Uncertainty-aware Machine Learning for Biosignal-based Healthcare Applications

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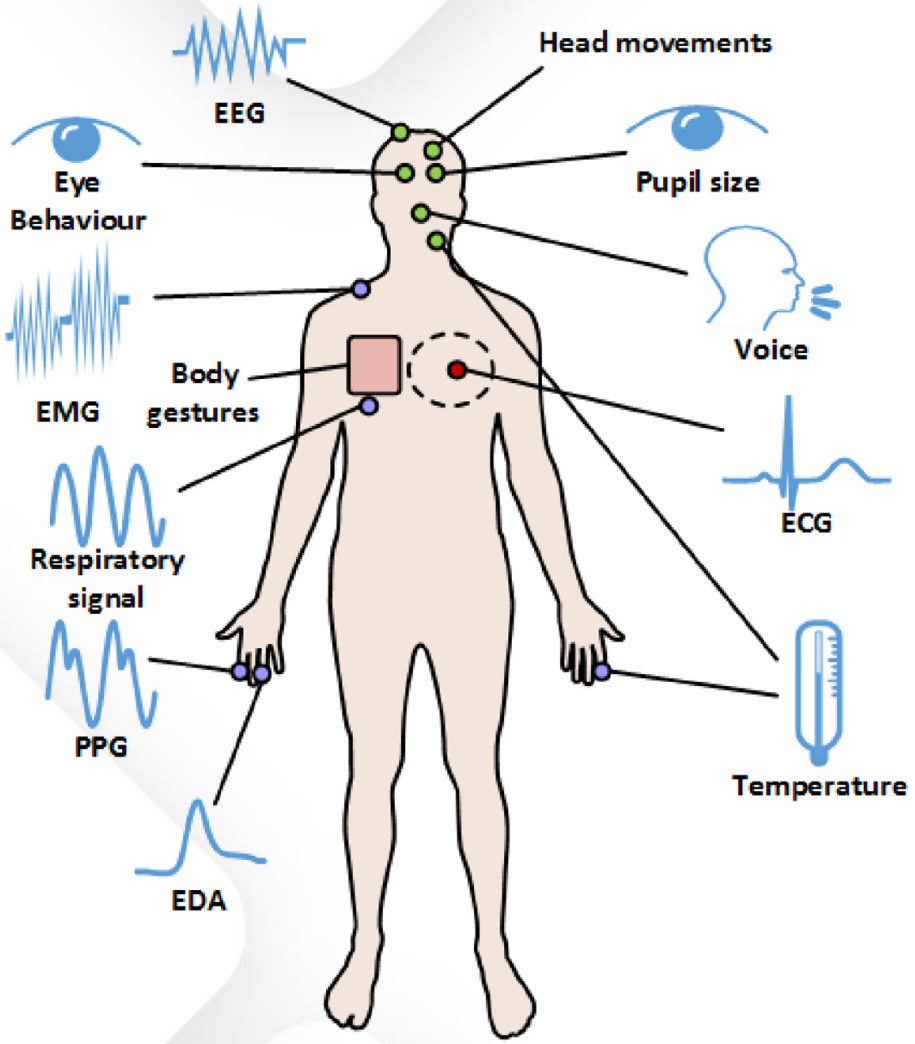


Fig. 4. Common physiological and physical measures related to stress investigated in this study.

A ***biosignal*** is a signal in human beings that can be continually measured like respiratory sound (breathing and cough), heart activity (ECG), brain waves (EEG), etc.

Affordable **+** ***Ubiquitous***

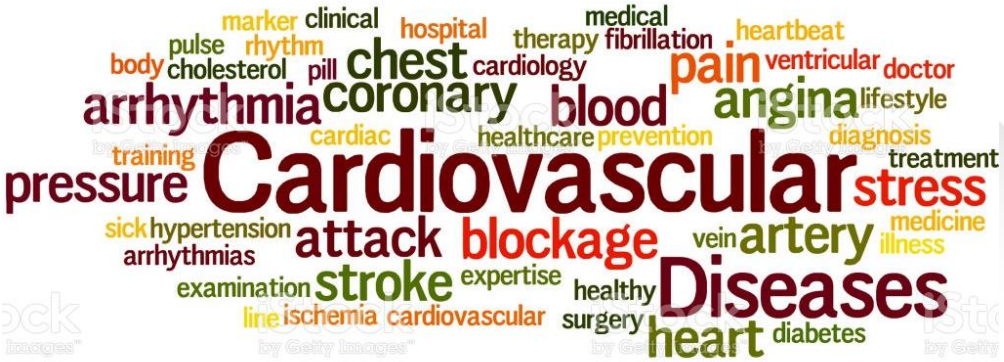


Figure from: Giannakakis, Giorgos, et al. "Review on psychological stress detection using biosignals." IEEE Transactions on Affective Computing (2019).

