WhiteBox
Symposium on Explainability
LOEWE Exzellente Forschung für Hessens Zukunft
Centre for Cognitive Science
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Man and Machine Walk Together

Human walking behavior is not sufficiently understood from a biomechanical or behavioural point of view. Prescriptive models can precisely predict gait behavior based on data, while descriptive models (based on biomechanics) can in principle explain gait behavior, but have not yet allowed quantitatively accurate predictions.

Goal: We combine the positive properties of both approaches by using the approximation capability of the DNNs as a black box model, combining them with unchangeable physical principles. For this purpose, special DNNs (e.g., Deep Lagrangian Network[1]) are trained to synthesize an implicit black box model for human walking behavior and later explainable methods are adopted to interpret the model.

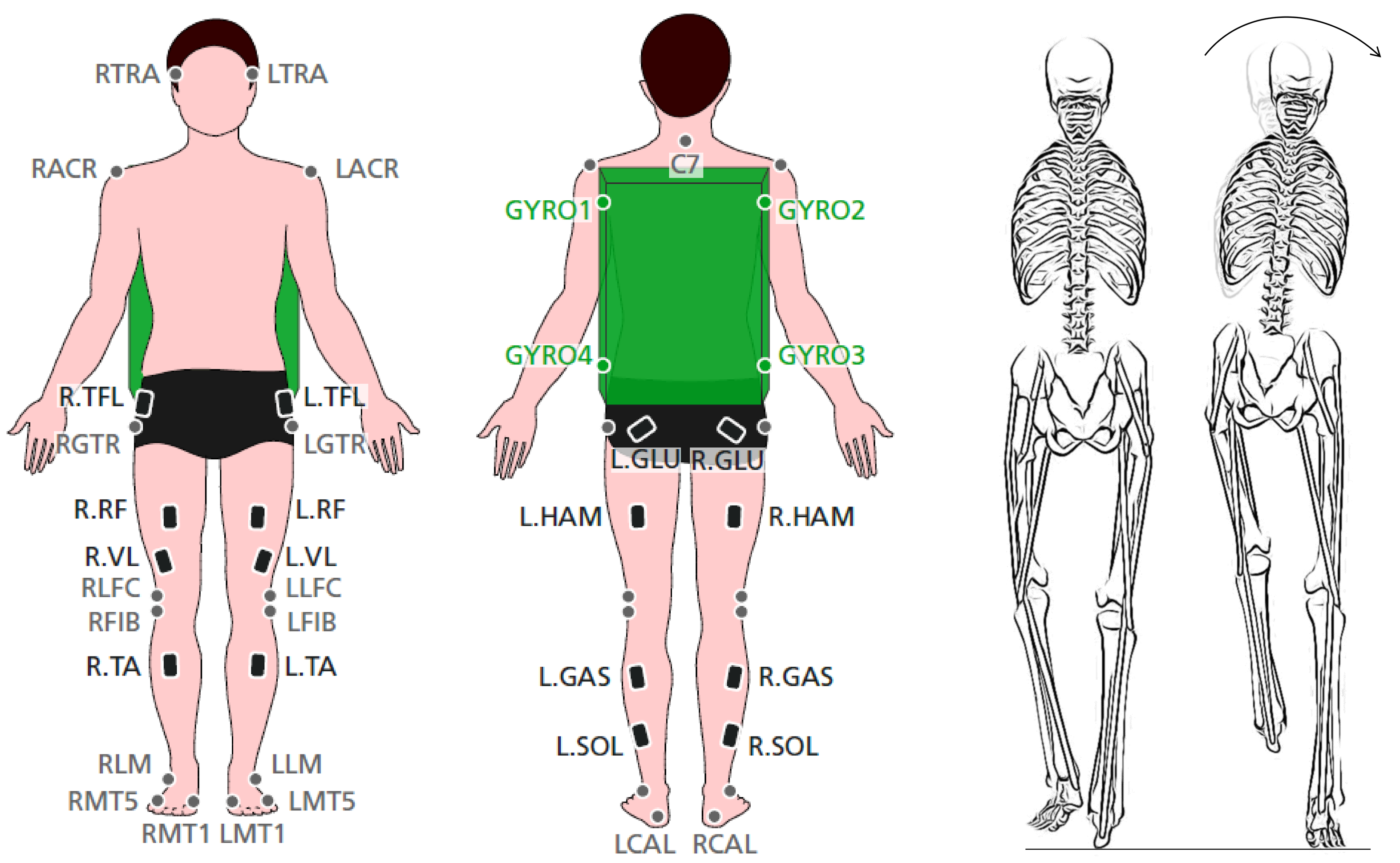
Procedure

Analysis

- Understanding the underlying principles of simple motor patterns (e.g., walking)
- Understanding the systematic adaptation in face of external perturbations
- Develop new neuromechanical models of human gait movements
- Develop special DNNs (e.g., Deep Lagrangian Network) to model human walking behavior

