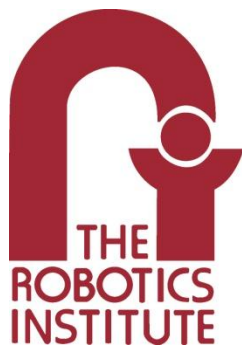


Regulating Speed and Generating Large Speed Transitions in a Neuromuscular Human Walking Model

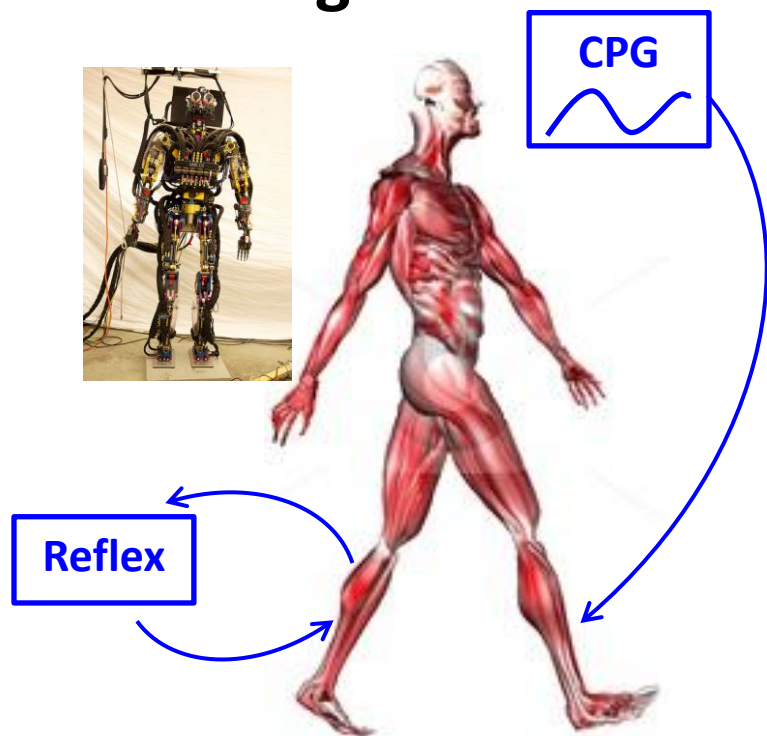


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W911NR-11-1-0098

Local Reflex Control Has a Large Potential for Controlling Robotic Legs



Humanoid vs Human Control



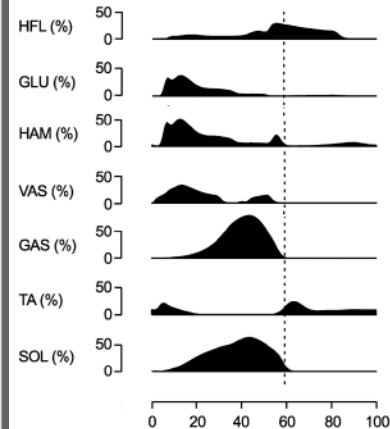
Local Reflex Control

Humanoid: HONDA (ASIMO), Boston Dynamics (PETMAN)

CPG + reflex: Taga et al. (1991), Ogihara et al. (2001)

Robotic ankle: iWalk BiOM

Our Reflex Based Neuromuscular Walking Model

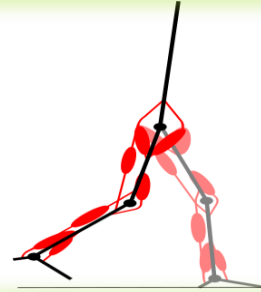


Current Limitations

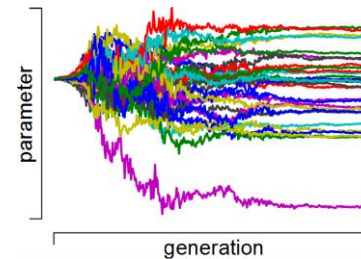
- Confined to the sagittal plane
- Only walks at a single speed

