Using Template Models to Identify Exoskeleton User Intent

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Introduction

- **Motivation:** Increase fluency in Human-Robot Interaction for lower-limb exoskeletons used to restore mobility after neuro-muscular injury
- Identify when user wishes to **speed up** or **slow down** using only sensors already **onboard** exoskeleton (motor encoders & current commands)

- Develop intent recognition strategy for able-bodied **(AB)** individuals & non-able-bodied **(NAB)** individuals with chronic spinal cord injury (SCI)
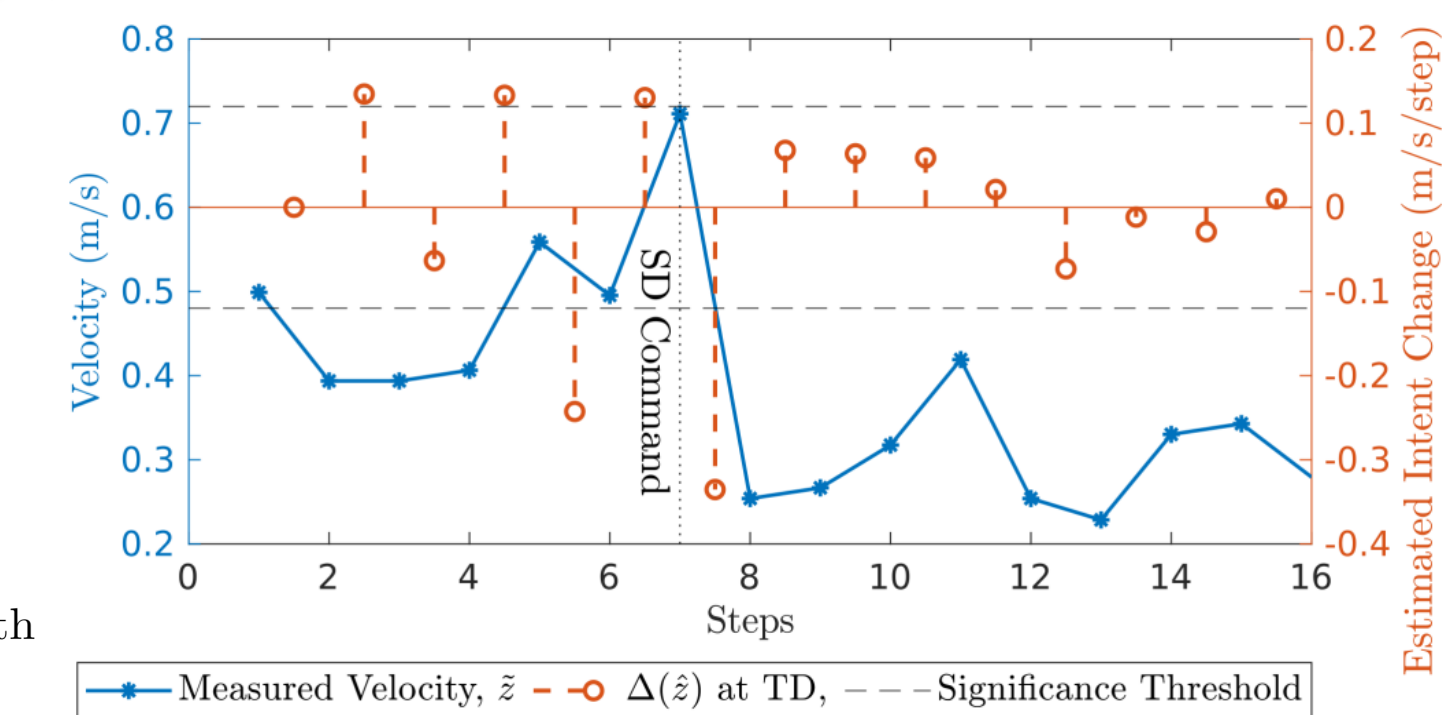
Human Trial Data

