Prediction of major complications affecting Very Low Birth Weight infants

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Goal of this paper

Time series prediction of 3 major complications affecting preterm infants

Aims of the project

Study of vital trends

- Oxygen saturation, supplementary oxygen, blood pressure, respiration, nutrition & growth

A look at prediction opportunities

- What can we predict, using what data, and how early?

Intended outcomes

- Quality control, better resource allocation, improved quality of care

Background

- Neonatal Intensive Care Unit (NICU) at the Helsinki University Children's Hospital treats 120–150 Very Low Birth Weight (VLBW, birth weight <1500 g) infants/year
- Patient data collection started 1999
- We have studied 2059 VLBW infants treated in 1999–2013

Description of the data

2059 VLBW infants born in 1999–2013

- Median gestational age 202 days (~29 weeks), birth weight 1105 g
- Median length of NICU stay 14.2 days
- 185 patients (9%) died in the NICU, median age at death 5 days

175 GB of timestamped data

Sensor output

- heart rate, respiratory rate, oxygen saturation, blood pressure, body temperature
- 2 minute averages

Manual observations

- length, weight, head circumference

Care parameters

- diagnoses, medication, nutrition

Diagnoses

Bronchopulmonary dysplasia (BPD)

- Problem with immature lung development
- Related to oxygen saturation
- Diagnosed at 28 days
- Results in significant morbidity and mortality

Retinopathy of prematurity (ROP)

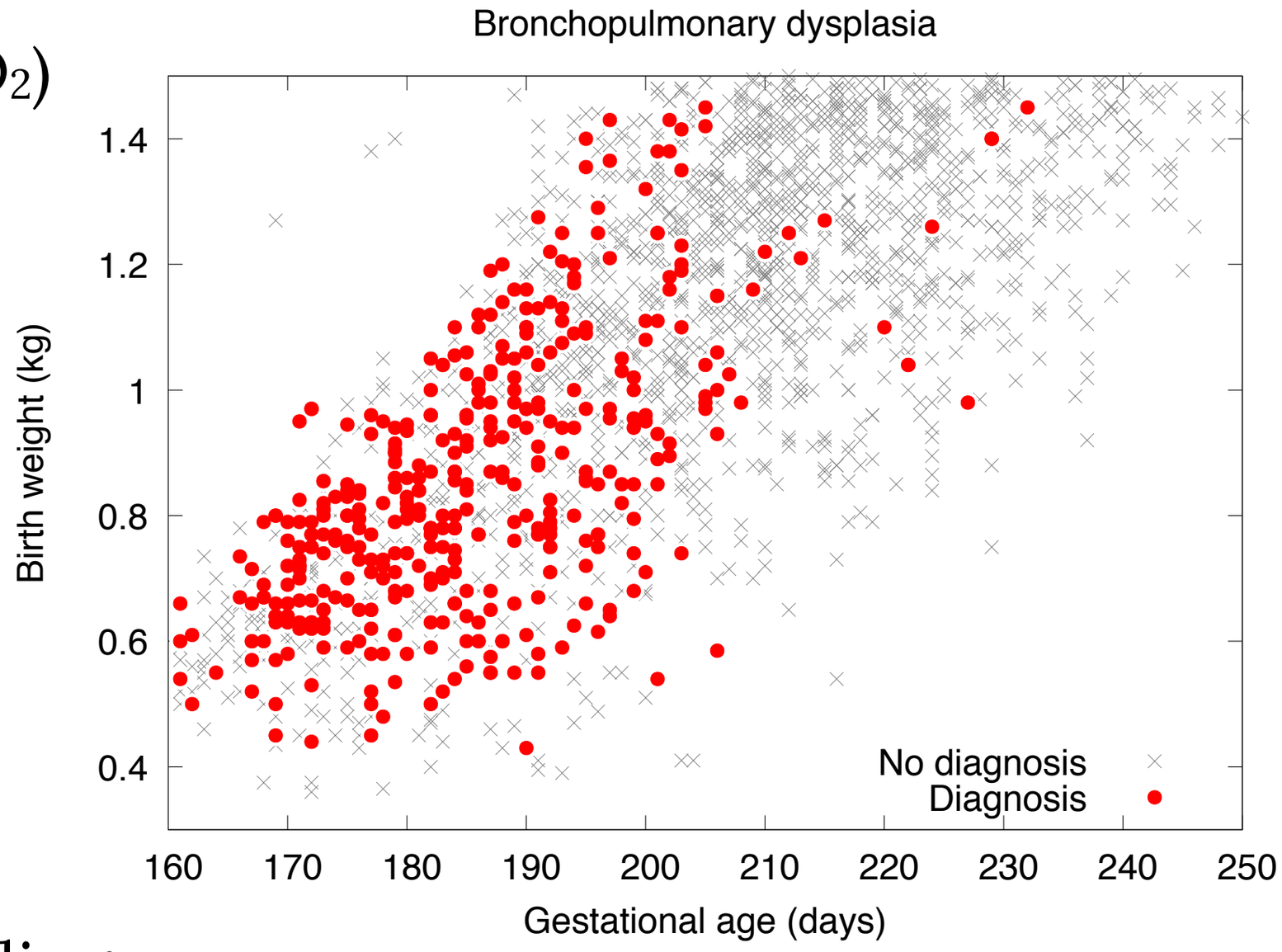
- Problem with immature eye (retina) development
- Related to oxygen saturation: too much O_2 -> patient develops ROP (blindness), too little O_2 -> patient dies

