A machine learning approach for determining whole body angular momentum(WBAM) from wearable sensors

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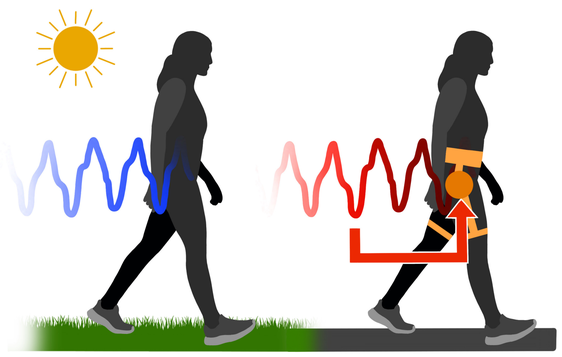
Why do we need WBAM estimation?

- Quantify WBAM in **outside-of-lab** settings
- **Real-time control** for stabilizing exoskeletons

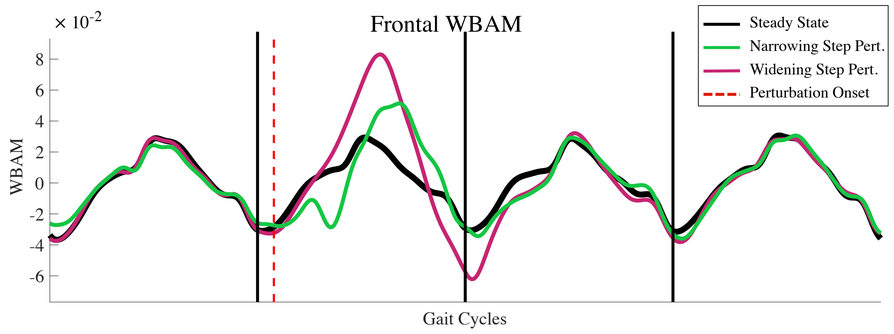
Ideal scenario: Sensors on every segment of the body
Ideal use case: Sensors on limited segments



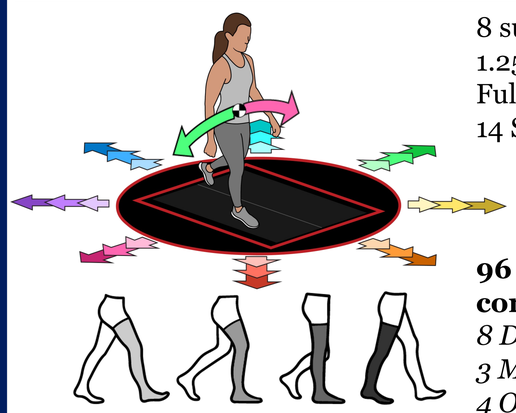
Perturbations cause deviations to steady state WBAM

Complexity of perturbation reactions requires a robust model and data set for accurate estimation of WBAM. [1][2]

Check out some videos of perturbations here!



