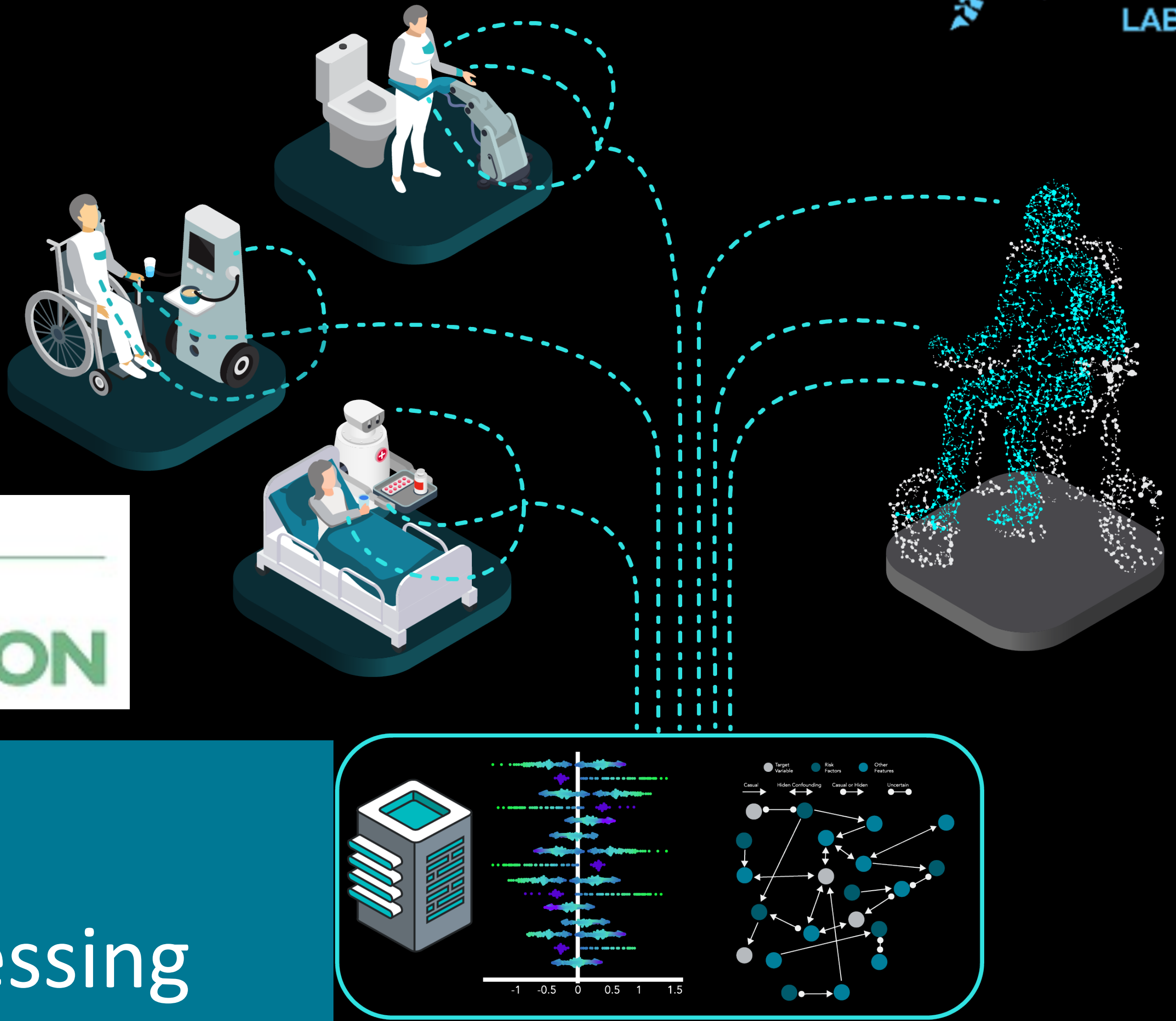
ETH zürich

Schweizer Paraplegiker Zentrum

Schweizer Paraplegiker Forschung

CAI LAB



2024 SUMMER SCHOOL ON

SSNR NEUROREHABILITATION

Workshop: Machine Learning Processing for Wearable Data in Healthcare

ETH Zürich, Switzerland | 17 June 2024

Workshop: Machine Learning Processing for Wearable Data in Healthcare

Classification and Regression Cases in Rehabilitation Event Detection

Dr Diego Paez
Mehdi Ejtehadi, Yanke Li, Bertram Fuchs

WS Day 1: Feature Extraction in Healthcare Data for ML Modelling

Content and Learning Outcomes:

1. Healthcare monitoring and data in the rehabilitation process.
2. Introduction to learning from patient data.
    1. Classification algorithms: Basics of boundaries and similarity metrics in latent spaces (reduced dimensions)
3. Time series data preprocessing and classification methods
    1. Preprocessing steps: Imputation, Labelling check,
4. Tutorial with multimodal time-series data in activities of daily living.
    1. Introduction to the dataset – scai-sensei
    2. Pre-processing steps: .
    3. Toolbox for feature extraction
    4. Decisions in pre-processing (windowing, normalization, quality)

WS Day 2:
Evaluation Metrics for Acceptable Machine Learning

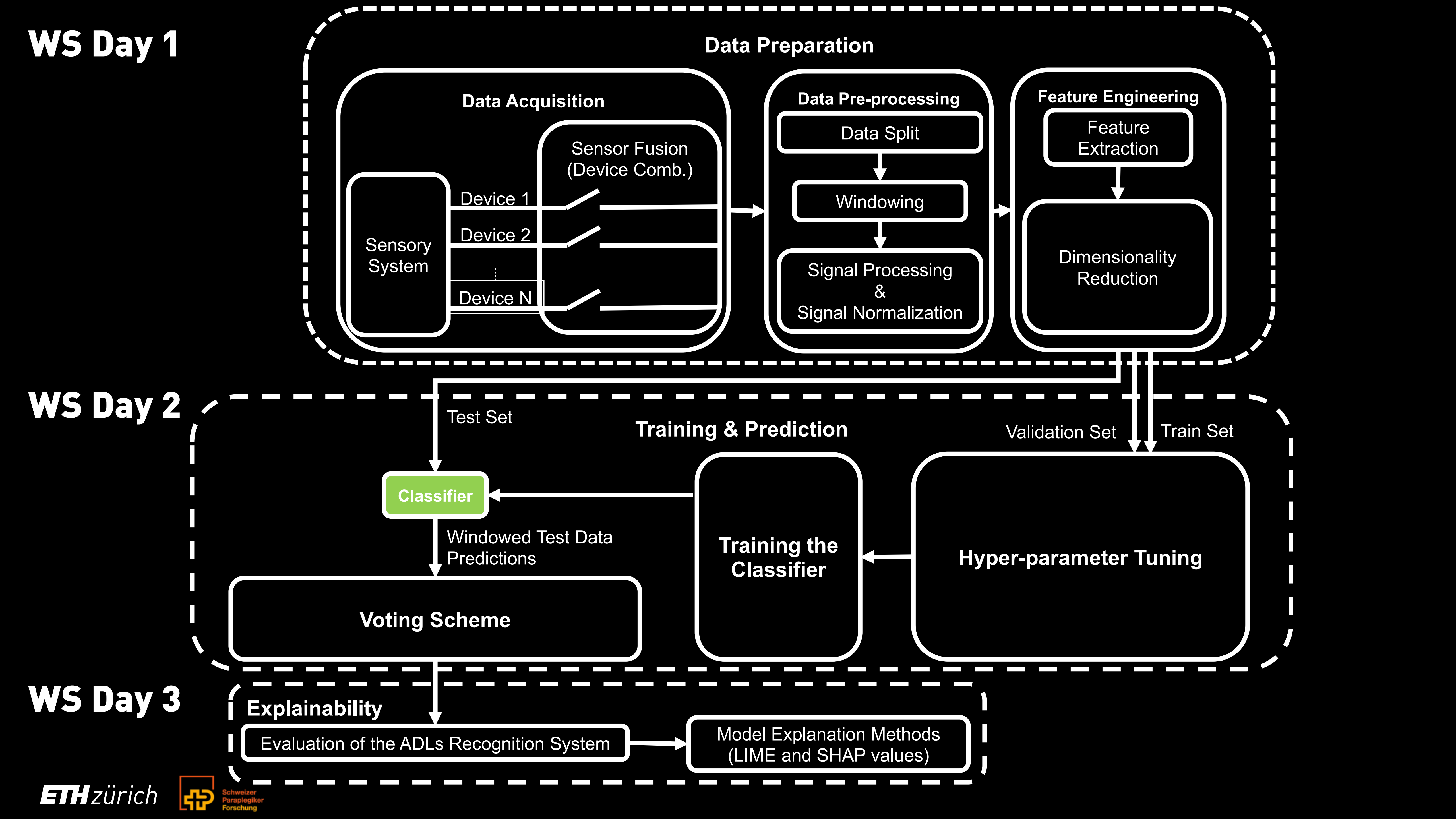
Content and Learning Outcomes:

1. Data-driven model principles: Bias variance trade-off, model training, and generalization. Yanke Li
2. An introduction to data quality assessment and model evaluation metrics with a focus on explainability, robustness and generalization. Diego Paez
3. Tutorial for model training and feature selection methods in time-series
    1. Feature Selection Methods
    2. Building Classification Models

WS Day 3:
Learning Interpretability and Explainability Metrics

Content and Learning Outcomes:

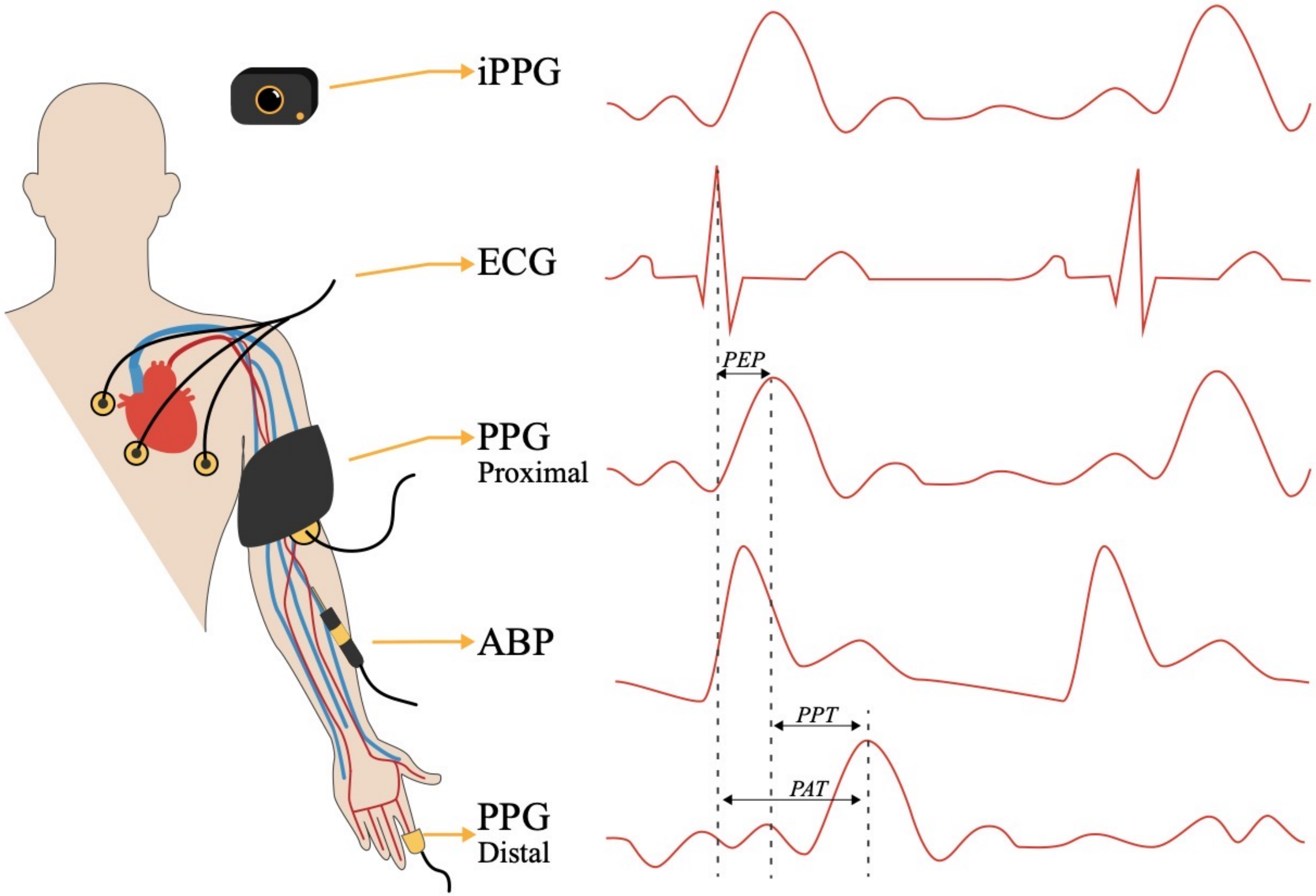
1. Transparency and Explainability in AI for Healthcare
2. Causal feature selection in time series (Markov Blanket) as an explainability method for Robust transferability across datasets. Yanke Li
3. Tutorial for explainable methods in classification:
   1. LIME
   2. SHAP Values
4. Presentations by groups:
   1. Model results, explainability and generalization


WS Day 1
Data Preparation
Data Acquisition
Sensory System
Device 1
Device 2
Device N
Sensor Fusion (Device Comb.)
Data Pre-processing
Data Split
Windowing
Signal Processing & Signal Normalization
Feature Engineering
Feature Extraction
Dimensionality Reduction
WS Day 2
Test Set
Training & Prediction
Validation Set
Train Set
Classifier
Windowed Test Data Predictions
Training the Classifier
Hyper-parameter Tuning
Voting Scheme
WS Day 3
Explainability
Evaluation of the ADLs Recognition System
Model Explanation Methods (LIME and SHAP values)
ETH zürich
Schweizer Paraplegiker Forschung

Self Introduction

Group Building

Periodic Time Series

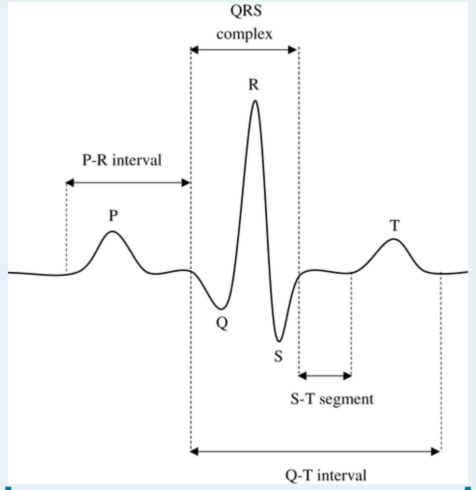


A. Cisnal, I. Podder, L. Grossman, K. Dherman, and D. Paez-Granados. "Standardizing Cuffless Blood Pressure Research: A Systematic Review of Methods and Reporting Frameworks". Under Review. 2024.