Necrotizing enterocolitis (NEC)

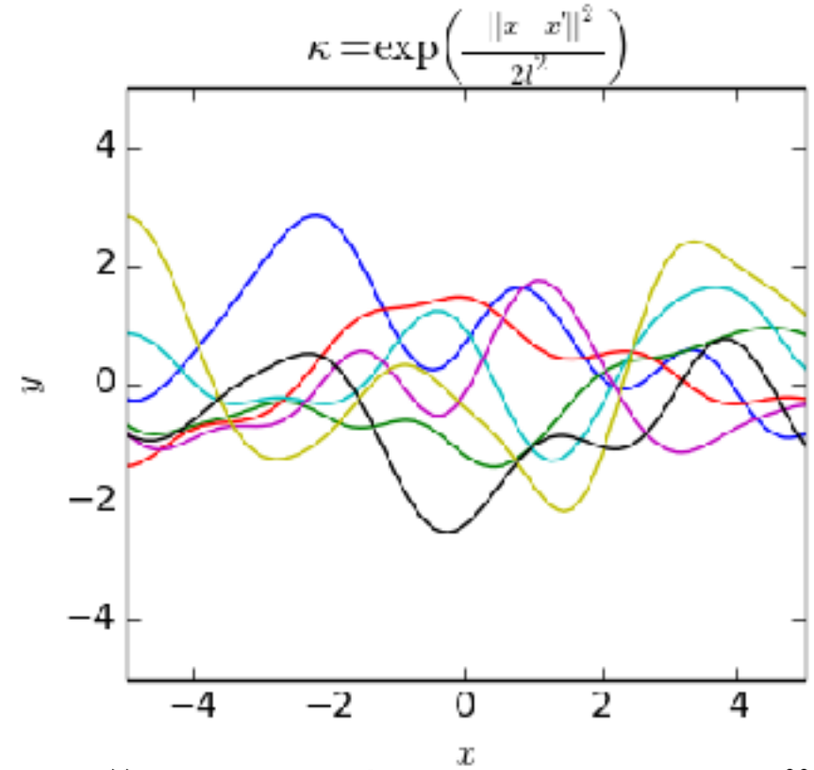
- Intestinal tissue death
- Develops during NICU stay
- Diagnosis requires radiography (X-ray imaging)
- 2nd most common cause of preterm infant mortality

