Real-time Prediction of Leg Joint Kinematics During Steady-State Walking and Task Transitions

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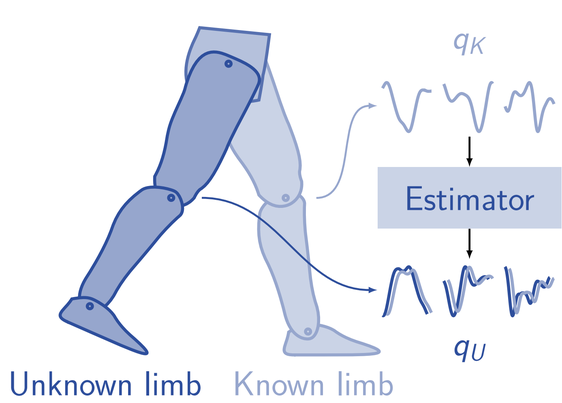
To compensate for locomotion disabilities, advanced devices are being developed. Control of such technologies is a key research challenge. A reference kinematic profile for the affected joints is often required. This poster introduces a novel method for estimating reference kinematics of leg joints from kinematic signals of the contralateral leg.

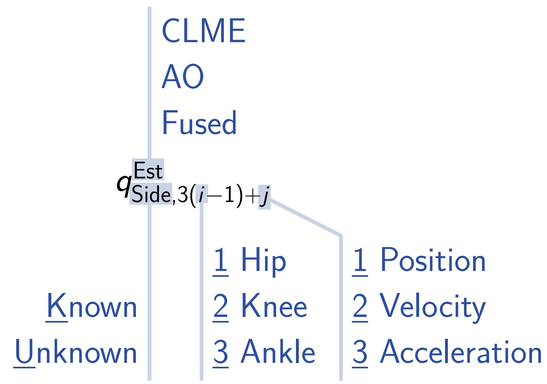
Estimate one leg kinematics from contralateral leg only

Kinematics references are needed to control devices — Orthosis/Prosthesis

Locomotion is divided into two categories:
- Discrete movements
- Rhythmic movements

Combining specific estimators
- Complementary Limb Motion Estimator (CLME) — Discrete movements
- Adaptive Oscillators (AO) — Rhythmic movements

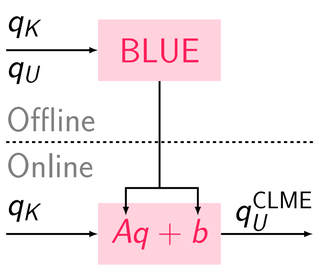


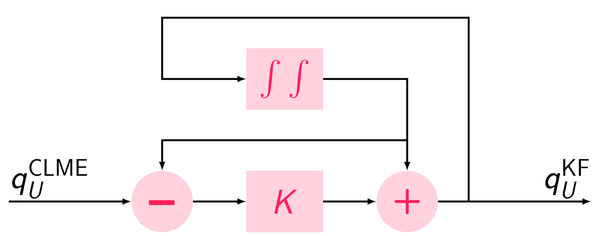


CLME infers motions from contralateral leg

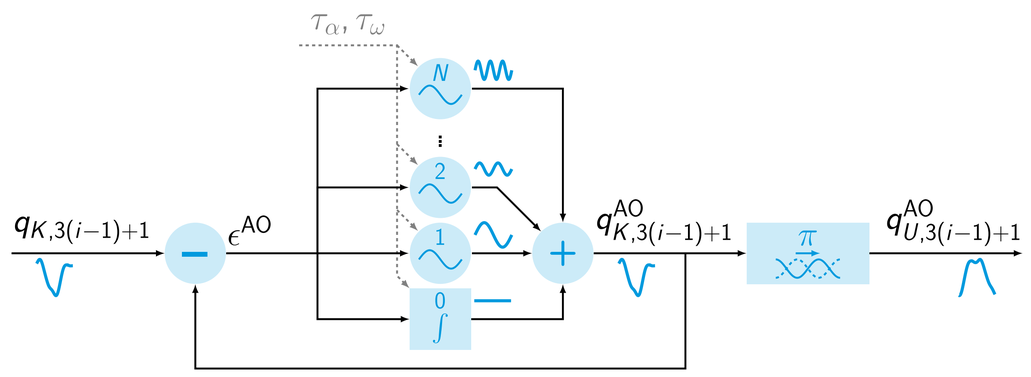
CLME is trained with Best Linear Unbias Estimator