Machine Learning for Biosignal Modelling

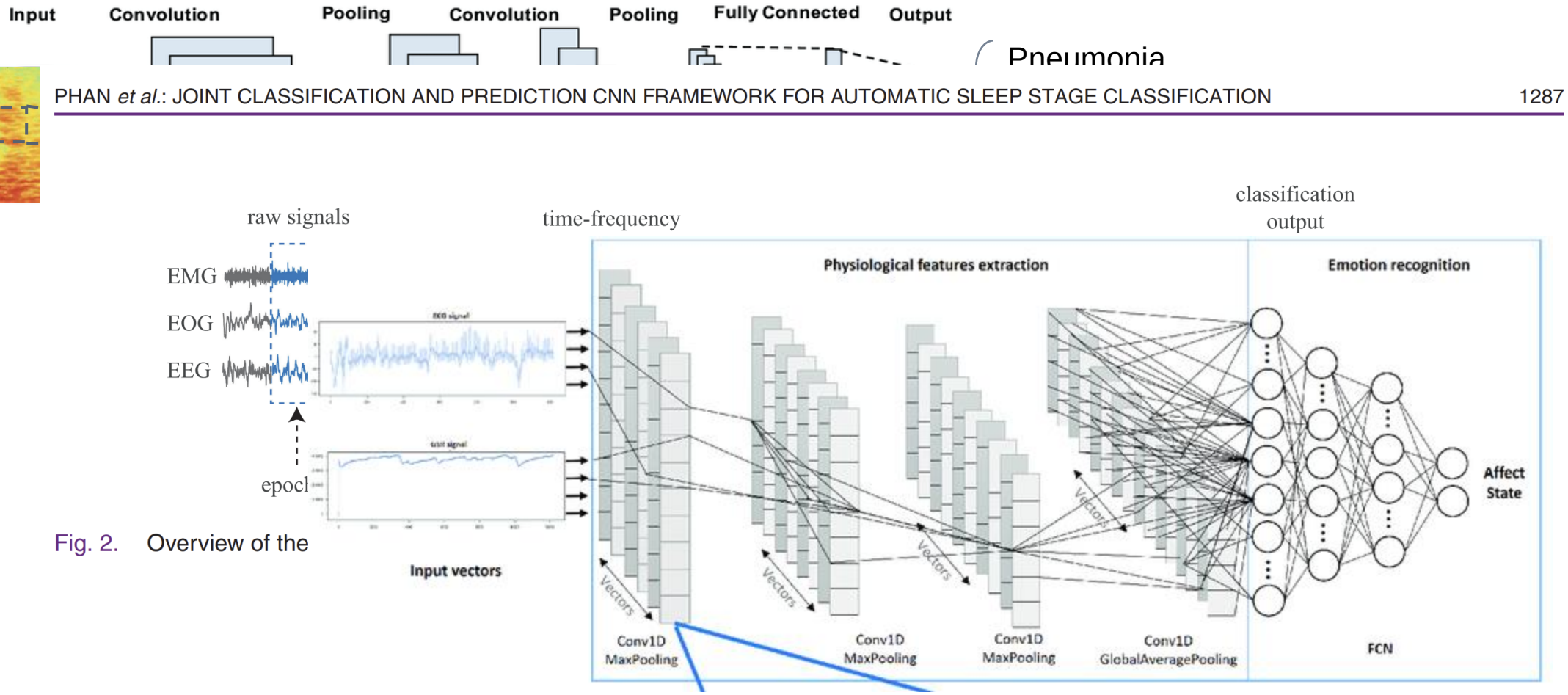
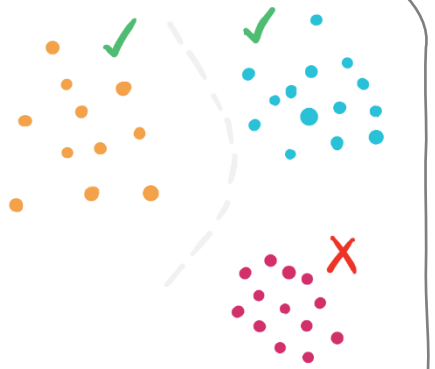


Fig. 2. Overview of the

Udantha R et al. ***Cough sound analysis can rapidly diagnose childhood pneumonia****.*
Annals of biomedical engineering, 41(11):2448–2462, 2013

Is deep learning still promising in the real application?