Time Series Data Problem

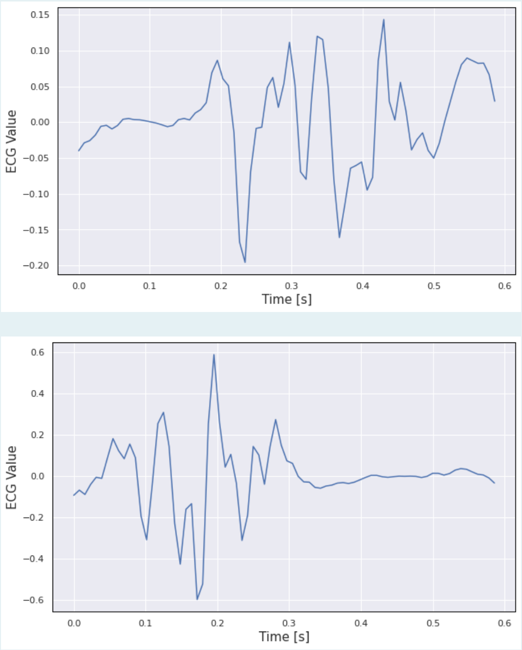
Electrocardiogram (ECG)

Theoretical ECG template



ECG template

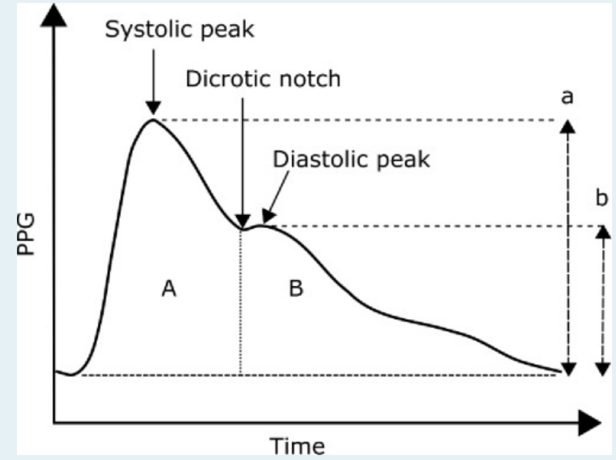
Actual ECG template



Noisy, unreliable

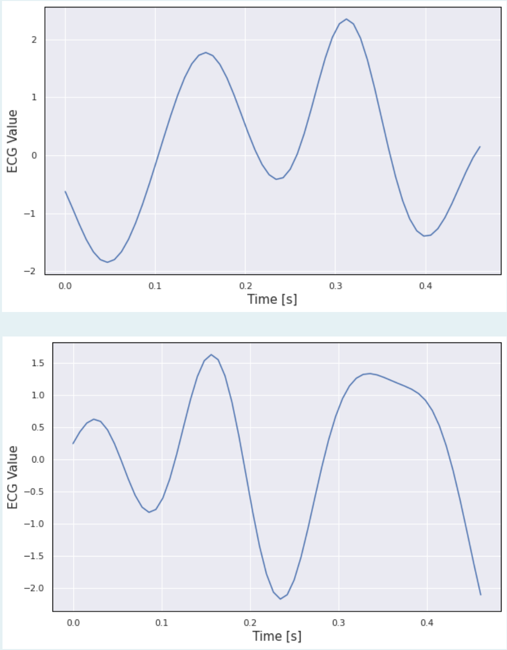
Photoplethysmogram (PPG)

Theoretical PPG template



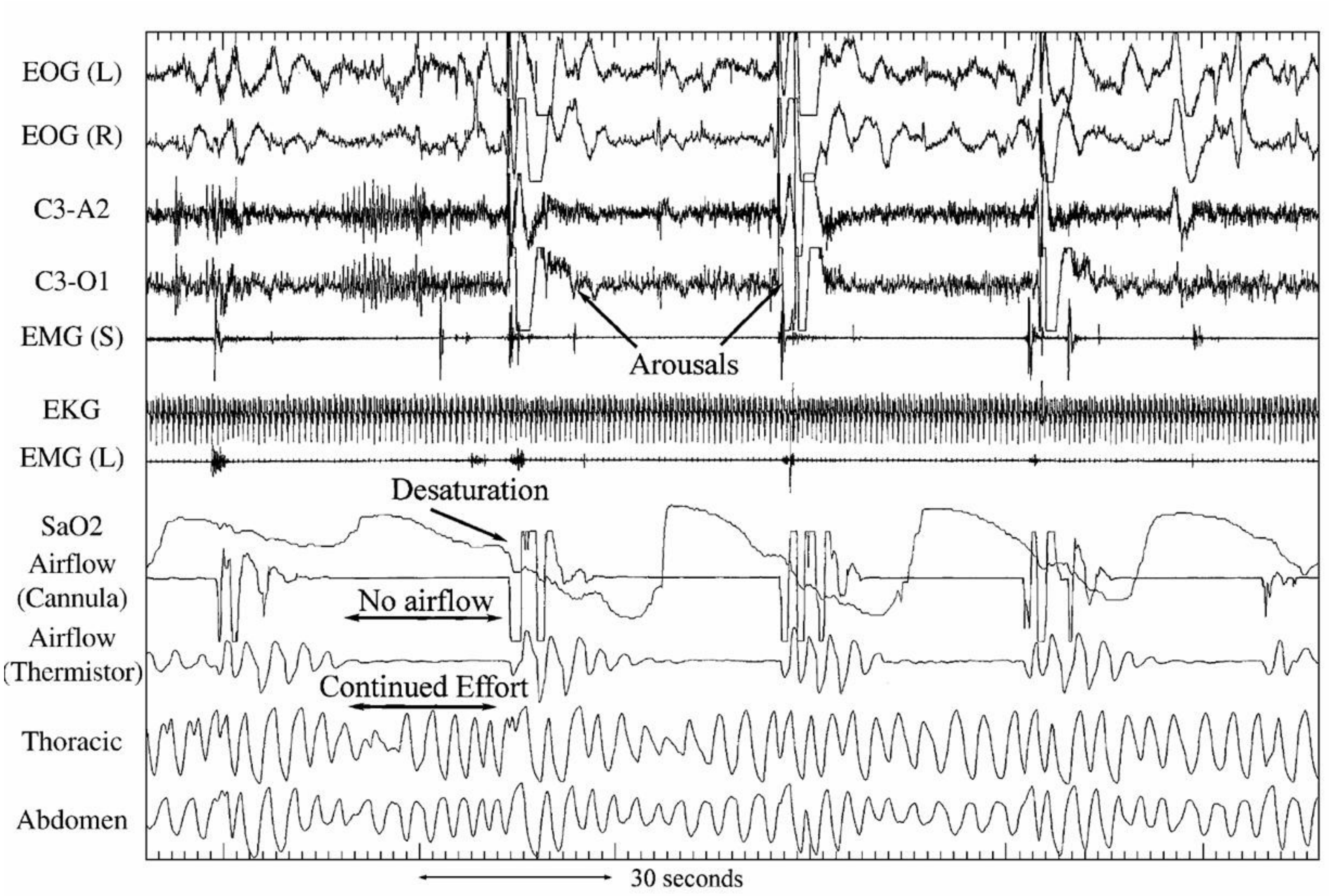
PPG template

Actual PPG template



Noisy, unreliable

Non-periodic Time Series



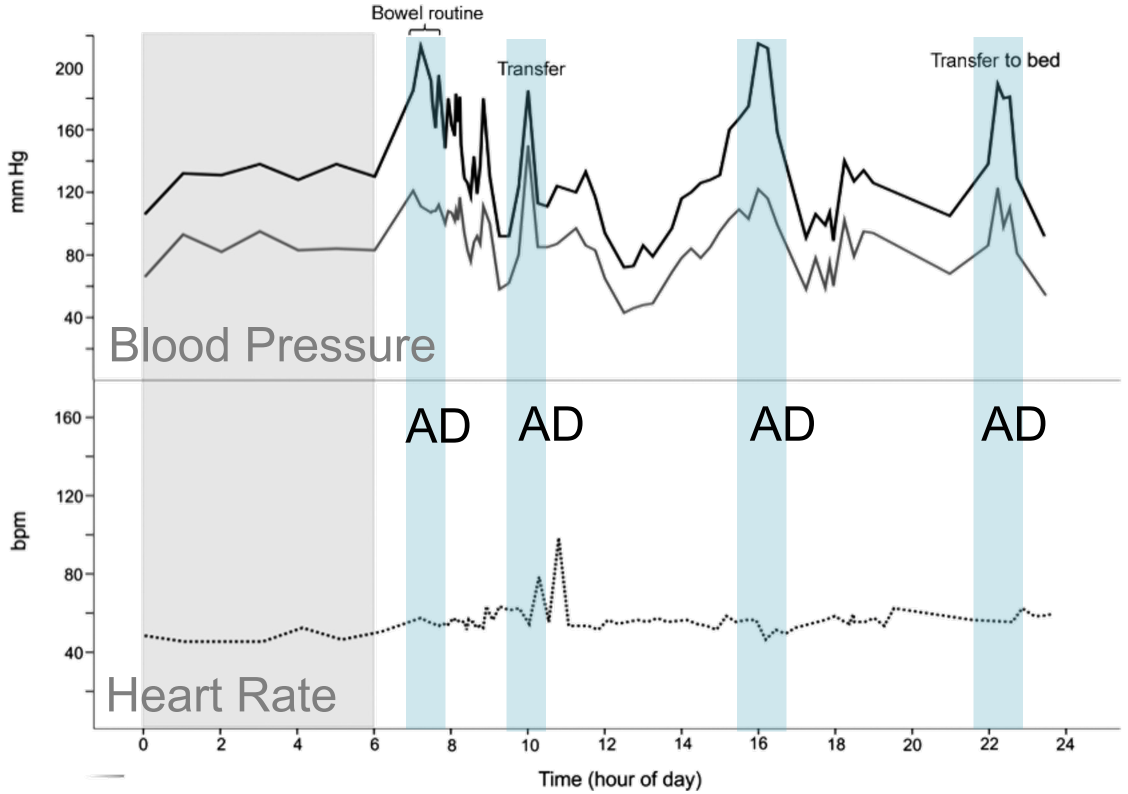
SOURCE: https://www.smart-stats.org/content/biosignals

Brain-Machine Interface

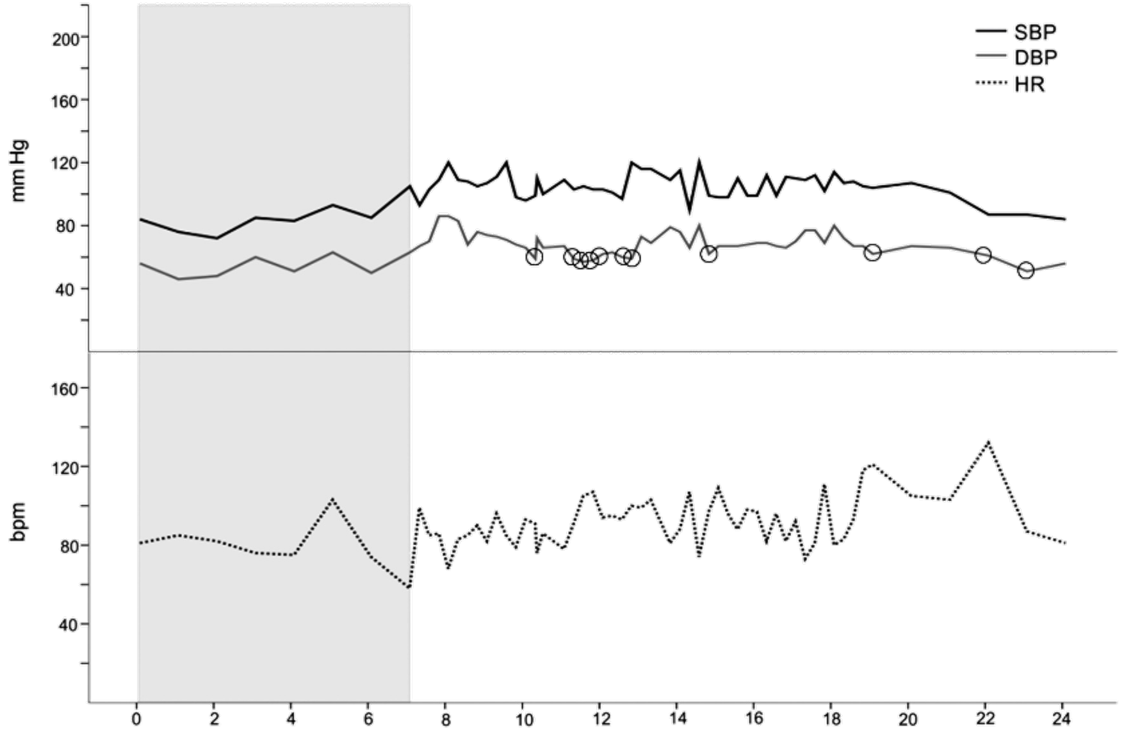
Not ready yet!

