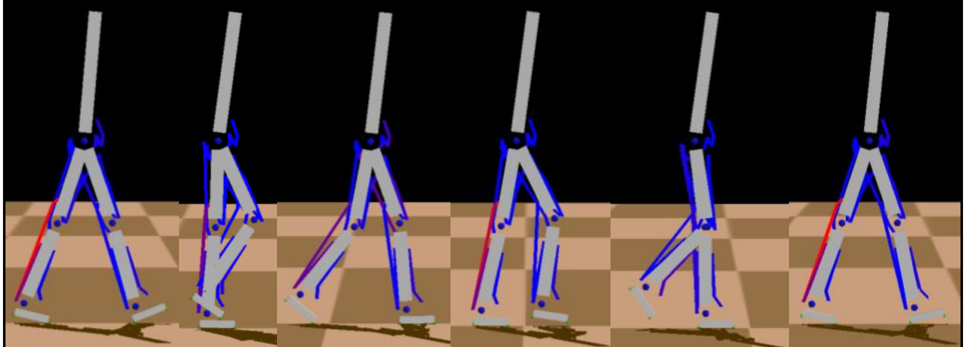
Objective



Covariance Matrix Adaptation

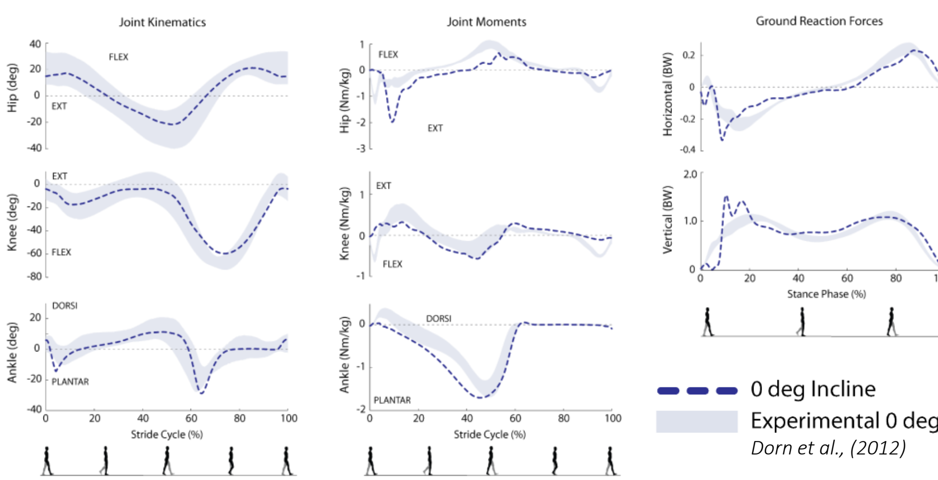
- Derivative free
- Stochastic sampling
- Escape local minima

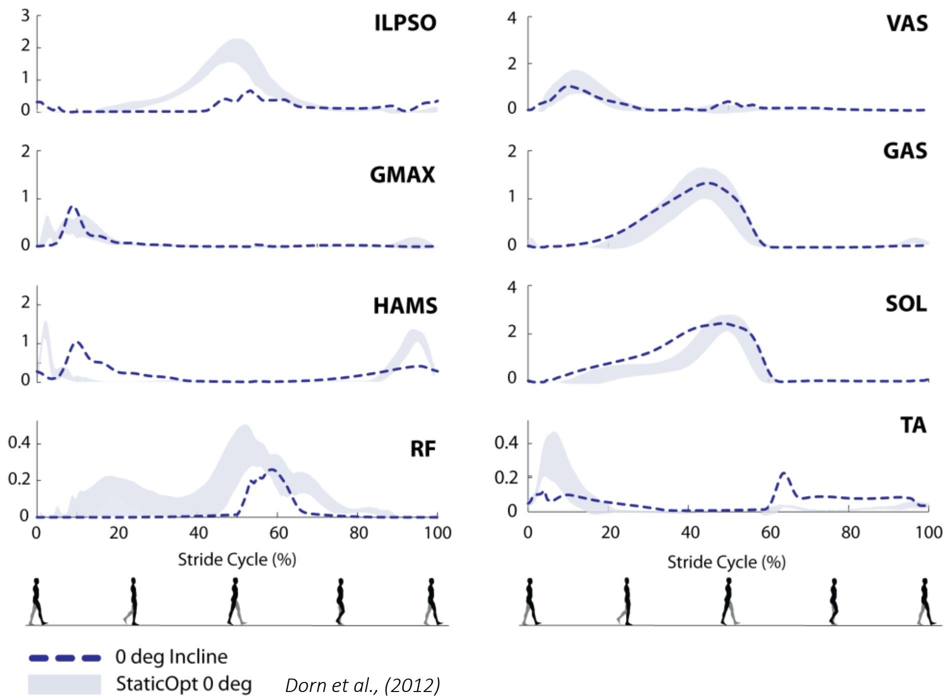
Normal Walking Simulation (1.45 m/s)