Walking Speed Adaptation of the Human Model

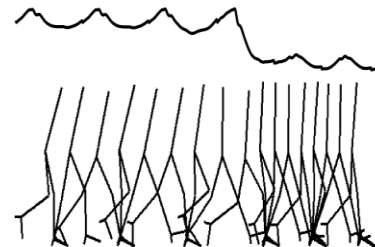
1. Neuromuscular Model

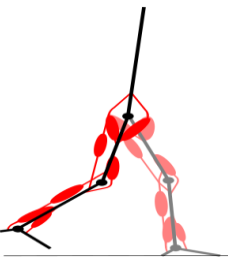


2. Optimization



3. Speed Adaptation





Control Groups and Underlying Principles

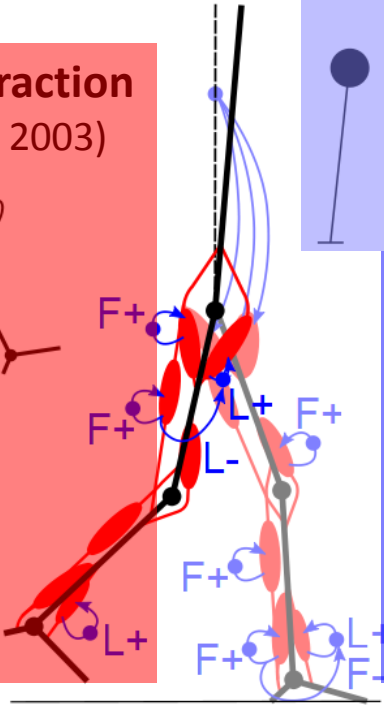
Swing-leg retraction
(Seyfarth et al., 2003)

Swing-leg Initiation
(Mochon et al., 1980)

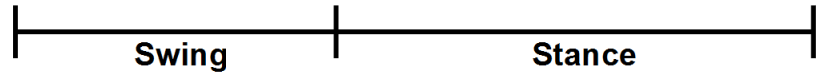
PD trunk control
(Gunther et al., 2003)

Knee stability
(Seyfarth et al., 2001)

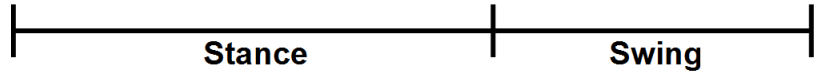
Spring mass model & F+
(Geyer et al, 2003 and 2006)



