DYNAMIC ANALYSIS OF HUMAN GAIT USING FULLY CARTESIAN COORDINATES WITH MIXED COORDINATES

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Introduction

Inverse dynamic analysis (IDA) is a powerful tool to obtain important insights regarding human movement, such as, joint moments or joint reaction forces. In sports it is used to enhance athlete's performance and to reduce injuries [1], while in clinics it is usually used for studying disease etiology, support medical decision, and evaluate treatment effects [2]. When applied to ergonomics it can provide valuable insight into the risk of occurring musculoskeletal injuries while performing manual tasks in industrial settings.

MultiBody System Dynamics is an efficient and validated methodology that has been successfully applied to perform IDA of biomechanical systems with large number of degrees-of-freedom (DOF) in a non–invasive way. Here, Fully Cartesian Coordinates (FCC) [3] are combined with Mixed Coordinates (MC) [4] to assure the solution of the IDA and, simultaneously, the kinematic consistency of the underlying biomechanical model with the experimental data.

Methods

In planar systems the FCC formulation requires the use of 4 generalized coordinates per rigid body (RB), respectively the Cartesian coordinates of a point located at its center of mass (CoM) and the Cartesian coordinates of the components of a direction unit vector [3]. Additionally, if MC are considered, an additional angular coordinate expressing the orientation of each RB needs to be added to the vector of generalized coordinates (**q**). Consequently, the number of constraint equations becomes less than the number of generalized coordinates. To overcome this situation, additional kinematic constraints in the form of trajectory constraints, are added. Each trajectory constraint adds two equations per marker, leading to an overconstrained system that is solved, for each timestep, using a least square approach. The proposed methodology was implemented in an in-house software developed in Python and applied to the analysis of 3 gait cycles, at natural cadence, of a female subject. Kinematic and kinetic data were acquired at 100 Hz using 14 infrared Qualysis™ cameras and 3 AMTI force plates. The biomechanical model has composed by 12 segments [5]. IDA results are compared with similar ones obtained from the literature [6].

Results

The IDA solution procedure showed good convergence for the analyzed gait cycles. Calculated results (Fig. 1) presented similar patterns and values to those from the literature [6], exhibiting a maximum and minimum normalized ankle moments of 1.95 $Nm.Kg^{-1}$ and -0.07 $Nm.Kg^{-1}$ and a maximum and minimum ankle power of 5.99 $W.Kg^{-1}$ and -0.79 $W.Kg^{-1}$, respectively.

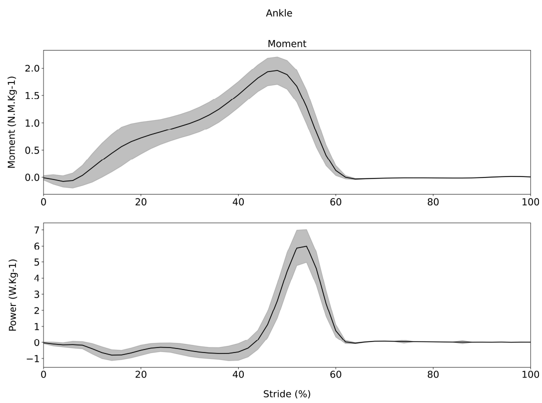

Figure 1: Representation of ankle moment (upper) and ankle Power (lower) during normalized gait cycle. Grey area – literature data. Black line – experimental data.

Discussion

The use of the local coordinates of each experimental marker with respect to the segment where it's located computed during the static trial, in association with the use of MC and the least square approach ensures model kinematic consistency and minimizes the difference between model segments positions and orientation with respect to experimental markers. Future work will address the implementation of the proposed methodology for spatial models.

References

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