Extracting Motion Primitives from Human Biomechanics using Deep Learning

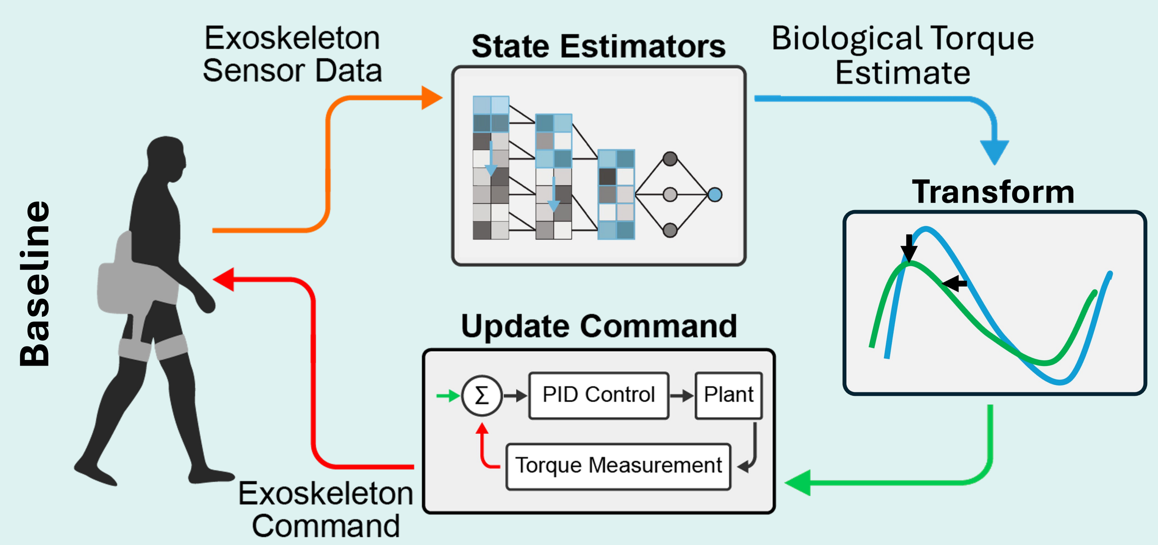
[1,2]Carlos Carrasquillo. **Advisors:** [1,2]Anirban Mazumdar, [3]Lena Ting, [1,2]Aaron Young

[1]*George W. Woodruff School of Mechanical Engineering,* [2]*Institute for Robotics and Intelligent Machines,* [3]*W.H. Coulter Department of Biomedical Engineering*

scan for more

Background

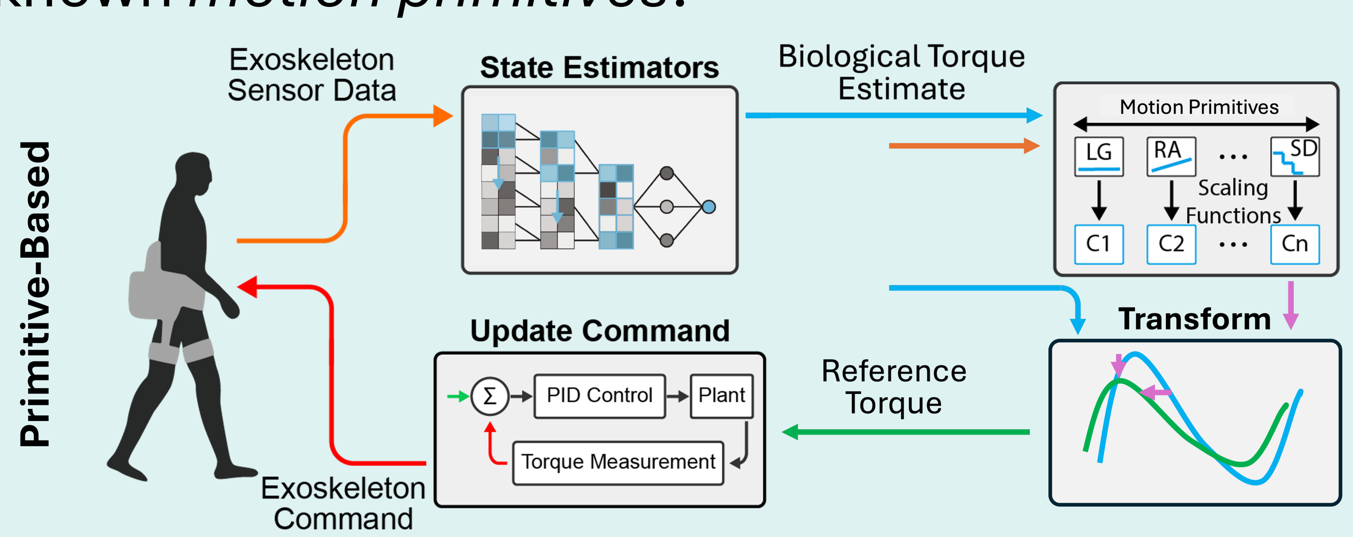
Biological torque control is the current state-of-the-art technique for user independent exoskeleton assistance [1].