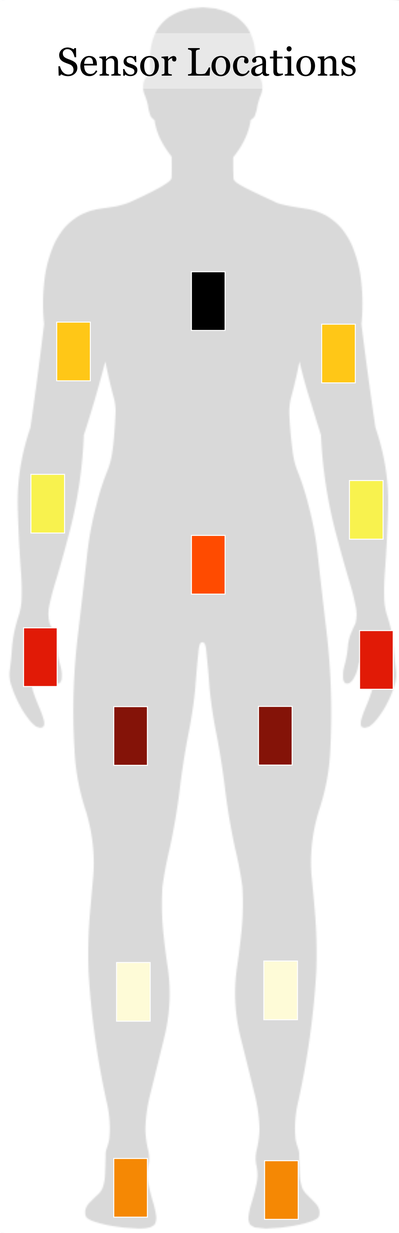
Data Set



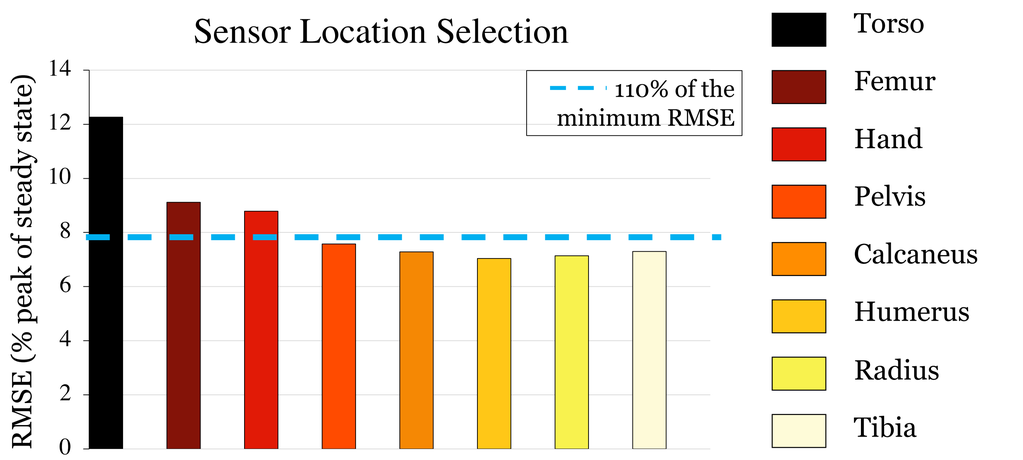
8 subjects
1.25 m / s
Full body market set
14 Simulated IMUs [3]

96 perturbation conditions: [4]
8 Directions
3 Magnitudes
4 Onset Times

Sensor Locations

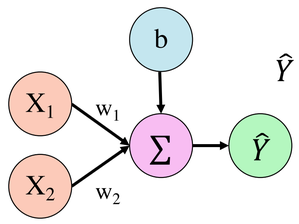


What sensors are the most helpful?



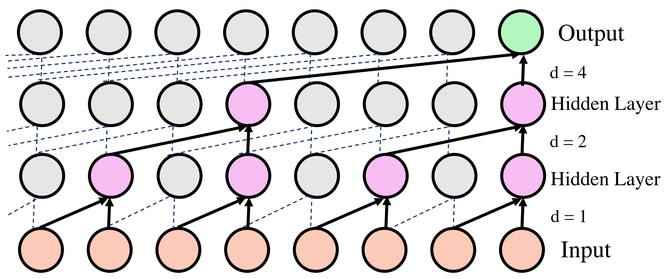
Deep Learning for WBAM Estimation

Standard Perceptron:



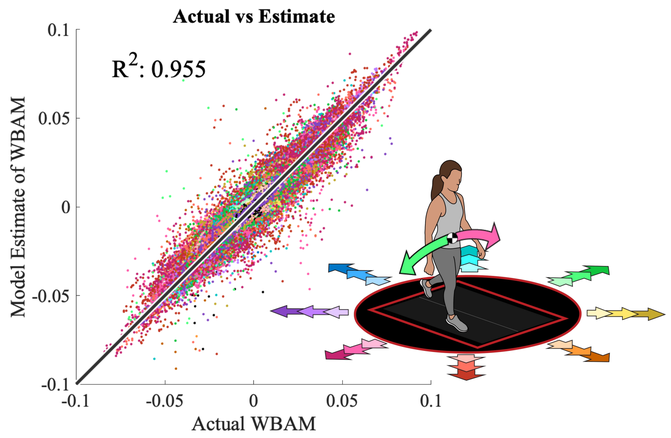
$$\hat{Y} = w_1 * X_1 + w_2 * X_2 + b$$

Temporal Convolutional Network (TCN):



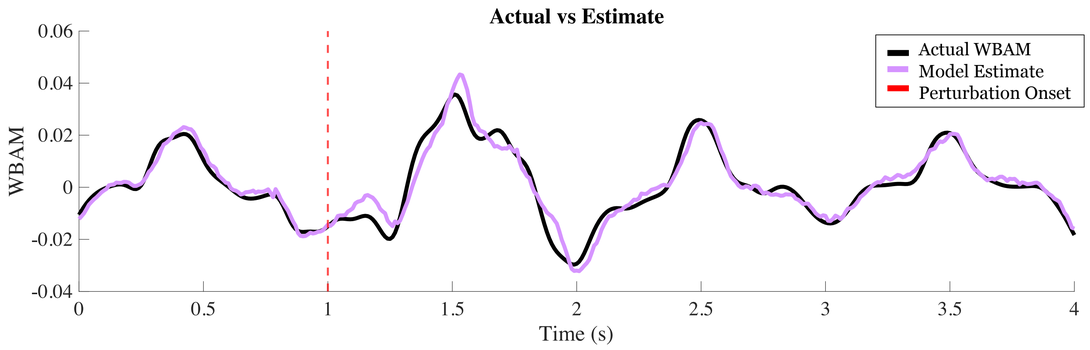
Hyperparameters Swept: Dropout, Kernel Size, Hidden Size, Levels, and Learning Rate [3]

Analysis of WBAM estimation model



The model using the best 4 sensor groups (Torso, Femur, Hand, and Pelvis) performed with high accuracy, even at the extremities.

In the time series below, the model estimates the spontaneous peaks in WBAM that were caused by the perturbation.



Questions

1. What is an acceptable error range for this method? At what point will people begin to use it readily?
2. Will this model work on all types of perturbations, such as slips and COM pulls?
3. Will the use of real-time IMUs affect the performance of this model trained on simulated IMUs?

References & Acknowledgements

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[1] Herr and Popovic 2008; [2] Pickle et. al 2018; [3] Molinaro et. al 2022; [4] Leestma et. al 2022 (under review)