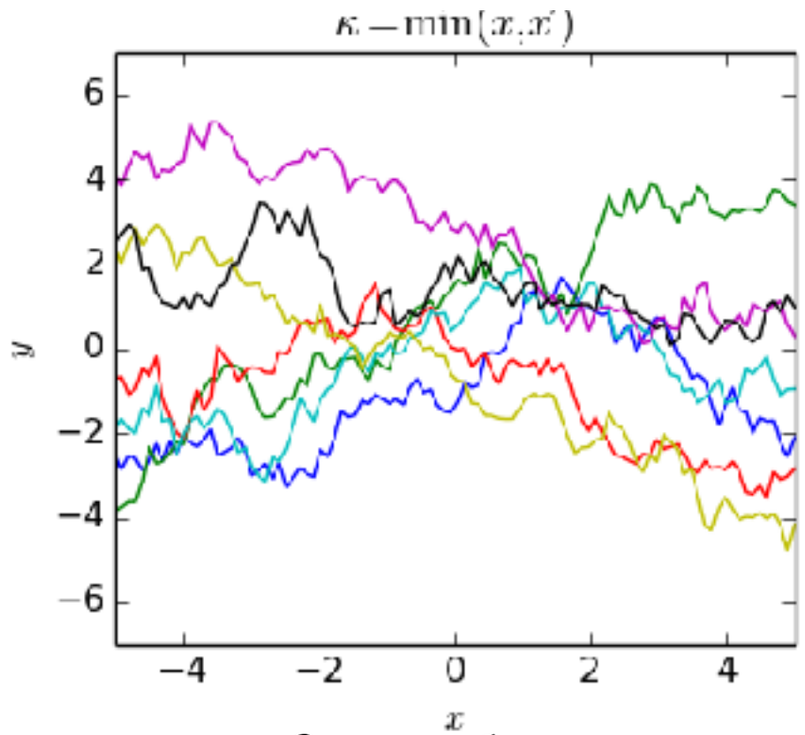
Data and methods

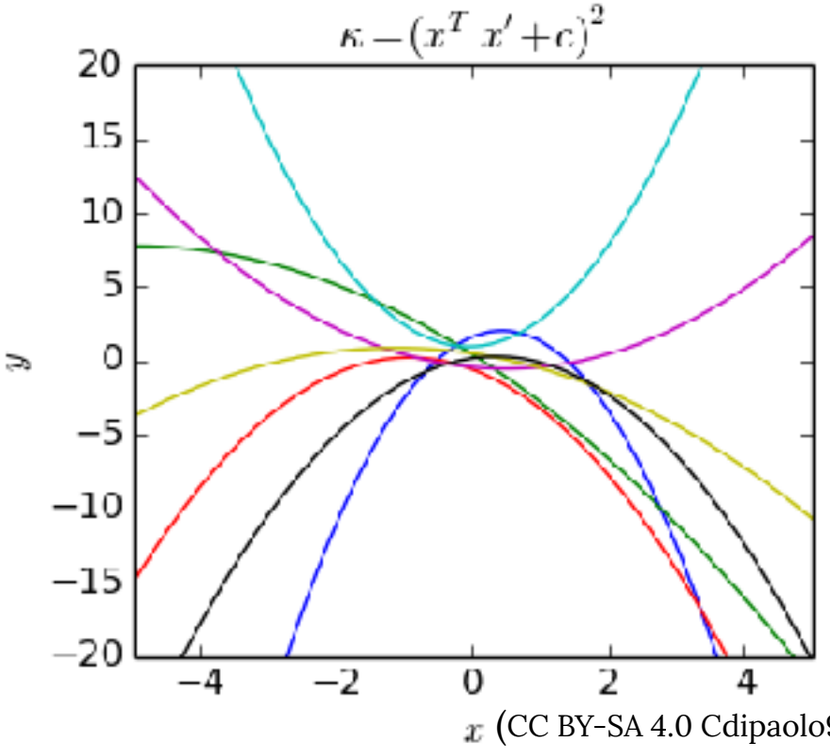
- **Features used**
  - Clinical values/scores determined at or near time of birth: gestational age, birth weight, SNAP-II, SNAPPE-II
  - 24h/72h time series data: systolic/mean/diastolic arterial blood pressure, ECG heart rate, oxygen saturation (SpO_2)
- **Diagnoses**
  - 20% BPD, 3% NEC, 7% ROP
- **Classification**
  - Binary classification: likely/not likely to be affected
  - Benchmark: SNAP(PE)-II thresholding