Left leg cycle



Right leg cycle

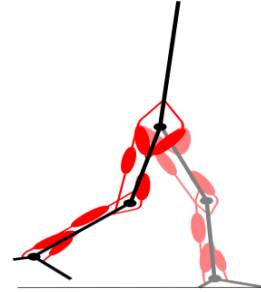


Right leg control

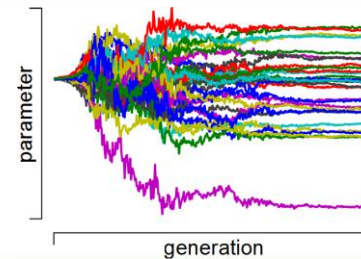


Walking Speed Adaptation of the Human Model

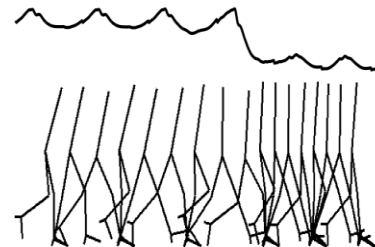
1. Neuromuscular Model

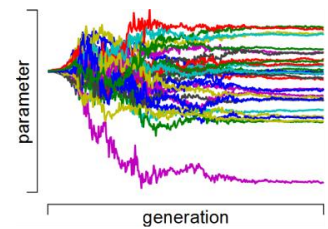


2. Optimization



3. Speed Adaptation

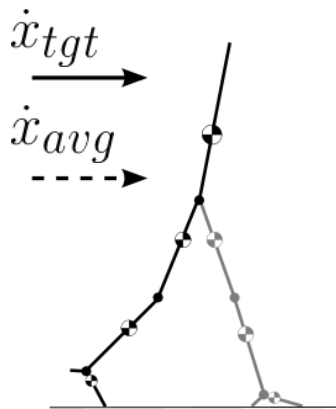




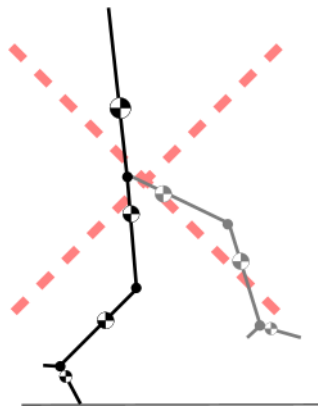
The Cost Function Includes Walking Speed, Energetic Cost, and Pain