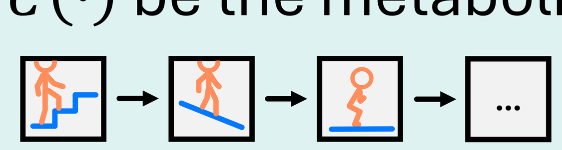
Problem: Commanding biological torque is not globally (i.e., across all tasks) optimal.

Hypothesis

Idea: We can create a globally optimal exoskeleton controller by optimizing a parametrization of biological torque for a set of known *motion primitives*.



Hypothesis: Let $C(\cdot)$ be the metabolic cost of completing some circuit:



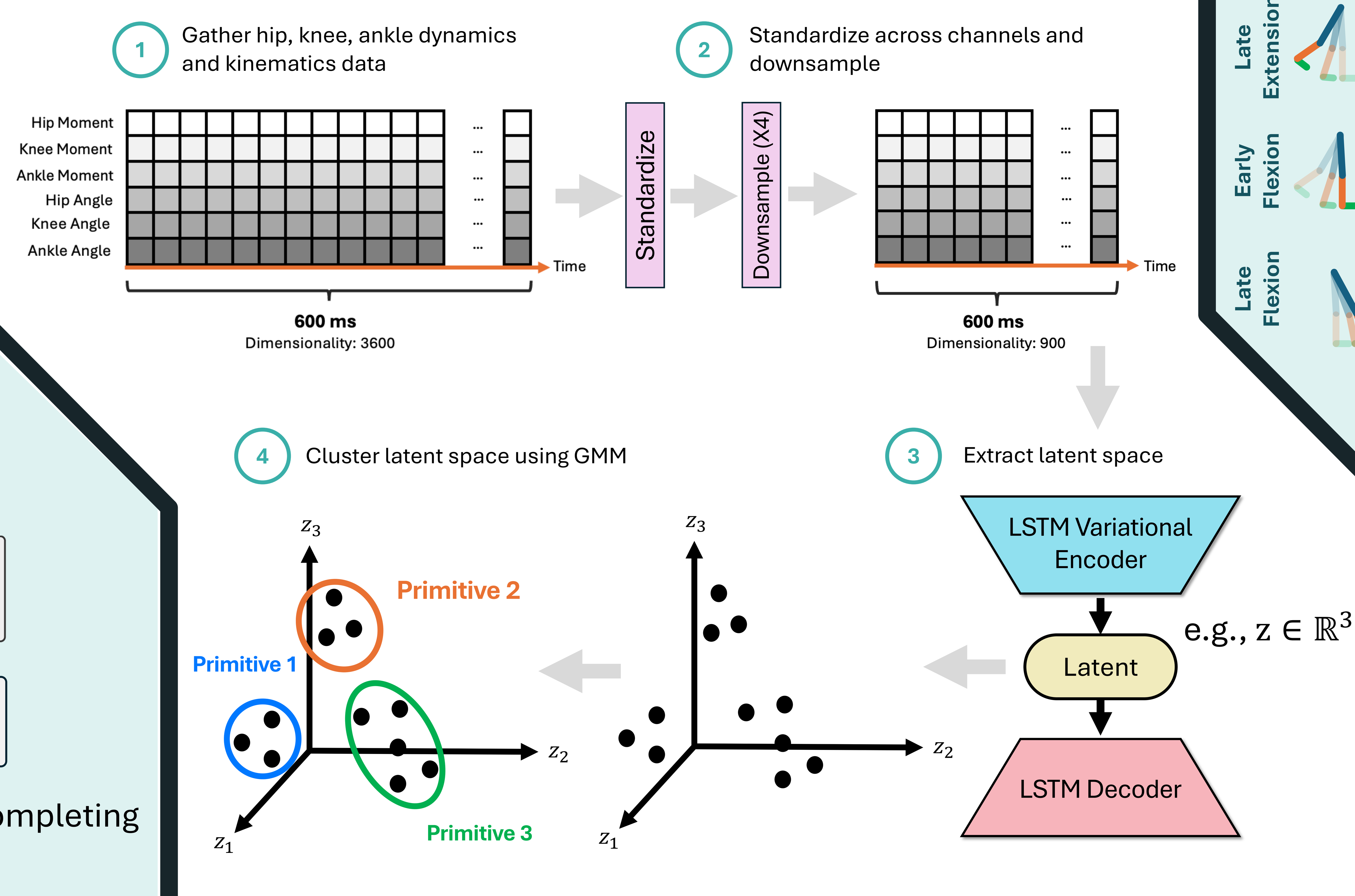
Then, $C(\text{Primitive} - \text{Based}) < C(\text{Baseline})$

Methods

Steps:

1. Generate set of motion primitives
2. Classify primitives in real time
3. Perform human-in-the-loop optimization on each primitive
4. Compare the primitive-based bio torque controller against the baseline bio torque controller