Out-of-distribution

Input → Black Box → Output

Over-confident

Lack of interpretability

Risk-management

Uncertainty Estimation

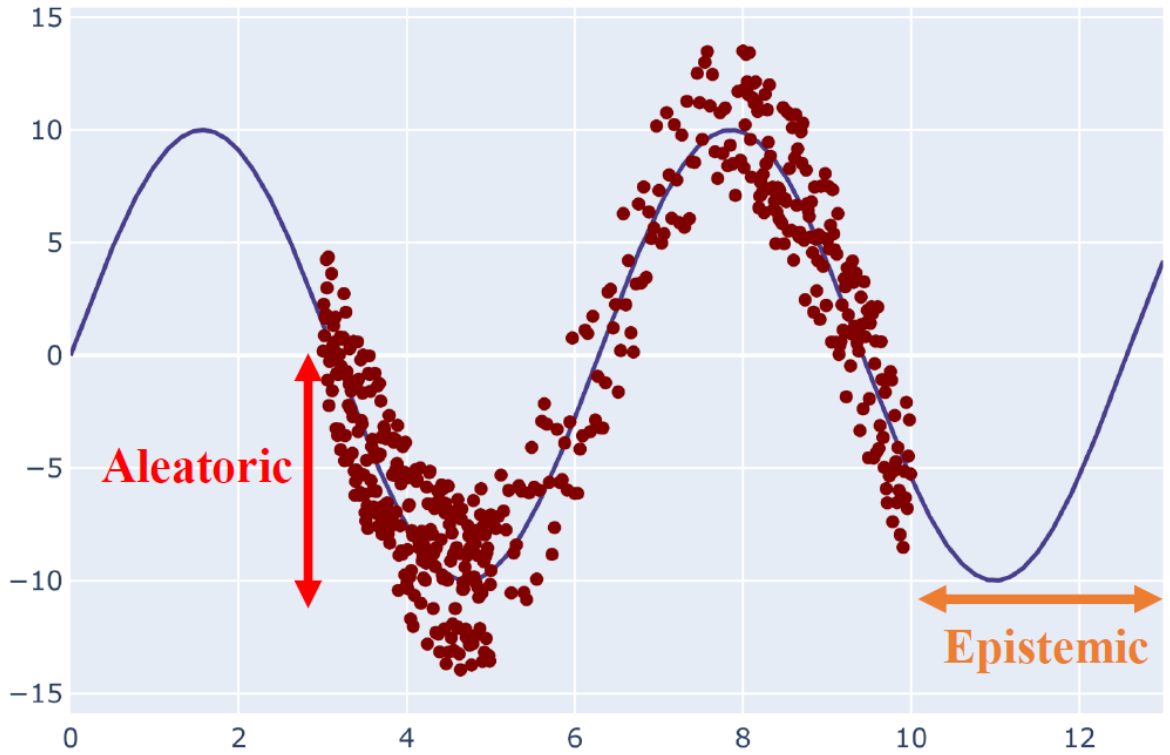
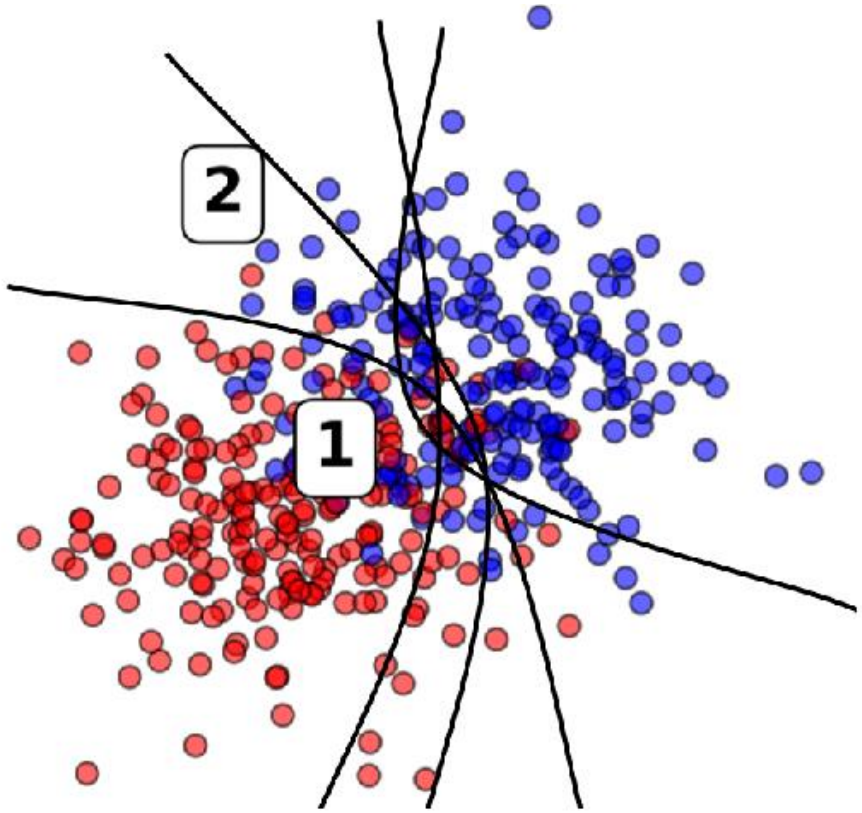
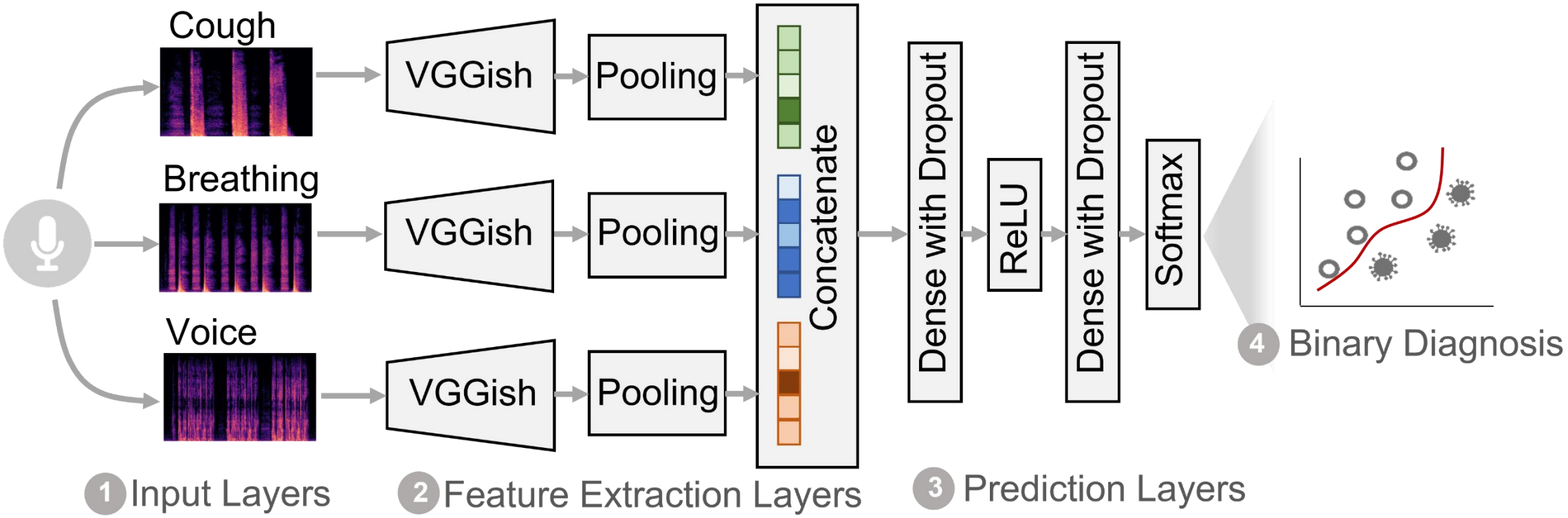


