UniMTS: Unified Pre-training for Motion Time Series

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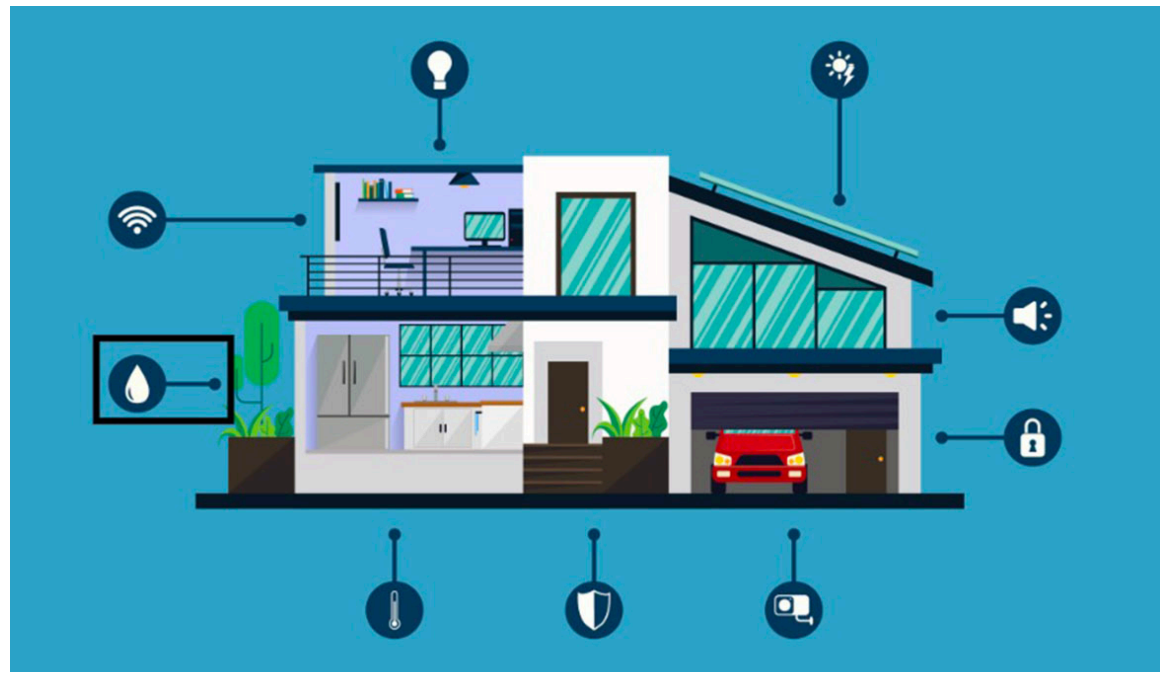
Introduction

Background

- **Motion Time Series Classification** (or Human Activity Recognition) identifies human activities using time series readings from wearable devices
- Applications: healthcare, motion tracking, smart home automation, etc.

Healthcare

Motion Tracking

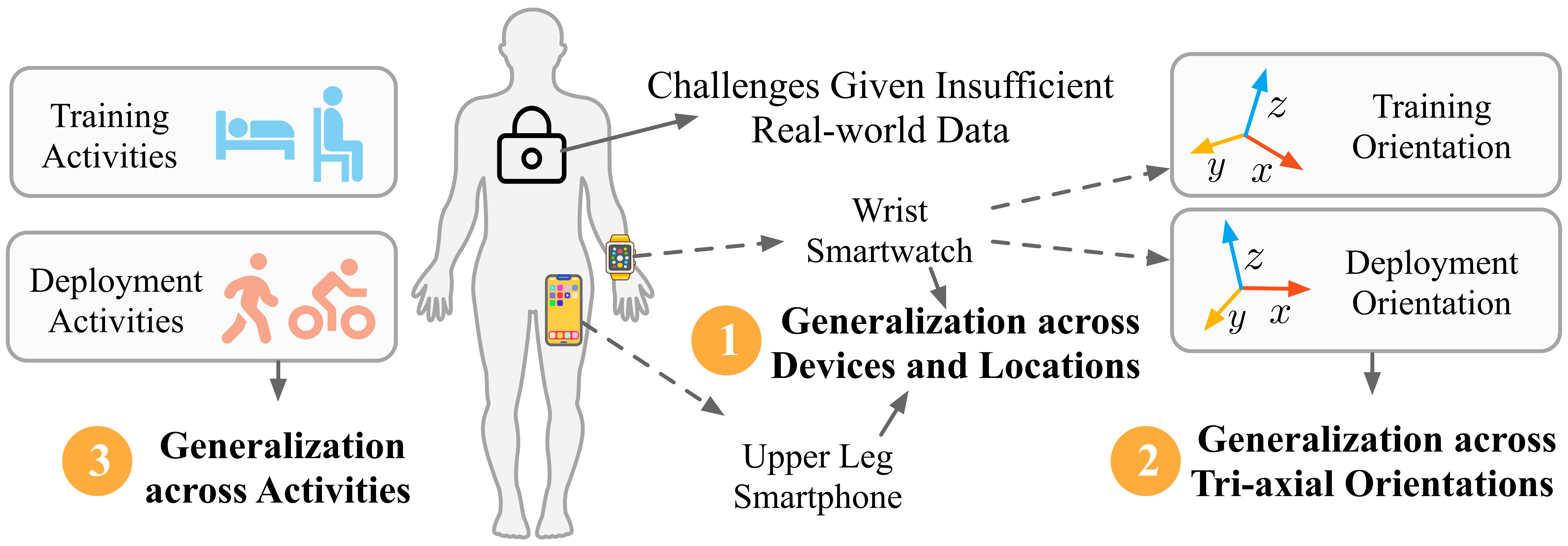


Smart Home Automation

Introduction

Challenges

- Insufficient training samples
- Do not generalize across
  - Devices or Locations
  - Orientations
  - Activities



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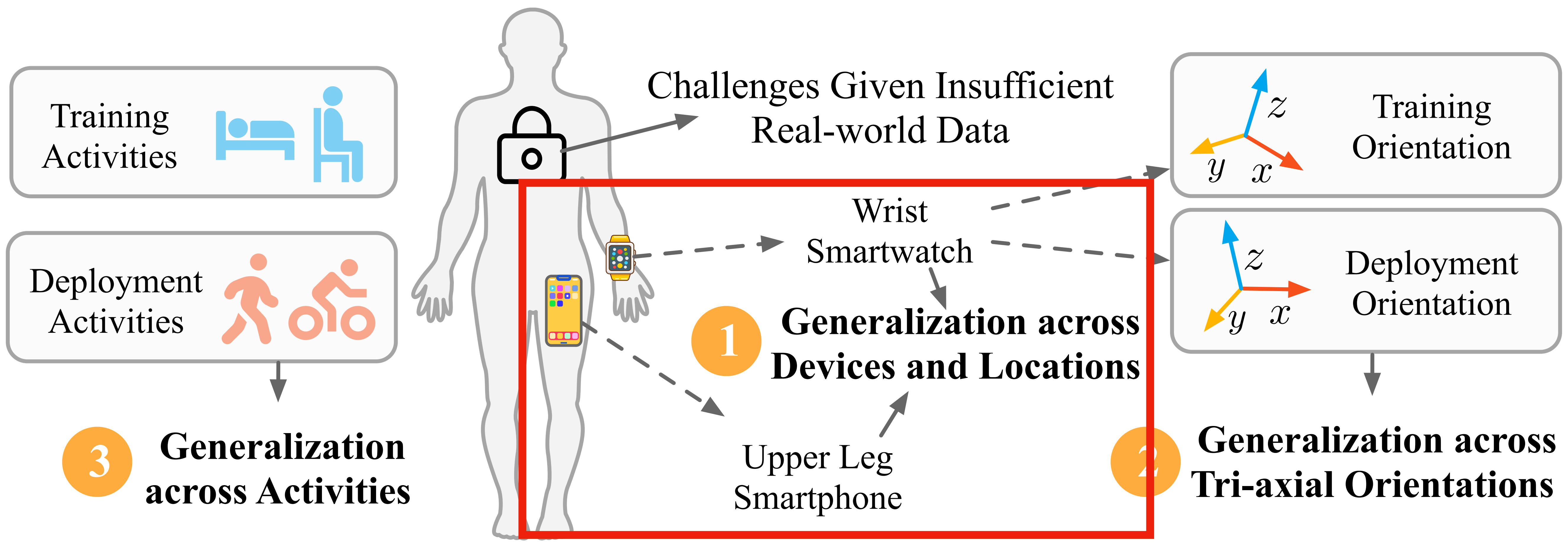

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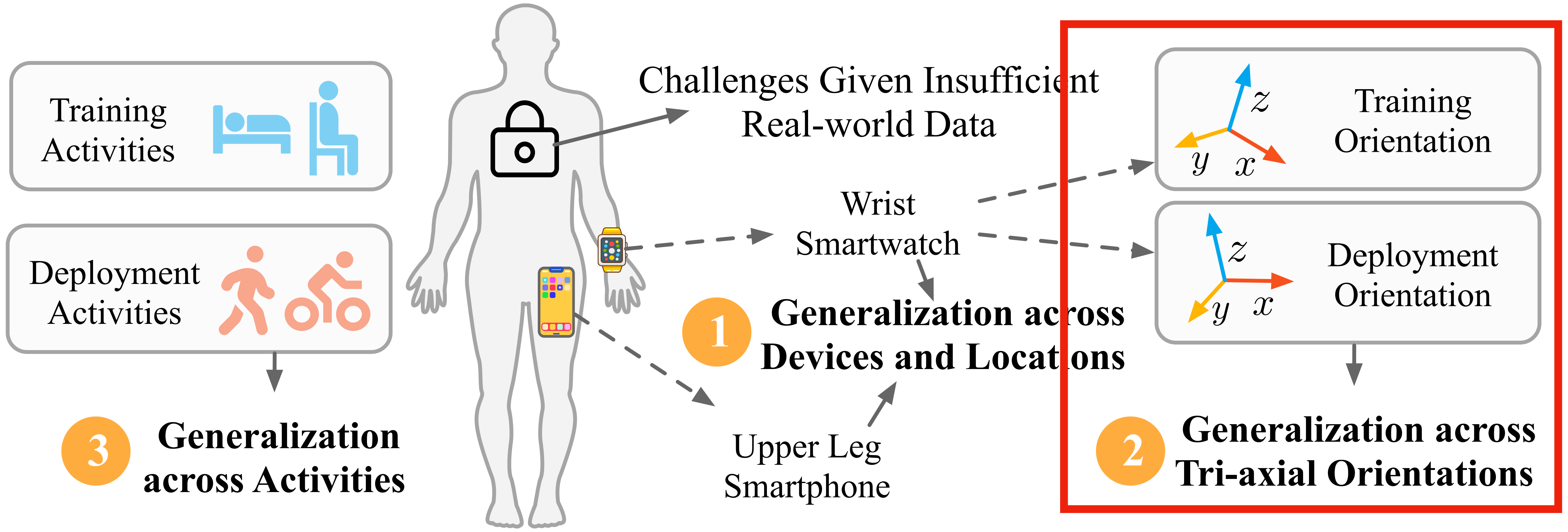