Step 1: Classify primitives in real time

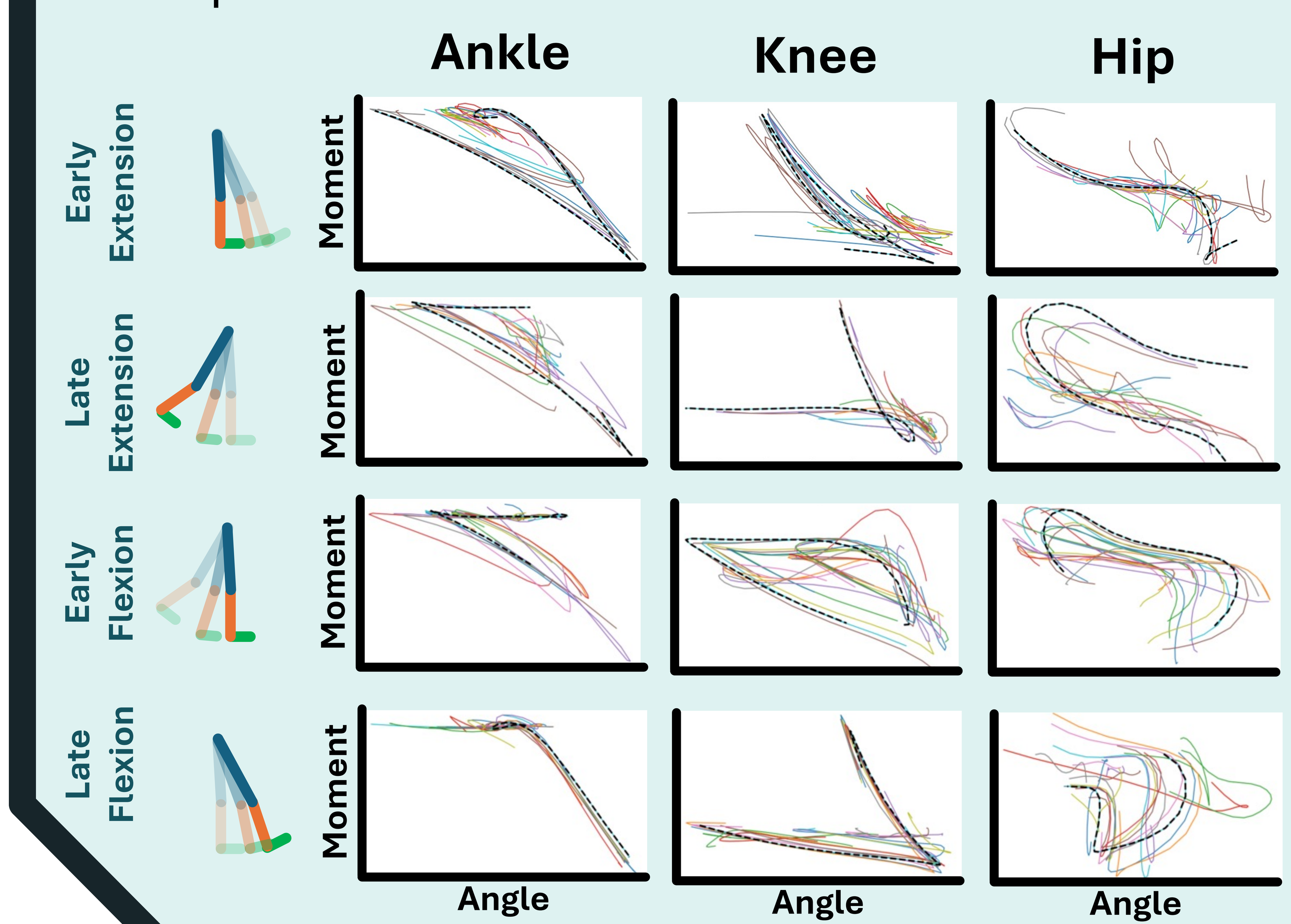


Steps 2-4 are future work.

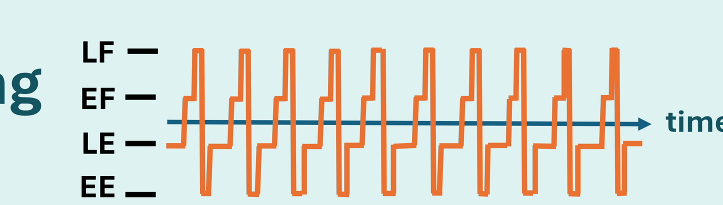
Preliminary Results

Example: Level ground walking

- N=8-2 train-validation split
- model spec: 400 ms window size, 3 layers
- 4 primitives



Offline Walking Trial Analysis



Impact

Understanding what a globally optimal task and user-independent control profile looks like could bring us one step closer to developing a true end-to-end controller and facilitate the widespread adoption of active wearable exoskeletons.

References & Acknowledgements

This work is supported in part by an NDSEG fellowship sponsored by the Army Research Office. The authors would like to thank Aakash Bajpai, Joshua Fernandez, Keaton Scherpereel, Justine Powell, and Marilyn Braojos for their contributions to the ideation, development, and guidance of this project.

[1] Dean D. Molinaro *et al.*, Estimating human joint moments unifies exoskeleton control, reducing user effort. *Sci. Robot.* **9**, eadi8852(2024). DOI:10.1126/scirobotics.adi8852