

ECG-Based Driver Drowsiness Detection Using a CNN–LSTM Framework

Aristotelis Styanidis^{1,2}, André Lourenço^{2,3,4}, Carlos Carreiras², Christer Ahlström^{5,6}, Apostolos Ziakopoulos¹, George Yannis¹

¹NTUA, ²CardioID, ³ISEL, ⁴NOVA LINCS, ⁵LiU, ⁶VTI

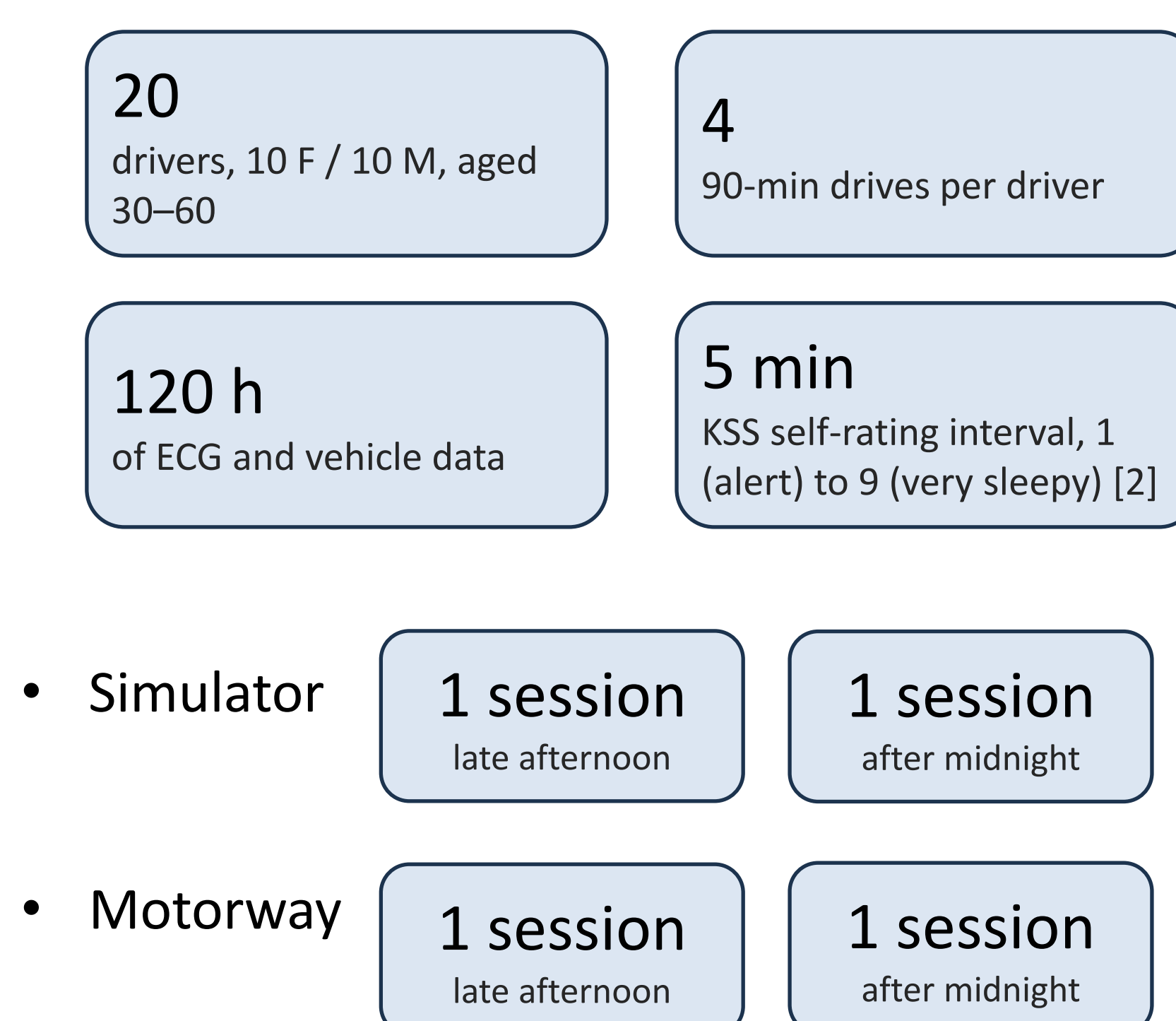
Motivation

- Drowsiness is a major cause of road crashes: slower reactions, impaired decisions, loss of vehicle control.
- EEG detects drowsiness well, but needs many electrodes and is noise-sensitive, so it is hard to deploy in a car.
- ECG reflects autonomic activity and can be recorded unobtrusively by steering-wheel or seat sensors.
- Yet most ECG studies still rely on handcrafted HRV features and classical machine learning [1].