Non-Periodic Time Series

Lesson level: C5

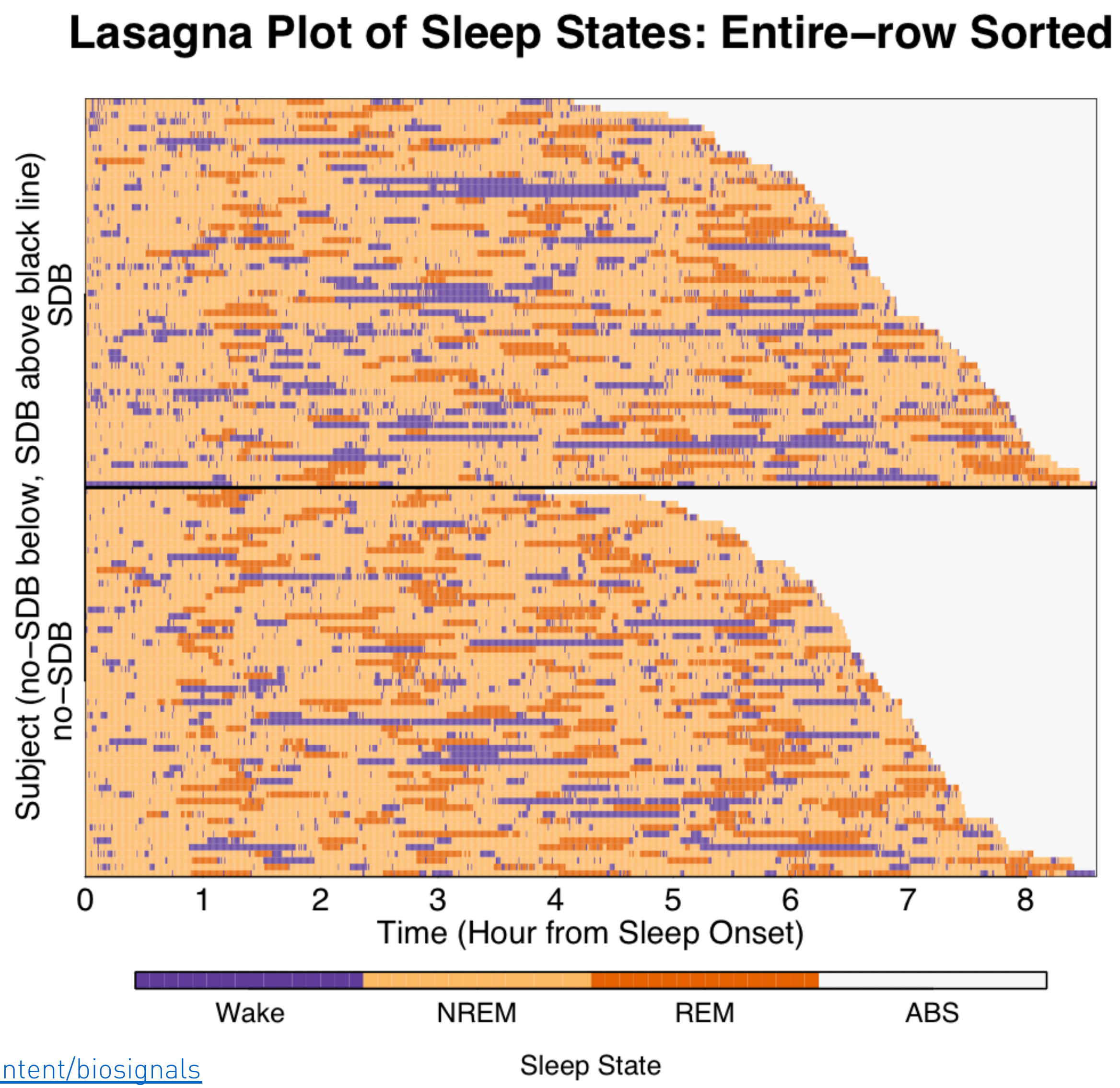


Lesson level: T4



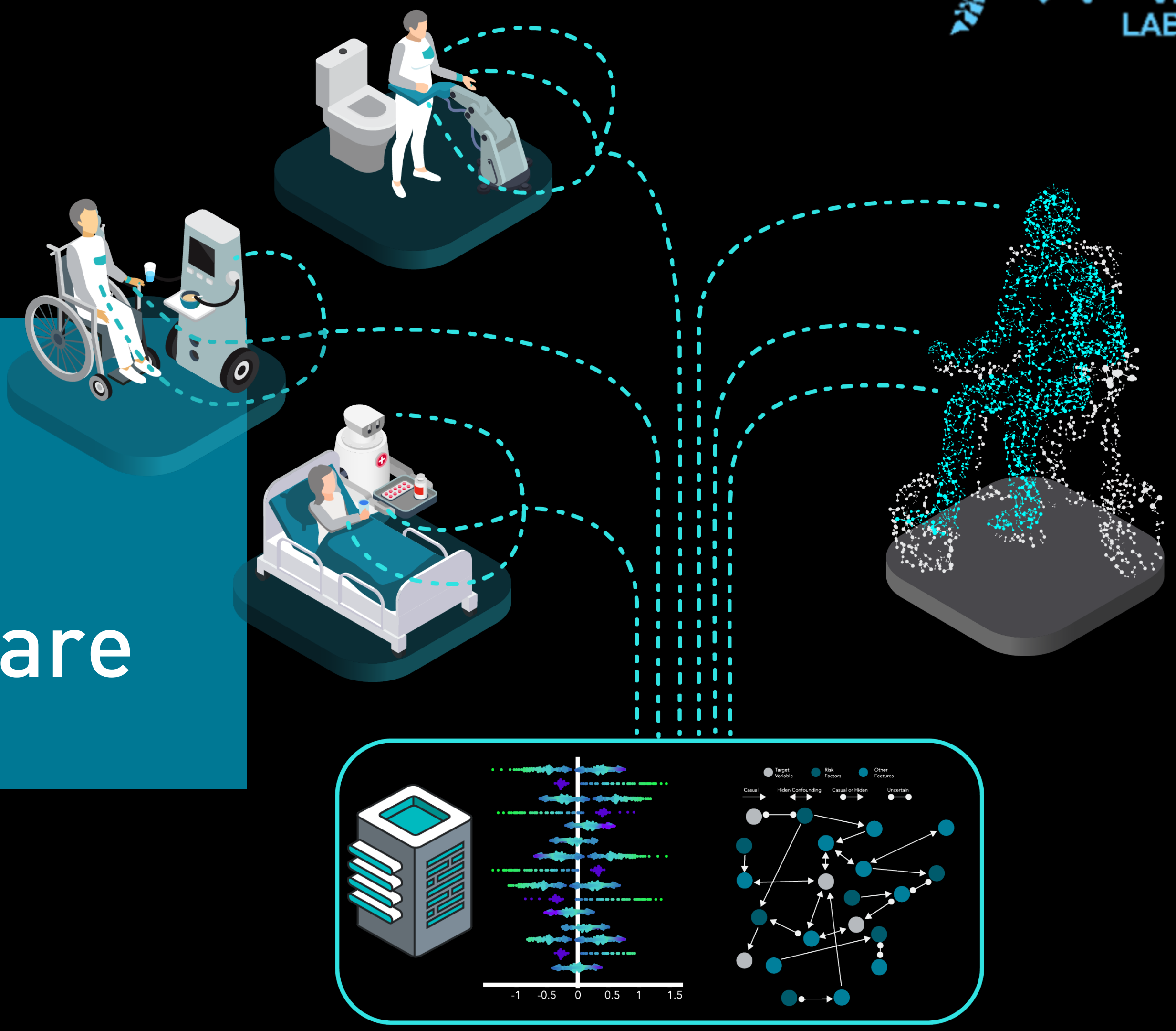
Hubli, M., Gee, C. M., & Krassioukov, A. v. (2015). Refined assessment of blood pressure instability after spinal cord injury. *American Journal of Hypertension*, *28*(2), 173–181. https://doi.org/10.1093/ajh/hpu122

Non-Periodic Time Series



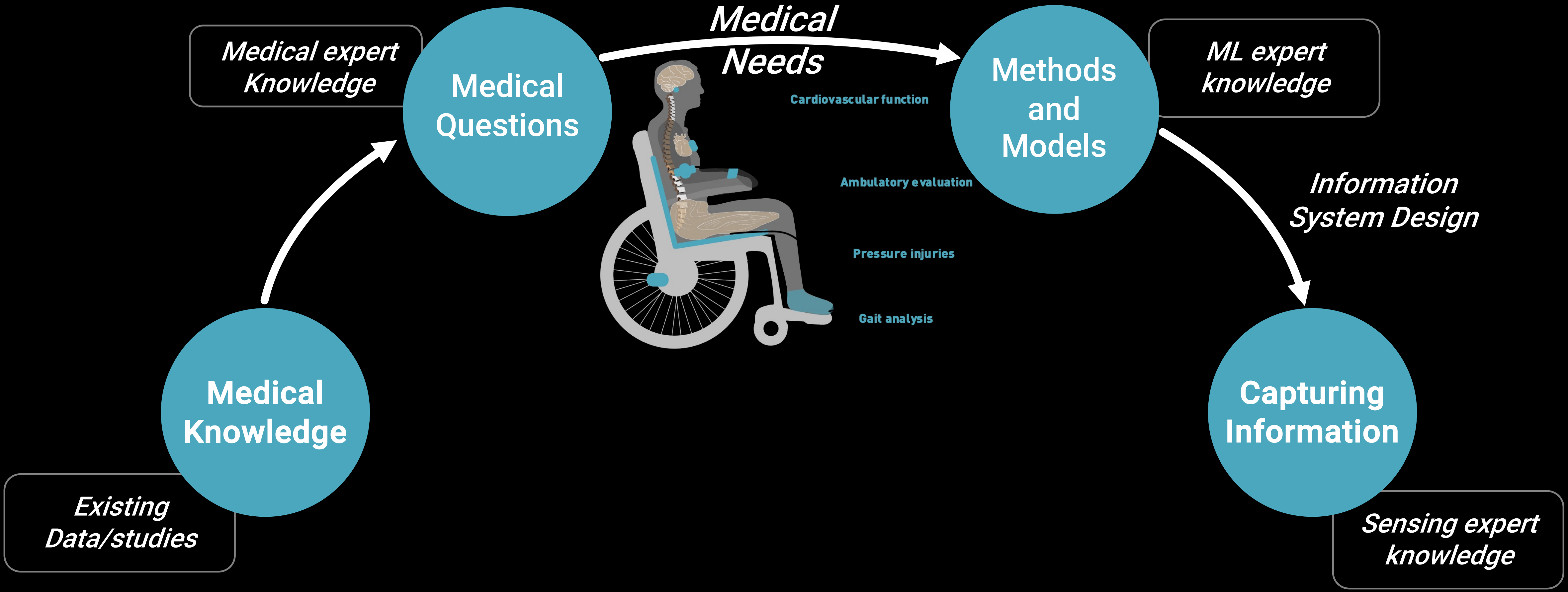
[SOURCE: https://www.smart-stats.org/content/biosignals](https://www.smart-stats.org/content/biosignals)

AI in Life-long Rehabilitation and Monitoring in Healthcare



Dr. Diego Paez-Granados
Head of SCAI Lab, ETH Zürich
Digital Health Care & Rehabilitation
Group Leader, SPF

ETH Zürich, Switzerland | 17 June 2024



Long Term Rehabilitation and Healthcare

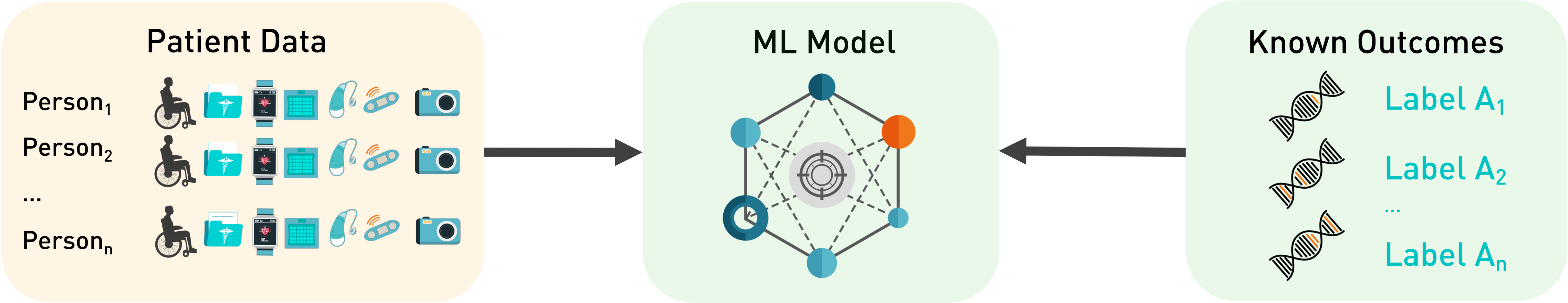
Needs during Outpatient Long-term living with Chronic Conditions