Gaussian process







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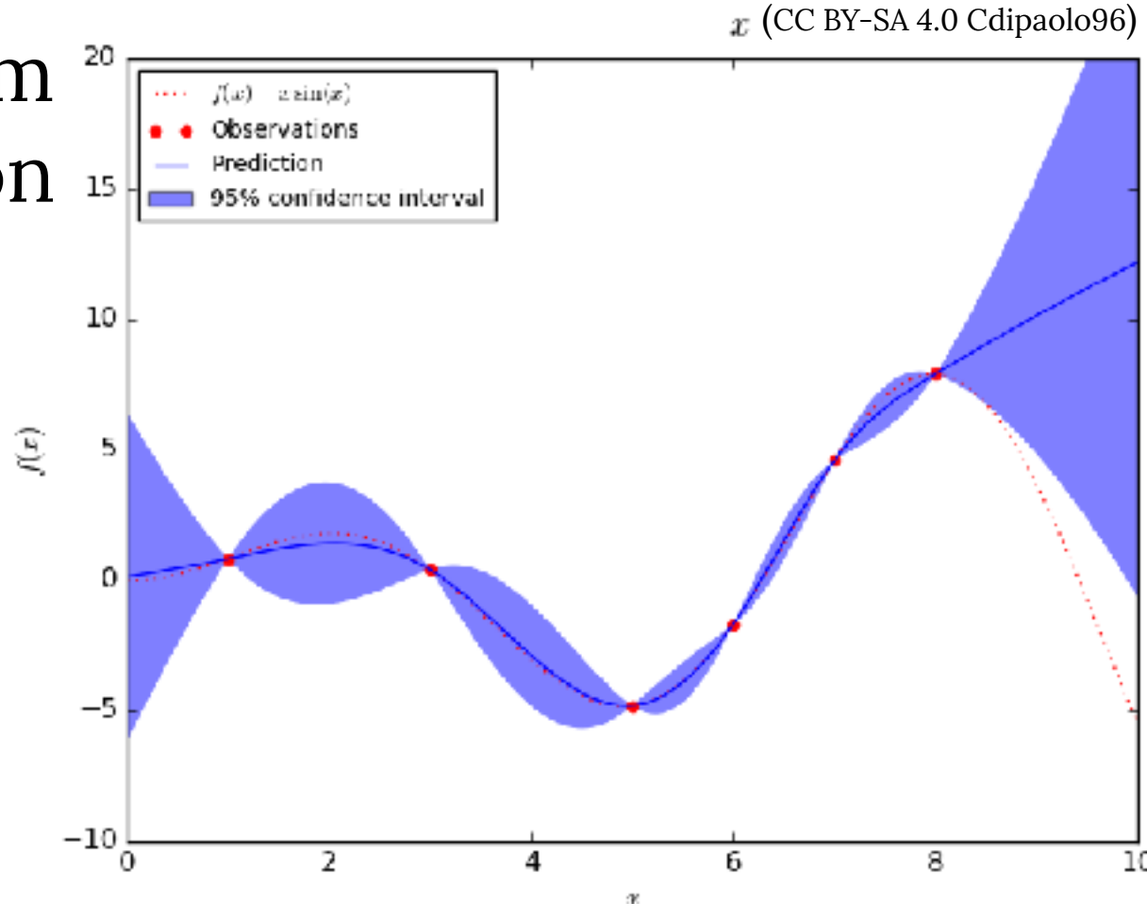
- "Gaussian process" = a set of random variables where the joint distribution of any (finite) subset is a Gaussian
- Defined by mean function $\mu(x)$ and covariance matrix $k(\mathbf{x},\mathbf{x}')$

  GP can be used to find a distribution over functions $f(x)$ consistent with the observed data