Research Question

Can drowsiness-relevant representations be learned directly from the raw ECG, without handcrafted features?

Dataset: SleepEye



Healthy, non-shift, non-professional drivers. ECG recorded at 256 Hz (Vitaport 3) [3].

Preprocessing & Labels

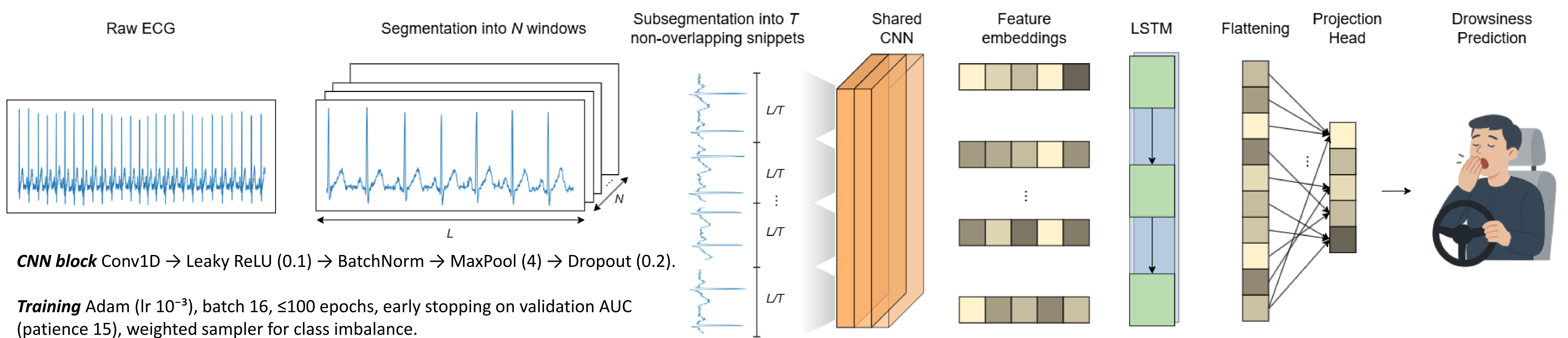
1. Resample 256 to 128 Hz
2. Band-limit to 0.5–40 Hz (Butterworth high- and low-pass) and remove 50 Hz powerline noise (notch)
3. Cut into non-overlapping 2-min windows
4. Discard windows with saturation or extreme amplitude (motion artifacts)
5. Normalize amplitude per subject

Binary Label from KSS:

- Alert: KSS < 7
- Drowsy: KSS ≥ 7

Last KSS rating in each window; windows without a rating are excluded.