Needs during Inpatient Phase

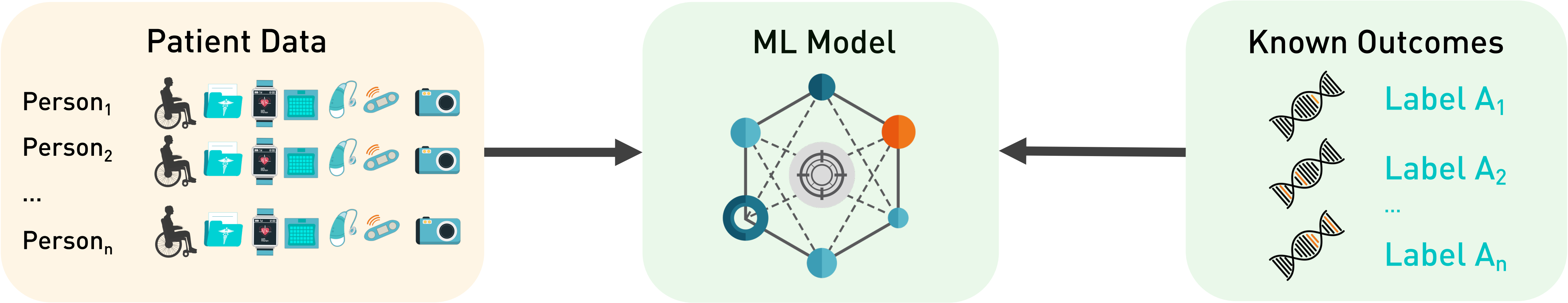
Needs during Outpatient Rehabilitation and re-integration phases

Learning from Patient Data

Machine Learning Pipeline for Medical Care

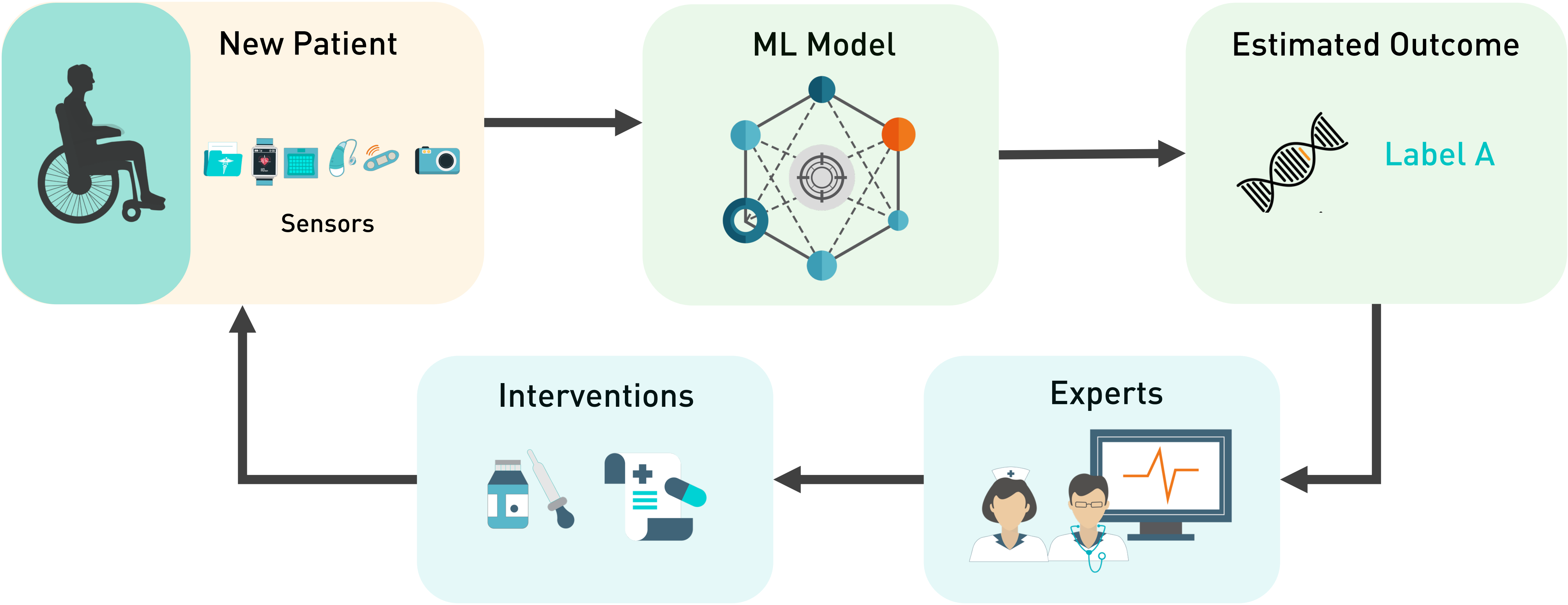


Machine Learning Pipeline for Medical Care

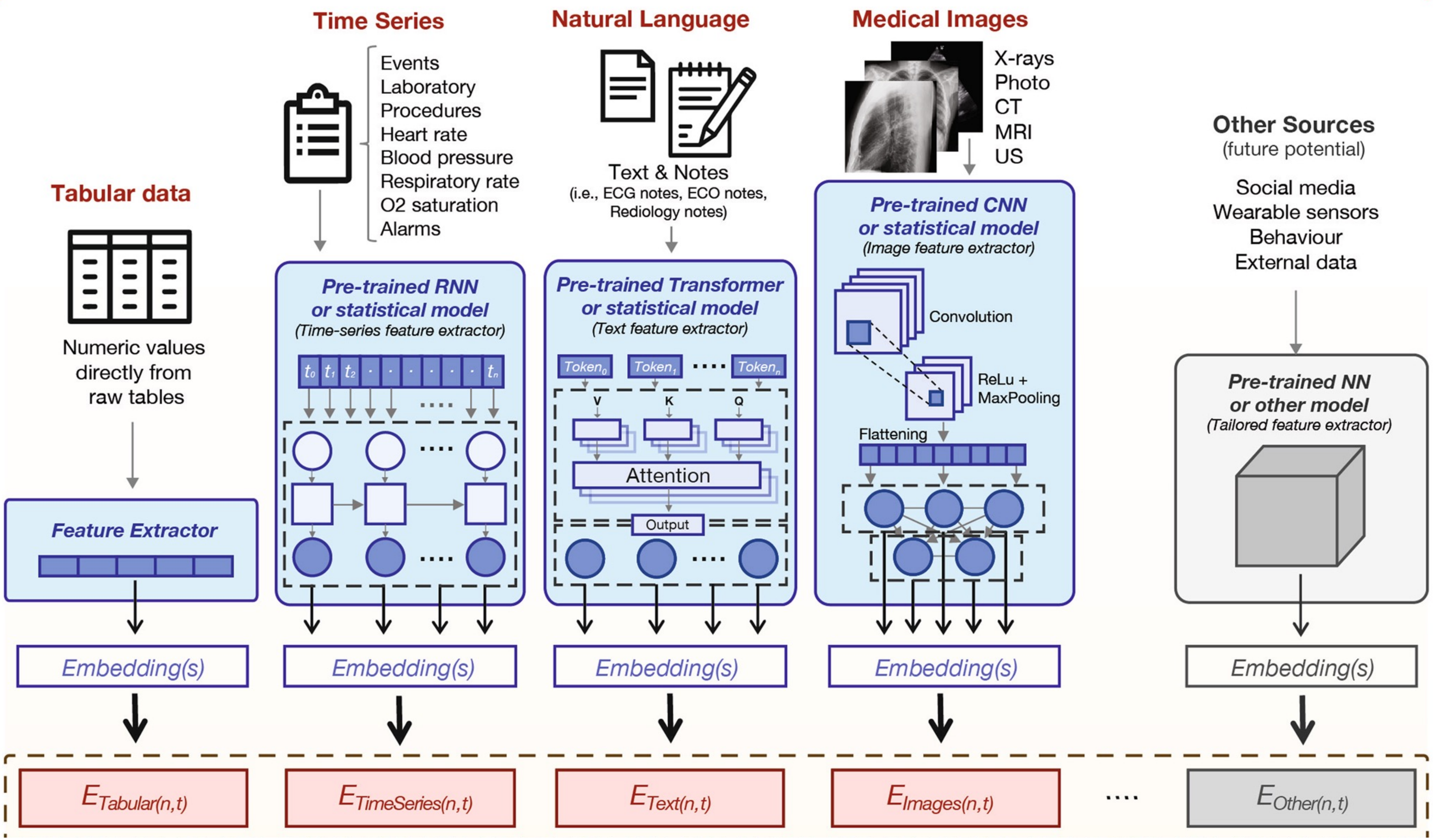


Machine Learning Pipeline for Medical Care

Ideal Case

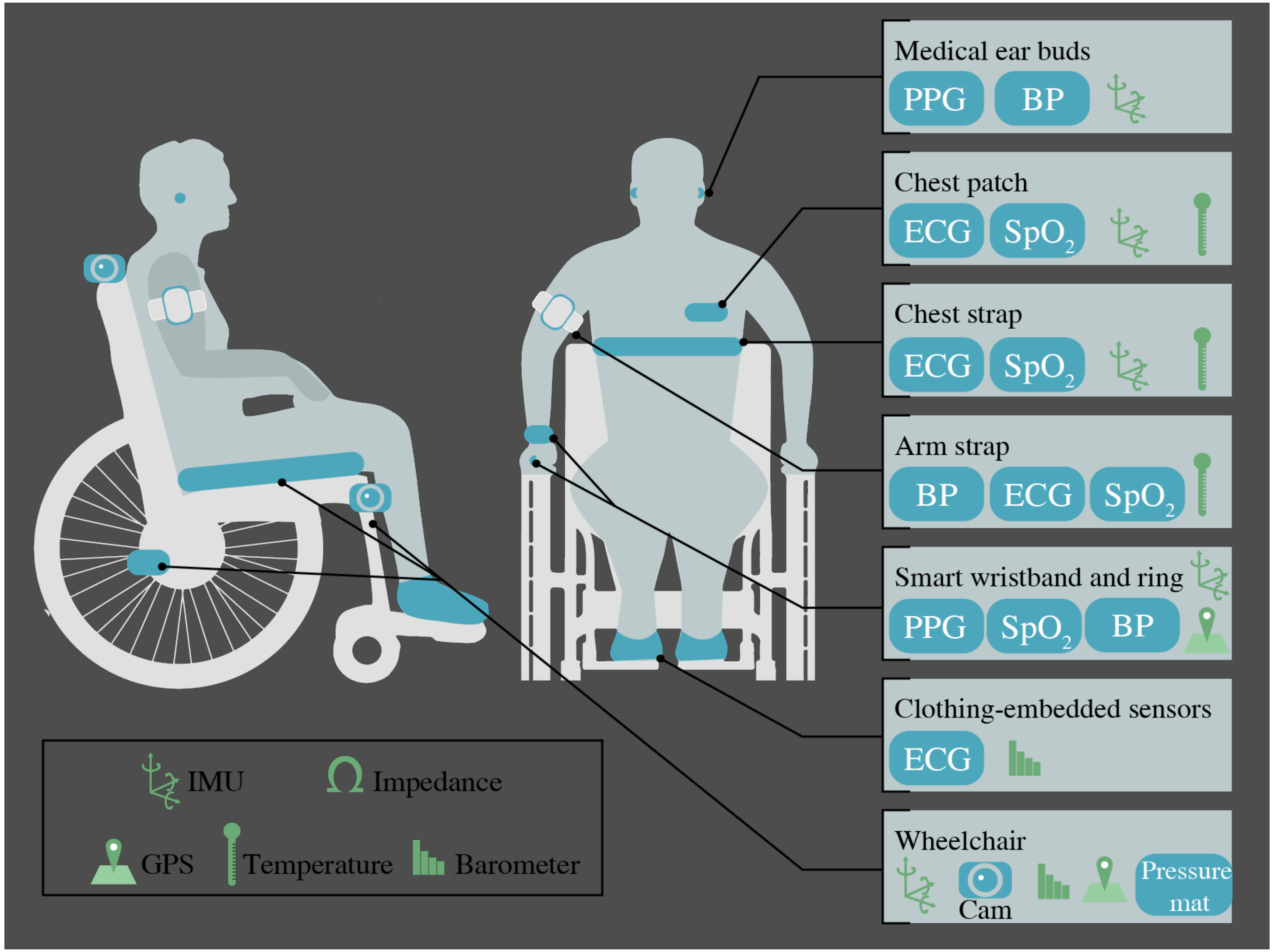


The reality of Healthcare and Rehabilitation Data



Soenksen, L.R., Ma, Y., Zeng, C. *et al.* Integrated multimodal artificial intelligence framework for healthcare applications. *npj Digit. Med.* **5**, 149 (2022). https://doi.org/10.1038/s41746-022-00689-4