- Subjects **with and without SCIs** using the EksoGT exoskeleton
- **Self-selected** gait speed
- Pseudo-random speed change command
- Walking assisted by **walker or crutches**

Footstep-based Intent Estimation

- **Two-stage estimator** leverages changes in foot placement to infer intended gait speed

$$(v_x^d - v_x) \propto \Delta l_{step}$$
v_x^d - Intended Gait Speed
v_x - Current Gait Speed
Δl_{step} - Change in Step Length

- **First stage:** Bayesian update uses a data-driven footstep placement model to update estimate at touchdown (TD)
- **Second stage:** Kalman filter updates at midstance (MS)

- Estimator termed a **Buttressed Kalman Filter (BKF)** as the Bayesian update reinforces the Kalman update
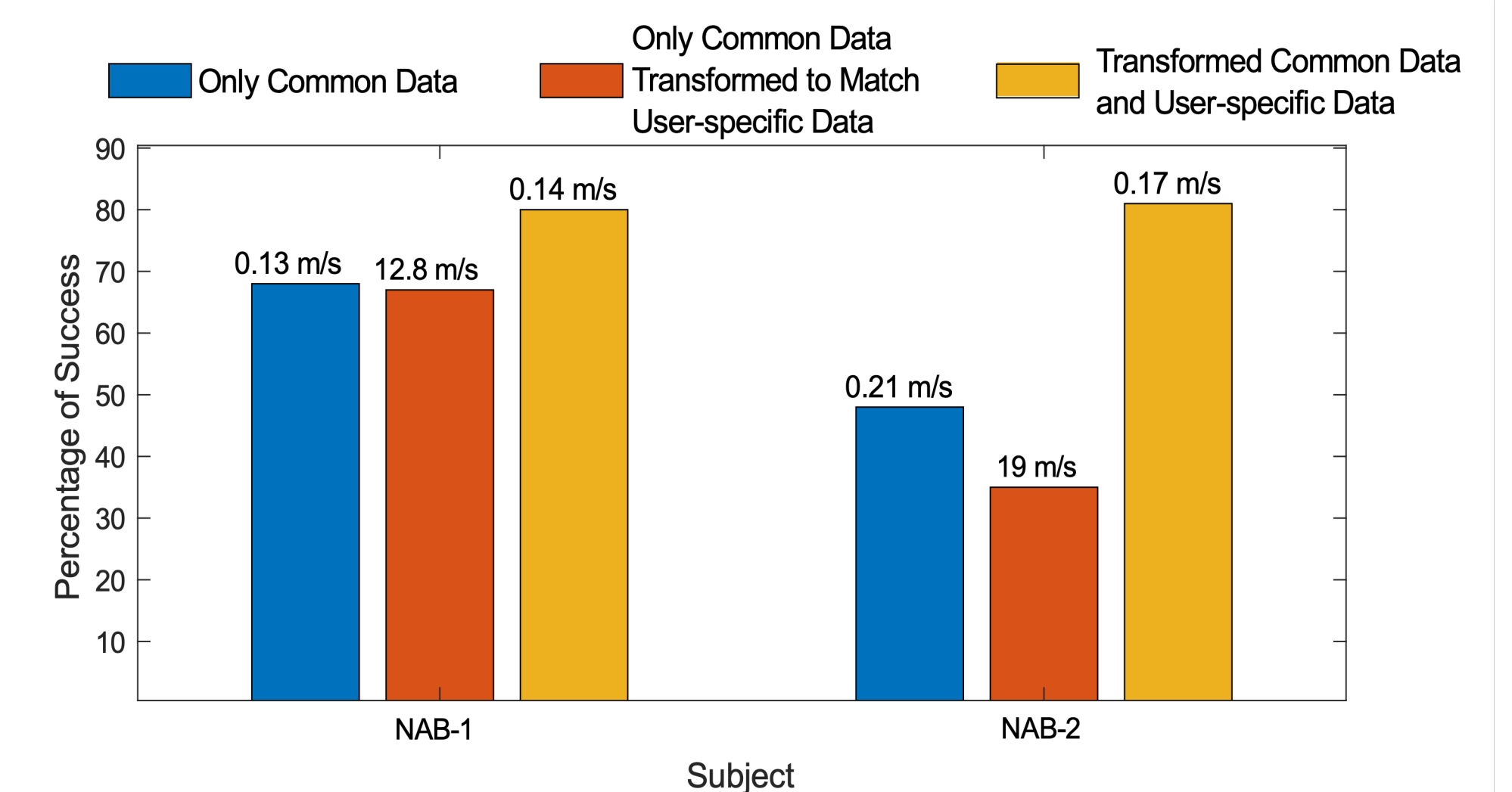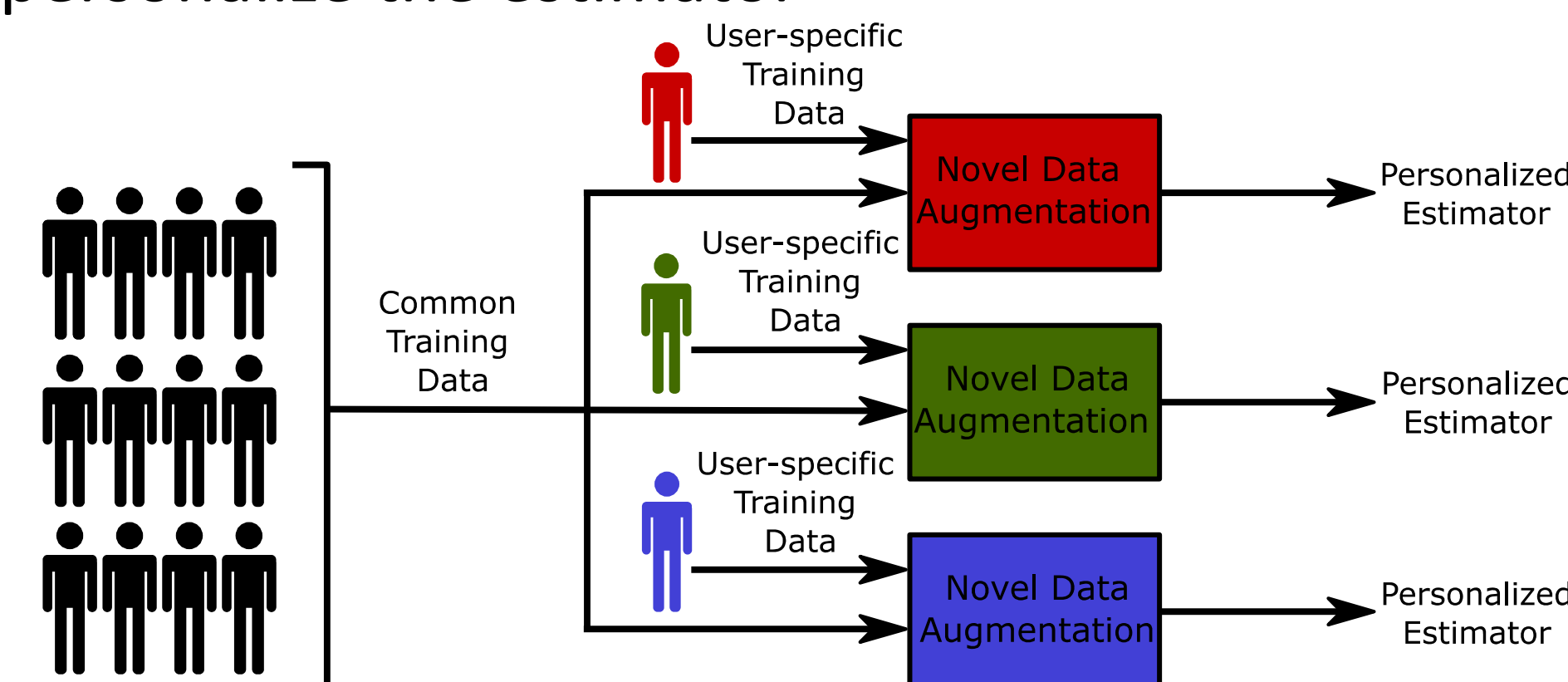
Estimator Personalization