End-to-end CNN-LSTM architecture

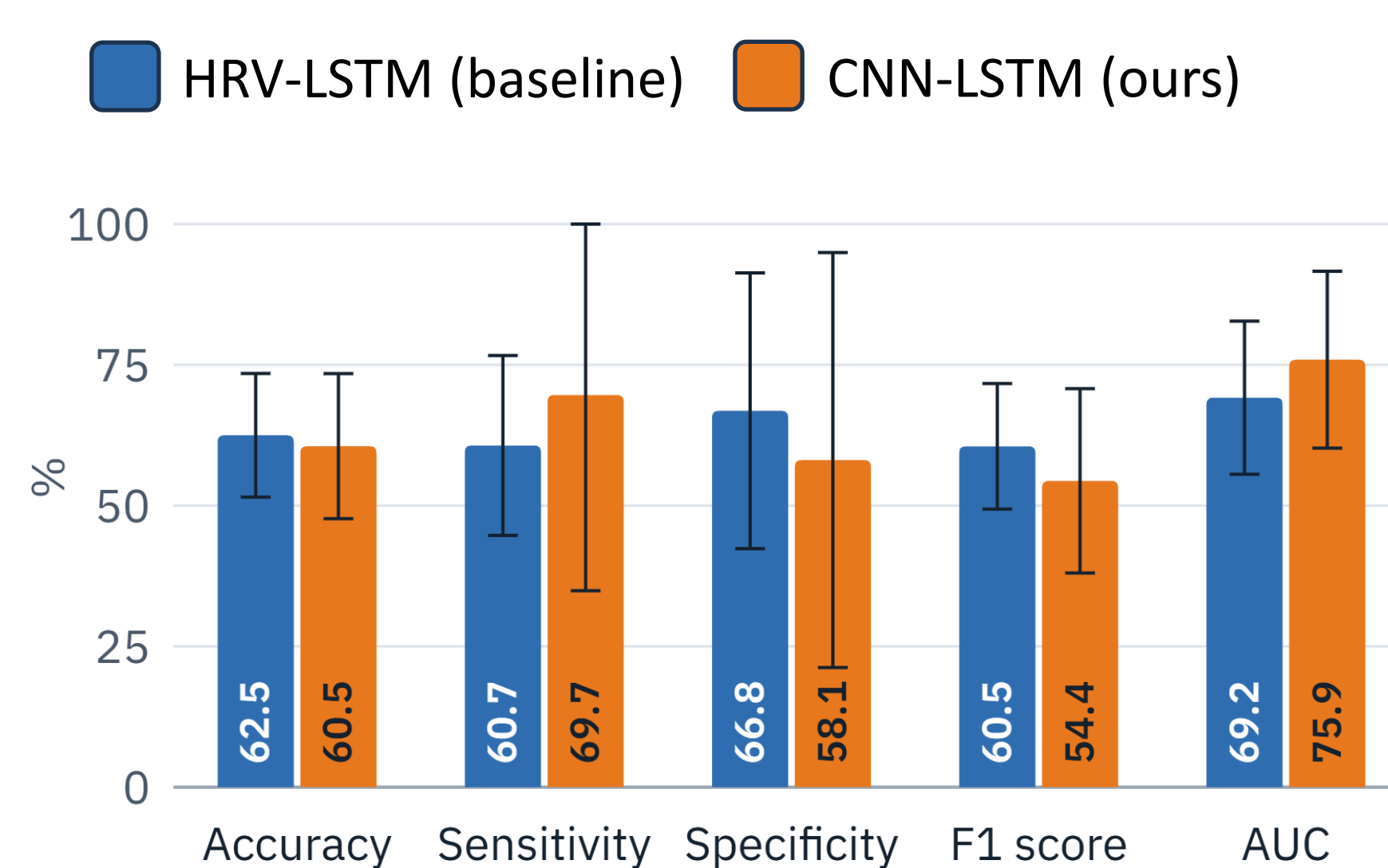


Evaluation protocol

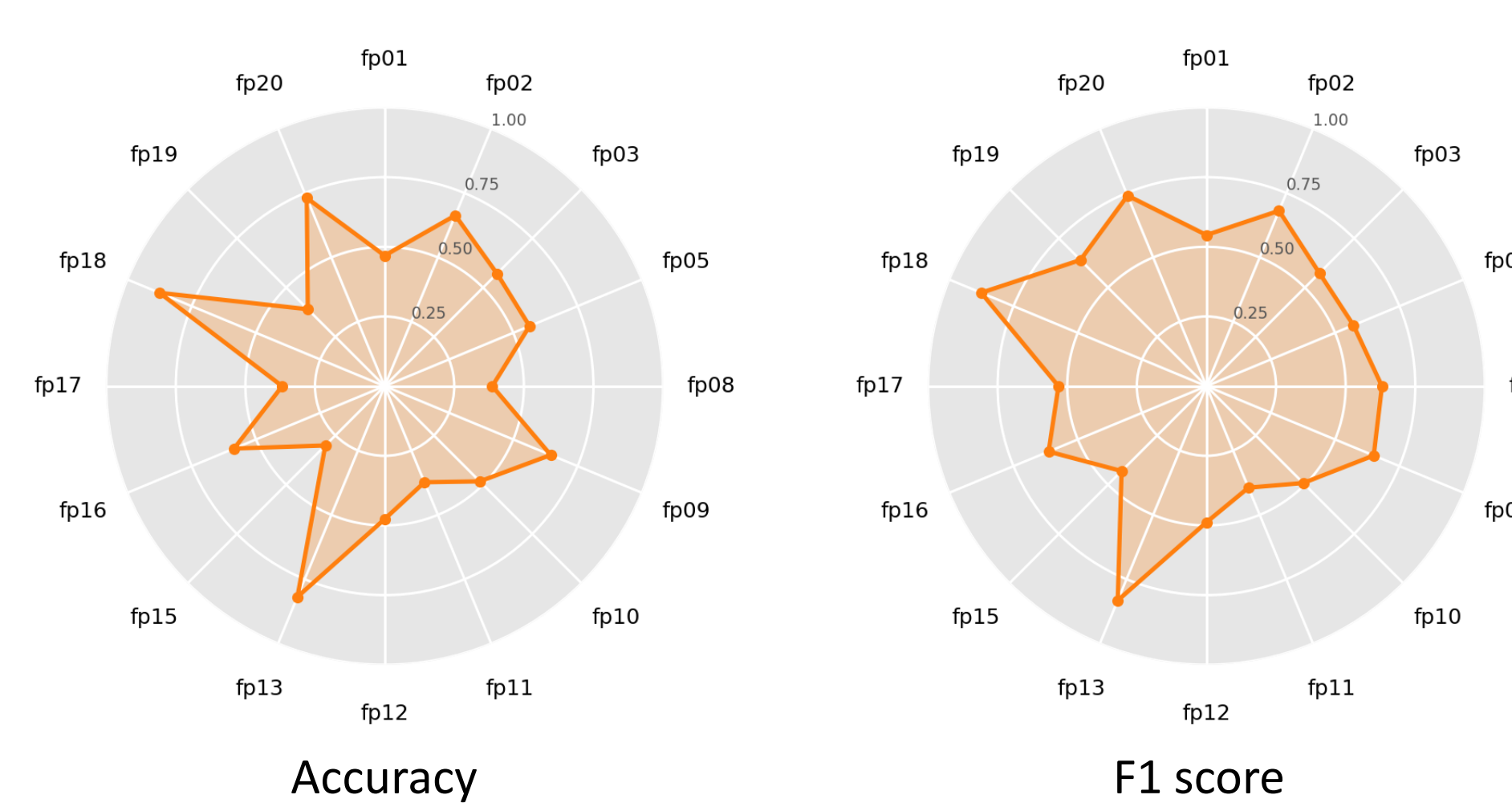
- **Leave-one-subject-out:** train, validation and test drivers are always disjoint. Metrics averaged over folds.
- **Baseline:** HRV-LSTM

19 time-domain HRV features per 30 s subsegment, fed to the same LSTM. Only the feature extractor differs.

Results



Inter-subject variability

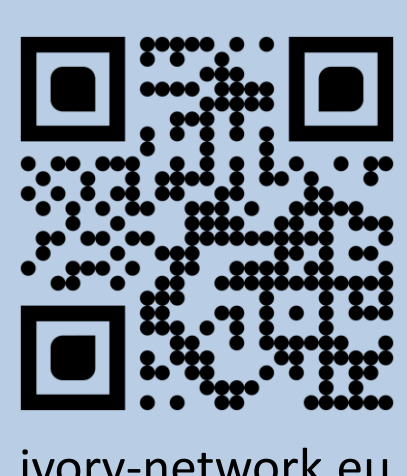


Conclusions

- Raw-ECG features learned end-to-end are competitive with HRV and give higher AUC.
- Inter-subject variability is the main bottleneck.
- **Next:** Cross-dataset evaluation and domain adaptation for subject-invariant features.

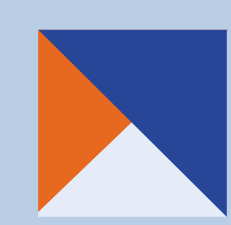
References

- [1] A. Persson et al., “Heart Rate Variability for Classification of Alert Versus Sleep Deprived Drivers in Real Road Driving Conditions”, IEEE Trans. Intell. Transp. Syst., vol. 22, 2021.
- [2] A. Anund et al., “Camera-Based Sleepiness Detection: Final Report of the Project SleepEYE”, VTI Rep. 2011-6, 2011.
- [3] T. Åkerstedt & M. Gillberg, “Subjective and objective sleepiness in the active individual,” Int. J. Neuroscience, vol. 52, no. 1–2, pp. 29–37, 1990.



Contact

Aristotelis Styanidis
astyanidis@mail.ntua.gr



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