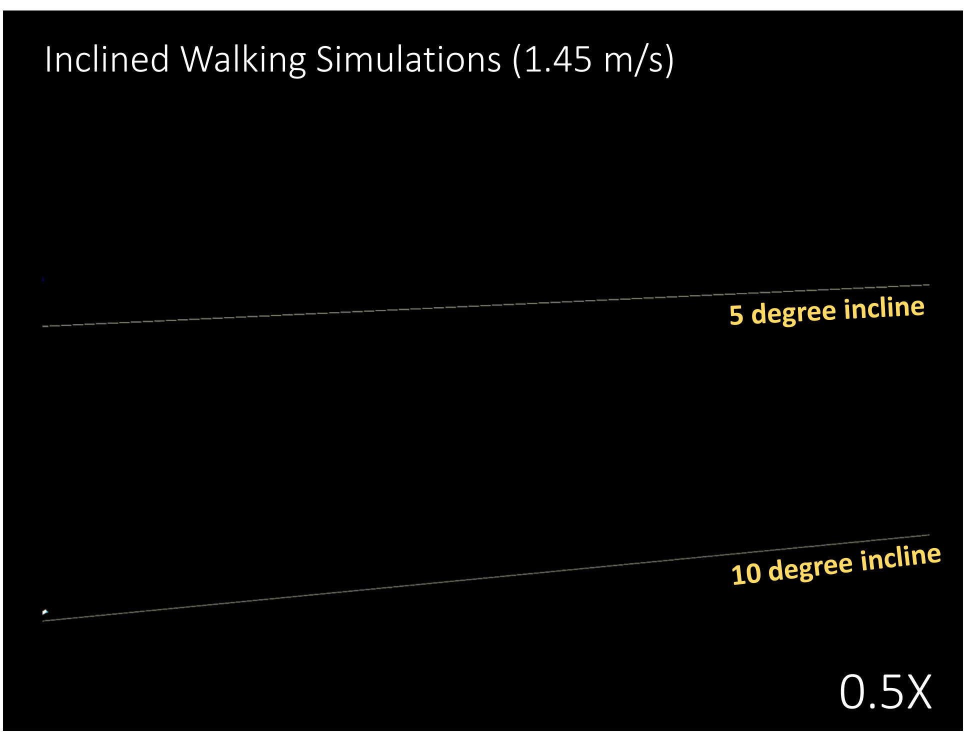


0.5X

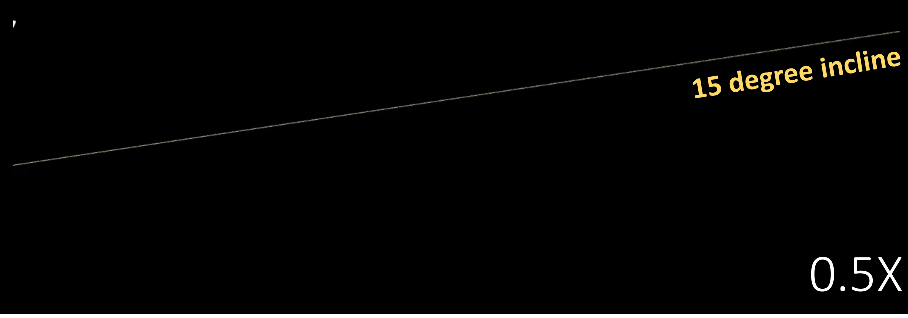
Normal Walking Simulation Mechanics (1.45 m/s)