Kalman Filter (KF) takes into account derivative relationships



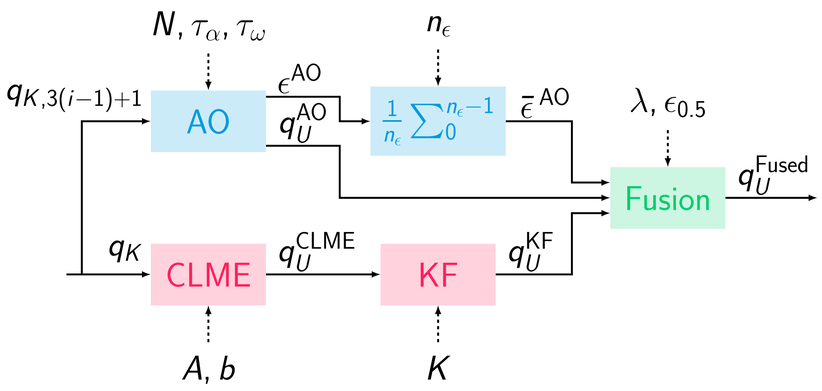


Adaptive Oscillators leverage rhythmicity of walking



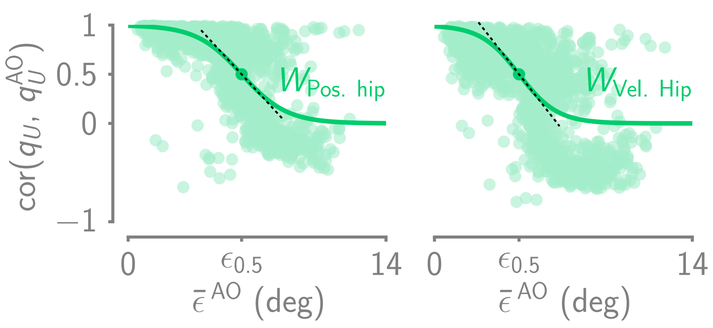
Combining CLME and AO into a fused estimator

$$q_U^{\text{Fuse}} = (1 - W)q_U^{\text{KF}} + W q_U^{\text{AO}}$$



Weighting function

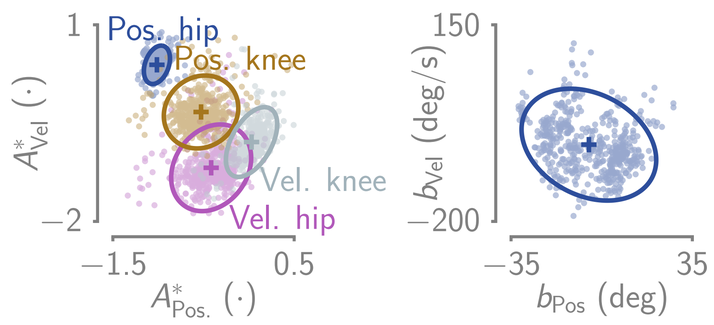
$$W = 1 - \frac{1}{1 + \exp\left(\lambda\left(\epsilon_{0.5} - \bar{\epsilon}^{\text{AO}}\right)\right)}$$