GP classification: parameters used

- **GPstuff** – Matlab/Octave/R toolbox
  `http://research.cs.aalto.fi/pml/software/gpstuff/`

- classifier = GP with a probit measurement model

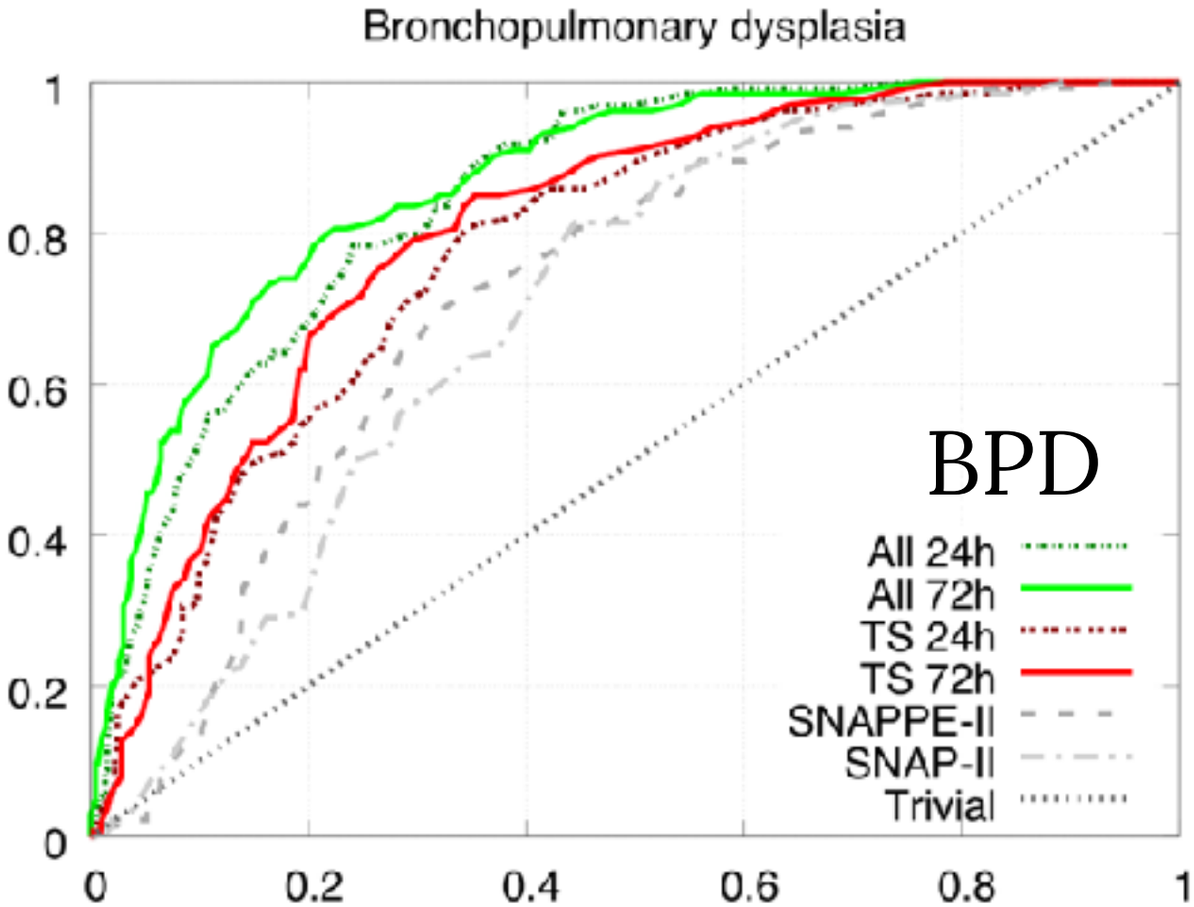
$$f(\mathbf{x}) \sim \mathcal{GP}(0, k(\mathbf{x}, \mathbf{x}')), \quad p(y_i \mid f(\mathbf{x}_i)) = \int_{-\infty}^{y_i f(\mathbf{x}_i)} \mathrm{N}(z \mid 0, 1)\, dz$$

