DeepSleep

A Ballistocardiographic-based Deep Learning Approach for Classifying Sleep Stages

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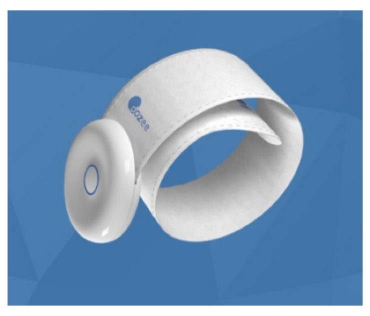
How can a sleep classification system be modelled using Ballistocardiographic (BCG) sensor data, and achieve a performance comparable with Polysomnography (PSG)?

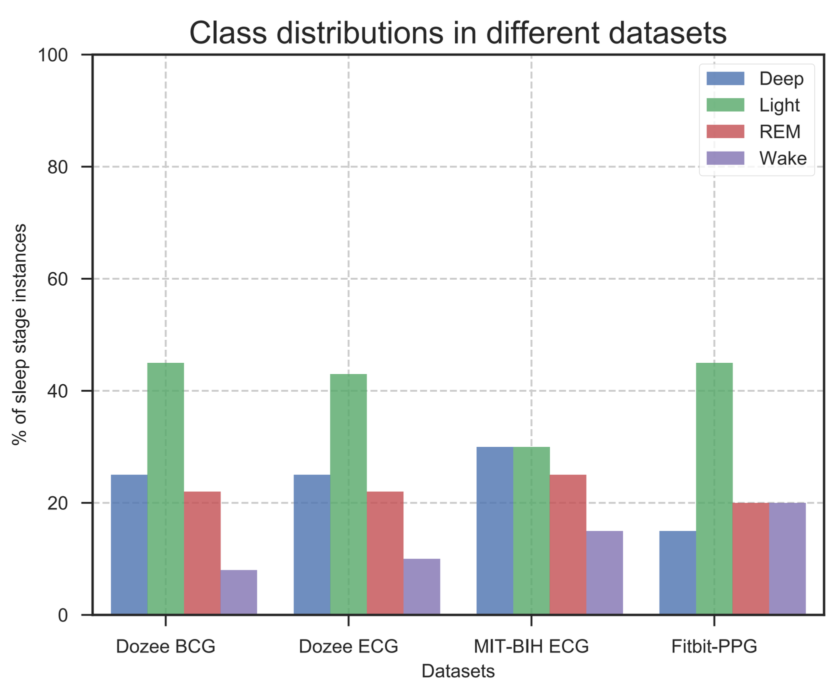
- PSG considered most accurate method for diagnosing sleep-related problems
- However, it is expensive, complex, time-consuming, and uncomfortable for users
- We propose a transfer learning approach using BCG data

Collecting BCG-based heart sensor signals



- 51 recordings, 25 subjects
- Training = 41; Validation = 7; Test = 3
- Ground truth annotated by 2 doctors from NIMHANS [1]
- Cohen's kappa, k = 0.80

