Compliant legged behavior of walking could be achieved by feedback control that shares springy oscillatory characteristics

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1 Introduction

Compliant legged walking model could demonstrate dynamics of human walking [1-2]. Many attempts to build controllers to achieve springy walking dynamics, or joint controls of running [3] showed time-varying non-linear characteristics of feedback gain without explicit link to compliant legged behaviors of human walking and running. In this study, with the constraint of the compliant legged behavior of the center of mass (CoM) of multi-segmental rigid pendulum, we examined whether the relationship between the joint torques and the joint kinematics could be formulated as a function of springy pendulum model parameters.

2 Method

We obtained the relationship between joint torques and the joint kinematics that could achieve CoM dynamics of human walking, which could be well represented by the compliant legged walking model. The equations of motion of three-segment pendulum were constrained to result in springy pendulum CoM motion. Then the equations of motion were rearranged to formulate the joint torques in terms of joint angles with small angle approximation, weak coupling assumption, and negligible torso dynamics assumption. Coefficients of joint angle were defined as a state feedback gain of joint torques, and were implemented to a feedback control simulation of human walking.

3 Result

The coefficients of joint kinematics of three-segment pendulum that generates springy CoM motion were obtained as a function of natural frequency of the springy pendulum as follows,

$$[T_{ank} \quad T_{knee} \quad T_{hip}]^T = K[\theta_{sh} \quad \theta_{th}]^T$$

$$, \textit{where} \quad K = [M_1]\frac{g}{2} + [M_2]\frac{(0.05\omega_n^{\ 2} - g)}{2} \cdot \cos(\omega_n t)$$

$$\therefore \quad T = \mathbf{K}(\omega_n^2 \quad \omega_n t) \cdot \mathbf{\Theta}$$

, where M_1, M_1 are mass matrixes that composed by body parameters, g and ω_h were gravitational acceleration and natural frequency of springy pendulum, respectively. Time varying proportional feedback gain as a function of natural frequency of the springy pendulum could well approximate the CoM dynamics of human walking (Fig. 1B and C). Time constant and the magnitude of feedback gain was proportional to the ω_h (Fig. 1D), as well as the walking speed.

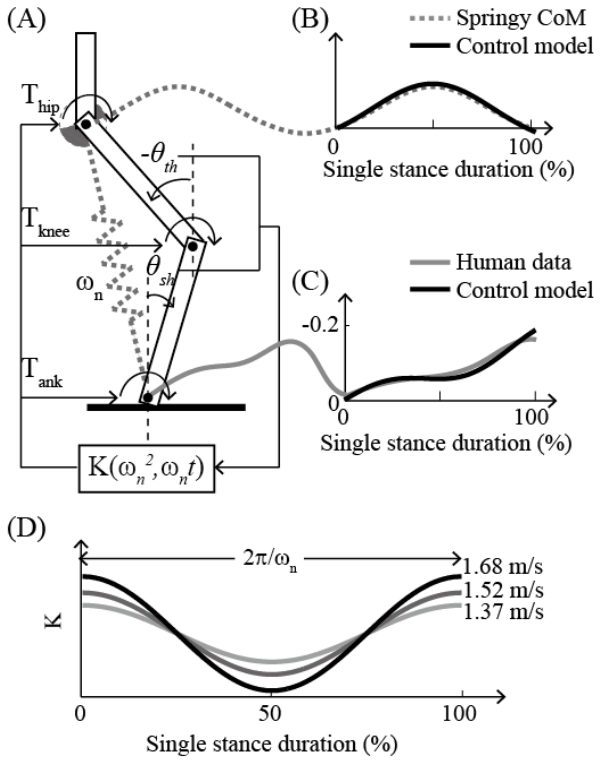

Figure 1: (A) Schematic of the compliant legged walking model and a 3-segmental rigid pendulum model with joint feedback control (B) the CoM motions of springy (dotted line) and rigid pendulums with feedback control (solid) (D) Feedback gain *K* at various walking speeds.

4 Conclusion

The results imply that the spring legged behavior of human walking could be achieved by proportional feedback control that also shares springy oscillatory characteristics.

References

[1] Geyer, et. al. "Compliant leg behaviour explains basic dynamics of walking and running," Proc Biol Sci, 2006.
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[3] Mombaur "A study on optimal compliance in running," Dynamic Walking, 2014.