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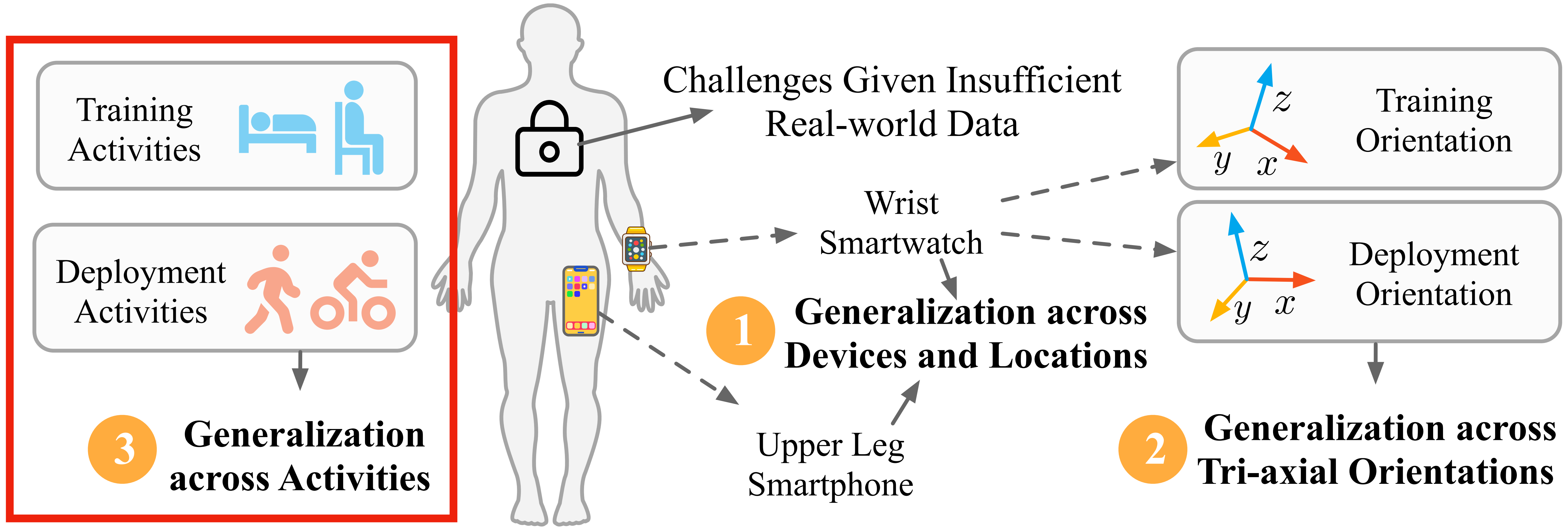
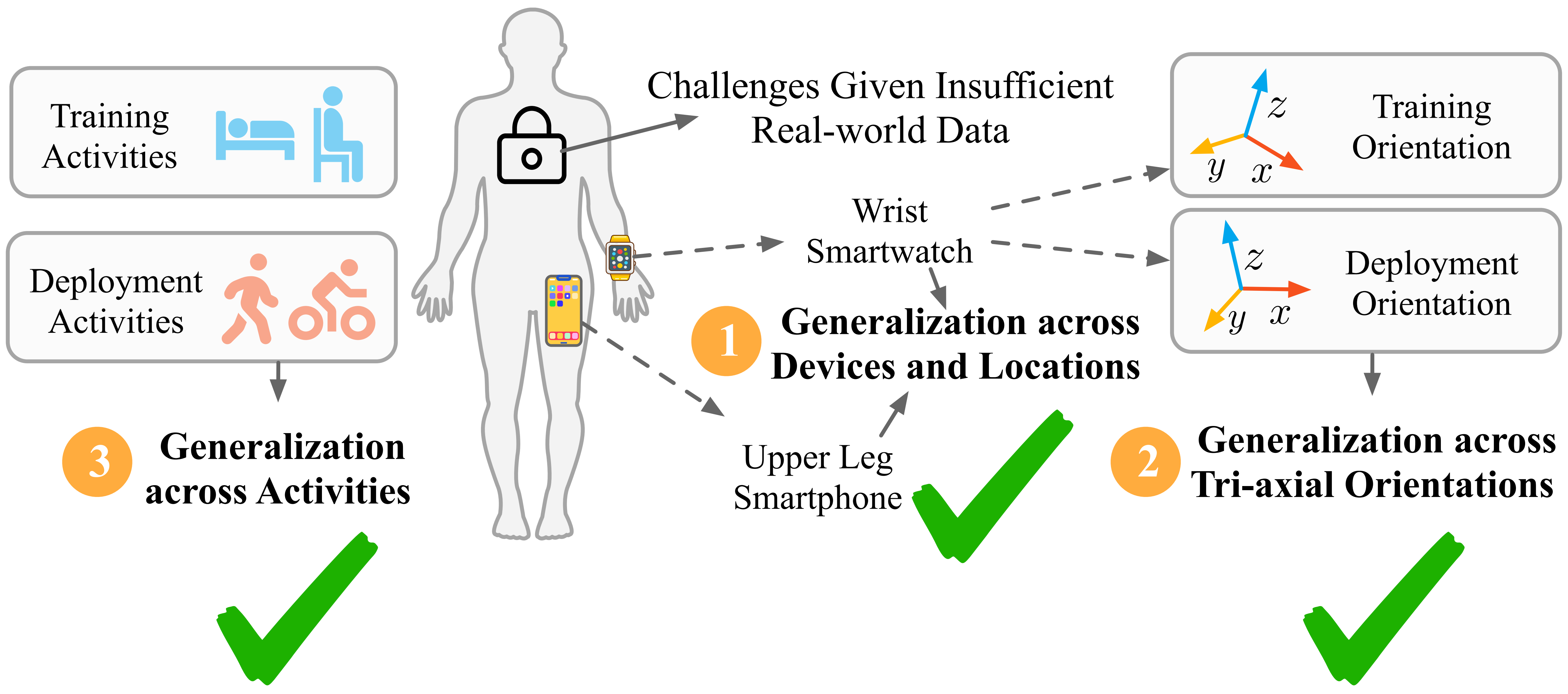


Introduction

Goal

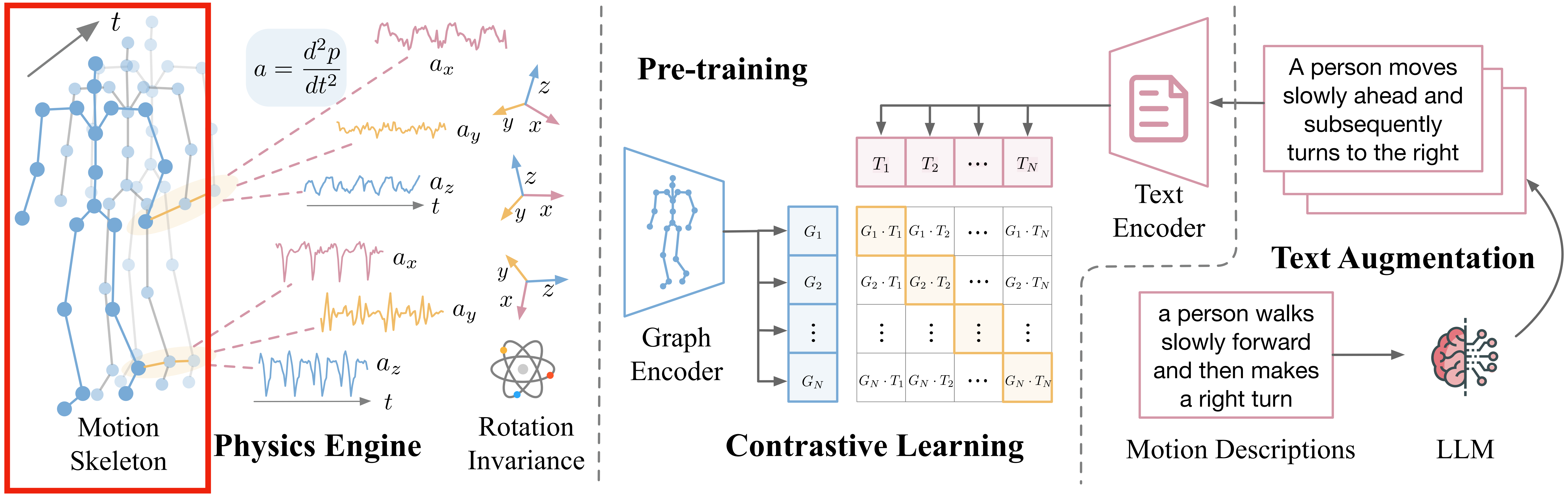
- A single framework that addresses all the above three challenges
- Generalize across
  - Devices or Locations
  - Orientations
  - Activities



Method

Pre-training

- Physics engine: simulate synthetic IMU data + rotation-invariant augmentation
- Contrastive learning: graph encoder + text encoder with text augmentation



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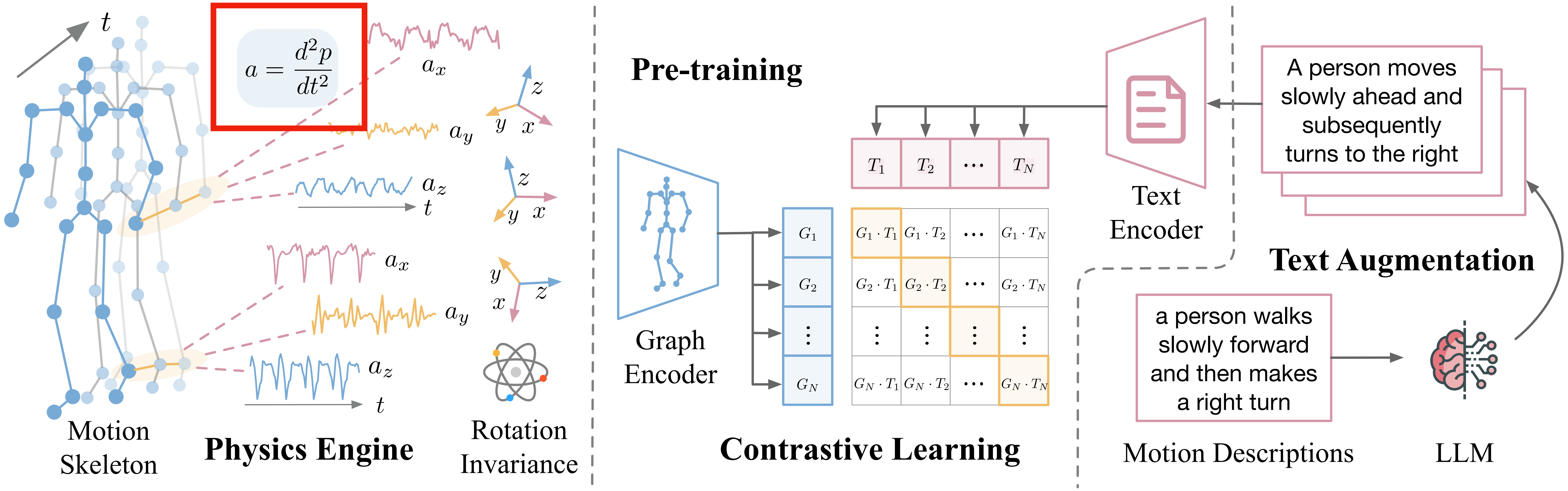