Dataset distribution



Measuring sleep quality

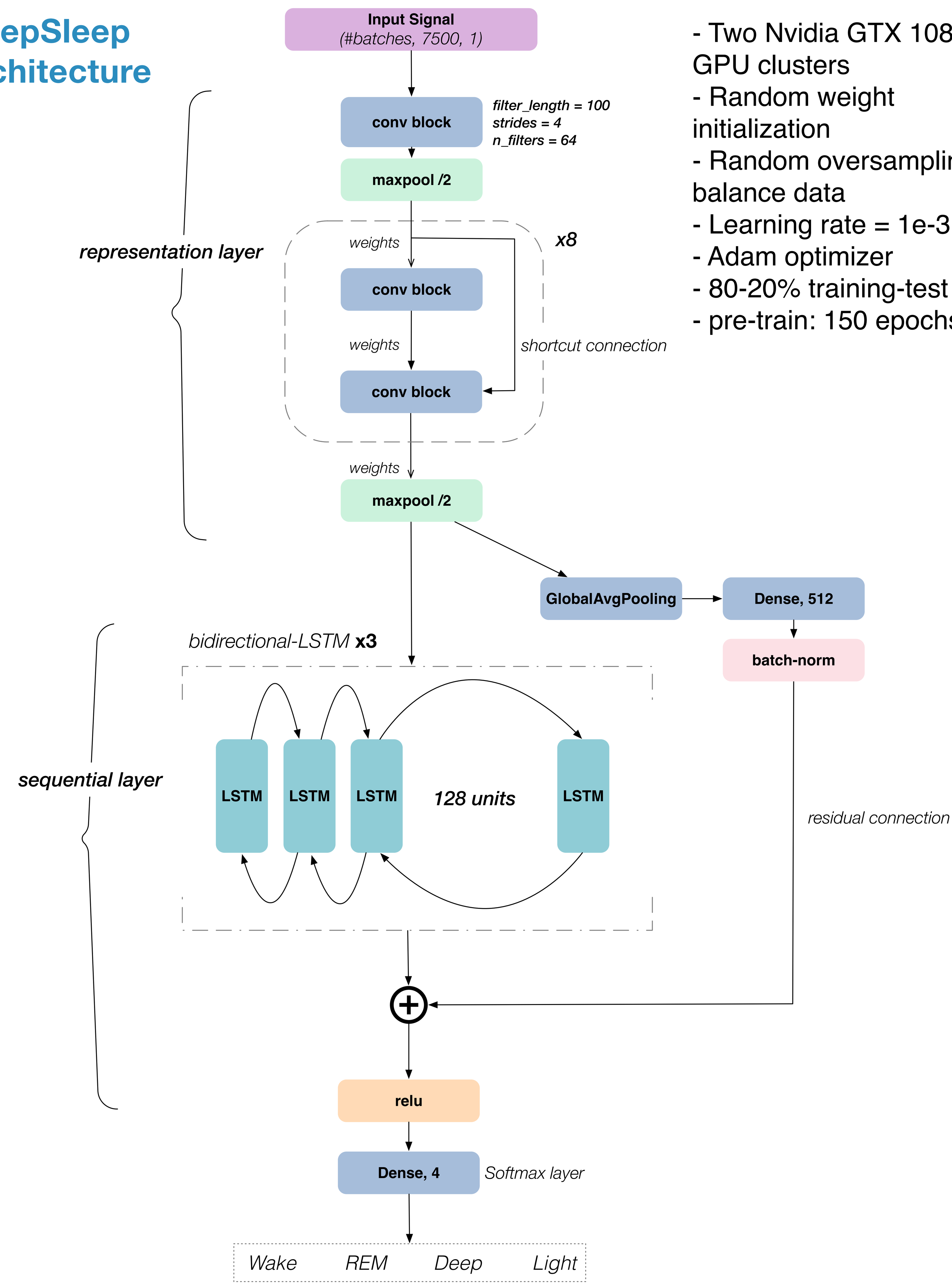
SATED questionnaire for perceived sleep quality

- SATED: Satisfaction, Alertness, Timing, Efficiency, Duration
- 16 subjects
- Scores recorded 1hr and 24 hr after PSG recording

Objective sleep quality

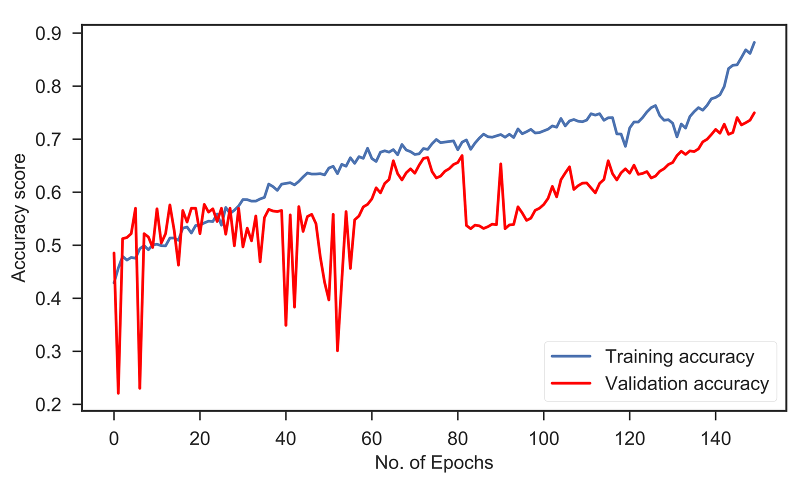
$$SQ = \frac{\text{REM (min)} + \text{NREM (min)} - \text{Awakening (min)}}{\text{Total Sleep (min)}}$$

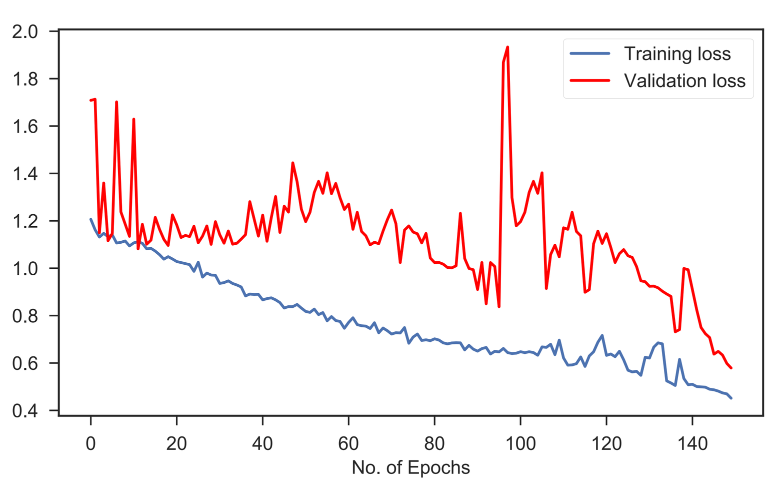
DeepSleep architecture



- Two Nvidia GTX 1080 Ti GPU clusters
- Random weight initialization
- Random oversampling to balance data
- Learning rate = 1e-3
- Adam optimizer
- 80-20% training-test split
- pre-train: 150 epochs