Learning ADLs for Monitoring Disease Progress in Outpatient Life



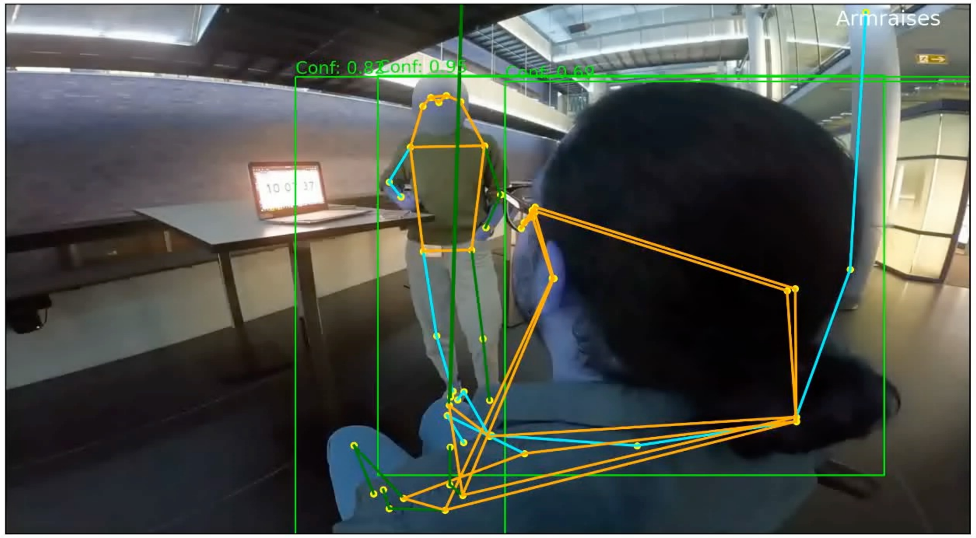
Methods

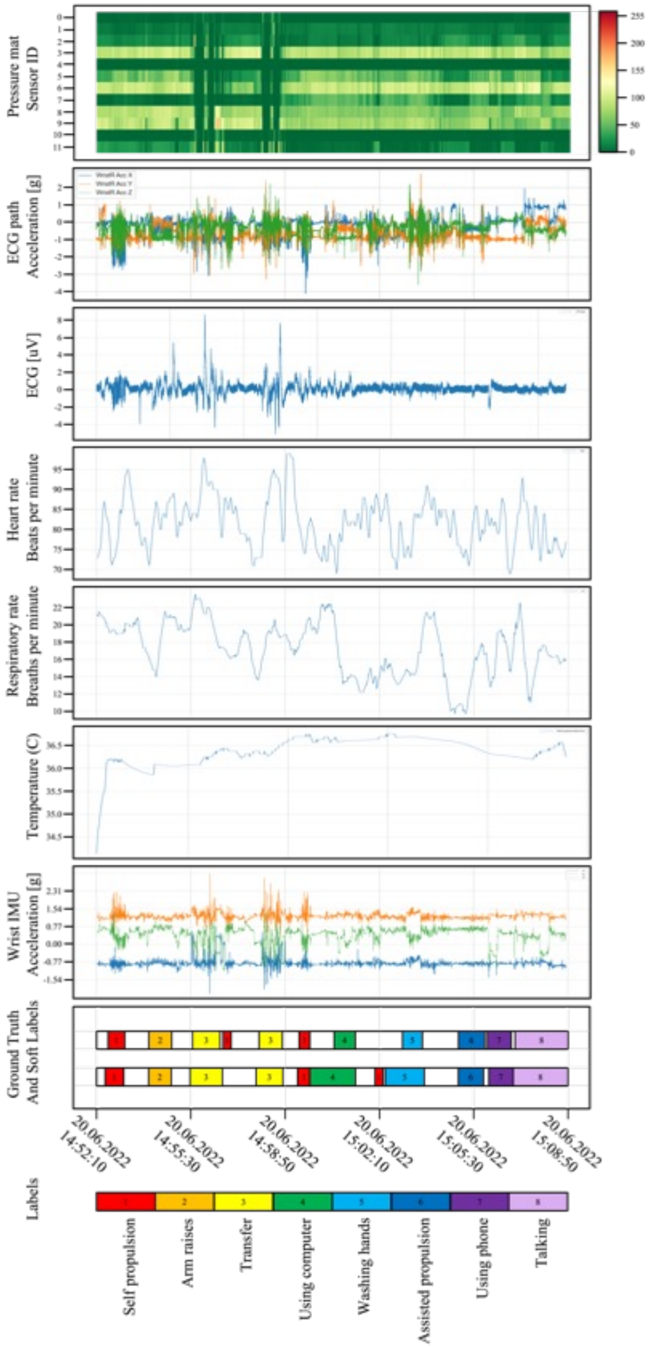
Centralized, compressed sensing of the body and the environment.
Long-term data collection for studying SCI morbidities.

Big Data Analysis for Precision Medicine and Rehabilitation on SCI

1. Functioning in daily life
2. Cardiovascular function
3. Neurology & Autonomic Dysreflexia
4. Pressure Injuries
5. Urinary system function

Time Series Data





S. Bensland, A. Paul, L. Grossmann, I. Eriks-Hogland, R. Riener, and D. Paez-Granados. "Healthcare Monitoring for SCI individuals: Learning Activities of Daily Living through a SlowFast Network". In: IEEE International Conference on System Integration. Jan. 2023. https://doi.org/10.1109/SII55687.2023.10039043

Learning ADLs for Monitoring Disease Progress in Outpatients

Arm Raises

Pressure Relief

Exercise

Using Phone

Using Computer

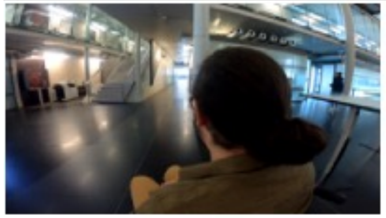
Leisure

Talking

Eating

Social

Assisted Propulsion



Self Propulsion

Mobility

Transfer

Transfer

Washing Hands

Changing Clothes

Self Care

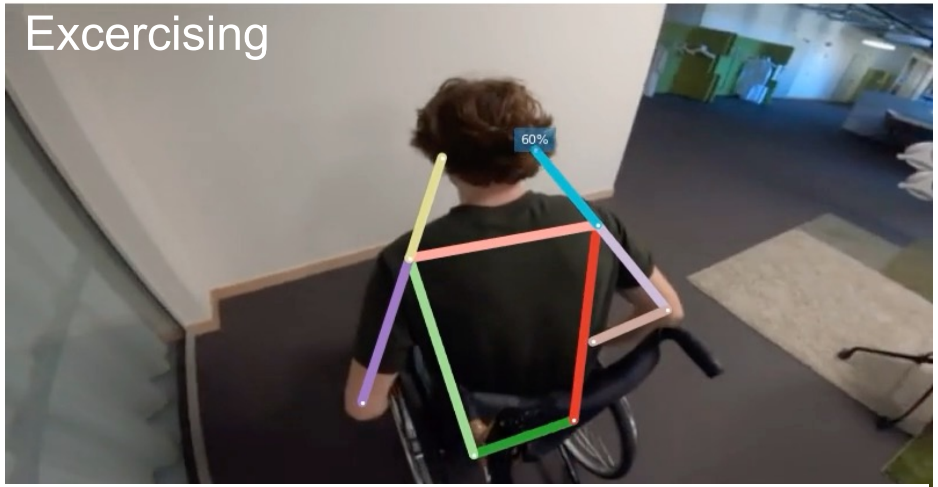
Resting

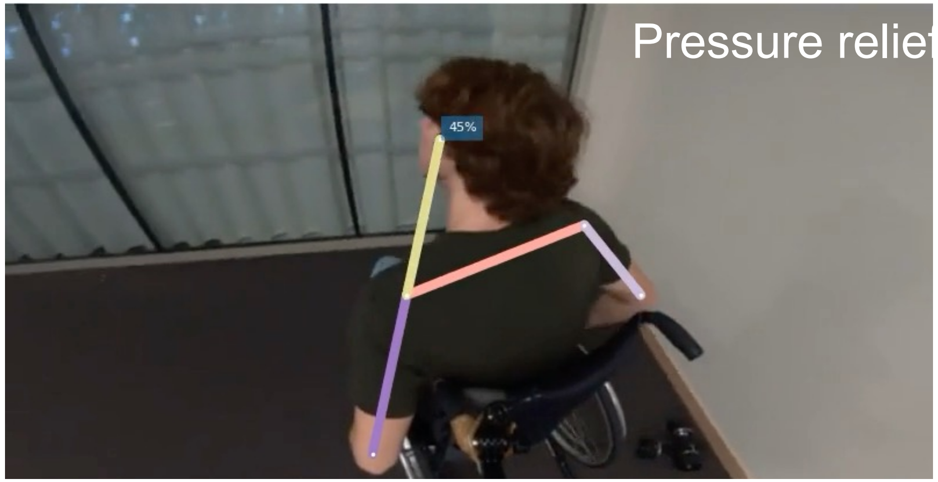
S. Bensland, A. Paul, L. Grossmann, I. Eriks-Hogland, R. Riener, and D. Paez-Granados. "Healthcare Monitoring for SCI individuals: Learning Activities of Daily Living through a SlowFast Network". In: IEEE International Conference on System Integration. Jan. 2023. https://doi.org/10.1109/SII55687.2023.10039043

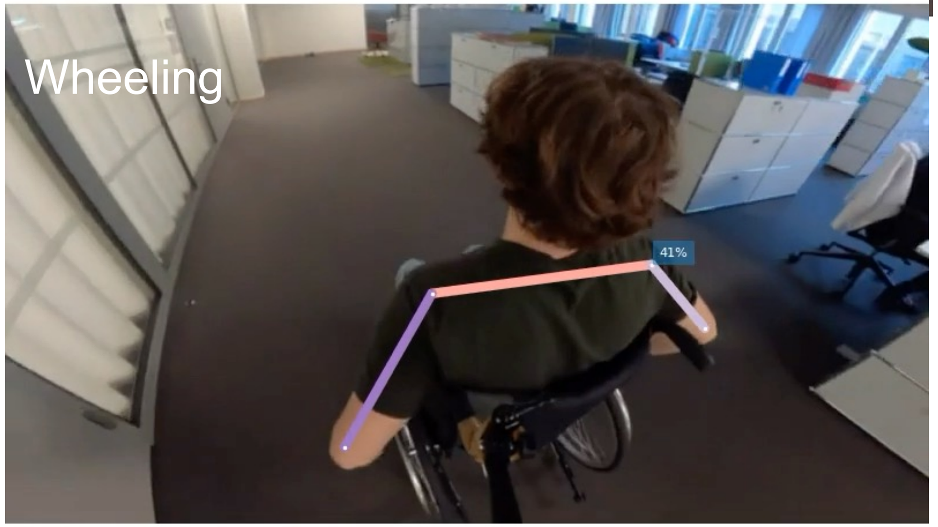
ETH zürich

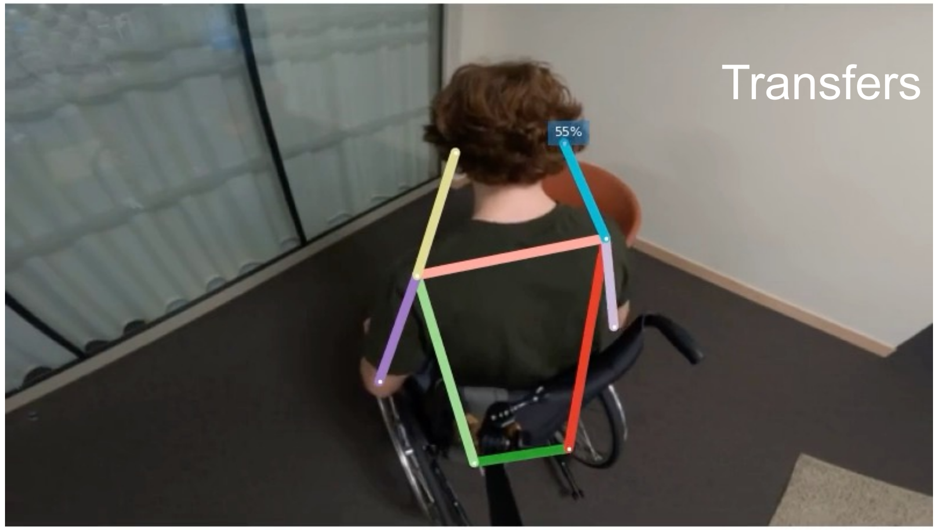
Schweizer Paraplegiker Forschung

Learning ADLs for Monitoring Disease Progress in Outpatients





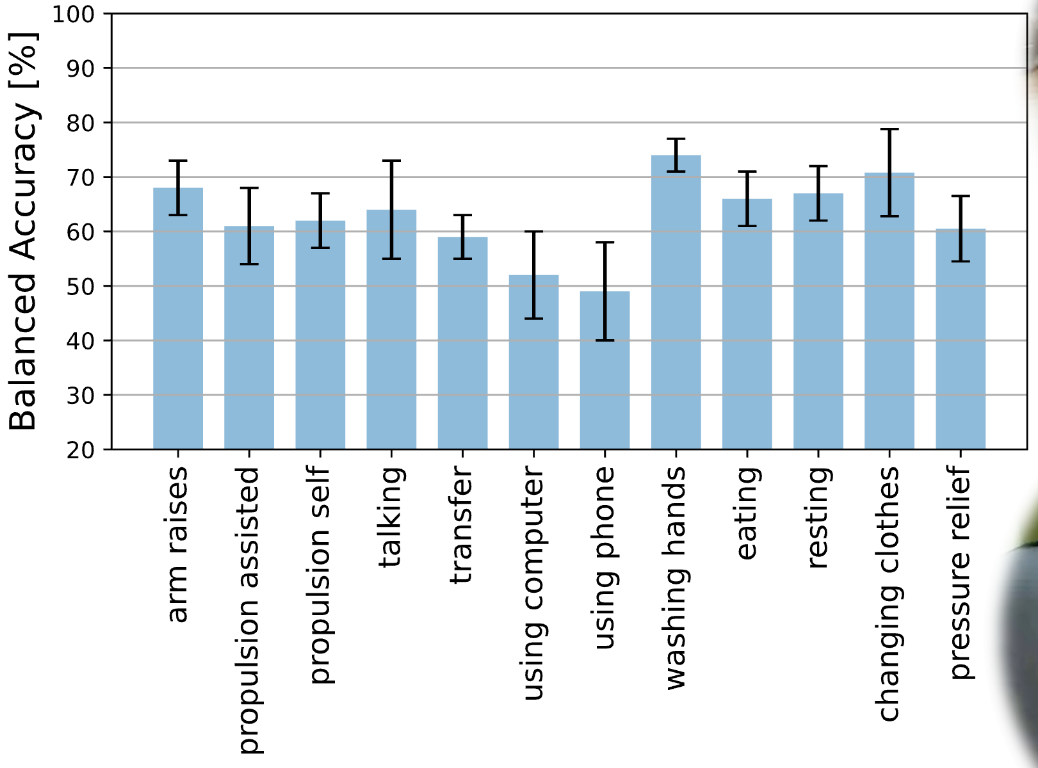




ADL Detection - N2N-video-based

Fine-tuned Slow-fast Network

Dataset	
Classes	12
Participants	3 wheelchair + 21 healthy
Total Videos	485
Videos per Class	
Self Propulsion	46
Assisted Propulsion	54
Transfer	36
Using Phone	74
Talking	85
Washing Hands	30
Arm Raises	30
Using Computer	45
Eating	38
Resting	34
Changing Clothes	16
Pressure Relief	31



