[75] Simulating the dynamics of a human-exoskeleton system using kinematic data with misalignment between the human and exoskeleton joints

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Abstract:

Musculoskeletal model-based simulation can be a powerful tool in the design and evaluation of exoskeletons [1]. They are used extensively during the virtual prototyping stage using motion data of the human without the exoskeleton. An ideal exoskeleton model, perfectly aligned with the human joint axes, can be used to co-simulate the human and exoskeleton dynamics. However, misalignment between the human and exoskeleton joints is commonly observed during the use of an exoskeleton, potentially leading to a loss in the effective assistance received by the user [2]. Motion data collected with the user wearing the exoskeleton should, normally, be able to capture the misalignment between the human and exoskeleton joints. Using misaligned motion data in the combined human-exoskeleton model can lead to complications in the virtual model and unrealistic outputs. One way to tackle these complications is to assume alignment between the human and exoskeleton joints in the model by kinematically constraining it.

This work presents a new method that facilitates the analysis of misaligned human-exoskeleton systems. This is achieved by introducing artificial segments between the human and exoskeleton models. These artificial segments, the so-called dummy segments, ensure kinetic alignment between the human and exoskeleton joints in the model without altering the observed kinematics from the actual trial. The method is demonstrated using an active lower-limb exoskeleton that aims to assist the elderly in stair negotiation. A single subject performed eight trials with the exoskeleton in a laboratory. Motion data of both the subject and exoskeleton were recorded using an optical marker-based motion capture system. Further, the measured ground reaction force and the exoskeleton assistive force were used as inputs in the combined human-exoskeleton model. The outputs from the inverse dynamics analysis of the model with the dummy segments were compared to those from a reference model, where the measured external forces were applied directly to the human model at the corresponding reference points, bypassing the human-exoskeleton interface model completely. The results of the knee compression force, knee flexion moment, and activation of vastus lateralis from the model with the dummy segments showed good agreement with the reference model. The use of the dummy segments allows the study of aligned kinetics and misaligned kinematics from the same model.

References:

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