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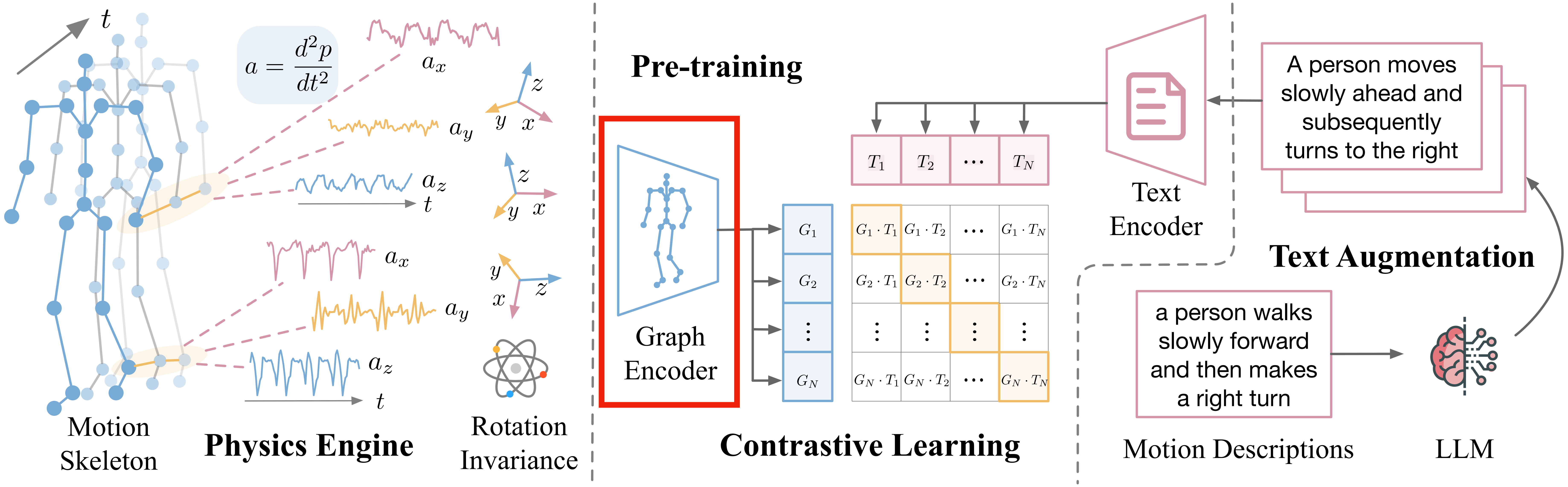

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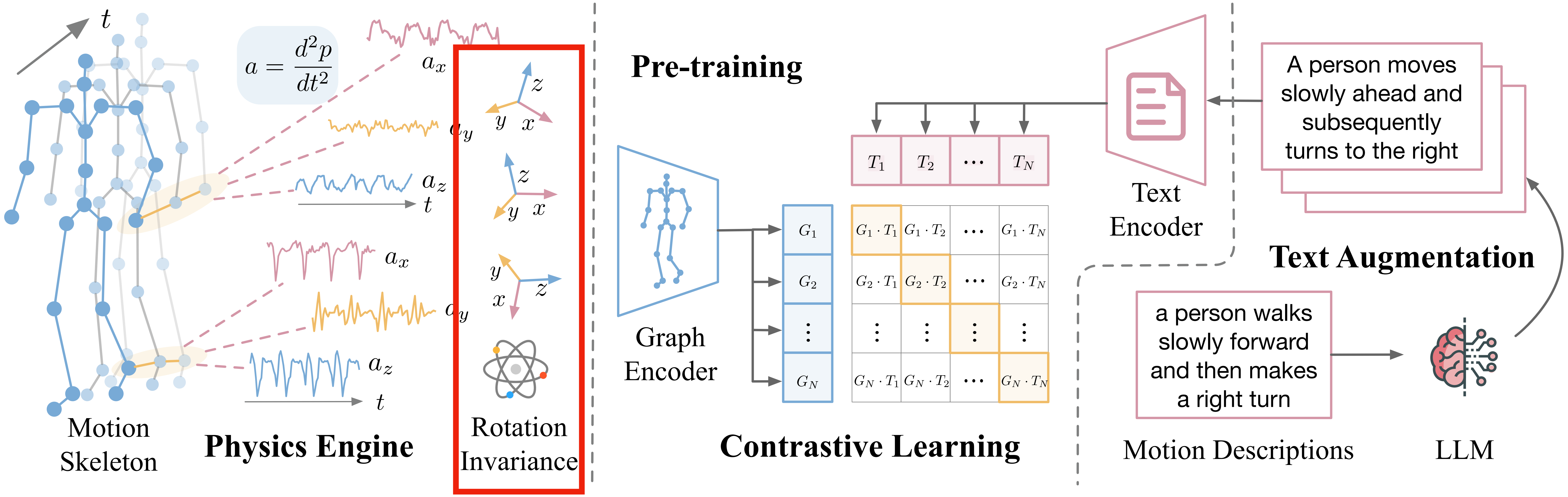

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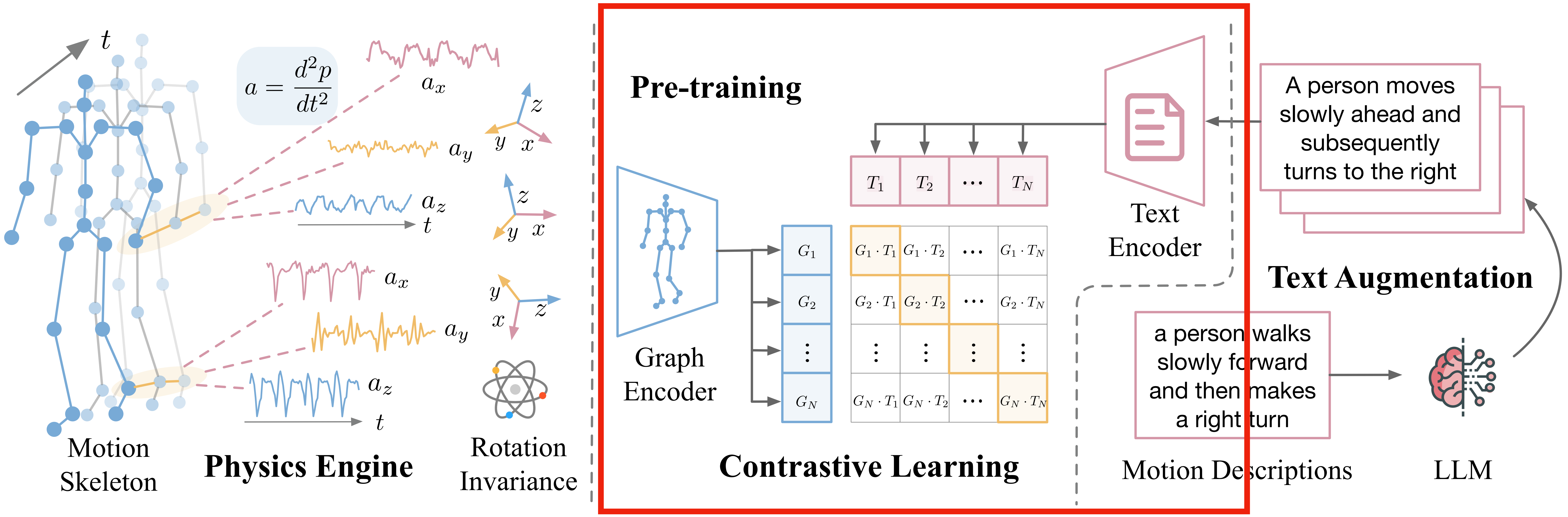

