An Improved Patient-Specific Mortality Risk Prediction in ICU in a Random Forest Classification Framework

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Critical Care Statistics – Australia/New Zealand

Australia
8.62 beds per 100,000 population

New Zealand
5.84 beds per 100,000 population

Source: ANZICS CORE Annual Report 2012–2013
SAPS II is a severity of disease classification system (Le Gall, Lemeshow, Saulnier, 1993). Its name stands for "Simplified Acute Physiology Score", and is one of several ICU scoring systems.

SAPS II was designed to measure the severity of disease for patients admitted to Intensive care units aged 15 or more.

24 hours after admission to the ICU, the measurement has been completed and resulted in an integer point score between 0 and 163 and a predicted mortality between 0% and 100%. No new score can be calculated during the stay. If a patient is discharged from the ICU and readmitted, a new SAPS II score can be calculated.

The parameters are: Age, Heart Rate, Systolic Blood Pressure, Temperature, Glasgow Coma Scale, Mechanical Ventilation or CPAP, PaO2, FiO2, Urine Output, Blood Urea Nitrogen, Sodium, Potassium, Bicarbonate, Bilirubin, White Blood Cell, Chronic diseases, and Type of admission.
## Critical Care Statistics – Australia/New Zealand

<table>
<thead>
<tr>
<th>Available Beds (from CCR and follow up of non CCR sites)</th>
<th>Australia (n=176)</th>
<th>New Zealand (n=30)</th>
<th>Total (n=206)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Admissions (as reported through CCR, APD and ANZPIC Registry)</td>
<td>143,009 (n=153)</td>
<td>17,977 (n=24)</td>
<td>160,986 (n=177)</td>
</tr>
<tr>
<td>Occupancy Rate</td>
<td>79.08% (n=113)</td>
<td>60.54% (n=21)</td>
<td>76.67% (n=134)</td>
</tr>
</tbody>
</table>

Source: APD, CCR, ANZPIC

n=number of sites

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*Source: ANZICS CORE Annual Report 2012–2013*
In 2012, an academic challenge, Physionet [1], prompted several research attempts to model and predict the risk of inpatient mortality of ICU patients. (Public dataset available online).

Parameters : Blood Pressure - Invasive (diastolic, mean, systolic), Blood Pressure - Non-invasive (diastolic), Blood Pressure - Non-invasive (mean), Blood Pressure - Non-invasive (systolic), Albumin, Alkaline phosphate, Alkaline transaminase, Aspartate transaminase, Bilirubin, Blood urea nitrogen, Cholesterol, Creatinine, Fractional inspired oxygen, Glasgow Coma Score, Glucose, Serum bicarbonate, Hematocrit, Heart rate, Serum potassium, Lactate, Serum magnesium, Mechanical ventilation, Serum sodium, PaCO2, PaO2, pH, Platelets, Respiration rate, SaO2, Temperature, Troponin-I, Troponin-T, Urine output, WBC, and Weight.

Snapshot : Five static variables and thirty-seven time series variables (recorded for vital signs) analysed over a period of 48 hours. (Not all variables were recorded for all patients and not all recorded variables were sampled in equal interval.)

The dataset comprised of information related to 4000 ICU stays of adult patients who were admitted to cardiac, medical, surgical and trauma ICUs.

SAPS score was provided for baseline comparison.

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ICU Risk/Mortality Prediction – Feature Extraction

“Watch the gradient”

Extracted Features:
- Data for every time series was further sampled at every second hour for the entire 48-hour period.
- The mean, maximum, minimum values and the standard deviation of each of these intervals within the 48-hour period, for each time series attribute and the static variables were concatenated to create the feature vector for a particular patient.
ICU Risk/Mortality Prediction – Random Forest

- feature vector $\mathbf{v} \in \mathbb{R}^N$
- split functions $f_n(\mathbf{v}): \mathbb{R}^N \rightarrow \mathbb{R}$
- thresholds $t_n \in \mathbb{R}$
- classifications $P_n(c)$

ICCV 2009 tutorial
ICU Risk/Mortality Prediction – Random Forest

- Try several lines, chosen at random
- Keep line that best separates data – information gain

Recurse

- feature vectors are $x$, $y$ coordinates: $v = [x, y]^T$
- split functions are lines with parameters $a$, $b$: $f_n(v) = ax + by$
- threshold determines intercepts: $t_n$
- four classes: purple, blue, red, green
ICU Risk/Mortality Prediction – Random Forest

• Try several lines, chosen at random

• Keep line that best separates data
  – information gain

• Recurse
• Try several lines, chosen at random

• Keep line that best separates data
  • information gain

• Recurse
Physionet Challenge - Validation

- Dataset size 4000 patients with outcome.
- A ten-fold cross-validation was employed and common evaluation metrics like the true positive rate (TPR, or Sensitivity), false positive rate (FPR), positive predictive value (PPV), negative predictive value (NPV) and accuracy were computed to evaluate the performance of the classifier. Receiver Operating Characteristic (ROC) curve analysis was employed to measure the performance of the models, with the c-statistic (or AUC), representing the area under the ROC curve, also used as a measure of discrimination and model performance.
- Ten fold cross validation implies out of 4000 patients the model was trained with 3600 patients data and validated with 400 patients.

Physionet Challenge - Results

True Positive Rate (TPR or Sensitivity) = \(\frac{TP}{TP + FN}\)
False Positive Rate (FPR) = \(\frac{FP}{FP + TN}\)
Positive Predictive Value (PPV) = \(\frac{TP}{TP + FP}\)
Negative Predictive Value (NPV) = \(\frac{TN}{TN + FN}\)
Accuracy = \(\frac{TP + TN}{TP + TN + FP + FN}\)

Random guessing score :- 0.139
SAPS score for the dataset :- 0.296

<table>
<thead>
<tr>
<th></th>
<th>TPR</th>
<th>FPR</th>
<th>PPV</th>
<th>NPV</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Forest</td>
<td>0.78</td>
<td>0.5</td>
<td>0.8</td>
<td>0.87</td>
<td>0.87</td>
</tr>
</tbody>
</table>

Physionet Challenge - Results

Physionet challenge score = minimum (TPR, PPV)

<table>
<thead>
<tr>
<th>Model</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistic regression</td>
<td>0.44</td>
</tr>
<tr>
<td>Cluster analysis</td>
<td>0.39</td>
</tr>
<tr>
<td>SVM</td>
<td>0.71</td>
</tr>
<tr>
<td>Bayesian Ensemble</td>
<td>0.30</td>
</tr>
<tr>
<td>Random forest (proposed)</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Physionet Challenge - Results

Mean AUC = 0.79 (10 fold cross-validation)

Conclusions

- An automatic ICU mortality risk prediction system has been proposed with a random forest classifier.
- The method outperforms the traditional SAPS-1 scoring method often used in hospitals.
- The prediction model validated with a large dataset.
- It performs better than some of the state-of-the-art predictive models like logistic regression and SVM.
Thank You.
Questions?