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SKELETAL MULTIBODY MODEL FOR LEG-ORTHOSIS CONTACT FORCE ESTIMATION IN SCI SUBJECTS

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ABSTRACT

The purpose of this work is to propose a multibody model and analysis method which provide an estimation of the leg-orthosis contact forces appearing during the assisted gait of a spinal cord injured (SCI) subject. Moreover, the calibration and validation of the model is addressed too. This topic is relevant, as excessive contact forces may lead to skin wounds and loss of adherence to the use of the orthotic device by the subject, with the corresponding reduction of physical activity and the subsequent negative impact in his general health state. Having the possibility of getting an estimation of the contact forces from a simple motion/force capture allows to select the most suitable orthotic device or to customize it for a specific patient.

Most current motion capture systems do not provide sufficient accuracy to discriminate the motion of leg and orthosis, which prevents the application of inverse-dynamics based analysis to the multibody model of human and device, animated both with the captured motion. In the proposed procedure, a model is built in which the human and the orthotic device are indeed considered as independent entities but, while the human model is animated with the captured motion, the orthotic device is left to its own dynamics. Two options are explored: (i) a forward-dynamics based analysis of both the human and the orthosis, where the captured human motion is tracked by a controller; (ii) a forward-dynamics based analysis of the orthosis only, where the captured human motion is simply prescribed. Model calibration is addressed in two ways. On the one hand, tests are performed on the orthosis to characterize the motor and the foot-drop support and, on the other hand, tests are carried out with a unilateral patient wearing the orthosis, which includes a load cell just above the knee joint, to adjust the parameters of the contact elements modeling the straps and other connecting parts. The calibrated model is validated in additional tests with the patient.

The estimated contact forces are compared when the patient uses the orthosis in two different modes: (i) locked knee, which emulates a conventional passive device; (ii) active knee, for which a sensor detects swing intention and the motor launches a knee flexion-extension cycle as in normal gait. Conclusions are drawn based on the obtained comparison results.