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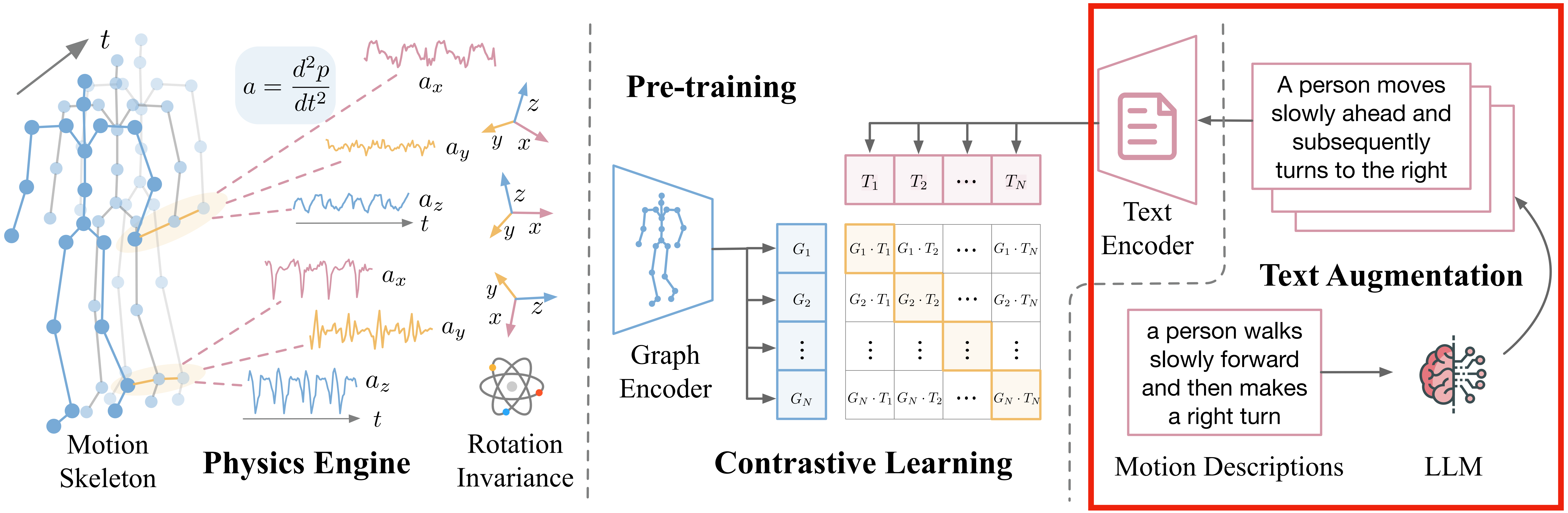
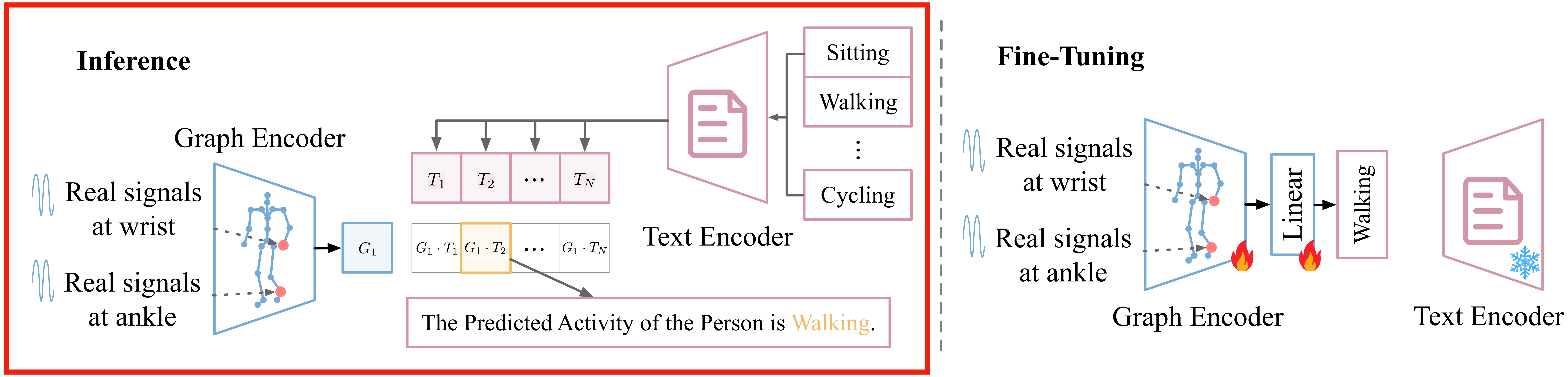


Method

Fine-tuning and Inference

- Inference: compare the similarity scores with all label candidates
- Fine-tuning: cross entropy



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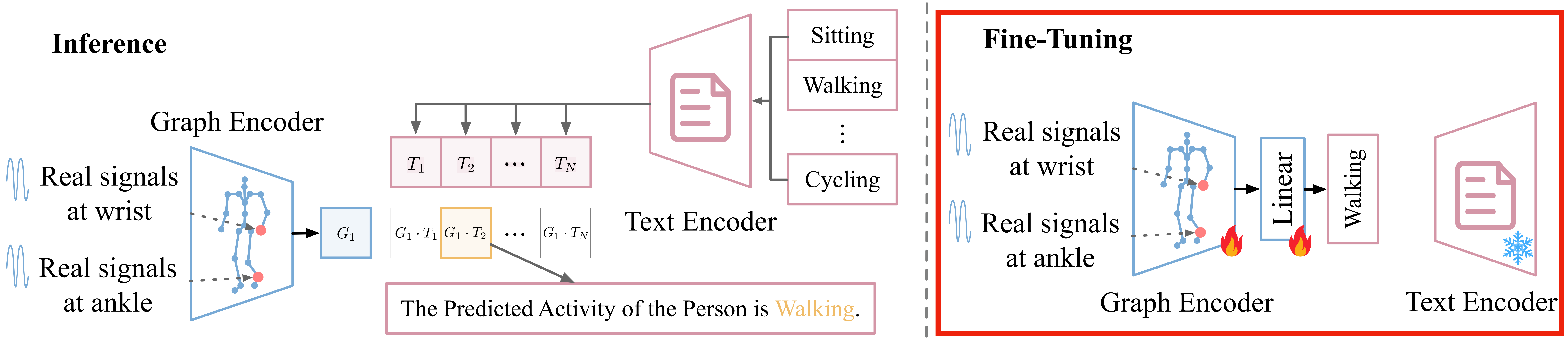


Experiments

Datasets

- State-of-the-art performance on 18 HAR benchmark datasets
    - 8 easy datasets (<10), 8 medium datasets (10-20), 2 hard datasets (> 20)

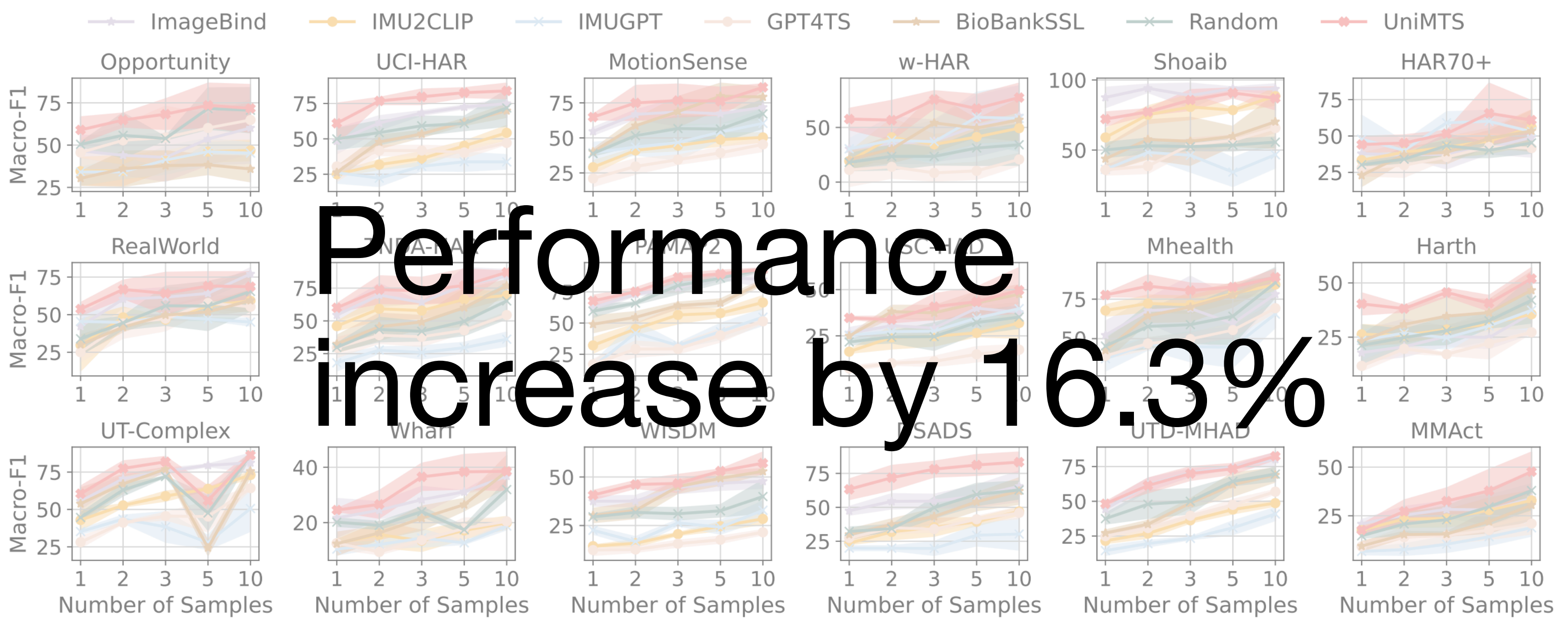
Experiments

Main Results

- State-of-the-art performance on 18 HAR benchmark datasets
  - 8 easy datasets (<10), 8 medium datasets (10-20), 2 hard datasets (> 20)

