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Synthesis of two-dimensional human walking: a test of the λ-model. (English) Zbl 1084.92004

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Summary: To test the λ-model version of the equilibrium point hypothesis both for feasibility and validity with respect to the control of terrestrial locomotion, we developed a two-dimensional, eleven-segment musculoskeletal model of the human body including 14 muscle-tendon complexes per leg, three-segment feet, and a physiologically based model of foot-ground interaction. Human walking was synthesized by numerical integration of the coupled muscle-tendon and rigid body dynamics. To this end a control algorithm based on the λ-model was implemented in the model providing muscle stimulation patterns that guaranteed dynamically stable walking including a balanced trunk. Thus, the timing of the movement is not preset by a central pattern generator but emerges from the interaction of the musculoskeletal system with the control algorithm.

The control parameters were found in a trial-and-error approach. The feedforward part of the control scheme consists of just two target configurations each of which is composed of a set of one nominal length per muscle (λ-model). Variation of gravity reveals that (1) the synthesized walking patterns are close to ballistic walking and (2) this muscularly induced natural walking can only be initiated and maintained in the range between about a tenth and three times earth-bound gravity. Our walking patterns are robust both against parameter variations and shuffling of the swing leg. We discuss our model with respect to gravity scaling, speed control, feedback delay, and the terms "equilibrium point hypothesis" and "central pattern generator."

MSC:

92C10 Biomechanics
93C95 Application models in control theory

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