ECG-Based Electrolyte Prediction: Evaluating Regression and Probabilistic Methods

Philipp Von Bachmann[1,2], Daniel Gedon[2], Fredrik K. Gustafsson[2], Antônio H. Ribeiro[2], Erik Lampa[2], Stefan Gustafsson[2,3], Thomas B. Schön[2], Johan Sundström[2,4]
[1]University of Tübingen, Germany; [2]Uppsala University, Sweden; [3]Sence Research AB, Sweden; [4]University of New South Wales, Australia.

Motivation

Setting: ECGs from emergency departments (EDs)

Goal: Predict electrolyte concentration from ECG

Contribution:

- Deep learning based prediction model for regression of electrolyte concentrations
- Explore probabilistic regression approaches

Background

1. Deep direct regression: MSE loss, $\hat{y} = m_\theta(x)$
2. Ordinal regression:
   - continuous range → k intervals
   - use rank-consistent ordinal regression to neighbourhood monotonicity
3. Probabilistic regression:
   - Aleatoric: irreducible ambiguity from the experiment itself
     - Gaussian model $p(y \vee x;\theta) = N\left(y;\mu_\theta(x),\sigma_\theta^2(x)\right)$
   - Epistemic: lack of knowledge → reducible
     - Ensemble methods

Methods

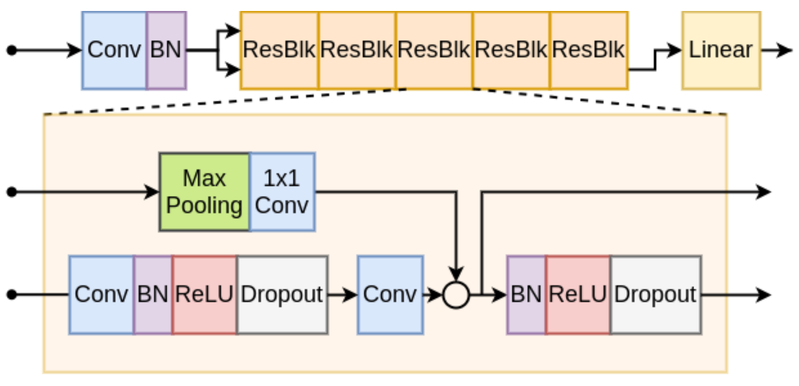
Data set:

- Standard 10 seconds 12-lead ECGs
- Patients at ED visits in Stockholm region, 2007-2016.
- Labels:
  - blood measurements of concentration level
  - Filter for blood test 60 min around ECG

	Potassium	Calcium	Sodium	Creatinine
Patients	165,508	79,577	163,610	166,908
ECGs	290,889	125,970	288,891	295,606
Age, m(sd)	61.3(19.6)	60.5(20.0)	61.4(19.7)	61.3(19.6)
Male, %	49.38	48.71	49.07	49.22

Model architecture:

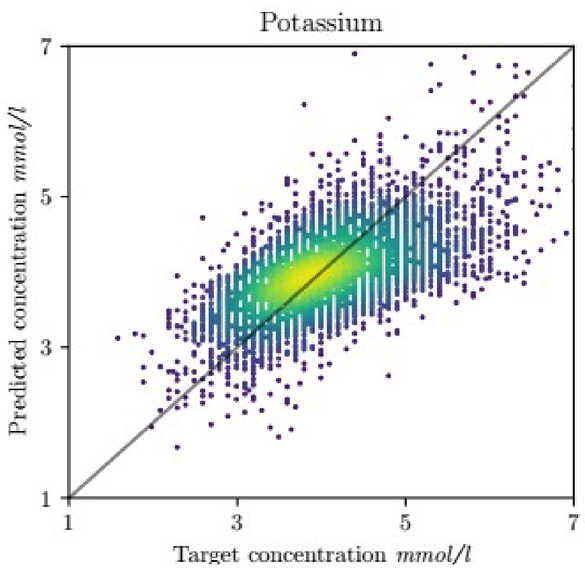
- ResNet backbone
- Network head and loss depends on method

