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Can split-belt treadmill walking be explained with a reflex-based model?

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Abstract:
Gait adaptation on split-belt treadmills provides insights on the underlying control structure for walking. For example, observations on infants and adults walking on split-belt treadmills with various speed configurations have led to a consensus that the locomotion controller consists of separate functional networks for each leg and for different locomotion modes (e.g., forward vs. backward walking). However, most of the interpretations of these experiments are based on an assumption that the spinal motor circuits are governed by central pattern generators (CPGs). Here, we investigate the possibility that humans adapt their gait without CPGs. In other words, we evaluated the extent to which human gait adaptation on split-belt treadmills moving the legs at different speeds can be reproduced in simulation by a spinal-reflex-based neuromechanical model, which consists of a network of spinal reflexes mediated by supraspinal control without CPGs. Our results show that the reflex-based neuromechanical model can successfully generate stable split-belt walking with one leg moving at 1.5 m/s and the other one at 0.5 m/s. Moreover, our preliminary results show that, when the reflex control parameters are optimized for minimum metabolic consumption, the model reproduces most of the stepping features observed in human split-belt treadmill walking. Specifically, we performed a one-sample t-test to find significant differences between the gait features of nine healthy subjects and those produced by our model and found that both the subjects and the model converged to the same step-position ($p=0.25$), step-time ($p=0.010$) and step-velocity ($p=0.056$). Interestingly, we found differences in the step length asymmetry reached by the simulation and the experimental results ($p<0.001$), suggesting that metabolic consumption may not be the only factor optimized in humans. We are currently investigating the effect of optimizing for different costs, including metabolic energy, muscle fatigue, and gait asymmetry, to explore the physiological basis of human gait adaptations upon sustained changes in the walking environment imposed by the split-belt treadmill. Once we identify the cost function driving locomotor

learning, we will further investigate the contributions of individual reflex pathways in the gait adaptation of the model. The findings will allow us to augment gait rehabilitation with devices such as the split-belt treadmill.
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