S. Bensland, A. Paul, L. Grossmann, I. Eriks-Hogland, R. Riener, and D. Paez-Granados. "Healthcare Monitoring for SCI individuals: Learning Activities of Daily Living through a SlowFast Network". In: IEEE International Conference on System Integration. Jan. 2023. https://doi.org/10.1109/SII55687.2023.10039043

Data Augmentation Techniques

Data Augmentation Techniques

- RandAugment
- RandAugment-T
- RandErase
- MixUp and CutMix

RandAugment [1]

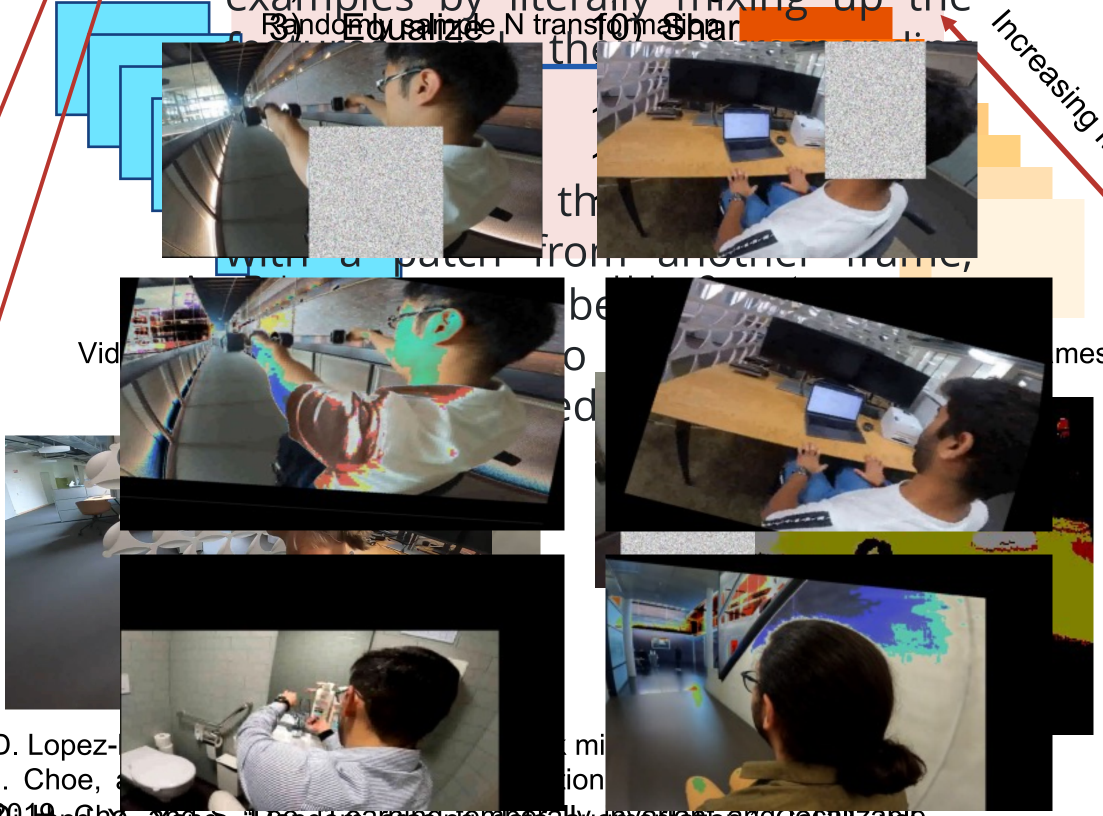
RandErase [3]

MixUp and CutMix [4, 5]

1) Identity
2) AutoContrast
3) Equalize
8) Contrast
9) Brightness

Randomly select N transformations

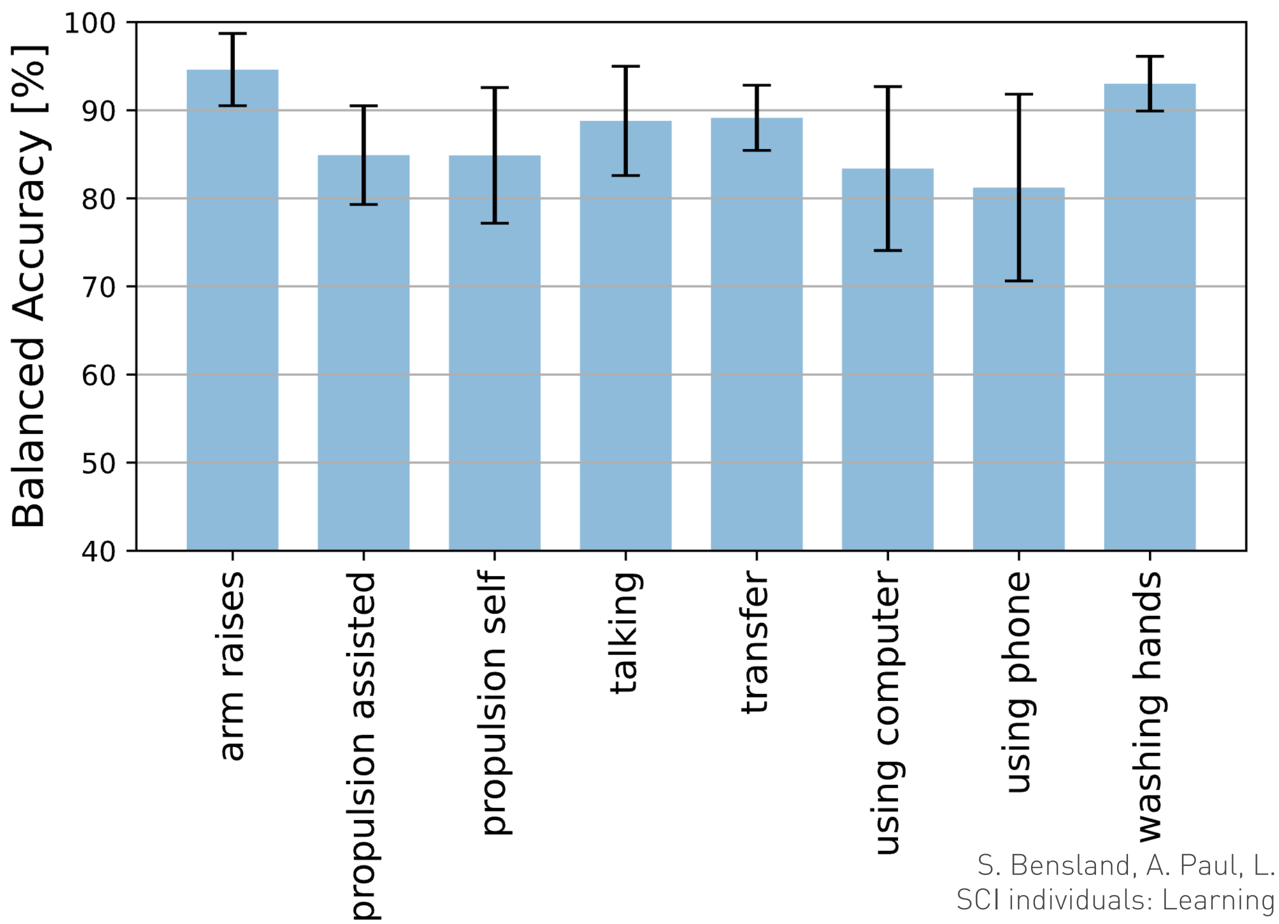
Increasing M

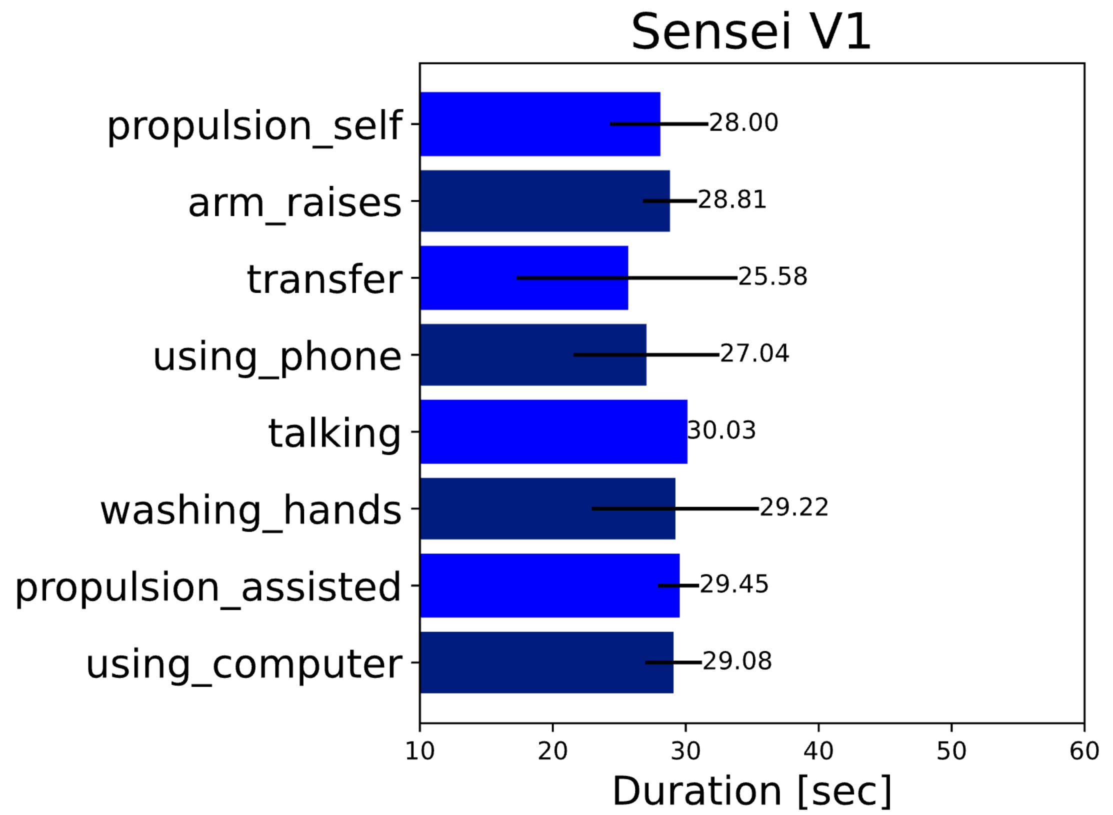


[4] H. Zhang, M. Cissè, Y. N. Dauphin, and D. Lopez-
[5] S. Yun, D. Han, S. J. Oh, S. Chun, J. Choe,
[3] Z. Zhong, L. Zheng, G. Kang, S. Li, and Y. Yang. "Random erasing data augmentation," CoRR, vol. abs/2008.05721, 2020.
[1] Ekin D.C., Barret Z. et al. "Randaugment: Practical automated data augmentation with a reduced search space".

Performance after Data Augmentation

- Per class balanced accuracy is computed for the best model with RandAugment-T and Random Erasing