Modelling

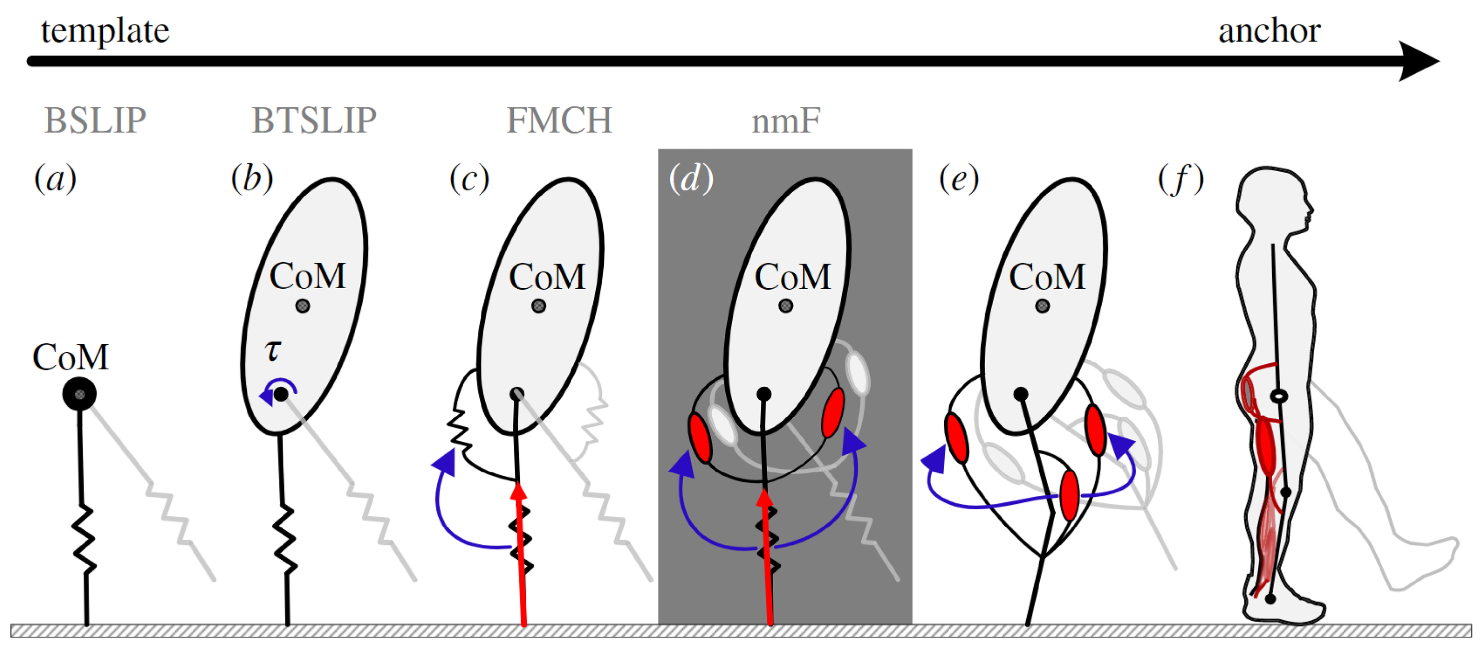
Gyroscopic Perturbed Walking Dataset



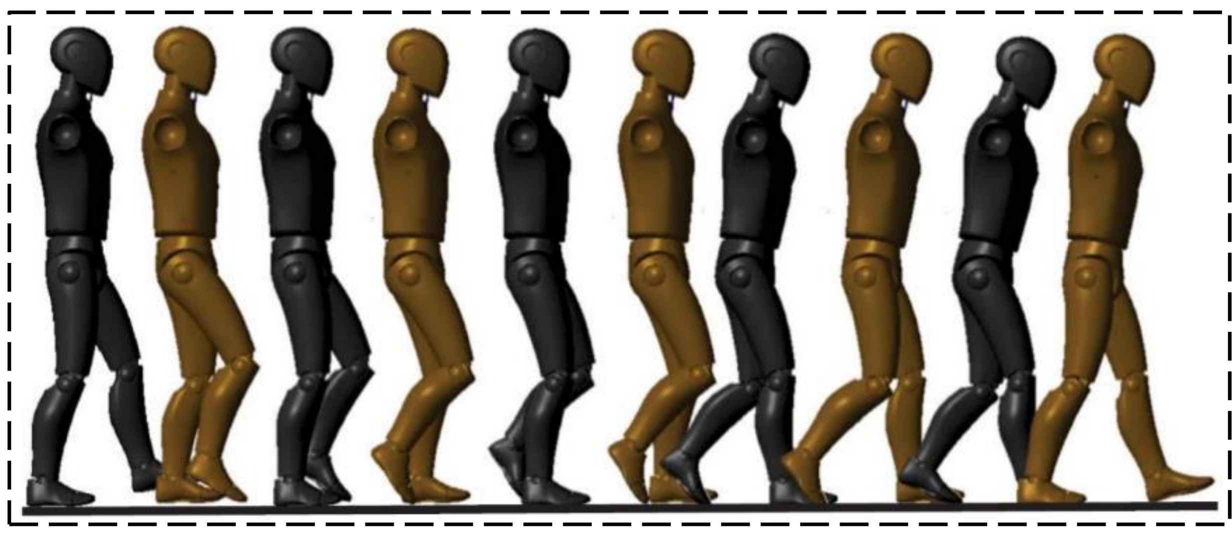
This dataset contains un/perturbed kinematic, kinetic, and EMG measurements of 14 subjects equipped with a gyroscopic Angular Momentum Perturbator (AMP) that induces perturbations with only minimal effect on Centre of Mass (CoM) excursions. This dataset allows for comparing the controller response (e.g., torque generation) with that of humans both in normal and perturbed walking. In addition it allows for the investigation of various aspects of human motor control, perturbation recovery strategies and balance schemes, roles of different segments and muscles in coping with perturbation, and other related questions.