Fig. 1: A schematic view of main differences between aleatoric and epistemic uncertainties.



Abdar, Moloud, et al. "A review of uncertainty quantification in deep learning: Techniques, applications and challenges." Information Fusion (2021).

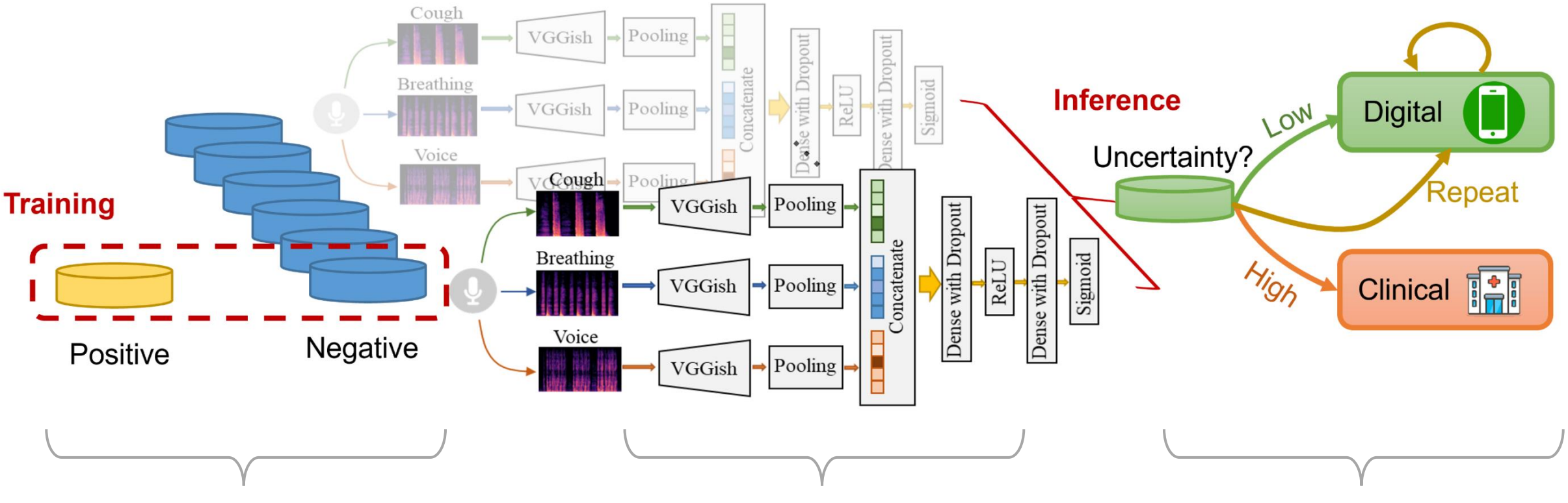
COVID-19 detection from sounds: is that safe?



A single deterministic CNN model using cough, breathing and voice for COVID-19 prediction