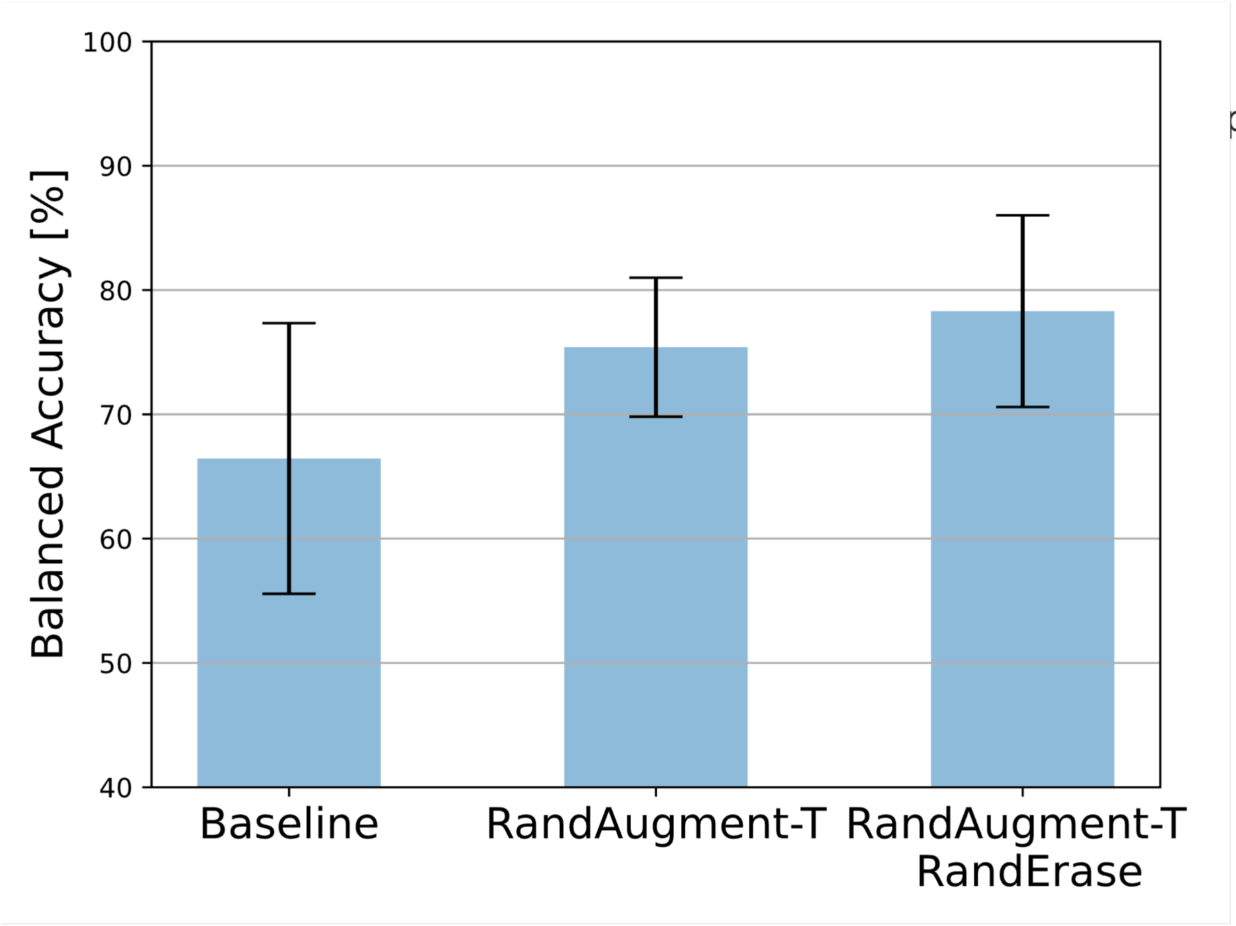


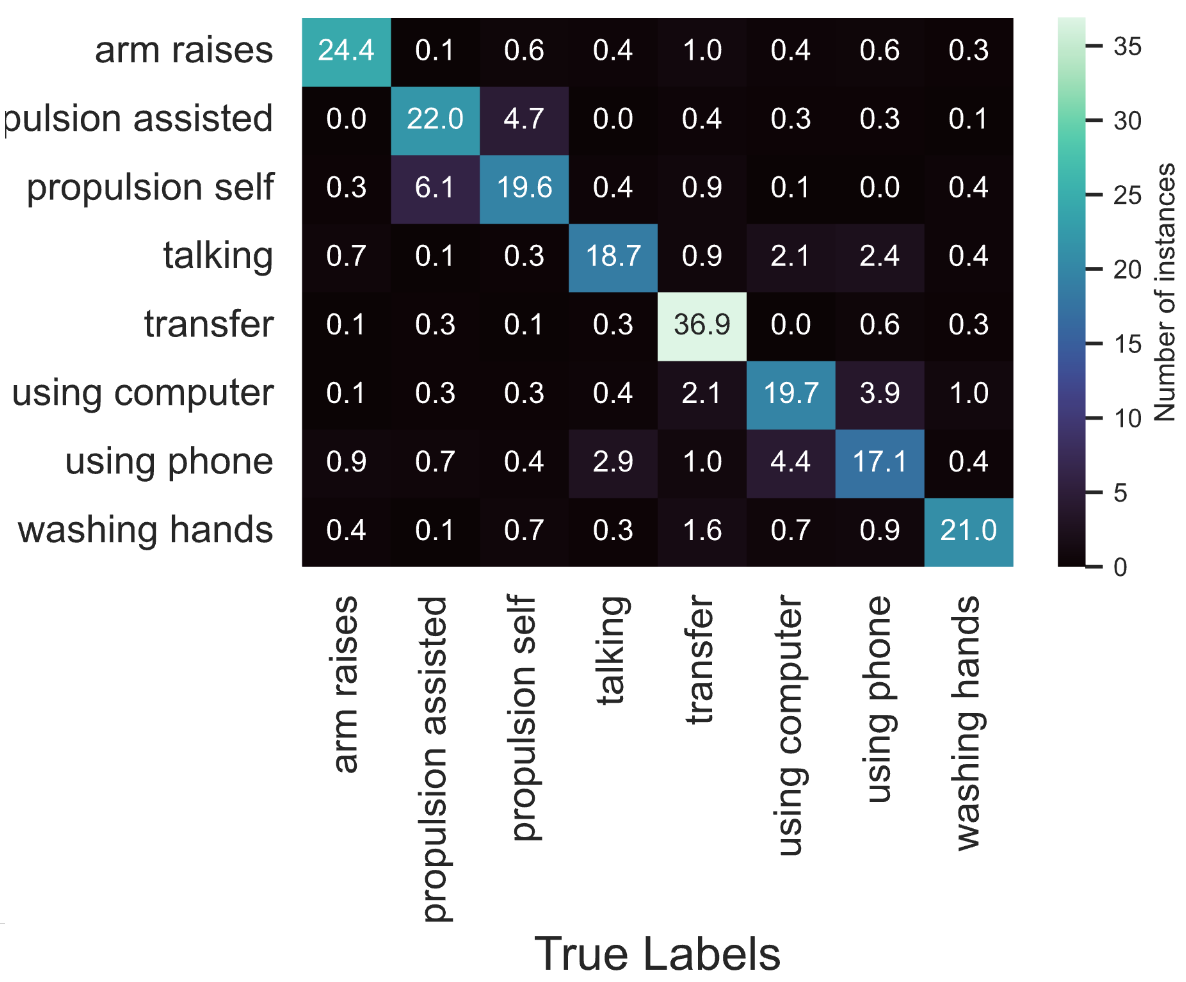


S. Bensland, A. Paul, L. Grossmann, I. Eriks-Hogland, R. Riener, and D. Paez-Granados. "Healthcare Monitoring for SCI individuals: Learning Activities of Daily Living through a SlowFast Network". In: IEEE International Conference on System Integration. Jan. 2023. https://doi.org/10.1109/SII55687.2023.10039043

Performance after Data Augmentation

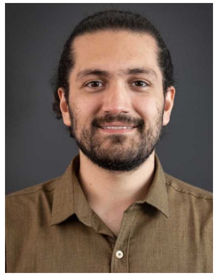
- Per class balanced accuracy is computed for the best model with RandAugment-T and Random Erasing



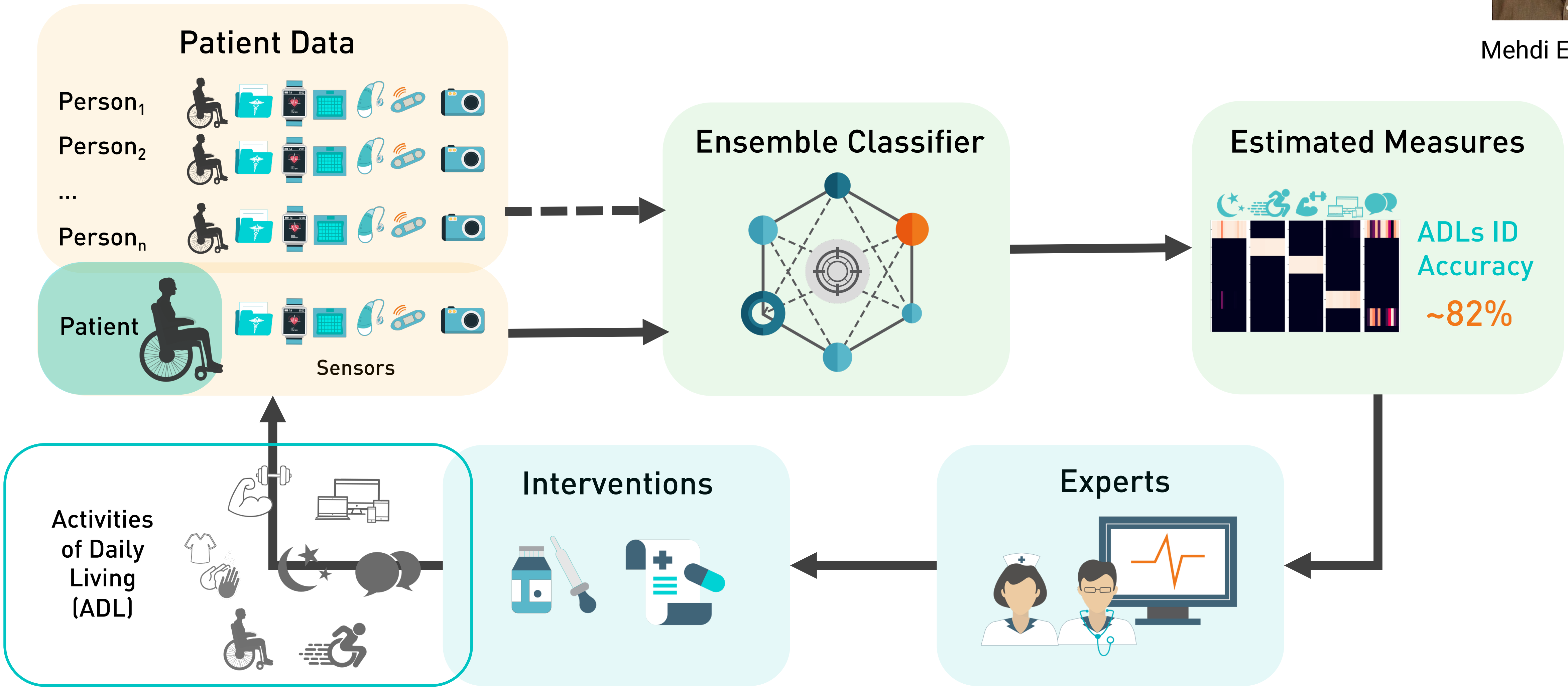


ETH zürich Schweizer Paraplegiker Forschung CAI LAB

Day 1: Time Series for Monitoring in Daily Life



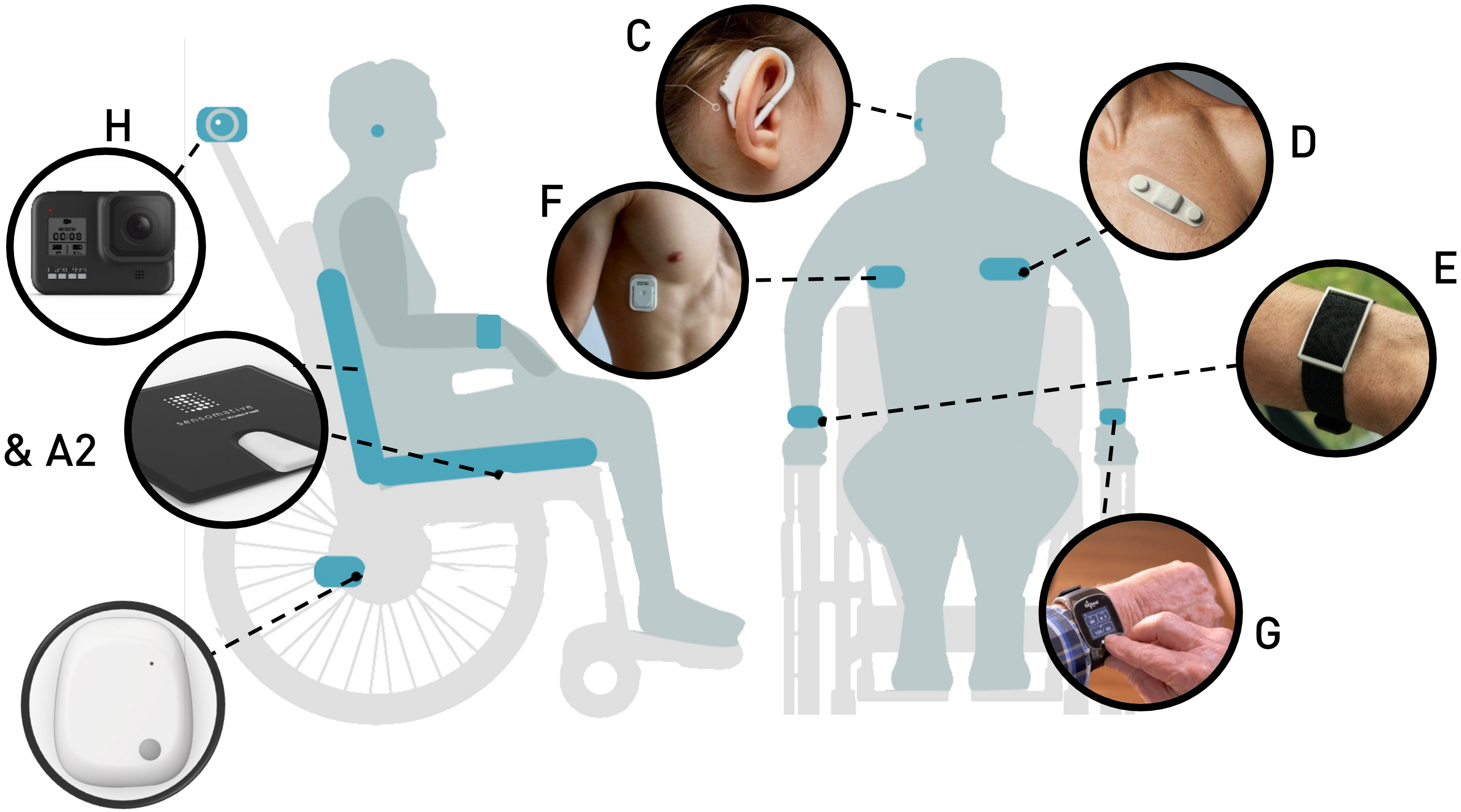
Mehdi Ejtehadi



M. Ejtehadi, S. Amrein, I. Eriks-Hogland, R. Riener, and D. Paez-Granados. "Learning Activities of Daily Living from Unobtrusive Multi-modal Wearable Sensors: Towards Monitoring Outpatient Rehabilitation". In: IEEE International Conference on Robotics and Rehabilitation. Sept. 2023. DOi: 10.3929/ ethz-b-000619499.