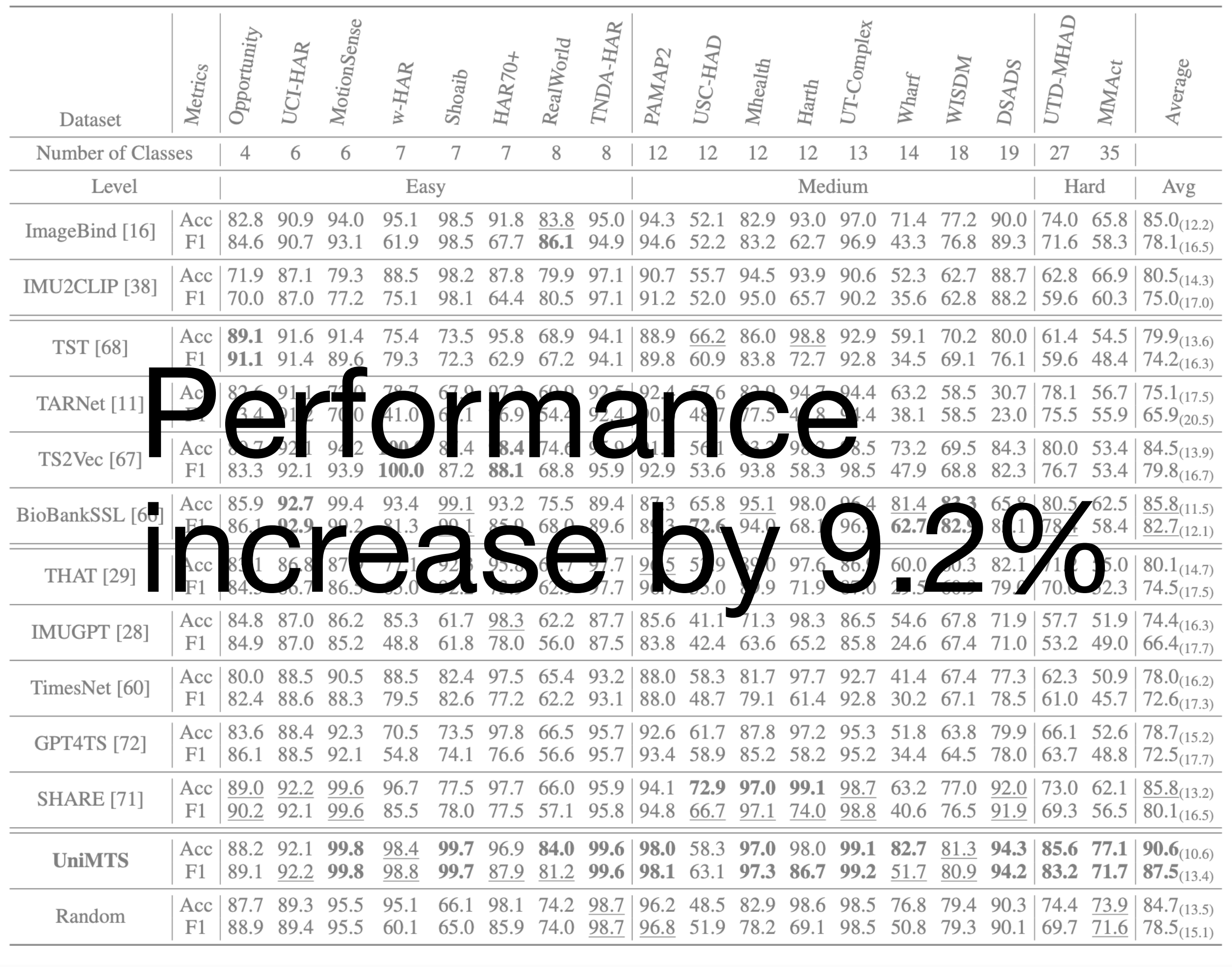
Performance increase by 340%

Zero-shot Setting



Performance increase by 16.3%

Few-shot Setting



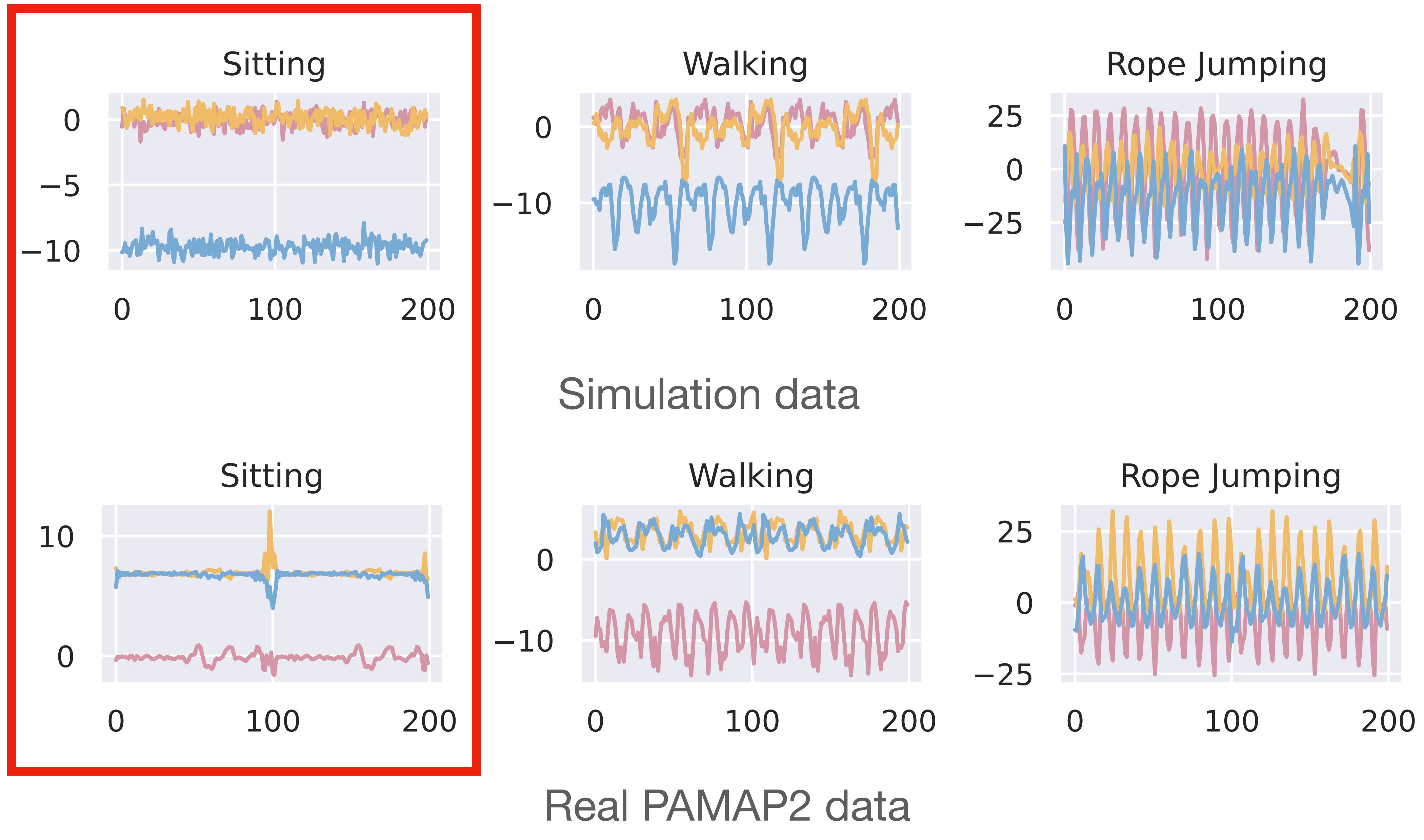
Performance increase by 9.2%

Full-shot setting

Experiments

Visualizations

- Simulated data have similar patterns as real data



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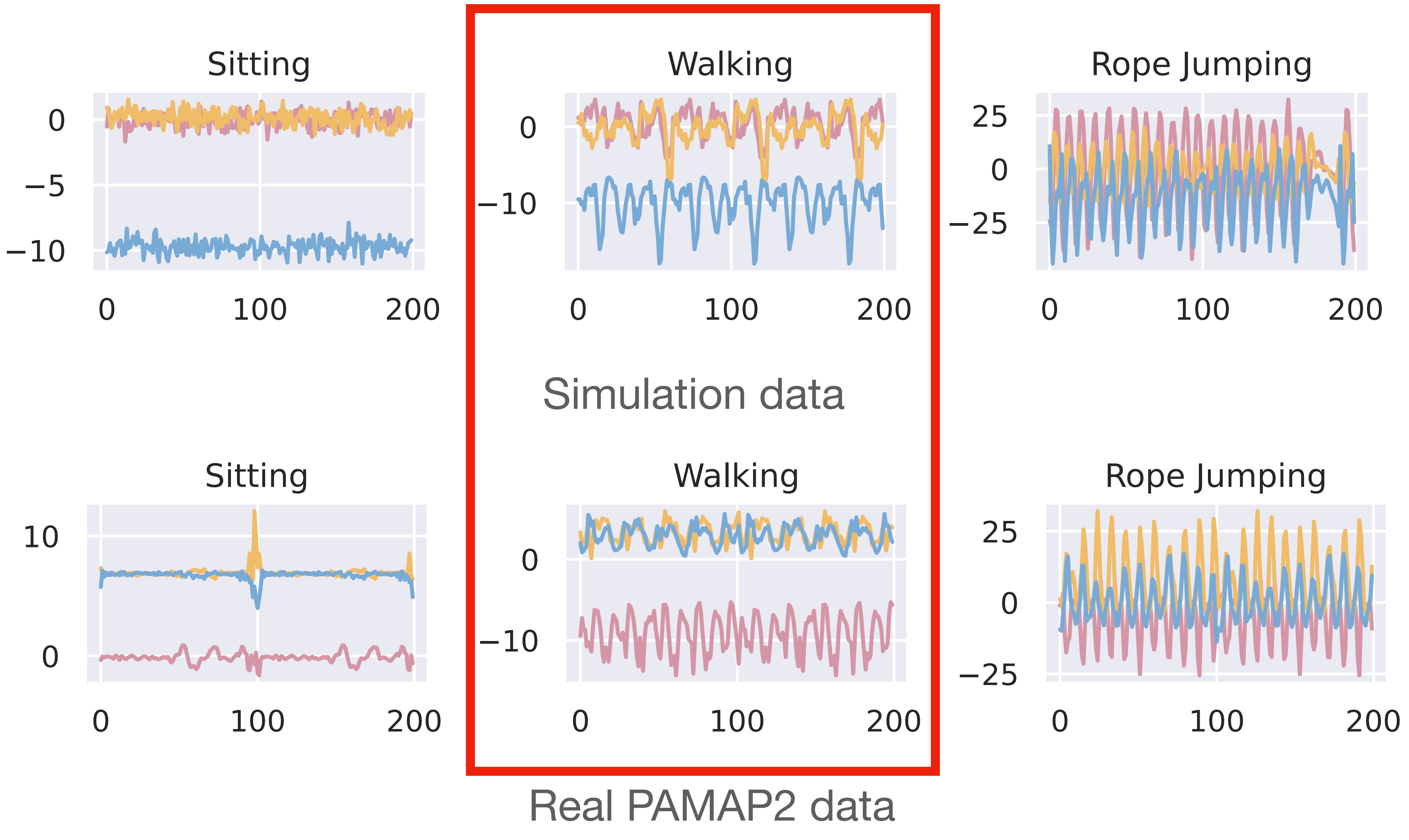

