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Gait analysis of incomplete spinal cord injured subjects walking with an active orthosis and crutches

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ABSTRACT

The analysis of powered assisted gait is an open field of research in the biomechanics community. In the last years, a number of active orthoses and exoskeletons aimed at assisting human gait have been developed [1]. The objective of this work is to present results of the kinematic and dynamic analysis of the gait of incomplete spinal cord injured (SCI) subjects using crutches and the active orthosis presented in [2]. The target SCI patients are able to control hip flexor muscles and are classified with levels C or D in the ASIA impairment scale. The mentioned orthosis (stance-control knee-ankle foot orthosis, SCKAFO) has a compliant joint that constrains ankle plantar flexion and a powered knee unit with two systems: a mechanical locking system that is active during the stance phase and a conventional motor-gearbox group that assists the knee rotation during swing [2]. The developed controller uses the information of on-off plantar sensors, ankle encoders and inertial gyroscopes placed at the thighs to control the two systems installed at the knee.

The gait of an incomplete SCI subject using elbow crutches and the two orthoses is captured in the lab by twelve infrared cameras that detect passive markers attached to the subject's body and crutches. Foot-ground contact wrenches are measured using two force plates and crutch-ground contact forces are estimated through extensometry using three Wheatstone bridges on the crutch. A 3D whole-body model has been developed using a multibody dynamics formulation to solve the inverse dynamics problem. The two orthoses and the two crutches are assumed to be rigidly attached to body segments. The model incorporates the subject's body segment parameters (BSP), as well as the orthoses and crutches geometric and inertial parameters. The control algorithm is also modelled in order to determine the motor assistance torque at the knee at each time step.

From the motion capture data, the BSP and the ground reaction forces, the net joint torques are calculated following an inverse dynamics procedure. In order to validate the results, two approaches are used. First, the global ground reactions, which can be determined from kinematic information only, will be compared to those obtained from the force plate and extensometry measurements. Secondly, the experimental measurement of the knee assistance torque during swing will be compared to that obtained through the model. The development of this tool is aimed at analysing the motion and efforts of a specific patient to design a customized orthosis controller for his gait pattern, to evaluate the effect of different control strategies of the orthosis, to study the adaptation of the patient to the assistive device with training and to advance in the understanding of the interaction between the musculoskeletal system and the orthosis. It is expected that this will contribute to improve the design of such devices.

REFERENCES

[1] A.M. Dollar and H. Herr, "Lower extremity exoskeletons and active orthoses: challenges and state-of-the-art", *IEEE Transactions on Robotics*, **24**(1), 1-15 (2008).

[2] J.M. Font-Llagunes, R. Pàmies-Vilà, J. Alonso and U. Lugrís, "Simulation and design of an active orthosis for an incomplete spinal cord injured subject", *Proc. IUTAM*, **2**, 68-81 (2011).