$$J = \left| \dot{x}_{avg} - \dot{x}_{tgt} \right| + C_E + P$$

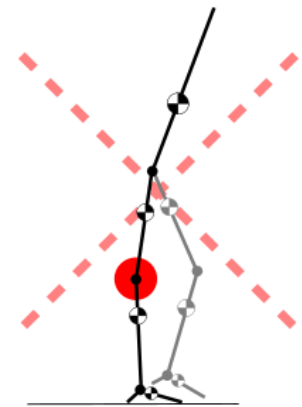
Target speed



Energy cost

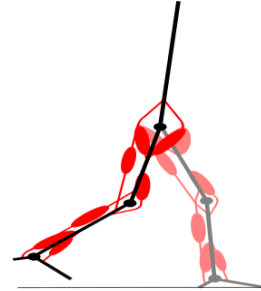


Pain

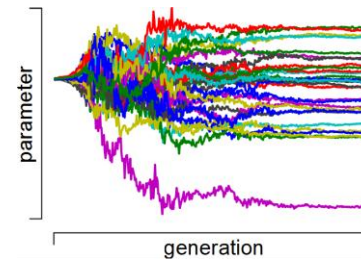


Walking Speed Adaptation of the Human Model

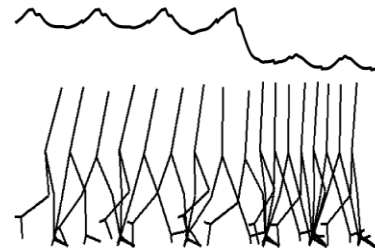
1. Neuromuscular Model



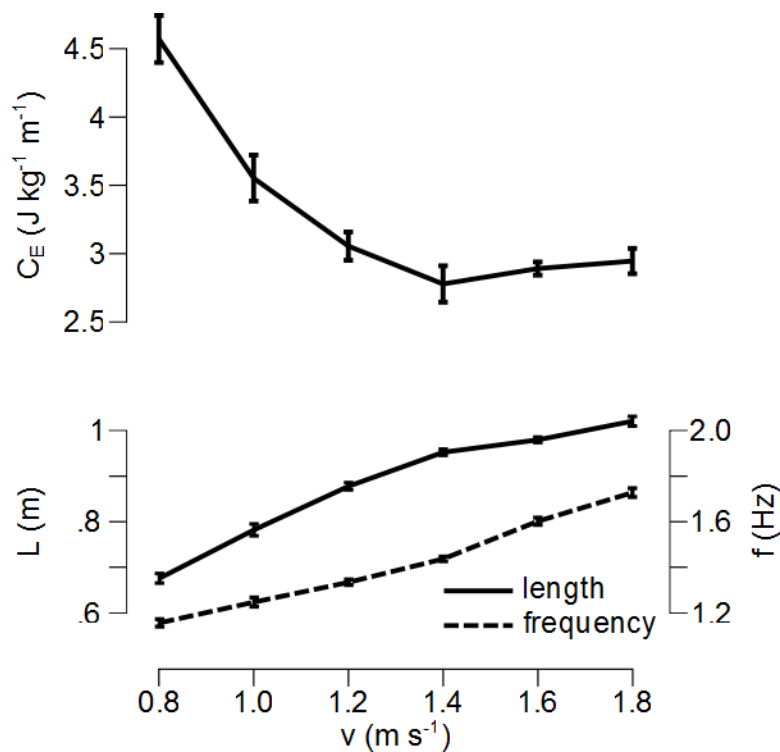
2. Optimization



3. Speed Adaptation



Optimization Results for Steady Walking Matches Human Data



0.8 ms^{-1}



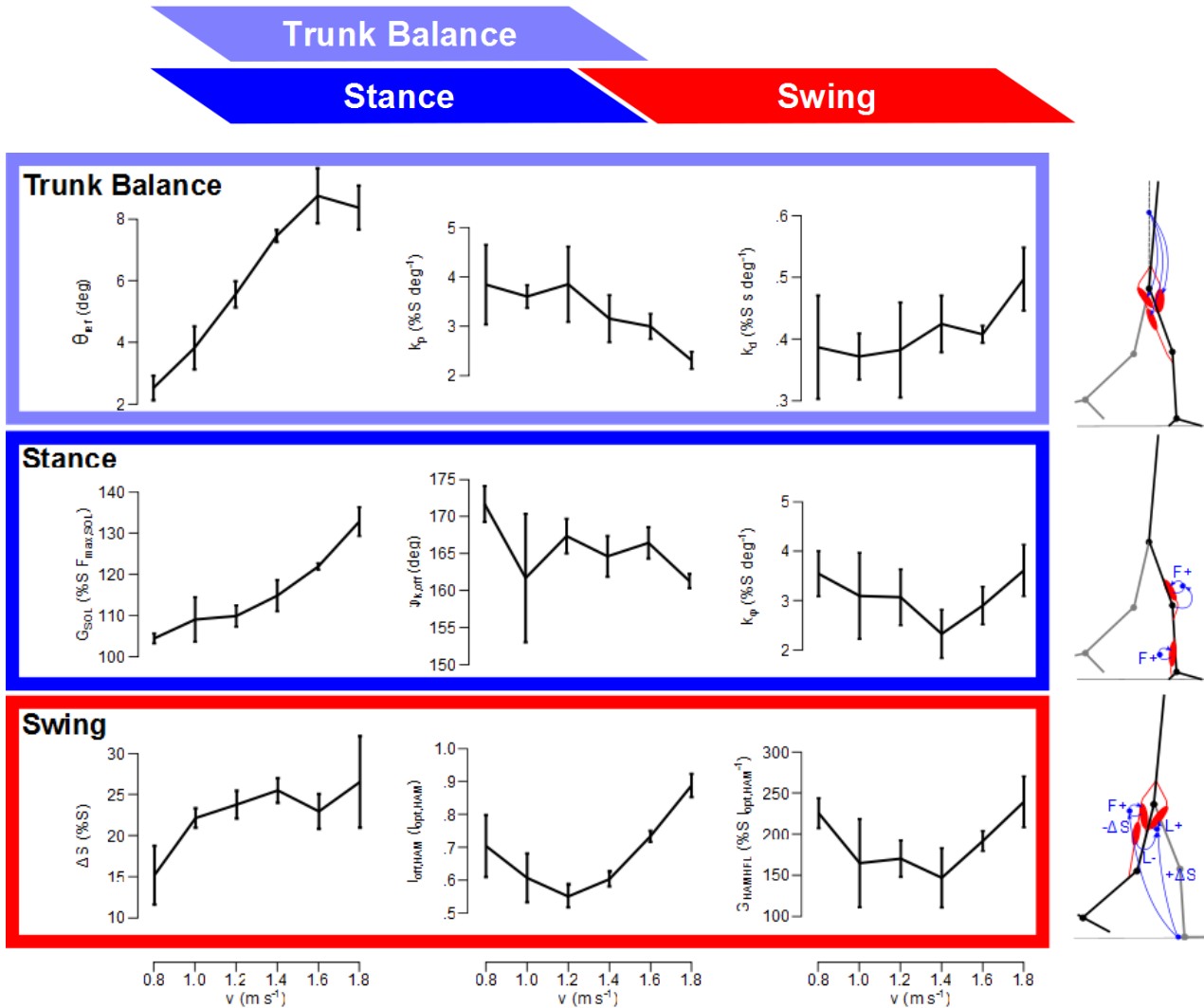
1.4 ms^{-1}

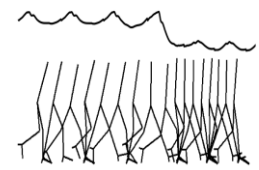


1.8 ms^{-1}



Nine Control Parameters Show Strong Trend



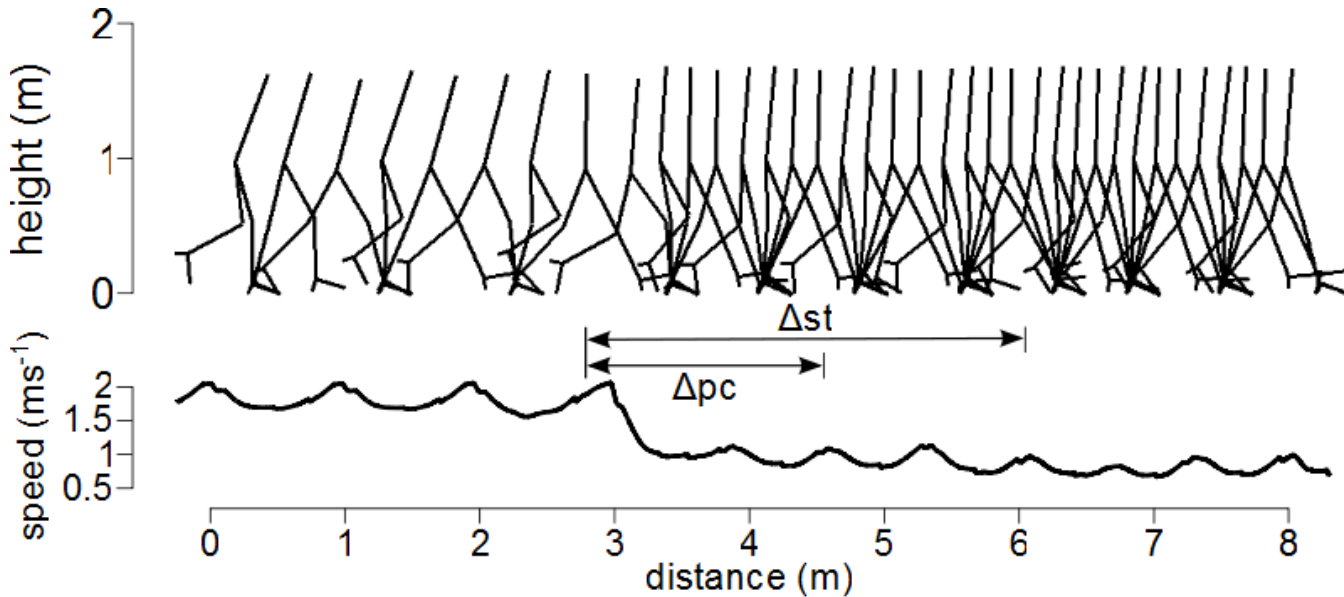


Generation of Speed Transition: Switch Between Steady Speed Walking Controls

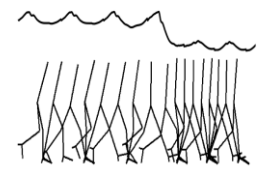


**Works for small speed transitions.
Fails for large speed transitions!**

Generation of Speed Transition: Explicit Transition Phase Control



$$J = \left| \dot{x}_{avg} - \dot{x}_{tgt} \right| + P_{\Delta st} + C_{E, \Delta st} + \underline{n_{step, \Delta st} + n_{step, \Delta pc}}$$



Successful Generation of Speed Transition: Explicit Transition Phase Control



Conclusion

We extended a local reflex based walking control to regulate walking speed and generate large speed transitions between 0.8ms^{-1} and 1.8ms^{-1}



An explicit transition control was required to generate large speed transitions

To walk faster the model ...

- leans forward
- makes stronger ankle push-off
- makes larger swing initiation