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 $O_2 \rightarrow$ patient develops ROP (blindness), too little $O_2 \rightarrow$ 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
• Features used

  Data and methods

  • 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 (SpO₂)

• Diagnoses

  • 20% BPD, 3% NEC, 7% ROP

• Classification

  • Binary classification: likely/not likely to be affected

  • Benchmark: SNAP(PE)-II thresholding
Gaussian process

\[ \kappa = \exp \left( -\frac{|x - x'|^2}{2l^2} \right) \]

- “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 \( k(x,x') \)
  - 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
  

- classifier = GP with a probit measurement model

\[
f(x) \sim \mathcal{GP}(0, k(x, x')) , \quad p(y_i \mid f(x_i)) = \int_{-\infty}^{y_i \cdot f(x_i)} N(z \mid 0, 1) \, dz
\]

- 2 classes: \( y_i \in \{-1, 1\} \)

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

\[
k(x, x') = \sigma^2_{\text{sc}} \exp \left( -\frac{1}{2} (x - x')^T \Lambda^{-1} (x - x') \right) + x^T \Sigma x' + \sigma^2
\]
**Prediction results**

**Bronchopulmonary dysplasia (BPD)**
- AUC: 0.87
- PPV: 0.67
- Sens: 0.52

**Necrotizing enterocolitis (NEC)**
- AUC: 0.74
- PPV: 0.11
- Sens: 0.17

**Retinopathy of prematurity (ROP)**
- 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