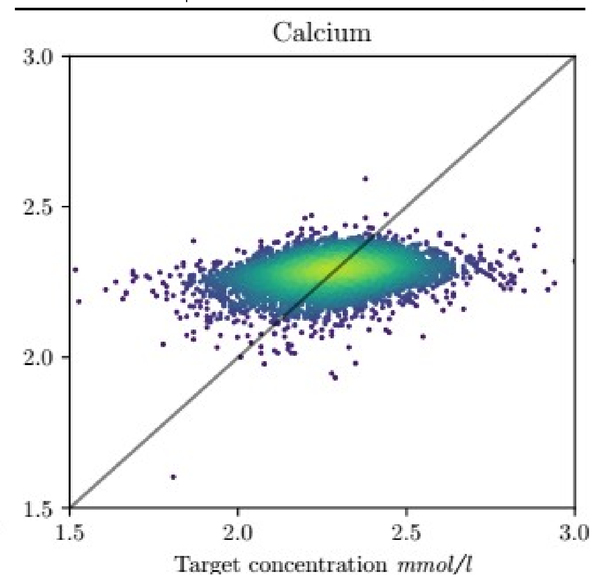


Results

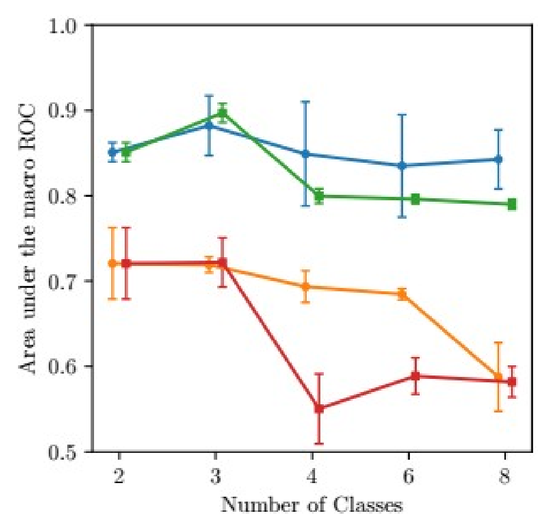
Deep direct regression:

	MSE (sd)	MAE (sd)
potassium	0.152(0.026)	0.285(0.015)
[1]	NA	0.531
[2] (valid)	NA	0.500(0.420)
calcium	0.015(2e−4)	0.088(5e−4)
sodium	12.59(0.111)	2.512(0.016)
creatinine	3719(86.04)	26.69(1.118)

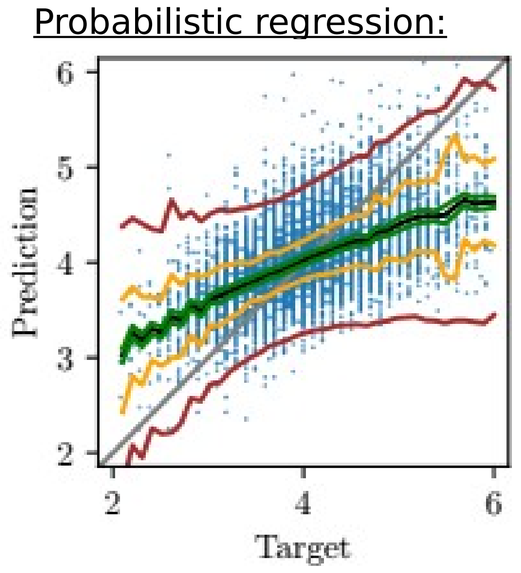


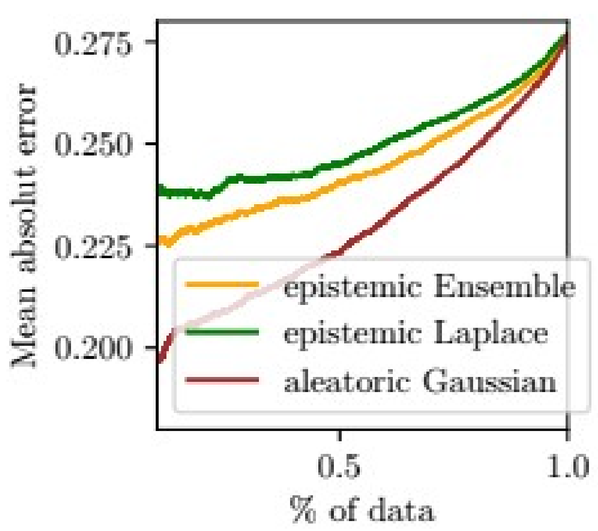


Classification and ordinal regression:



Probabilistic regression:



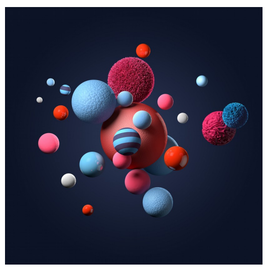


Acknowledgements
Supported by the Kjell and Märta Beijer Foundation, Anders Wiklöf, the Wallenberg AI, Autonomous Systems and Software Program (WASP) funded by Knut and Alice Wallenberg Foundation, and Uppsala University via AI4Research.

References

[1] C.-S. Lin, et al., "A deep-learning algorithm (ECG12Net) for detecting hypokalemia and hyperkalemia by electrocardiography: algorithm development," JMIR medical informatics, 2020
[2] Z. I. Attia, et al., "Novel bloodless potassium determination using a signal-processed single-lead ECG," Journal of the American heart Association, 2016.

Ai4Research



UPPSALA UNIVERSITET