- **Combine data** from healthy and injured users to personalize the estimator
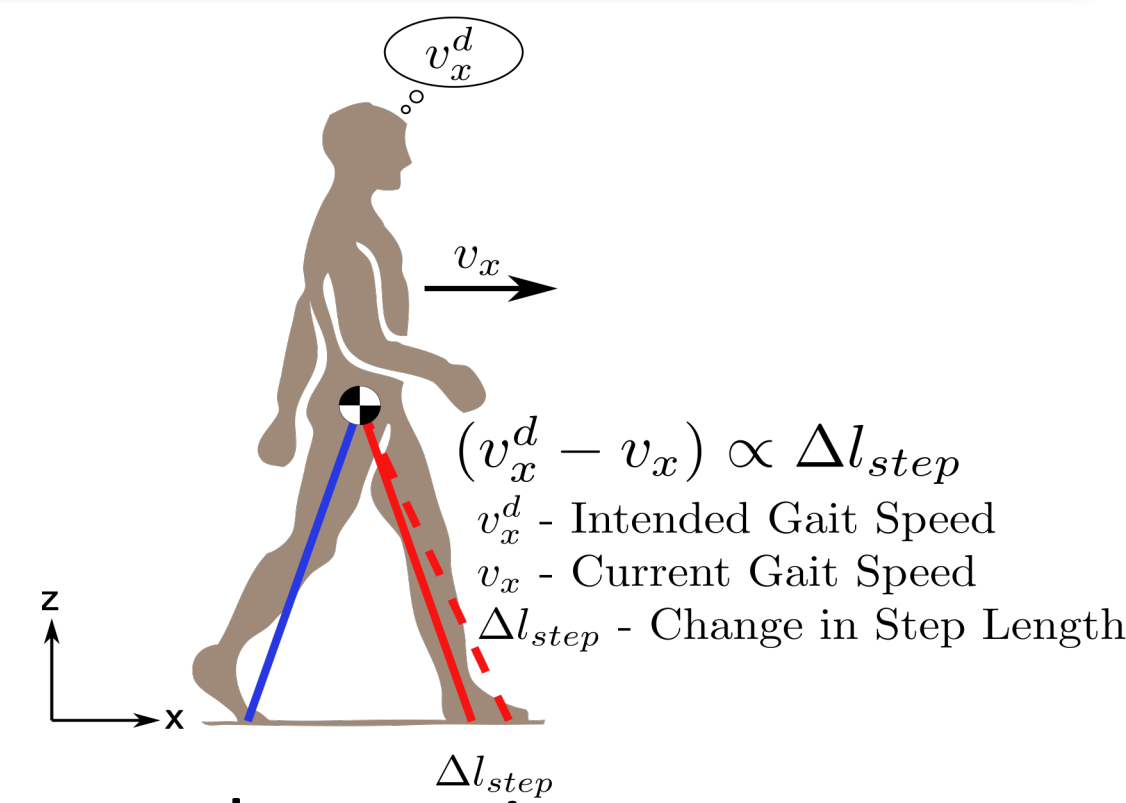
Evaluation on Human Data

- **Evaluated on AB and NAB data** for speed-up/slow-down trials

- Estimated intent change **provides a "speed-up/slow-down" signal** to the exoskeleton
- **Mutual-information**-based method to select appropriate data for model training
- Small amount of novel user-specific data used for personalization – **8-12 steps**
- Result: **Increased** estimator accuracy (bar height) and **decreased** RMS estimation error (bar label)

Broader Impacts:
- Decreased training data requirement for personalized assistance
- Greater control & maneuverability facilitate exoskeleton adoption outside of clinical setting