WhiteBox vs. BlackBox Modelling

Whitebox neuromechanical models of human gait movements can be used to explain gait behaviors[2] and verify the models extracted from neural networks.

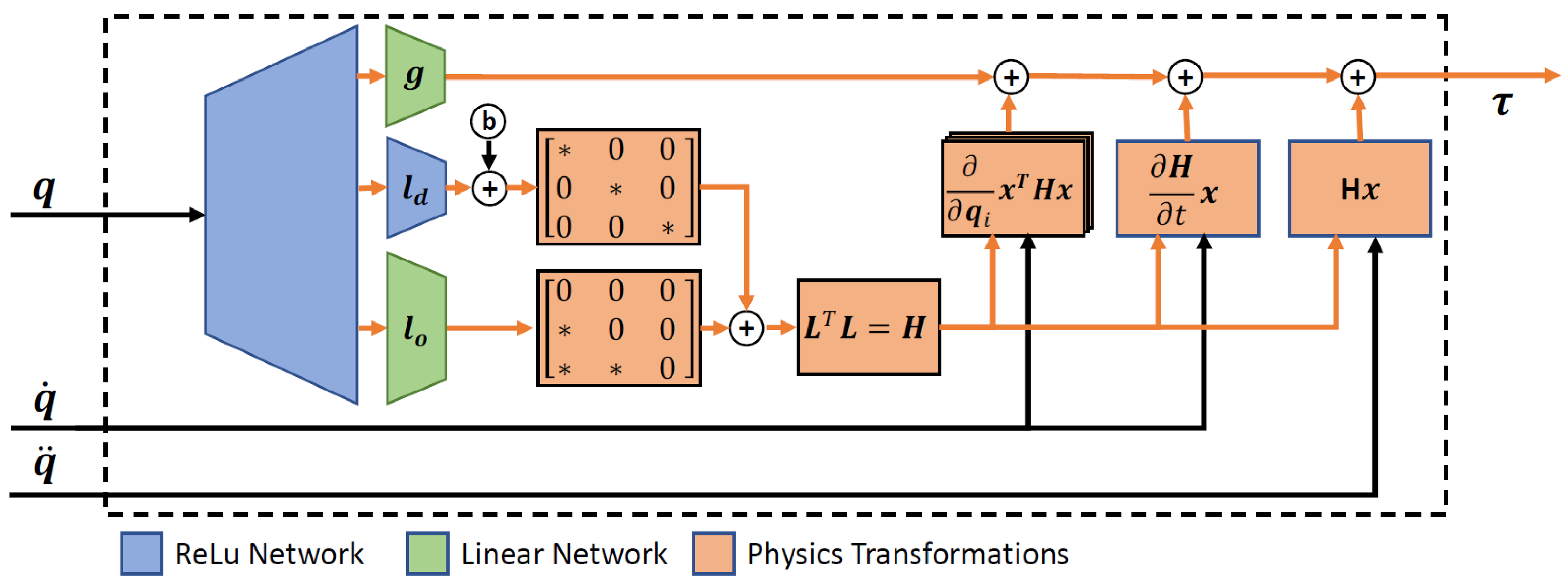


Whitebox model evolution from simple template (conceptual) models to complex neuromechanical anchor models



Currently developed WhiteBox model for un/perturbed walking prediction according to the gyroscopic perturbed walking dataset

In the next step, we plan to use a network topology called Deep Lagrangian Networks (DeLaN) encoding the Euler Lagrange equation originating from Lagrangian Mechanics. This topology can be trained using standard end-to-end optimization techniques while maintaining physical plausibility. For DeLaN only the system state and the control signal are specific to the physical system but neither the proposed network structure nor the training procedure.



computational graph of the Deep Lagrangian Network (DeLaN)

[1] Lutter, Michael, Christian Ritter, and Jan Peters. "Deep lagrangian networks: Using physics as model prior for deep learning." arXiv preprint arXiv:1907.04490 (2019).
[2] Firouzi, Vahid, Omid Mohseni, and Maziar A. Sharbafi. "Model-based Control for Gait Assistance in the Frontal Plane." 2022 9th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob). IEEE, 2022.