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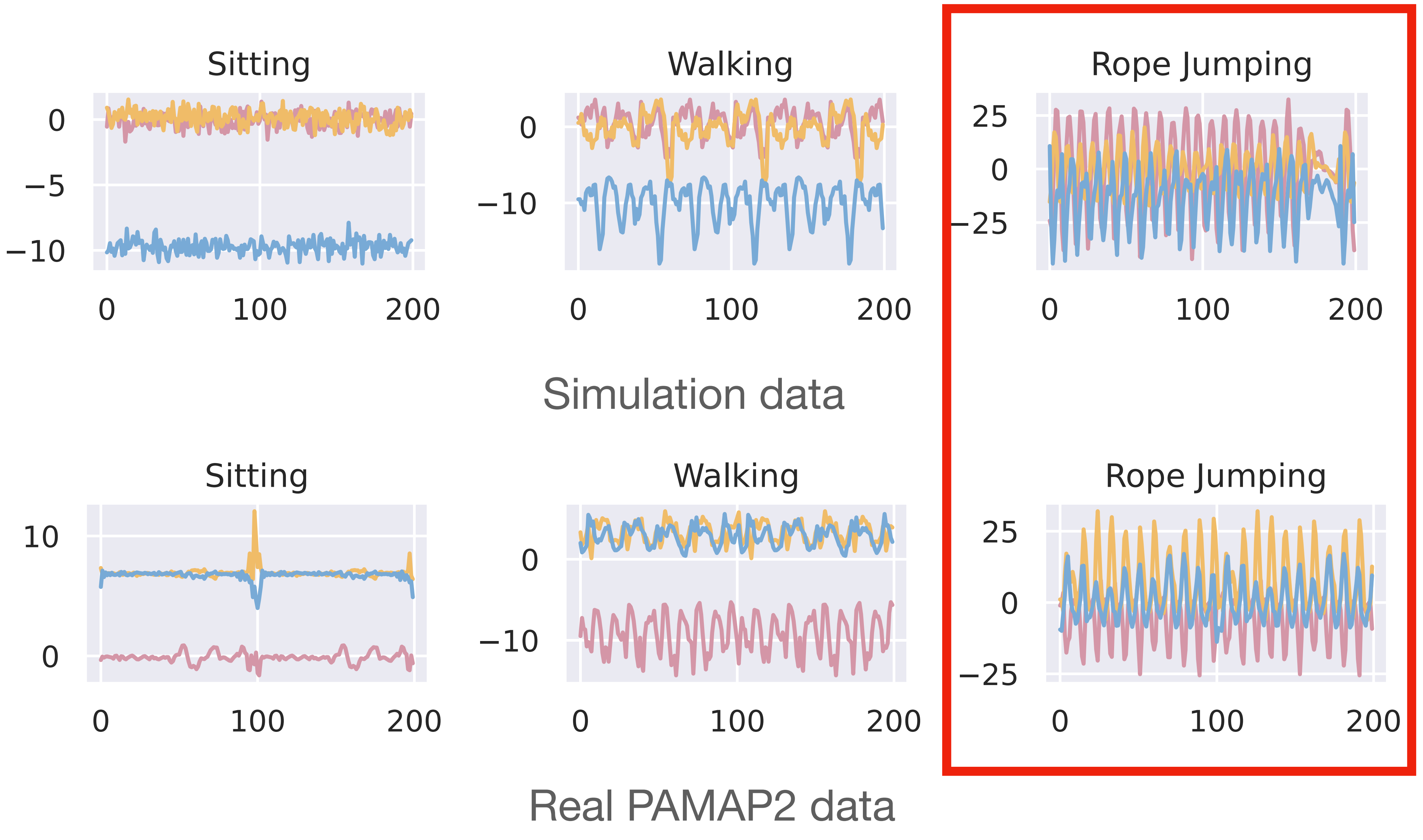
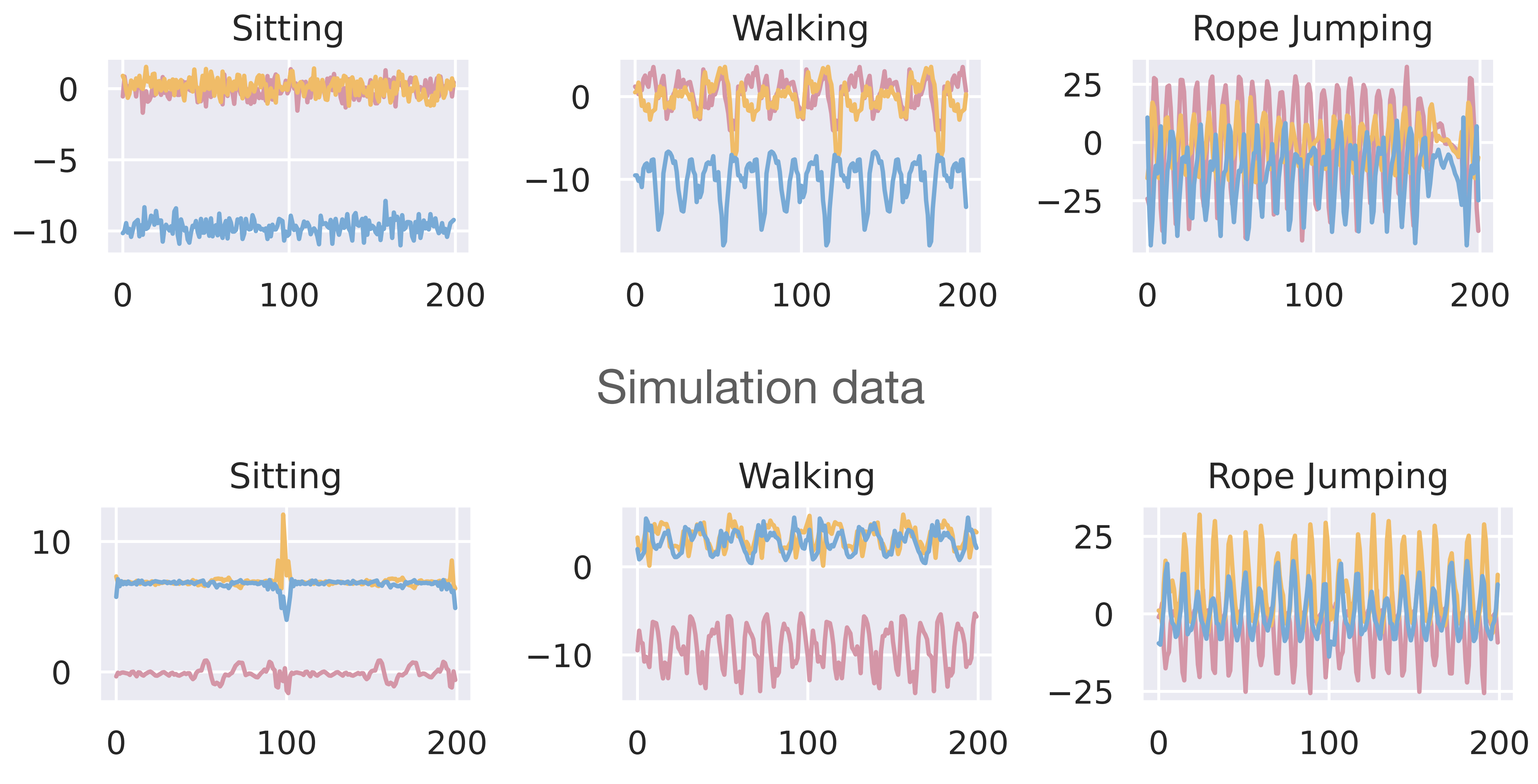


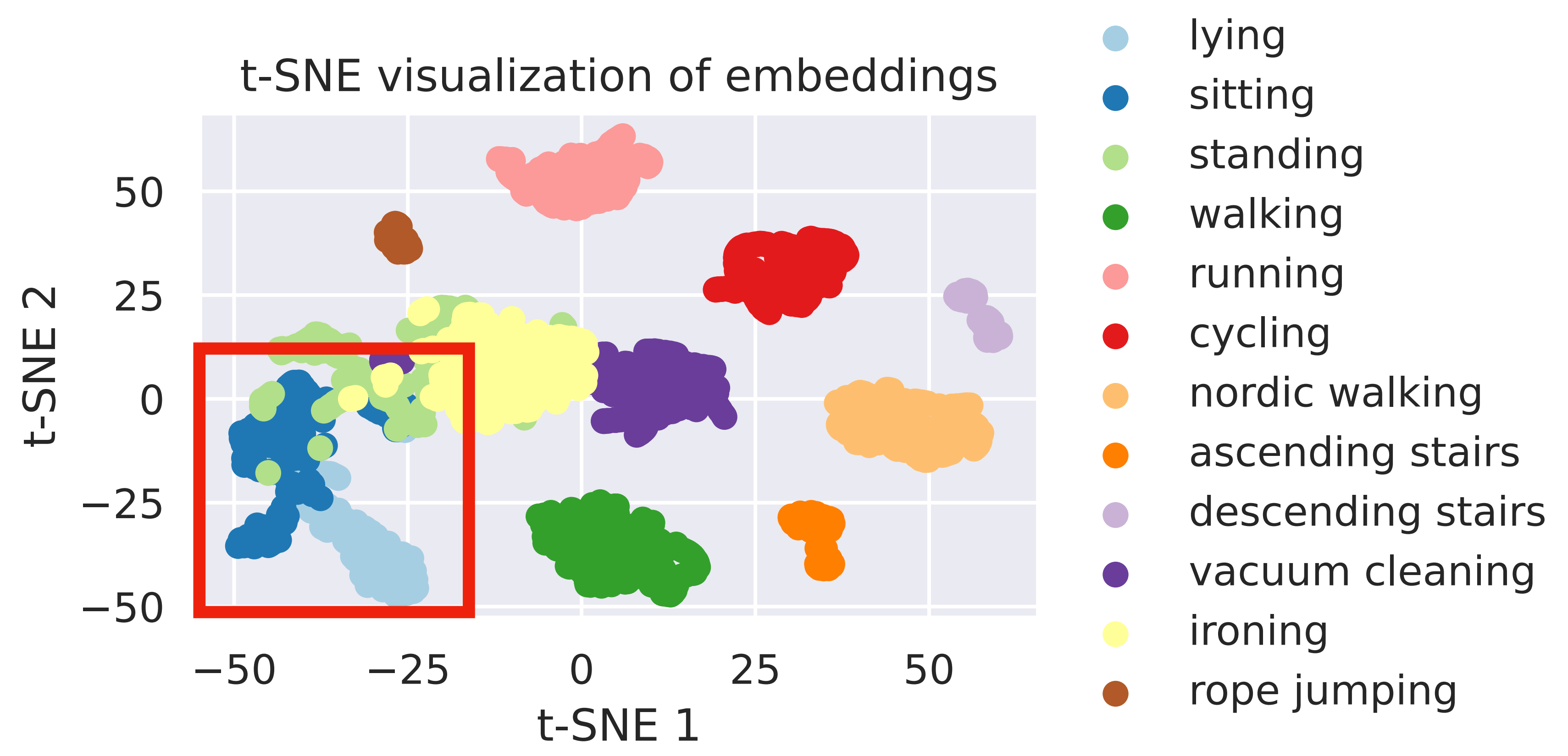
Experiments
Visualizations

- Simulated data have similar patterns as real data
- Contrastive pre-training learns the semantics of time series data