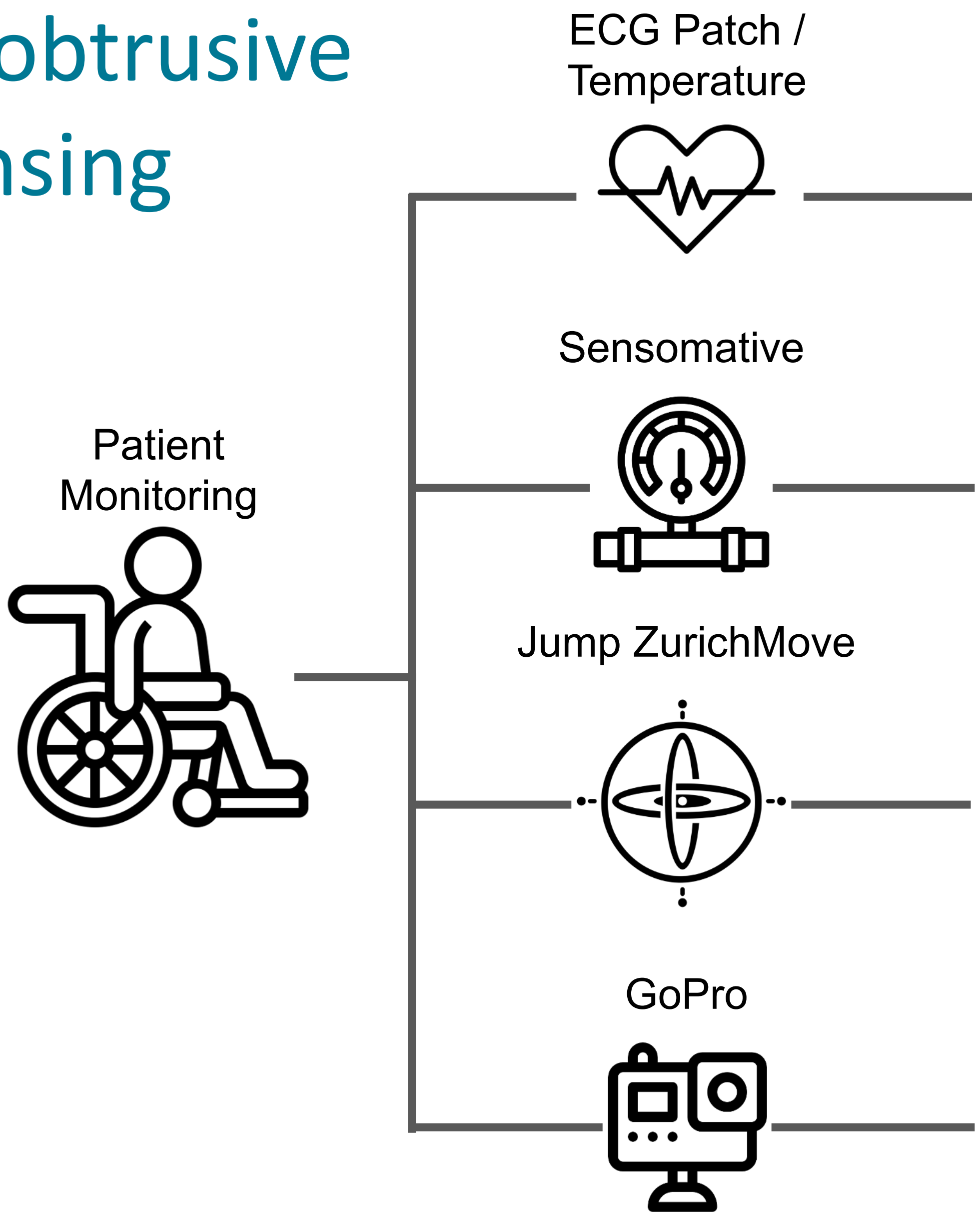
ETH zürich   Schweizer Paraplegiker Forschung

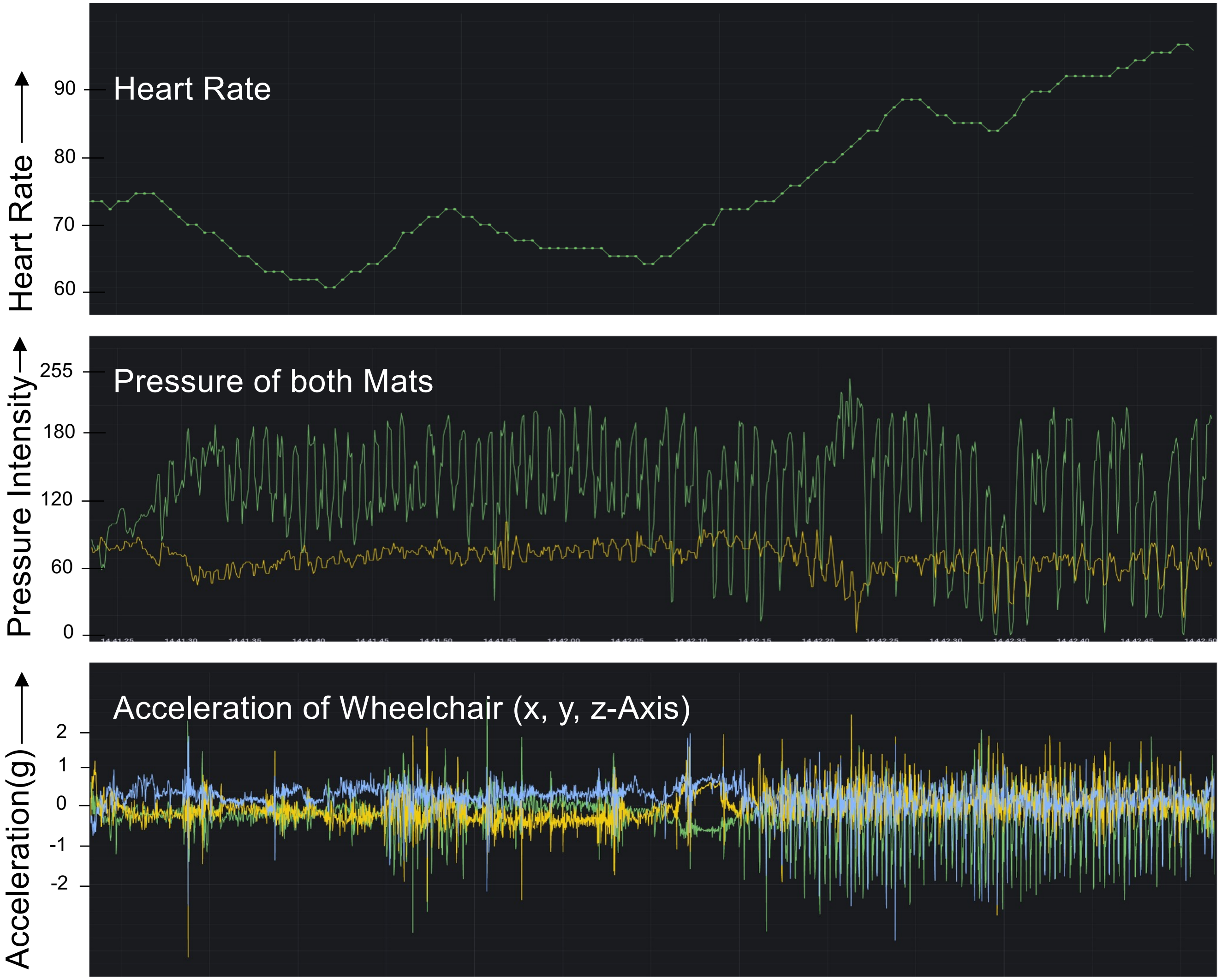
Unobtrusive Sensing for ADLs Monitoring



M. Ejtehadi, S. Amrein, I. Eriks-Hogland, R. Riener, and D. Paez-Granados. "Learning Activities of Daily Living from Unobtrusive Multi-modal Wearable Sensors: Towards Monitoring Outpatient Rehabilitation". In: IEEE International Conference on Robotics and Rehabilitation. Sept. 2023. https://doi.org/10.1109/ICORR58425.2023.10304743

Unobtrusive Sensing



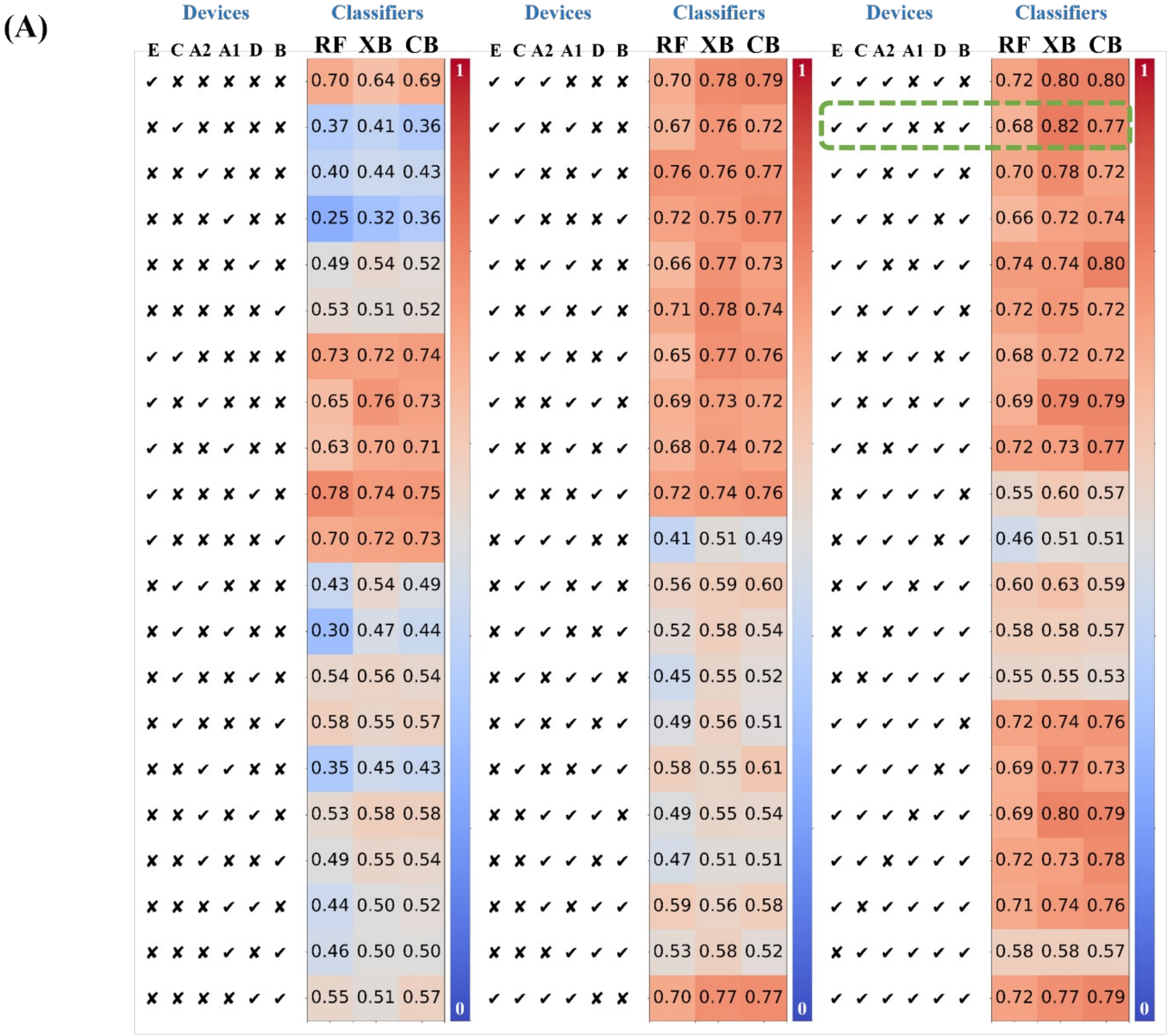


Time (s)

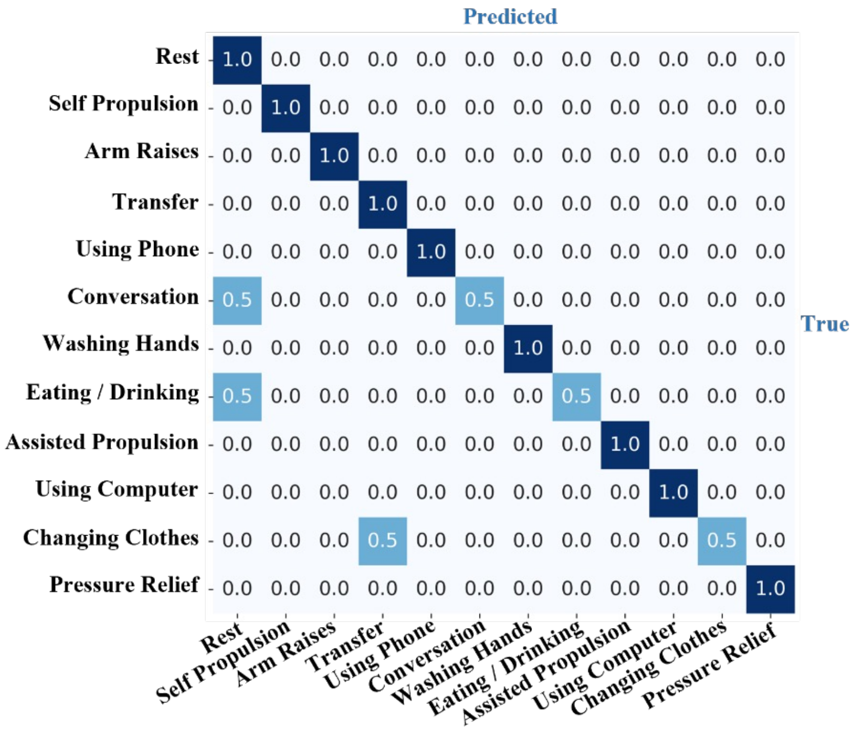
Self Propulsion on inclined Ramp

Results

(A)



(B)



Precision	0.5	1	1	0.67	1	1	1	1	1	1	1	1
Recall	1	1	1	1	1	0.5	1	0.5	1	1	0.5	1
F-1 Score	0.67	1	1	0.8	1	0.67	1	0.67	1	1	0.67	1

M. Ejtehadi, S. Amrein, I. Eriks-Hogland, R. Riener, and D. Paez-Granados. "Learning Activities of Daily Living from Unobtrusive Multi-modal Wearable Sensors: Towards Monitoring Outpatient Rehabilitation". In: IEEE International Conference on Robotics and Rehabilitation. Sept. 2023. https://doi.org/10.1109/ICORR58425.2023.10304743

ETH zürich

Schweizer Paraplegiker Zentrum

Schweizer Paraplegiker Forschung

LAB

Tutorial: Wearable Data in ADL Classification

ETH Zürich, Switzerland | 17 June 2024