Fine-tuning accuracy and loss





Dataset comparisons

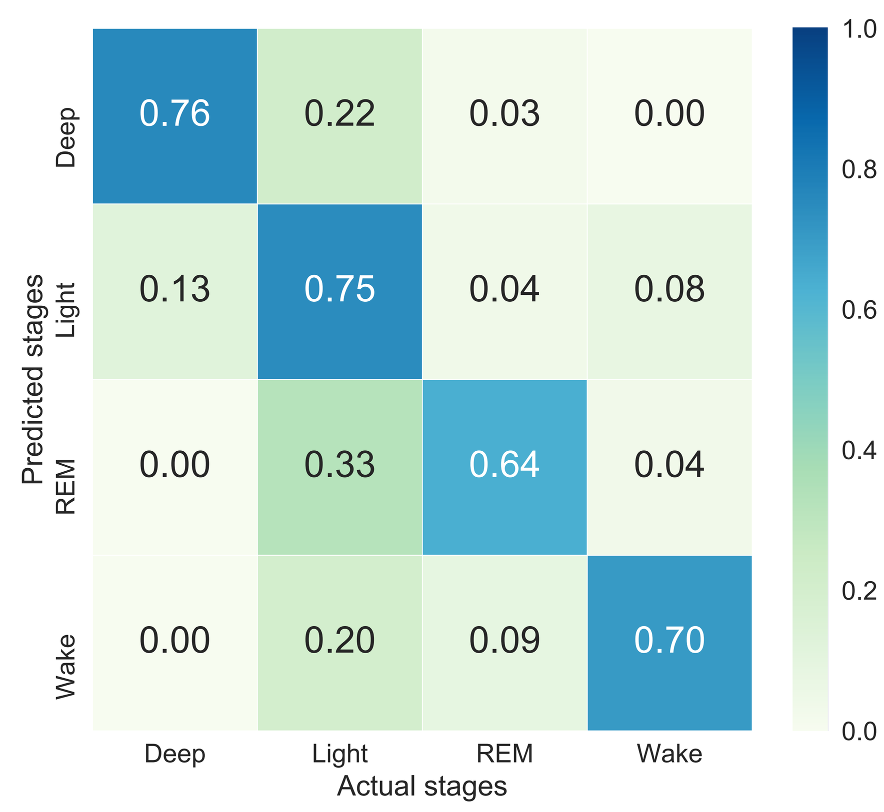
Study	Year	Sensor type	#Features	Classifier	Classes	Accuracy
Längkvist et al. [50]	2012	EEG, EOG, EMG	1	DBN, HMM	W, REM, NREM, L	72%
Samy et al. [72]	2014	BCG	6	KNN, SVM, Naive-Bayes	W, L, REM, Deep (NREM)	72%
Supratak et al. [77]	2017	EEG	1	1D-CNN + LSTM	W, REM, NREM, L	86%
Dong et al. [24]	2018	EEG, EOG	1	LSTM	W, REM, NREM, L	86%
Chambon et al. [13]	2018	EEG, EOG, EMG	1	1D-CNN	W, REM, NREM, L	87%
DeepSleep (proposed)	**2018**	**BCG**	**1**	**1D-CNN + bi-LSTM**	**W, L, REM, Deep (NREM)**	**74%**

Performance comparison between *DeepSleep* model and prior works that perform 4-class classification.

Dataset	Sensor type	#Features	#Recordings	Accuracy
Dozee BCG	BCG	1	51	74%
Dozee ECG	ECG	1	51	77%
MIT-BIH	ECG	1	80	82%
Fitbit-PPG	PPG	1	12	63%

Performance of DeepSleep model on different datasets and sensor types

Sleep classification performance



Conclusion

- Model identifies onset and period of sleep stages
- Differentiates between REM & Deep
- Avg. F1-score: 74%
- Avg. F1-score: 82% on ECG data (transfer learning)
- Positive correlation with PSG (r = 0.48) and SATED (r = 0.43), whereas r=0.54 between SATED and PSG

Future work

- Leave-one-out cross-validation
- Compare with non-NN approaches
- Better oversampling (e.g., Seq2seq)
- Multimodal learning

[1] NIMHANS - National Institute of Mental Health and Sciences

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