Simulation data

Real PAMAP2 data



Semantic learning

Experiments

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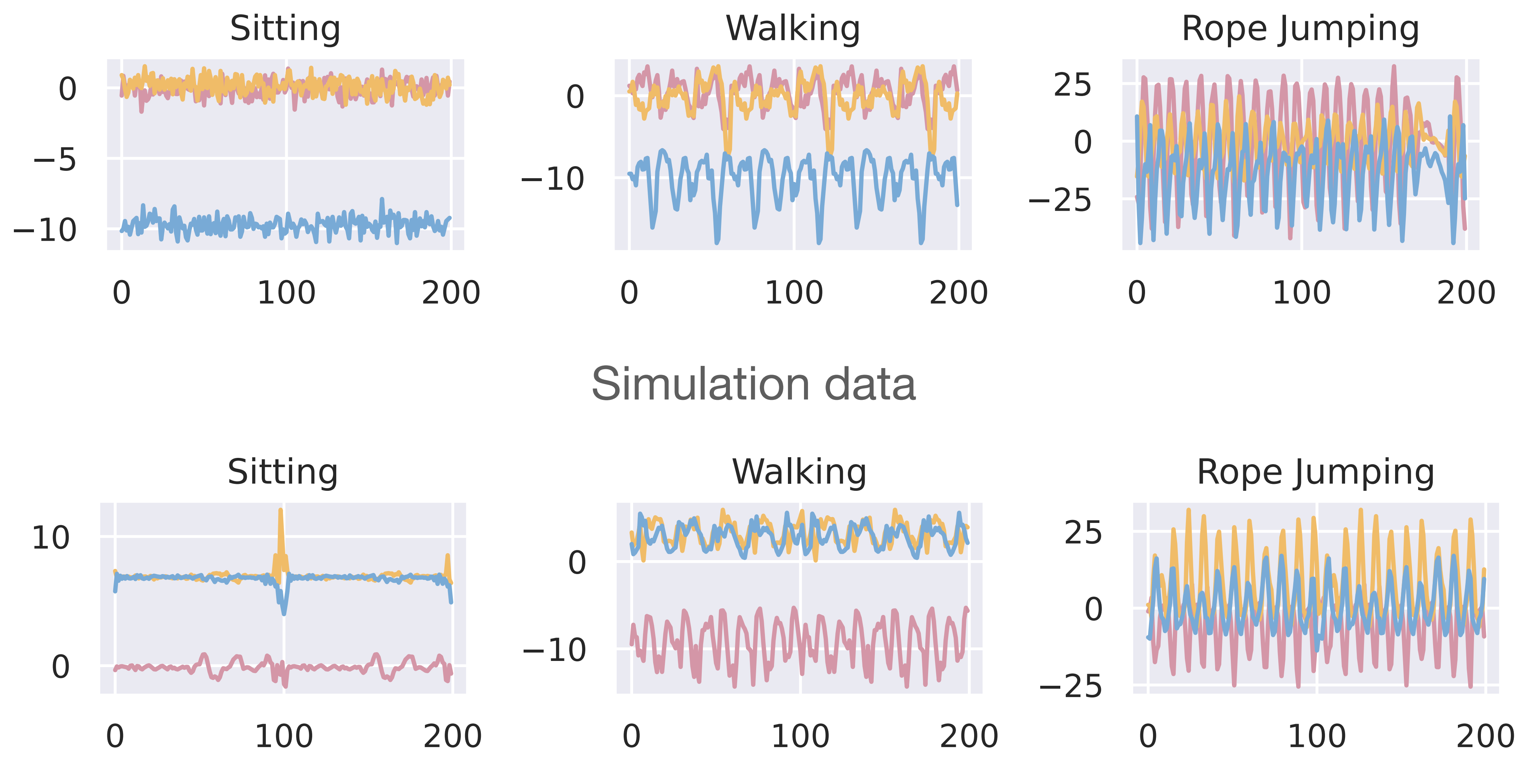

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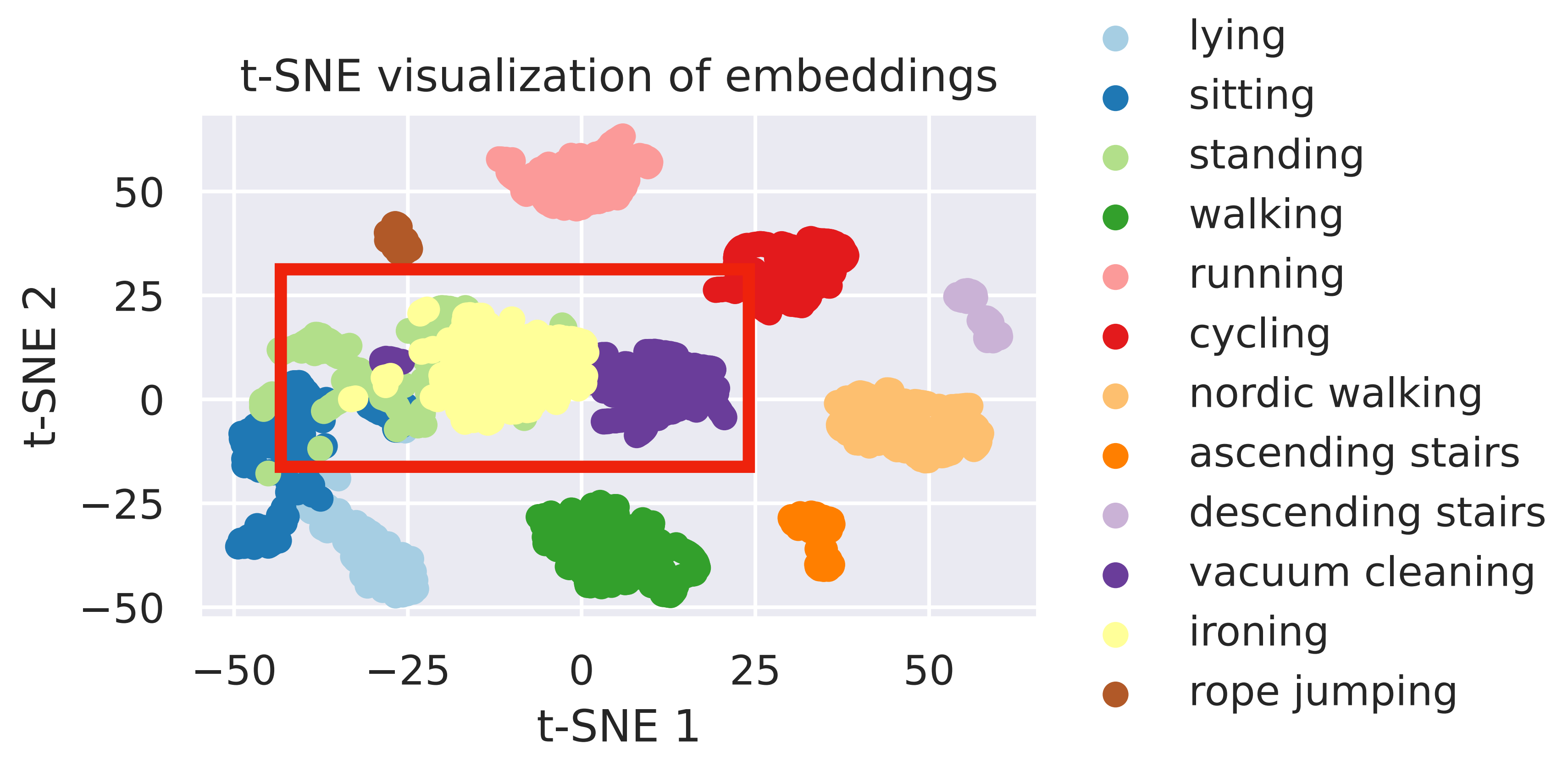

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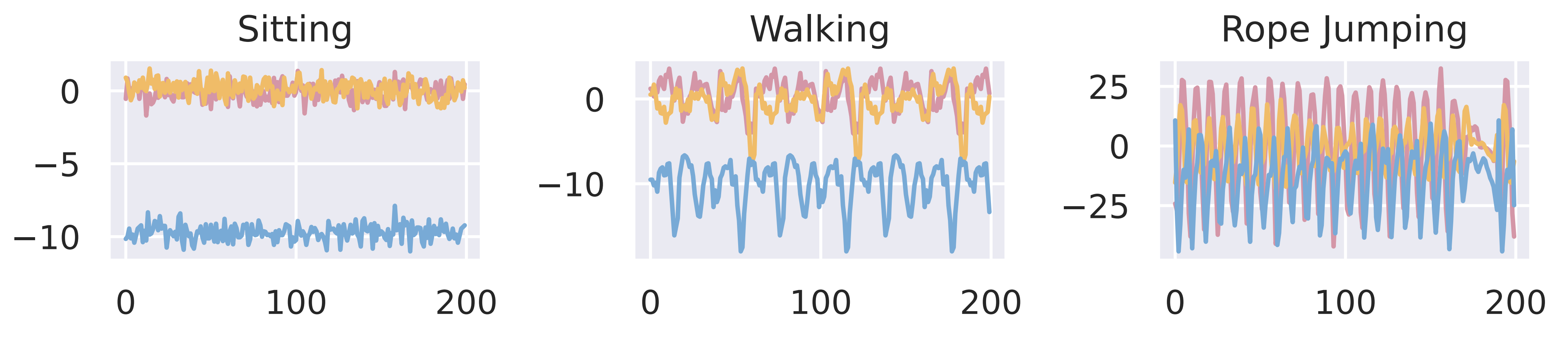

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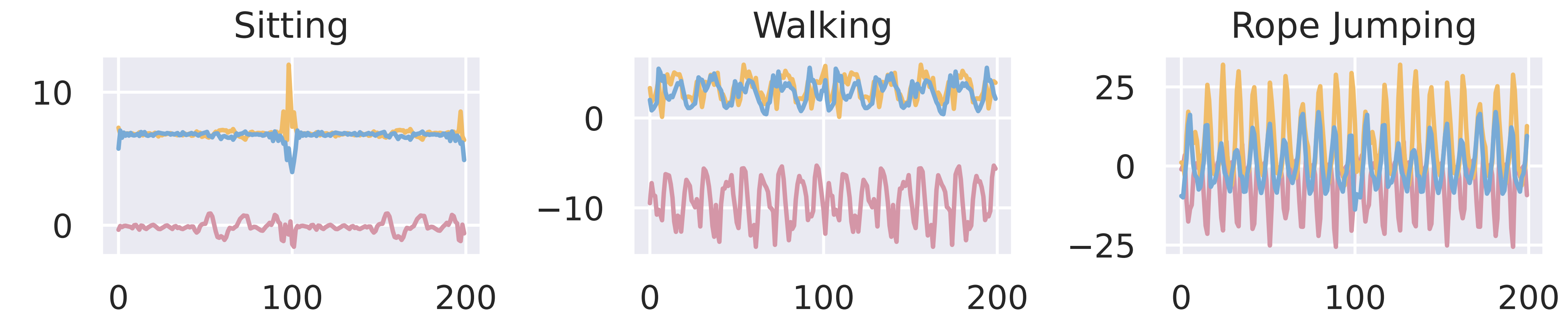

