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Foot-Ground Contact Models for Predictive Neuromuscular Simulations

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Abstract No. 59

Motivation
Predictive neuromuscular simulations *(NMS)* for bipedal walking facilitate detailed investigations of the human locomotor system. Aspects that among others influence the validity of the NMS results are the used muscle model, musculoskeletal geometry, neural control and optimization procedures and the foot-ground contact *(FGC)* formulation. [3]
The *FGC* is besides gravity the only interaction of the walking model with its environment and thus has a considerable influence on the predicted systems dynamics. In addition, *FGC* modeling largely impacts the simulation performance as solving contact problems is computationally expensive. In current research however, few attention is payed to *FGC* modeling and a systematic evaluation and validation for models is missing [3].

Project Goal
We use a 2D reflex-controlled *NMS* [1] and a bipedal robot to study the impulsive ankle push-off at the end of stance in human walking. As the ankle constitutes the direct connection of foot and remaining body, appropriate *FGC* modeling is particularly important to obtain meaningful results. Therefore we work on a systematic evaluation and experimental validation of FGC models. We investigate the influence of the mathematical contact formulation and how to model the foot's morphology.

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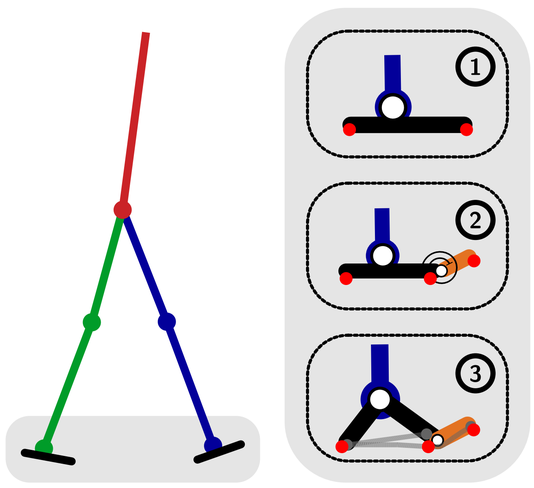
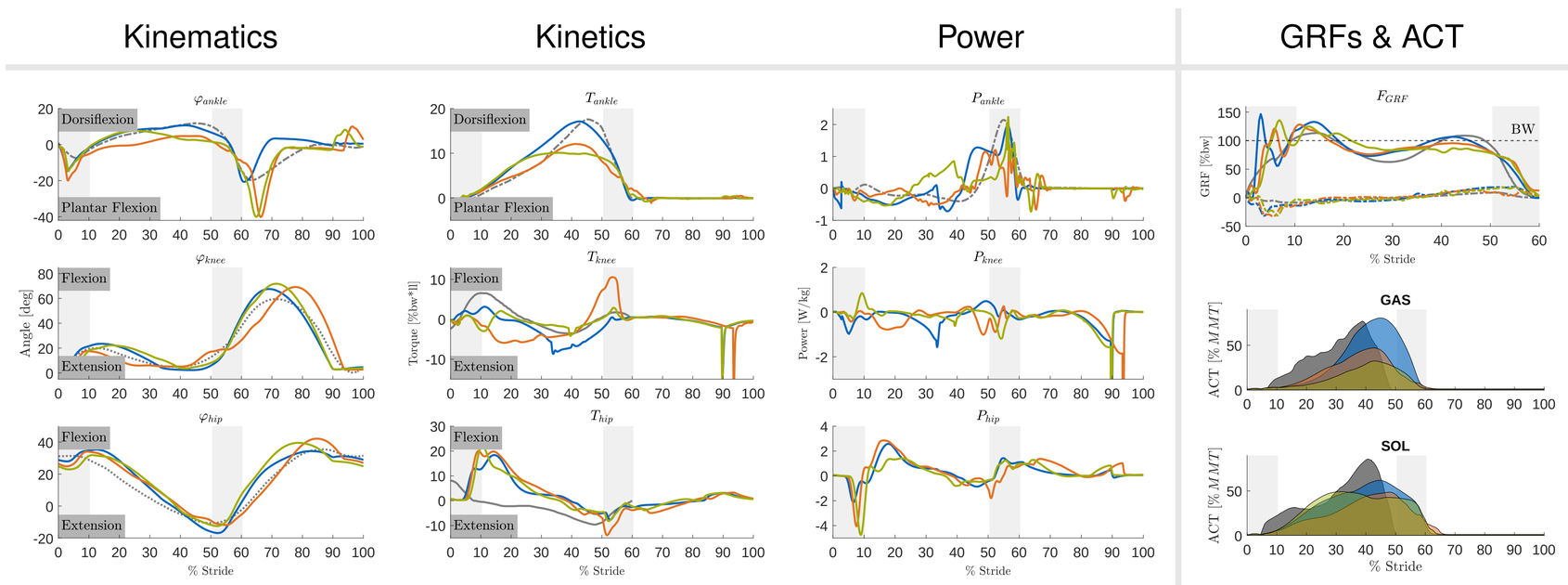
Neuromuscular Simulation - Models and Preliminary Results