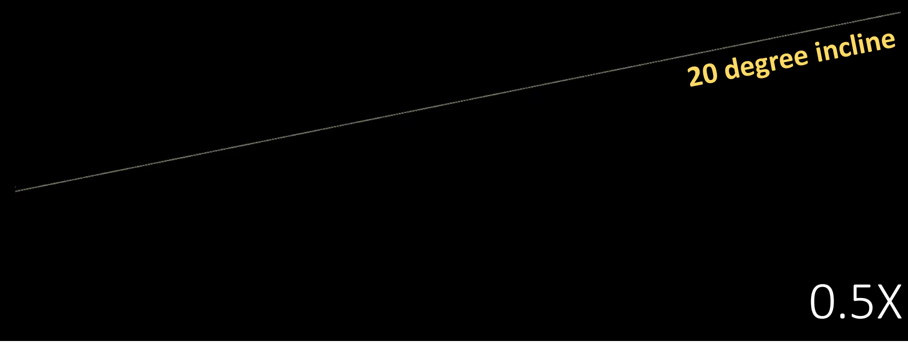

ILPSO
VAS
GMAX
GAS
HAMS
SOL
RF
TA
Stride Cycle (%)
Stride Cycle (%)
0 deg Incline
StaticOpt 0 deg
Dorn et al., (2012)

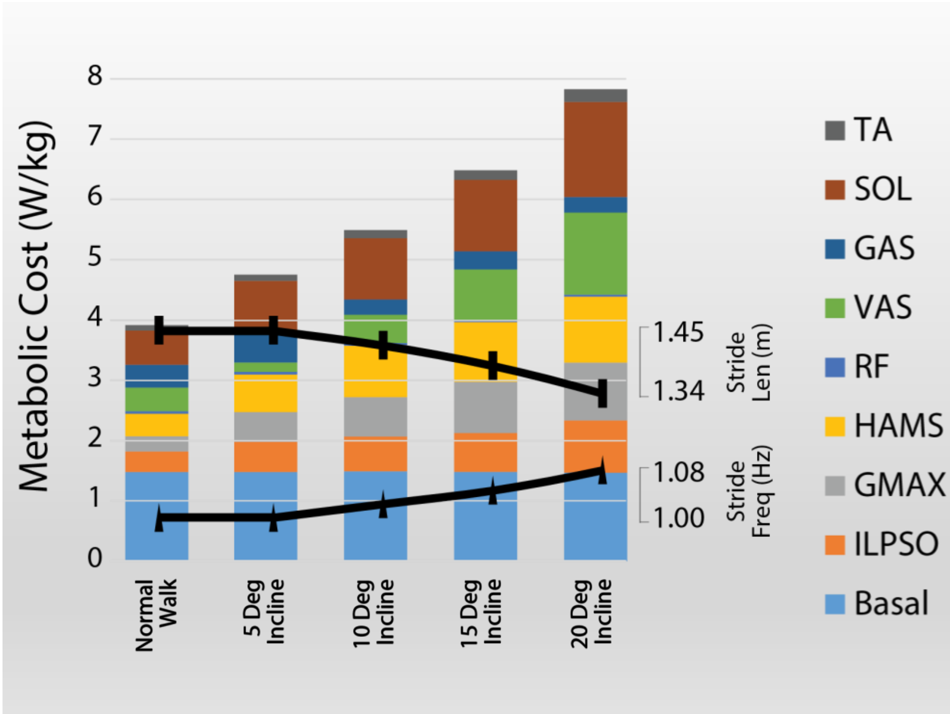

Inclined Walking Simulations (1.45 m/s)
5 degree incline
10 degree incline
0.5X

Inclined Walking Simulations (1.45 m/s)

