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Presentation Abstract

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Title:	Determining the contribution of the ankle and hip joint to human balance control using system identification techniques
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Abstract:

During human upright stance, the ankle joints create the most stabilizing torque for slow perturbations. When movements become larger and the perturbations faster, the hip joints also become involved in stabilizing the body. In this situation the body can be modelled as a double inverted pendulum.
To investigate the behaviour of this model, a three-segment (i.e., feet, leg and HAT) model of human balance, incorporating the ankle and hip joints and a stabilizing mechanism, was developed. This mechanism was determined using system identification. In order to identify the stabilizing mechanism of a two Degree-of-Freedom (DoF) model, the system needs to be perturbed, with two independent perturbations. Therefore, we have extended a previously used non-parametric closed-loop system identification method (Van Asseldonk, 2006) from one DoF (ankles) to two DoFs (ankle and hip joints). Specifically, we have adopted a method proposed by Schoukens and Pintelon, which states that an optimal choice of perturbation, using a periodic excitation, are two signals with the same frequency content and spectrum.
Simulations of this model were performed in Matlab to test the identification method. Subsequently, balance control experiments with humans were performed to show the feasibility of this approach and to determine the balance contribution of the ankle and hip joints. Two perturbations were applied: 1) with a motion platform and 2) a torque motor attached to the participant. Reactive torques and forces and body movements were measured. Trials lasted 3 min, in which the signal was repeated five times; each trial was repeated twice. Frequency response functions (FRFs) of the stabilizing mechanisms were calculated.
Simulations showed that it is possible to reliably identify the FRF of a two DoF balance control model using a MIMO identification method.
Experimental results showed an increased contribution of the hip above 1Hz, while the contribution of the ankle decreased above 1Hz.
Interaction between the joints (FRF Ankle angle to Hip Torque)

remained constant, whereas the gain from the FRF ankle torque to sway angle increased with increasing frequency.
In sum, we have shown that it is possible to give a) a reliable estimate of the stabilizing mechanisms underlying multi-segmental balance control as shown by model simulations using a MIMO identification method; b) this method is feasible in human subjects and c) non-parametric frequency response functions (FRF) can be reliably estimated in human subjects. In addition, ankle and hip torque are not only directly dependent on ankle and hip angle, but also influence the other joint, suggesting the existence of heterogeneous reflexes.

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system identification

ankle and hip strategy

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