

Masterthesis

Implementation and evaluation of a residual reduction algorithm for gait simulations in ArtiSynth

Content

In computer-aided biomechanics, combined multibody (MB) – finite element (FEM) simulations use the strengths of both methods to provide a comprehensive view of the underlying biological system. ArtiSynth (<https://www.artisynth.org>) is an open-source simulation platform for such combined simulations. A musculoskeletal simulation is only physically meaningful if the residual forces and moments that keep the model in balance stay small. OpenSim reduces them with the Residual Reduction Algorithm (RRA), which slightly adjusts the mass and inertia properties of the model to reduce residuals. ArtiSynth has no such counterpart, so its gait simulations currently carry residuals that dominate the computed pelvis joint moments. The aim of this thesis is to design, implement and evaluate an RRA-like residual reduction for gait models in ArtiSynth. The work builds on an existing data set of 100 gait trials simulated in both frameworks and on an implemented check of the physics-based acceptance guidelines of Gupta et al. (2022), so that the outcome can directly be measured against OpenSim directly.

Work packages

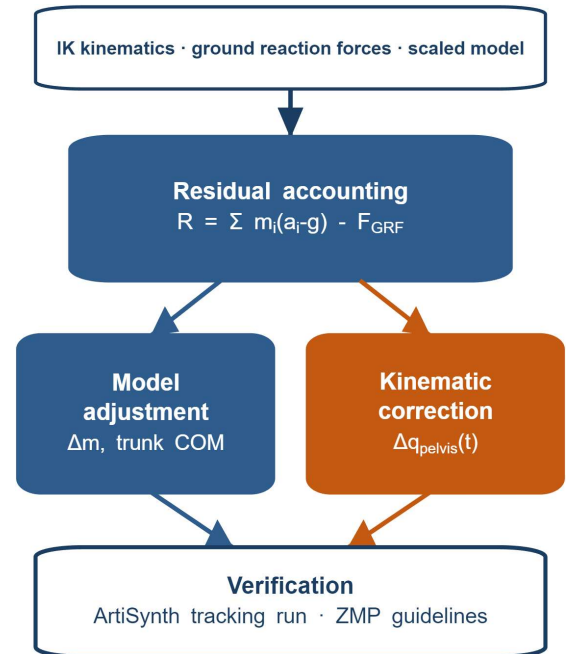
This work includes the following work packages:

1. Familiarization with ArtiSynth, the existing gait model and the MATLAB toolbox that drives it (knowledge of MATLAB is required, Java or object-oriented programming is desirable but not required).
2. Literature review on the dynamic consistency of musculoskeletal simulations, in particular:
 - Residual reduction in OpenSim (RRA) and the model and kinematic adjustments it applies
 - Physics-based acceptance criteria and more recent alternatives, such as AddBiomechanics or optimal control based approaches
3. Implementation of a whole-body residual accounting from kinematics, model mass properties and measured ground reaction forces, validated against the residuals both frameworks report.
4. Adjustment of the model mass properties, in particular total mass and trunk centre of mass, from the accounted residuals.
5. Implementation of a smooth and bounded correction of the tracked pelvis kinematics that minimizes the residuals without violating the marker tracking criterion.
6. Evaluation on the existing data set: residual reduction, guideline compliance, the effect on computed muscle forces, and comparison against the results of OpenSim's RRA.

Gained knowledges and skills

During this work the following knowledges and skills are gained:

1. Rigid body dynamics and inverse simulation of musculoskeletal models
2. Simulation-in-the-loop optimization: least squares fitting, regularization and identifiability
3. Verification, evaluation, and visualization of biomechanical simulation results in MATLAB and ArtiSynth



Workflow of the described master thesis