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On the use of multibody dynamics techniques for the inverse and forward dynamic analysis of human gait

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ABSTRACT

The dynamics of human gait can be studied from two different perspectives depending on the aim of the study. The inverse dynamic analysis (IDA) is used to calculate the ground reaction forces and net joint torques that the musculoskeletal system produces during human locomotion [1]. On the other hand, the forward dynamic analysis (FDA) is used to predict the body motion from known muscle forces (or net joint torques) [2]. This work presents a dynamic study of human motion by means of multibody dynamics techniques using a 3D whole-body model that consists of 18 segments with 57 degrees of freedom. Both, IDA and FDA are applied.

The gait of the subject is recorded in the laboratory using a motion capture system that provides the position along time of 37 markers attached to the body of the subject. Foot-ground contact forces are also measured by means of force plates. Position data are filtered and properly processed in order to obtain the kinematic consistent position histories and the corresponding velocity and acceleration values. Multibody dynamics techniques are used to compute the IDA. In order to solve the contact force-sharing problem during the double support phase, two methodologies are employed: a new strategy called “corrected force plate sharing method”, based on force plate measurements, and a 3D foot-ground contact model, based on sphere-plane contact, whose parameters are estimated through an optimization algorithm.

The results of the inverse dynamics are used as input data for the forward dynamic simulation, thus obtaining a prediction of the subject’s motion under specified dynamic conditions. This type of analysis requires the implementation of a controller and the use of a model to represent the interaction between the subject and the environment [3]. For the former, two different strategies are applied: a proportional-derivative (PD) controller and a control based on the extended Kalman filter. For the latter, the mentioned 3D foot-ground contact model is used. The FDA allows us to estimate both the contact forces between the biomechanical model and the ground (through the mentioned foot-ground contact model) and the resultant motion of the subject. The contact forces are compared with the force plate measurements and the resultant motion is compared with the captured one in the laboratory (input of the inverse dynamics analysis). The implementation of the two analyses (IDA and FDA) allows us to validate both the models used and the obtained results.

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