https://www.covid-19-sounds.org/en/

Uncertainty-aware COVID-19 detection from sounds



Data sampling

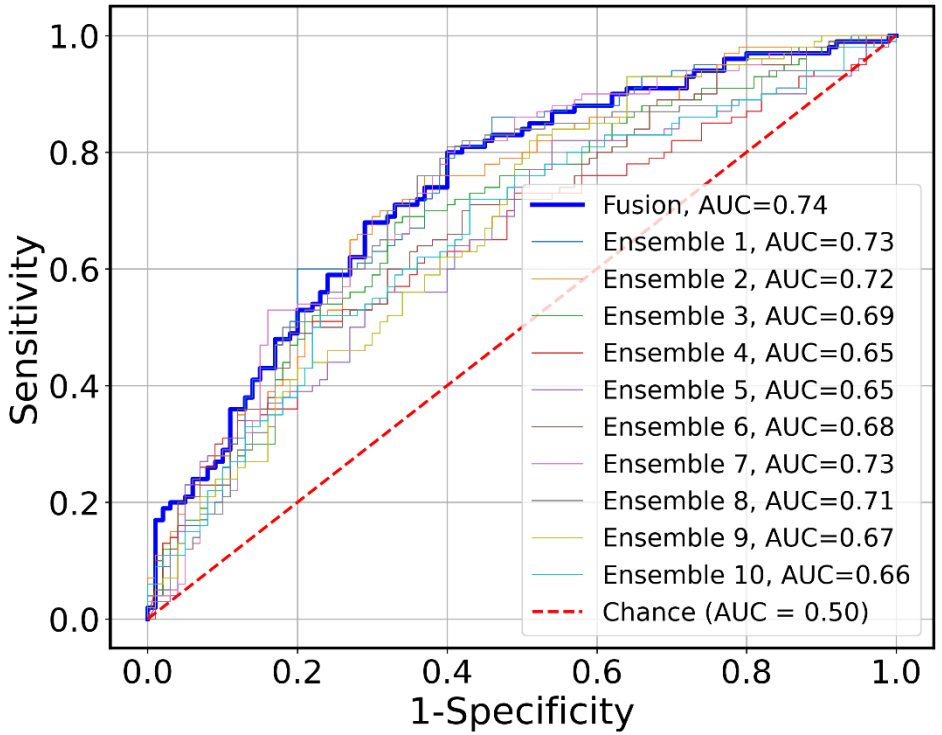
Model learning

Uncertainty qualification

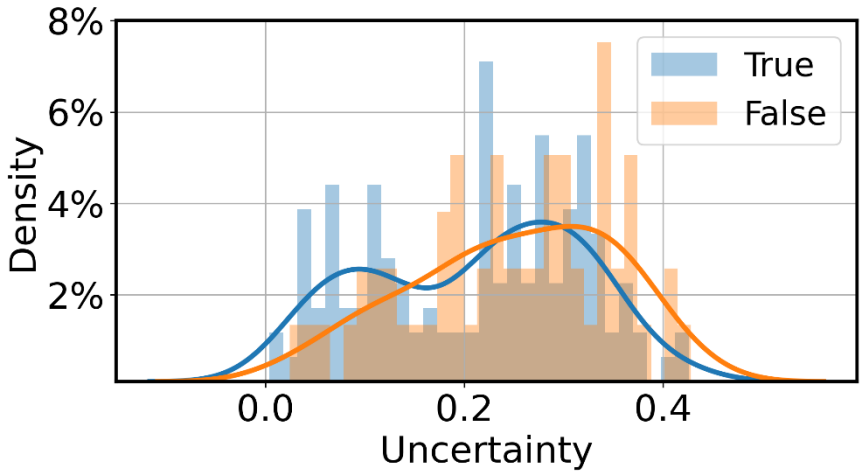
Xia, Tong, et al. "Uncertainty-Aware COVID-19 Detection from Imbalanced Sound Data." arXiv preprint arXiv:2104.02005 (2021).

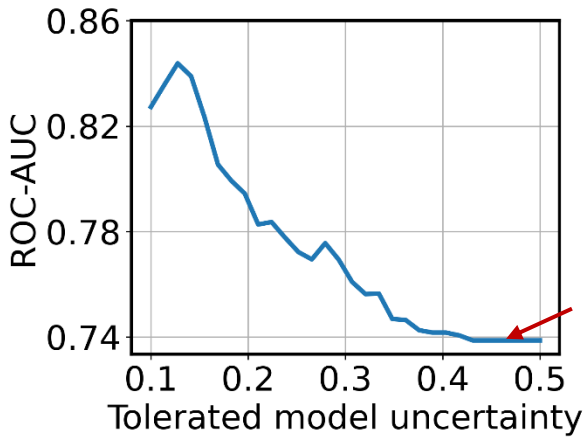
Uncertainty-aware COVID-19 detection from sounds

		ROC-AUC	Sensitivity	Specificity
Ensemble model	SVM	0.66(0.04)	0.63(0.05)	0.62(0.04)
	CNN	**0.74(0.03)**	**0.68(0.05)**	0.69(0.06)



Ensemble fusion outperform single unit.

