Haptic interaction models for learning stable locomotion

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General description. The present document is preliminary summary of the idea of human-in-the-loop haptic modelling of locomotion. The proposed approach is based on using human motor control skills to learn and stabilise virtual walking model. We propose to use a force feedback interface to provide mechanical inputs (forces) online to computer modelled locomotion. To model human locomotion we consider the spring-loaded inverted pendulum (SLIP) model as a basic approach to simulate dynamic walking behaviour [1], however, other models can be considered in future. For instance, the spring in SLIP model can be replaced by Hill-based muscle model [2].

A general view of human-SLIP model haptic interaction system is shown in Fig. 1. A human-subject manually interacts with 1-DOF force feedback device (i.e., Hi5 interface [3]) by wrist flexion/extension movements. The interface is equipped with a DC motor, force/torque sensor and angular displacement encoder. The movements of the wrist control the virtual SLIP model which is composed of point mass attached to a spring and placed in the gravitational field in the simplest case.

Interaction models. Here we present some of the possible ways for interaction interfaces between the human-subject wrist and the virtual SLIP model in the following scenarios: one-leg hopping, two-leg hopping and walking.

One-leg hopping. In this scenario (Fig. 2A) the task will be to maintain stable hopping (with desired magnitude/periodicity) by controlling the force, applied to a model's mass. Angular displacement of the wrist is sent to the SLIP model as a force, while the interaction forces of the mass with the spring and ground are sent back to the haptic device as force feedback.

Two-leg hopping. In this case, two force feedback devices control two-leg hopping model (Fig. 2C). The input devices will independently provide forces to masses in the model. The task of a human-subject will be to maintain stable hopping with selected magnitude and periodicity.

Walking. In walking scenario the task of a human-subject will be to maintain stable walking by providing control inputs to virtual dynamic walking model (Fig. 2B). In the case of SLIP model, the control input can be the force applied to the mass along the spring (or active force of the contractile element if Hill's model is used instead of the spring). In case if torso added to the SLIP model, force input from the haptic device can be transmitted as a torque applied to the leg from the torso. This scenario may require usage of two 1-DoF or one 2-DoF haptic interface(s).

References

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[3] A. Melendez-Calderon, L. Bagutti, B. Pedrono, and E. Burdet. Hi5: A versatile dual-wrist device to study human-human interaction and bimanual control. In *2011 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pages 2578–2583. IEEE, Sept. 2011.

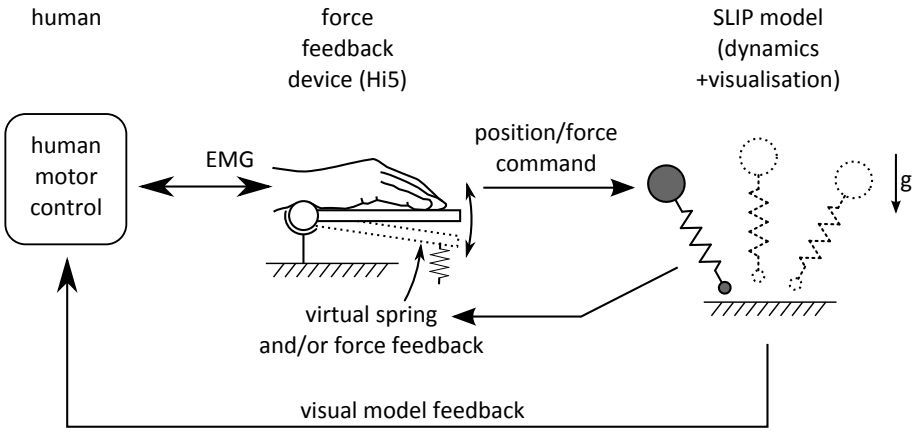

Figure 1: Schematic diagram of the experimental setup for human-SLIP model interaction study.

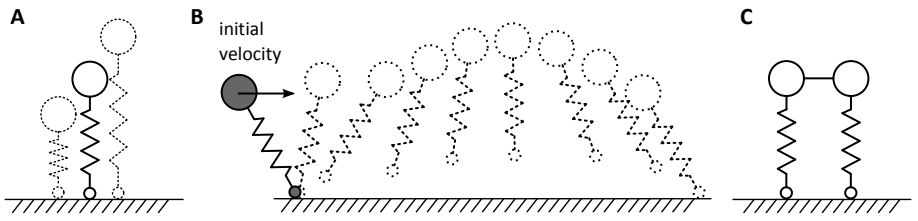

Figure 2: Haptic interaction scenarios for virtual dynamic models.