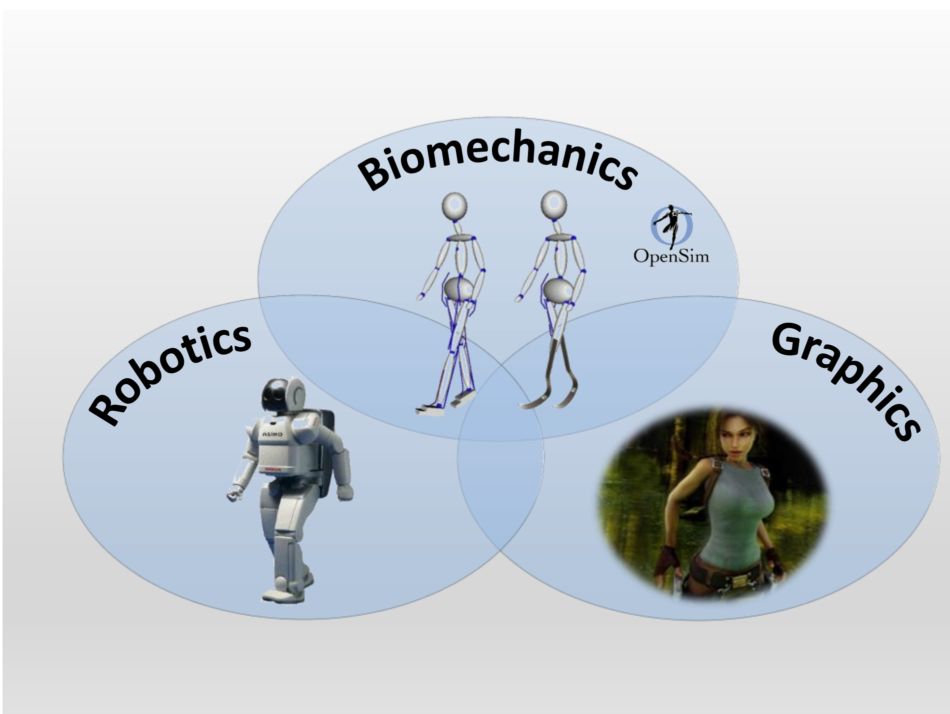


Inclined Walking Simulations (1.45 m/s)





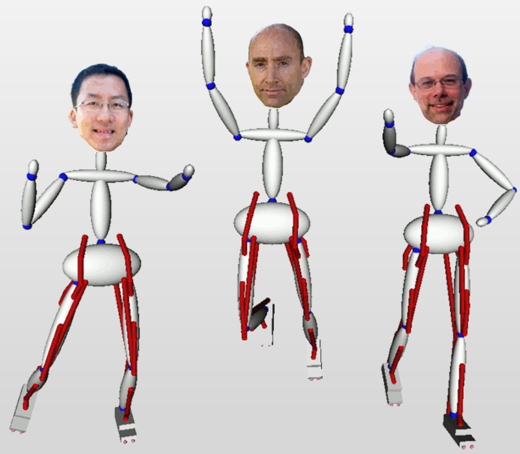
Metabolic Cost (W/kg)
8
7
6
5
4
3
2
1
0
Normal Walk
5 Deg Incline
10 Deg Incline
15 Deg Incline
20 Deg Incline
1.45
1.34
Stride Len (m)
1.08
1.00
Stride Freq (Hz)
TA
SOL
GAS
VAS
RF
HAMS
GMAX
ILPSO
Basal



Biomechanics
OpenSim
Robotics
Graphics

Acknowledgements

- Neuromuscular Biomechanics Lab
- OpenSim Development Team
- Simbios Postdoctoral Fellowship Funding
- DARPA Warrior Web Funding



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