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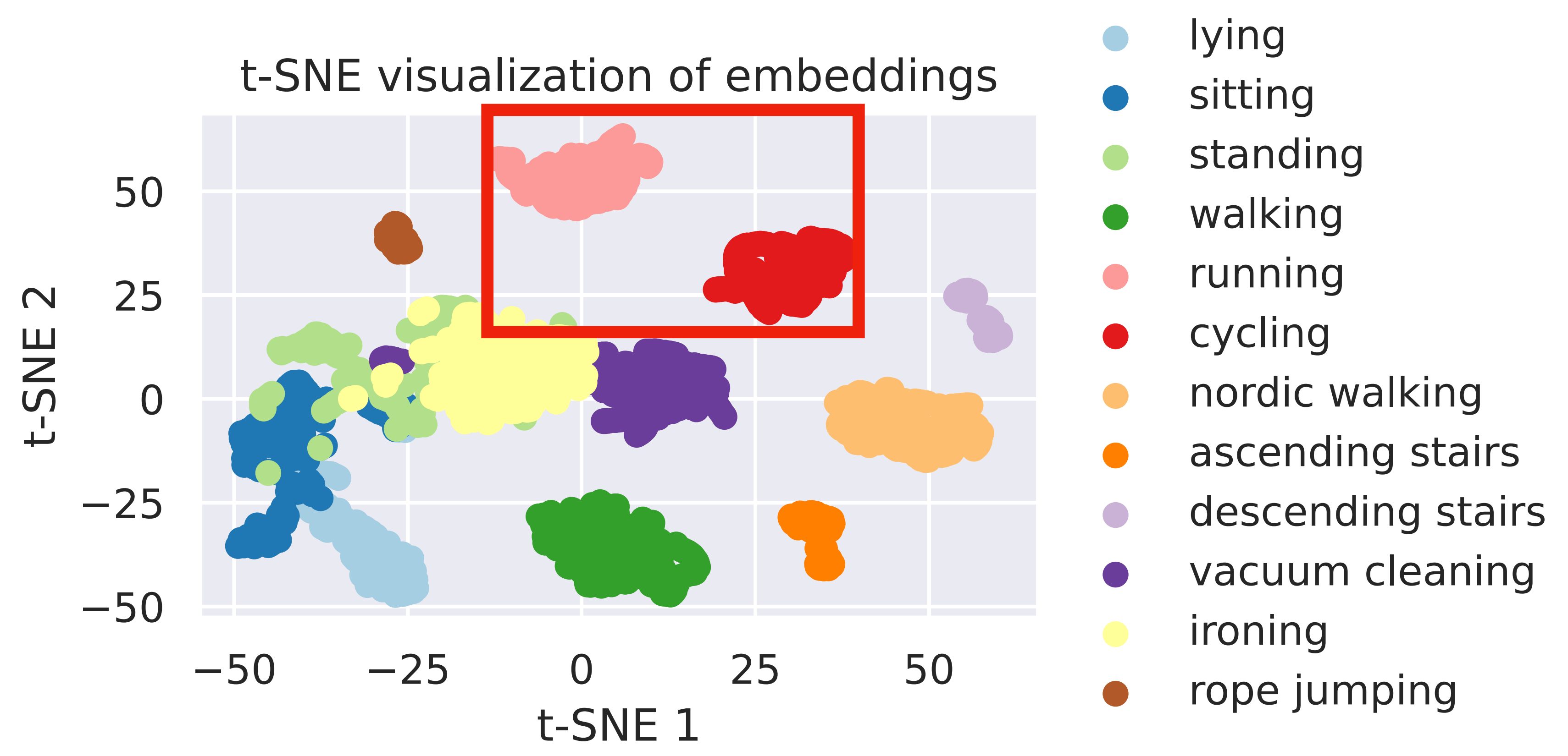
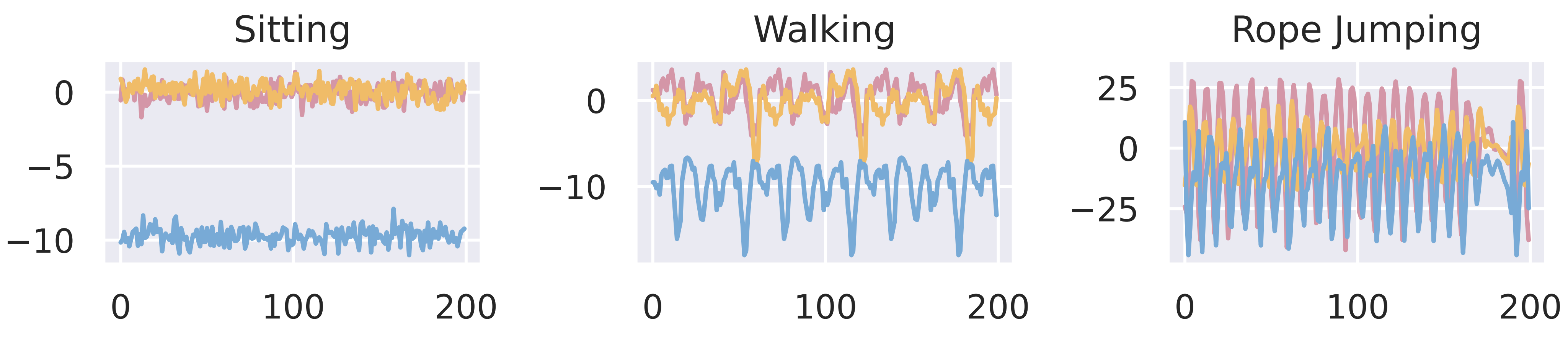


Semantic learning

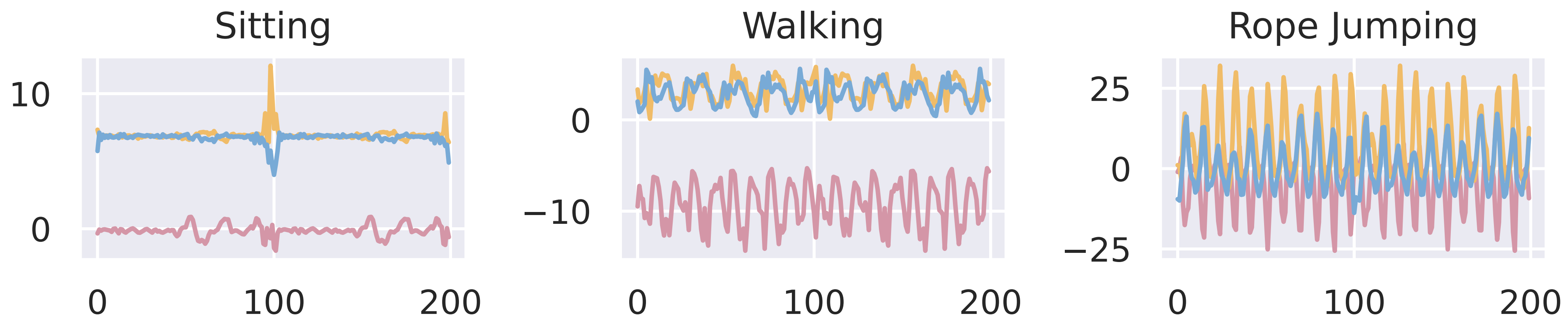
Experiments

Generalization to New Activities

- Simulated data have similar patterns as real data
- Contrastive pre-training learns the semantics of time series data



Simulation data



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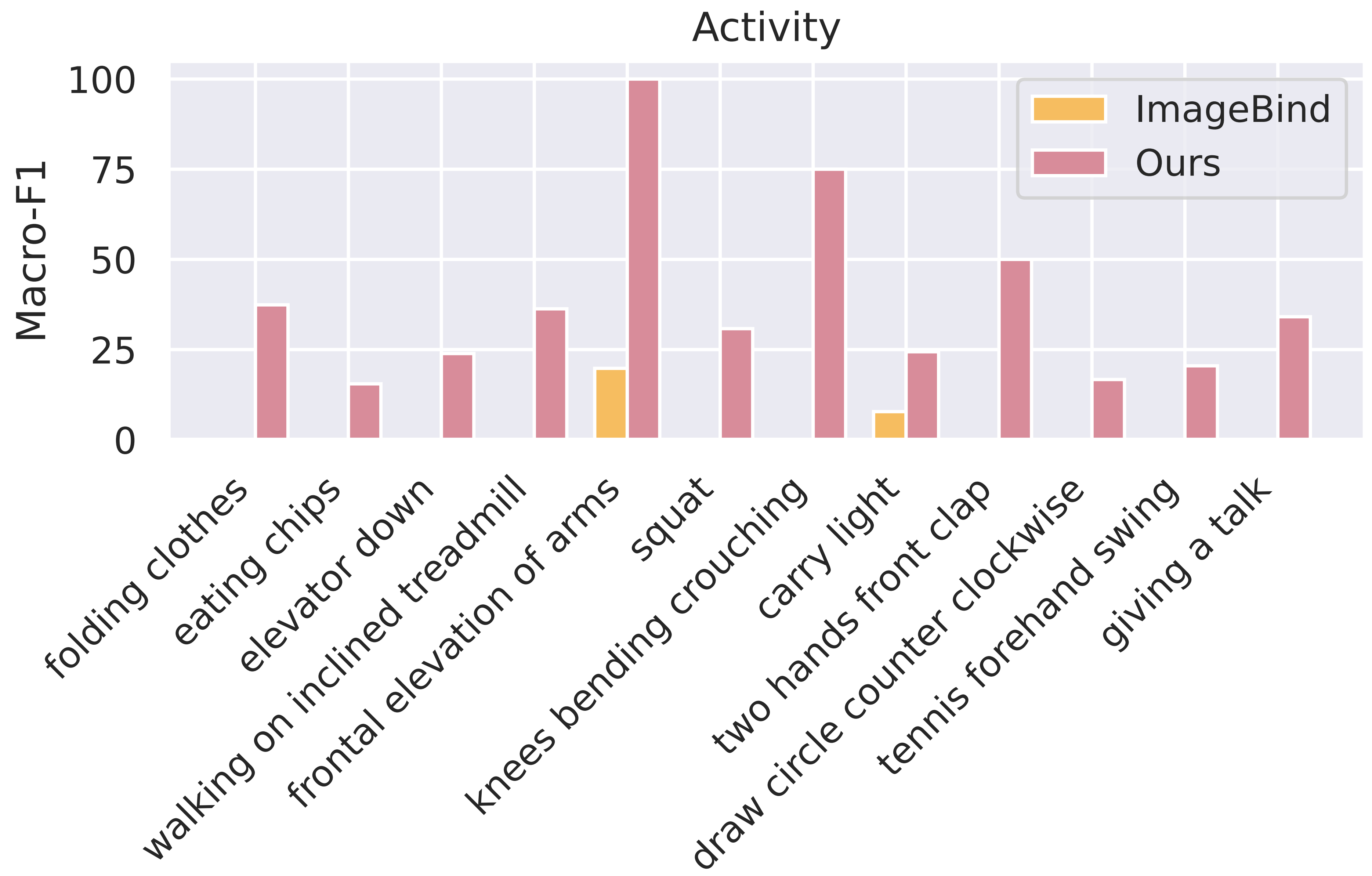

Zero-shot generalization to new activities

Thank you!

Contact: xiyuanzh@ucsd.edu

Code Release: https://github.com/xiyuanzh/UniMTS

Model Release: https://huggingface.co/xiyuanz/UniMTS