- 2 classes: $y_i \in \{-1, 1\}$

- kernel = squared exponential (RBF) + linear + constant

$$k(\mathbf{x}, \mathbf{x}') = \sigma_{\mathrm{se}}^2 \exp\left(-\frac{1}{2}(\mathbf{x} - \mathbf{x}')^{\mathsf{T}} \Lambda^{-1} (\mathbf{x} - \mathbf{x}')\right) + \mathbf{x}^{\mathsf{T}} \Sigma \mathbf{x}' + \sigma^2$$

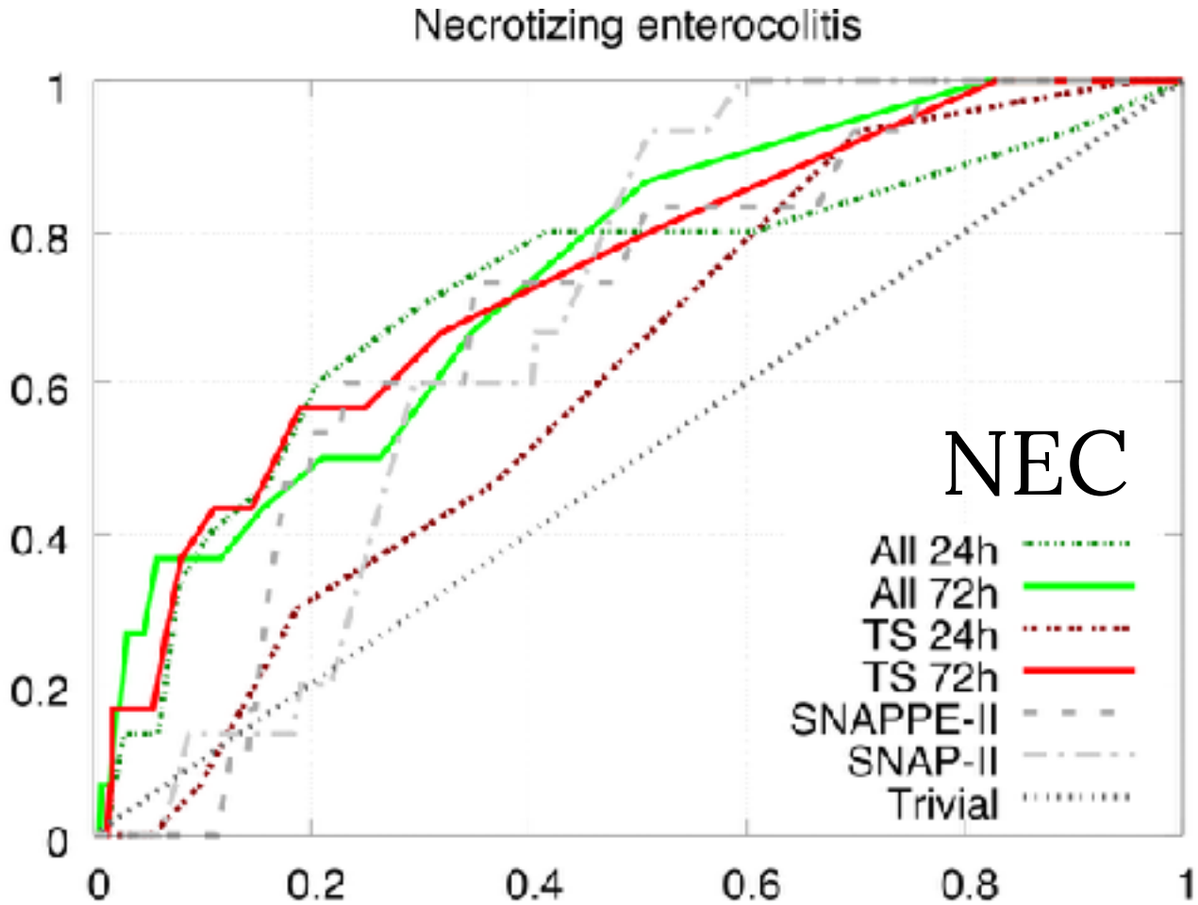
Prediction results



AUC 0.87

PPV 0.67

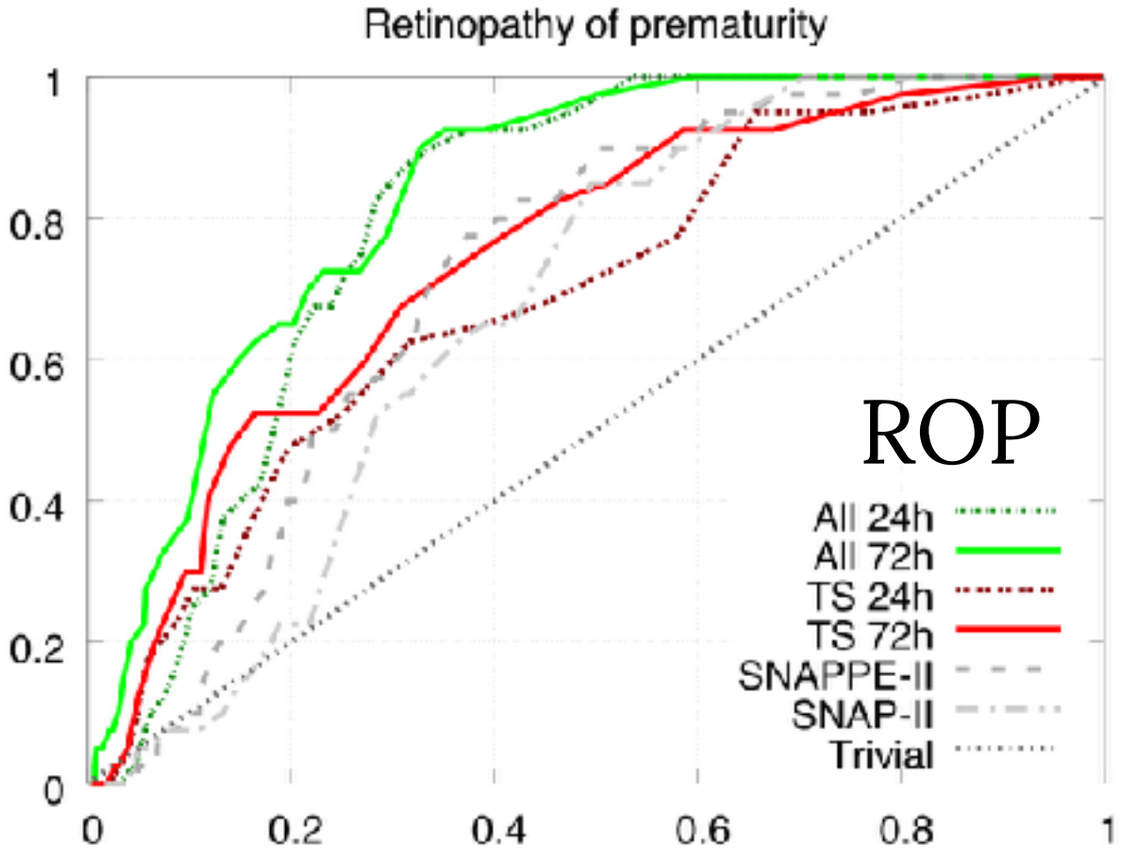
Sens 0.52



AUC 0.74

PPV 0.11

Sens 0.17



AUC 0.84

PPV 0.50

Sens 0.05

Summary and conclusions

- GP classification using time series data from the first hours of NICU care outperforms SNAP(PE)-II for predicting VLBW infant susceptibility to BPD
- Time series prediction accuracy can be improved with features/scores determined at birth, but…
- …conditions that develop during treatment will in general require on-line monitoring analysis

Future work

- Prediction of other diagnoses and patient deterioration
- Integration of machine learning in NICU care processes
- Prediction of patient post-NICU development