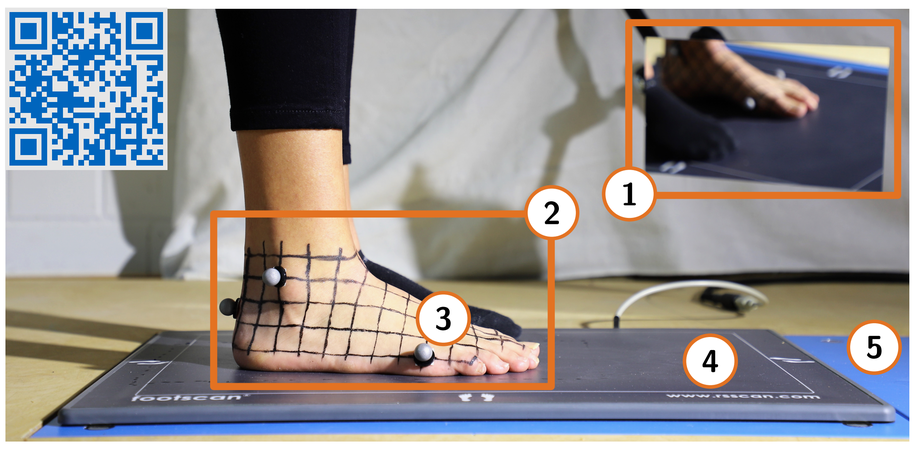
One segment, rigid
Two contact points (heel and ball)
Nonlinear contact model [1]

Two segments, rigid, toe with linear joint stiffness
Three contact points (heel, ball and toe)
Volumetric contact model (adapted from [4])

Three segments, deformable foot arch with ligaments (PA, PL)
Three contact points (heel, ball and toe)
Nonlinear contact model [2]

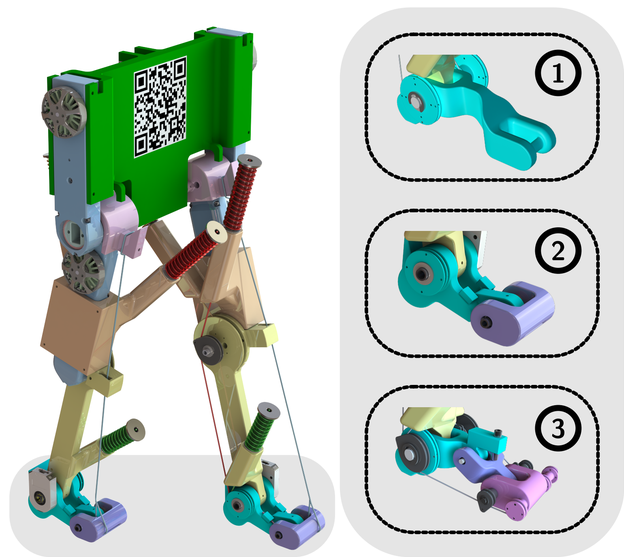


Experimental Setup



1 **First surface mirror**: 3D image reconstruction
2 **Foot with mesh**: visualized deformation
3 **Reflective marker**: global motion tracking
4 **Footscan®** mat: pressure distribution
5 **Force plates** (Kistler): ground reaction forces
6 **High-speed camera** Photron Nova S6: scan QR

Robotic Verification



We will test the three different foot geometries from simulation on our bipedal robot to validate simulation findings and get additional insights from hardware experiments.

References

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[4] Shourijeh, M. S. et al. "Foot–ground contact modeling within human gait simulations: from Kelvin–Voigt to hypervolumetric models". In: *Multibody System Dynamics* 35.4 (2015), pp. 393–407.

Acknowledgments

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