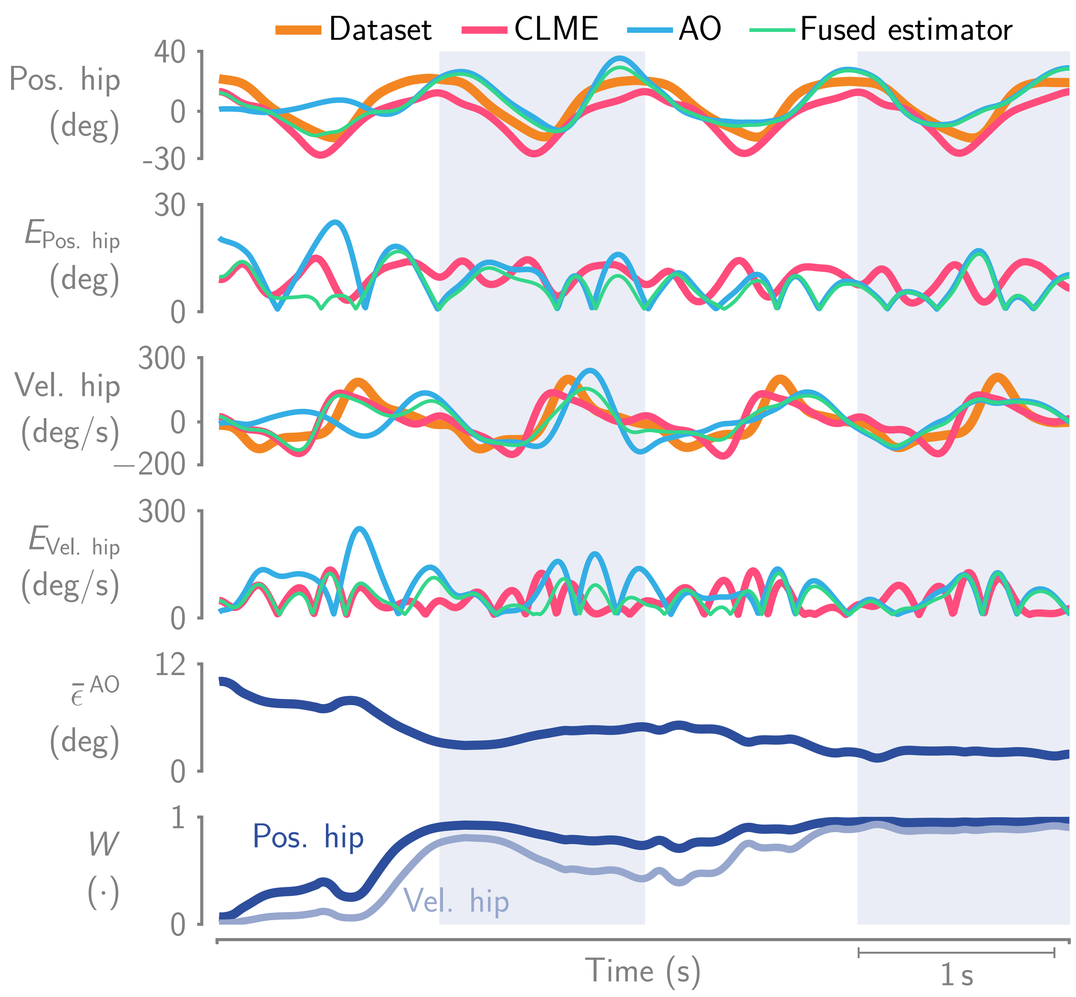
CLME Generalization

Computing gains

On multiple users datasets [1, 2]



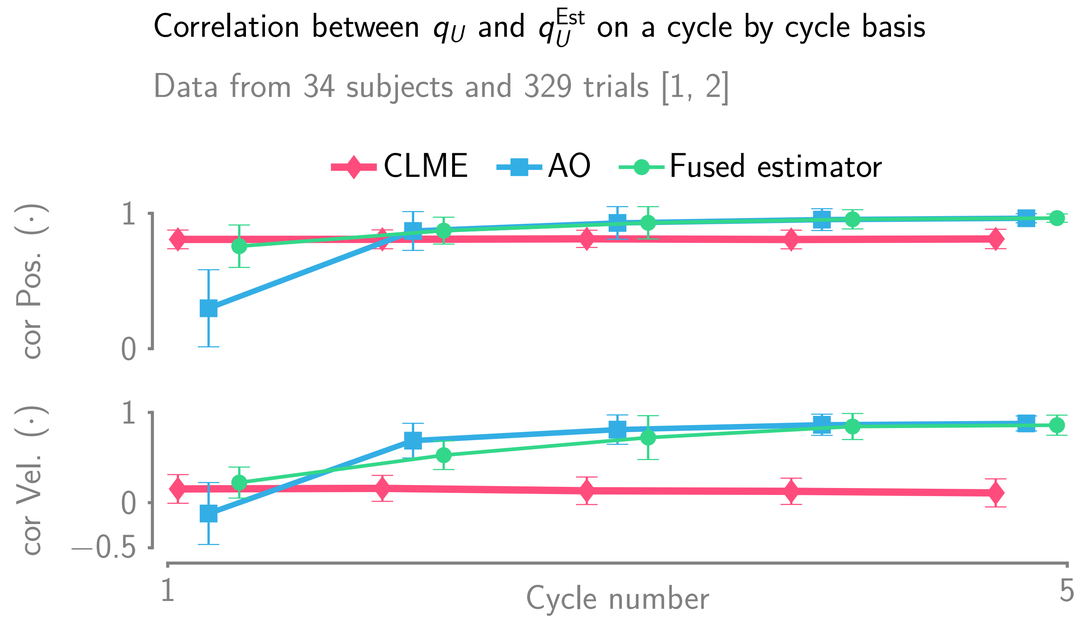
Fused estimator transitions from CLME to AO



Fused estimator follows the maximum correlation

Correlation between q_U and q_U^{Est} on a cycle by cycle basis

Data from 34 subjects and 329 trials [1, 2]



Perspective: Improving the Fused estimator

Tasks transitions from standing
- To walking
- To sitting

Calibrate CLME b vector

Experimental validation
- With IMUs
- In a realtime framework

Enhance evaluation metrics

This method combines two estimators to handle both discrete and rhythmic movements. The resulting kinematic profiles are more accurate due to adaptive fusion.

[1] Camargo et al., "A Comprehensive, Open-Source Dataset of Lower Limb Biomechanics in Multiple Conditions of Stairs, Ramps, and Level-Ground Ambulation and Transitions", 2021
[2] Scherpereel et al., "A Human Lower-Limb Biomechanics and Wearable Sensors Dataset during Cyclic and Non-Cyclic Activities", 2023

Louis Devillez is a research fellow of the Fonds de la recherche Scientifique - FNRS (#40011487)