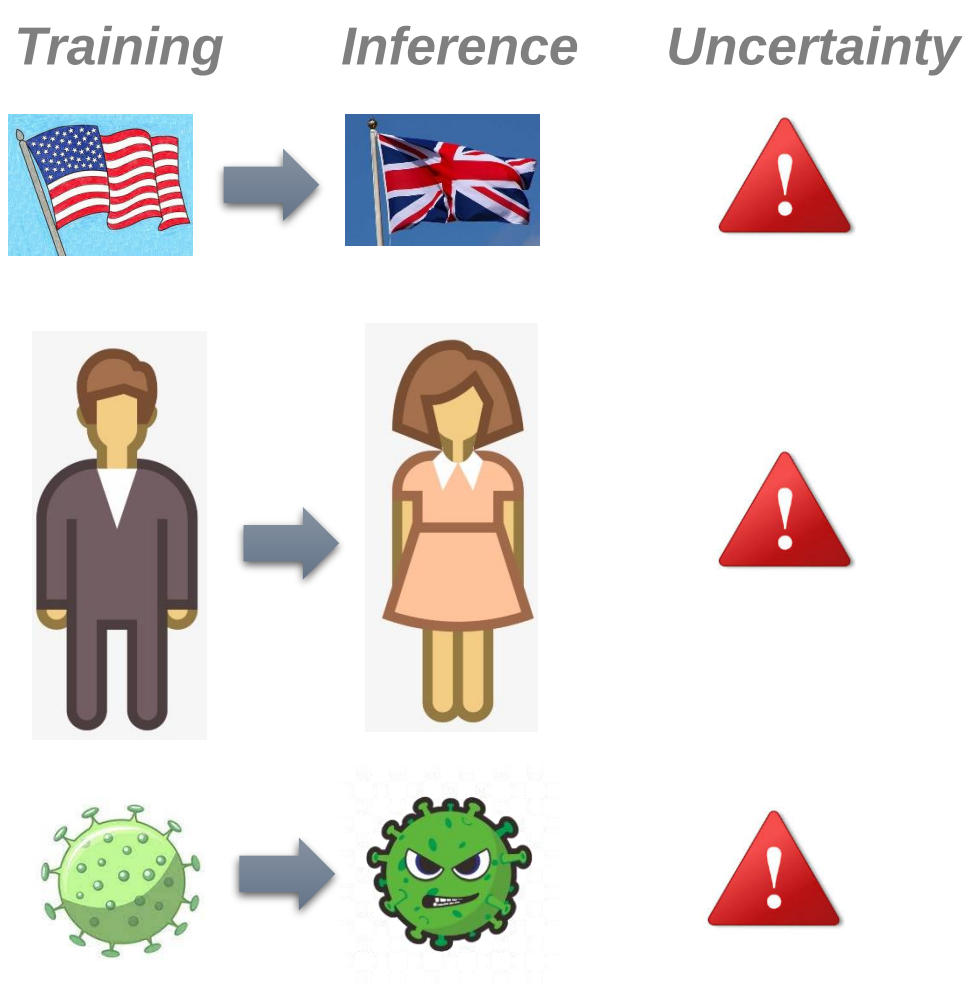


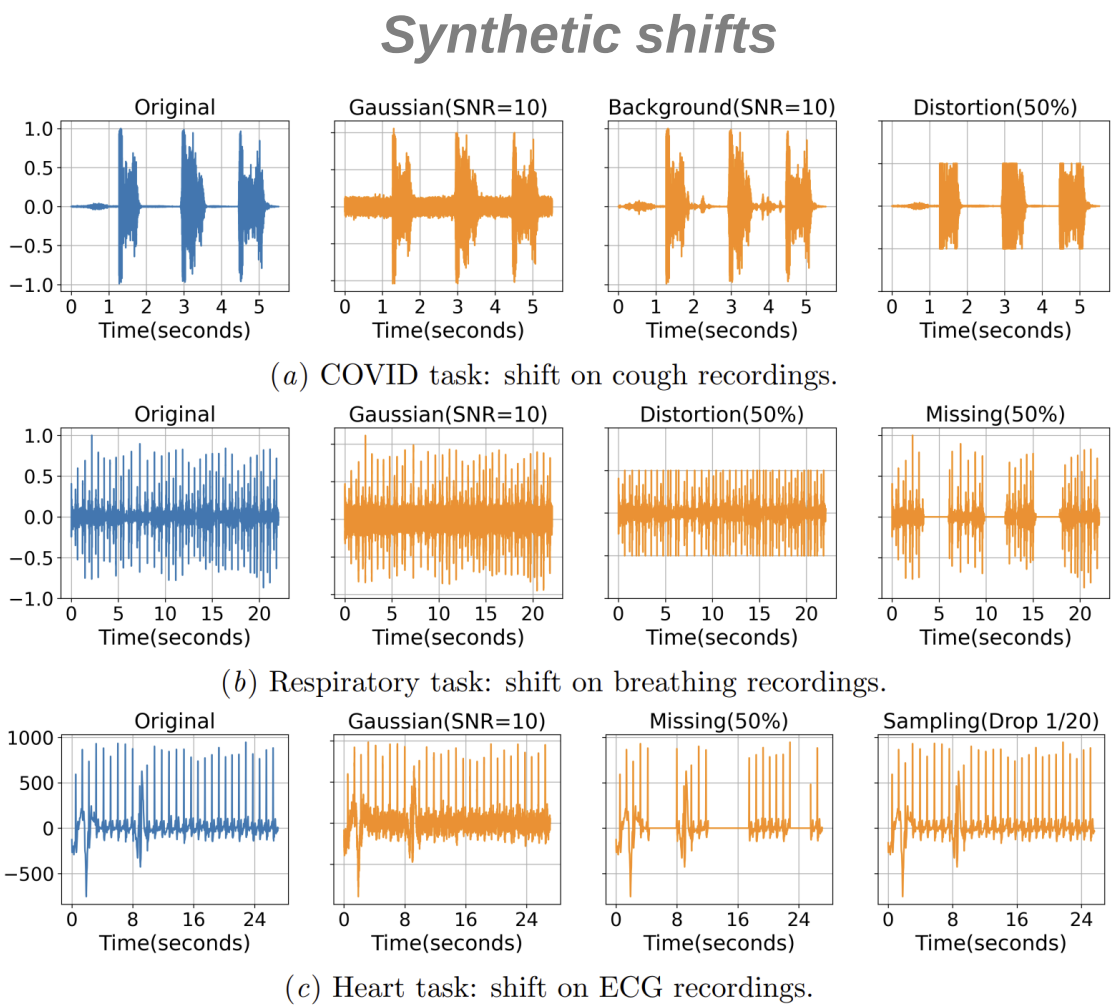


Reject the least confident predictions.

