Sleep Classification with Artificial Synthetic Imaging Data from Empatica E4 Wristband by Convolutional Neural Networks

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Introduction

- Sleep health is fundamental to human well-being.
- Laboratory polysomnography (PSG) is currently regarded as the gold standard in high-resolution sleep monitoring, but expensive.
- Wearable sensors are proposed as an alternative method to track sleep due to their convenience for both product users and practitioners.
- **Objectives:** propose a new analytic framework, "Artificial Synthetic Imaging Data (ASID) Workflow," for sleep classification from a wearable device comprising: 1) the creation of ASID from data collected by a non-invasive wearable device that permits real-time multi-modal physiological monitoring on heart rate, 3-axis accelerometer, electrodermal activity, and skin temperature, and 2) the use of an image classification algorithm, convolutional neural network (CNN), to classify periods of sleep by using both within-mode and cross-mode temporal features.

Methods

- A cohort of 24 users aged 22-to-35 years old wore Empatica E4 device on the wrist of their non-dominant hand for 48 hours. E4 device has 4 sensors.
- **ASID Workflow**
  - A. Artificial Synthetic Imaging Data
    - 1) Selection of Physiological Variables
    - 2) Alignment of Modalities and Variables
    - 3) Reshaping
  - B. Convolutional Neural Network as sleep classifier
    - Tune the number of convolution layers and other CNN systematic hyperparameters.
- **6 different HR scenarios and data resolution settings**
  - A. 2 HR scenarios (with and without the heart rate modality - "w/ HR" and "w/o HR")
  - B. 3 data resolutions: 30 sec, 1 min, and 5 min.
- **Comparison with competing ML algorithms**
  - logistic regression, random forest, SVM with linear and radial kernel, k-nearest neighbors, and Long Short-Term Memory.

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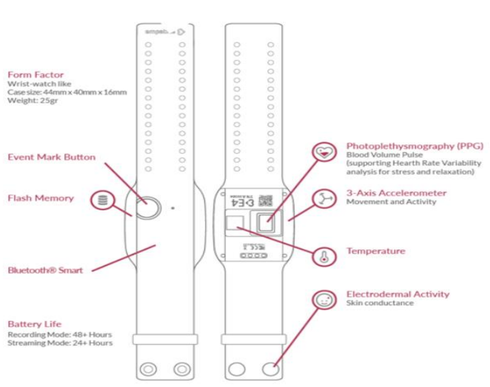
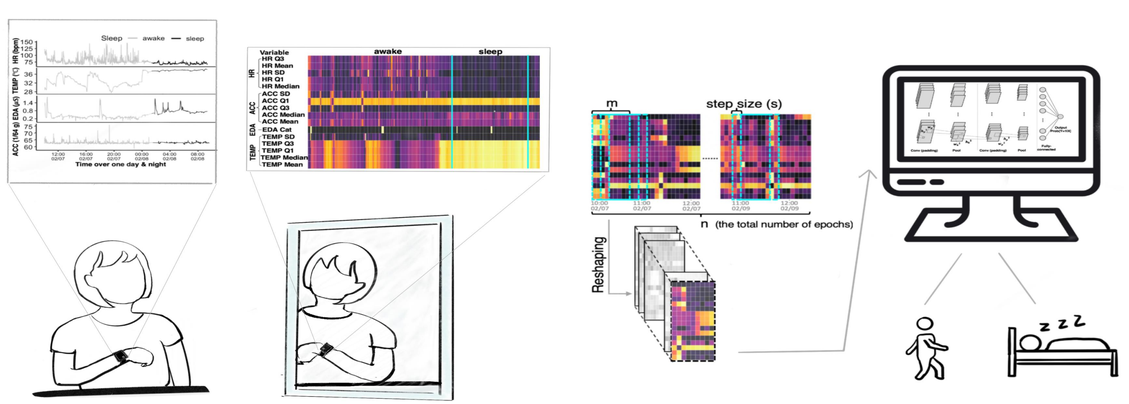




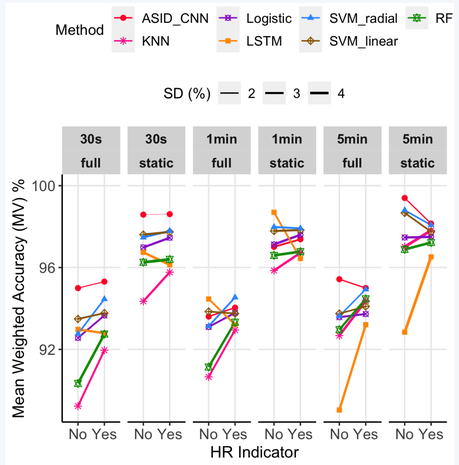
Results

- **Performance of ASID Workflow Across Settings**
  - The mean test weighted accuracy (wACC) among 6 settings reaches 94.7%;
  - The inclusion of HR enhances the performance of the ASID Workflow by only 0.11% among data resolutions.

ASID WORKFLOW: FULL-PERIOD POST-MV TEST WACC (%)

HR Scenario	Data Resolution			Overall
	30s	1min	5min	
w/ HR	95.3 (1.43)	94.0 (2.43)	95.0 (2.65)	94.8 (2.17)
w/o HR	95.0 (1.81)	93.6 (1.66)	95.4 (1.16)	94.7 (1.54)
Overall	95.2 (2.05)	93.8 (1.62)	95.2 (1.90)	94.7 (1.86)

- **Performances Compared Across Models**



- There are 4 settings where the ASID Workflow reaches the highest wACC.

- The superiority of ASID Workflow over other methods is maximized in full-period D-5min-w.o.HR.

Conclusion

- Applying CNN to ASID captures both temporal and spatial dependency among physiological variables and modalities by using 2D images' topological structure that competing algorithms fail to utilize.