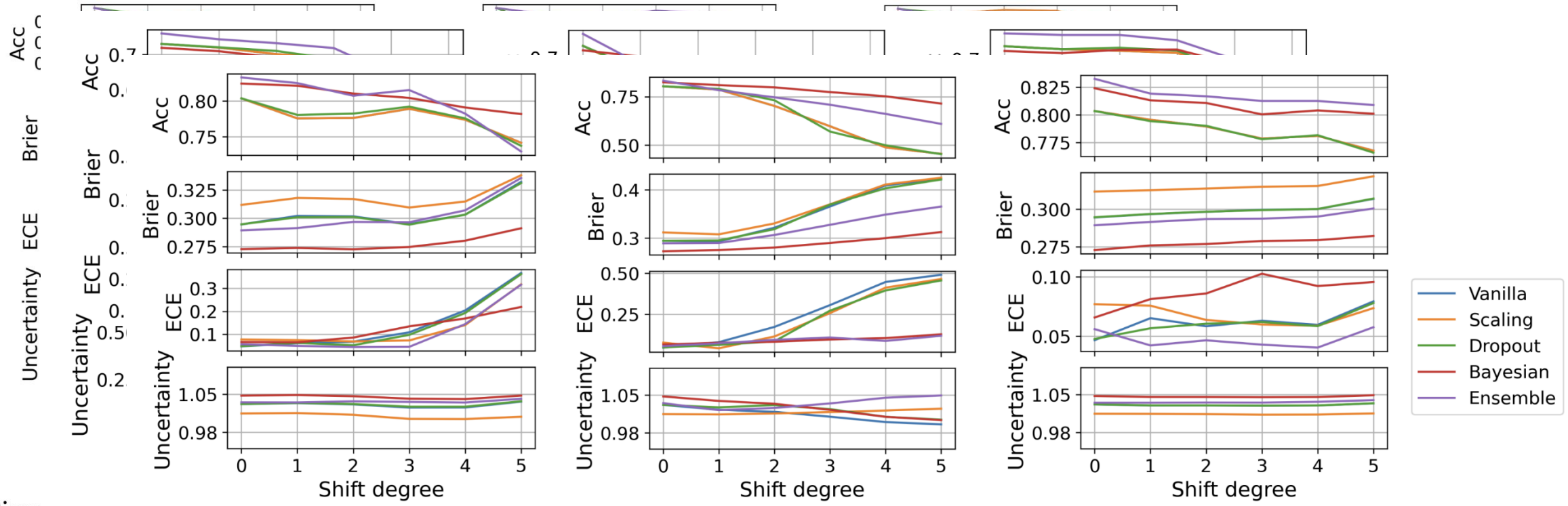
Can the uncertainty perform well in the real application?

Distributional shift between training and testing:





Can the uncertainty perform well in the wild?



Figu

(a) Gaussian shift. (b) Missing shift. (c) Sampling rate mismatch.

Figur

Accuracy as well the quality of uncertainty decline as the shifts become server, although ensemble methods relatively yield more reliable uncertainty estimations.

Beyond Accuracy: Evaluating Uncertainty under Dataset Shift for Biosignal Classification. Tong Xia, Jing Hang, Cecilia Mascolo. In submission.

Summary and future work

- **Benchmarks for time series based health tasks**.
  - *Biosignals*, such as ECG, PPG, sounds, and *wearable* data like accelerometers, are widely adapted for health monitoring.
  - In uncertainty literature, they are rarely explored. Can methods validated on images(MNIST, ImageNet, CIFAR10) still perform well on health data that can be more noisy/heterogeneous?

- **Interpretation and utilization of the uncertainty**.
  - Uncertainty can stem from the model or data. Disentangling them can enable self-supervised model adaption or active learning/continue learning.
  - Adapting the model to the test domain can improve the robustness.

- **Uncertainty-aware sensor/modality fusion**.
  - For multi-channel EEGs, artefact can happen in some channels from time to time. Uncertainty can be used to discard some windows.
  - Similarly, for wearables, for energy consumption concerns, accecemorater data is used for activity reorganization. Yet, when the uncertainty is high, other signals can be promptly involved.

Thank for Listening!

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