Insights from Predicting Paediatric Asthma Exacerbations from Retrospective Clinical Data

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Outline

- Prediction Task
- Baseline Results
- Improving Predictions by Employing Secondary Knowledge Sources
  - The PRAM Scoring System
  - Mapping PRAM attributes to our dataset
  - Inferring and Substituting Missing Values
  - Two-Set Approach using ‘Typical’ and ‘Non-Typical’ cases
- Experimental Set Up and Results
- Conclusions and Future Work
What is the Prediction Task?

- Assess pediatric asthma exacerbation with scant available information about patient’s condition (part of clinical DSS)

- New patient should be classified as MILD or OTHER
  - MILD stay in ED for less than 4 hours
  - OTHER (moderate/severe) stay in ED up to 16 hours or are admitted to a hospital

- OTHER is critical class
  - Misclassified OTHER more costly than misclassified MILD
  - Physician’s tend to diagnose conservatively

- Build predictive model that produces:
  - High Sensitivity (reduce number of false negatives)
    AND
  - High Specificity (reduce number of false positives)
Predictions for “OTHER”

- **Sensitivity (O)** = \( \frac{TP_{\text{OTHER}}}{TP_{\text{OTHER}} + FN_{\text{OTHER}}} \)

- **Specificity (O)** = \( \frac{TN_{\text{OTHER}}}{TN_{\text{OTHER}} + FP_{\text{OTHER}}} \)

<table>
<thead>
<tr>
<th></th>
<th>MILD</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>MILD</td>
<td>( TN_{\text{OTHER}} )</td>
<td>( FP_{\text{OTHER}} )</td>
</tr>
<tr>
<td>OTHER</td>
<td>( FN_{\text{OTHER}} )</td>
<td>( TP_{\text{OTHER}} )</td>
</tr>
</tbody>
</table>
## Baseline Results

<table>
<thead>
<tr>
<th>Classifier</th>
<th>Cases</th>
<th>Sens</th>
<th>Spec</th>
<th>Acc</th>
<th>Auc</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB</td>
<td>362</td>
<td>73</td>
<td>70</td>
<td>72</td>
<td>79</td>
</tr>
<tr>
<td>J48</td>
<td>362</td>
<td>71</td>
<td>57</td>
<td>65</td>
<td>59</td>
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<tr>
<td>NBT</td>
<td>362</td>
<td>72</td>
<td>65</td>
<td>69</td>
<td>73</td>
</tr>
<tr>
<td>LWL$_{NB}$</td>
<td>362</td>
<td>73</td>
<td>70</td>
<td>72</td>
<td>78</td>
</tr>
</tbody>
</table>
Secondary Knowledge Sources

- Use Secondary Knowledge to preprocess data for classification

- Secondary Knowledge Source: PRAM: Preschool Respiratory Assessment Measure

- Applied by mapping attributes from PRAM to corresponding values in our dataset (Not 1-1)

- PRAM was first used to infer likely values for some missing data

- It was then applied to partition data into separate sets for classification
PRAM Scoring System

- Developed for use in pediatric ED
- Uses 5 core clinical attributes to determine asthma severity
- Discriminates severity using a 12-point scoring scale where:
  - 0-4 = MILD
  - 5-8 = MODERATE
  - 9-12 = SEVERE
- For our dataset:
  - 0-4 = MILD
  - 5-12 = OTHER
### PRAM Scoring System

<table>
<thead>
<tr>
<th>Signs</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suprasternal Indrawing</td>
<td>absent</td>
<td></td>
<td>present</td>
<td></td>
</tr>
<tr>
<td>Scalenene retractions</td>
<td>absent</td>
<td></td>
<td>present</td>
<td></td>
</tr>
<tr>
<td>Wheezeing</td>
<td>absent</td>
<td>expiratory</td>
<td>inspiratory and expiratory</td>
<td>Audible without stethoscope/ absent with no air entry</td>
</tr>
<tr>
<td>Air entry</td>
<td>normal</td>
<td>decreased at bases</td>
<td>widespread decrease</td>
<td>absent/ minimal</td>
</tr>
<tr>
<td>Oxygen saturation</td>
<td>&gt;= 95%</td>
<td>92%-95%</td>
<td>&lt; 92%</td>
<td></td>
</tr>
</tbody>
</table>
Mapping PRAM to our dataset

- Need to infer some of the values because:
  - No Mapping for PRAM ‘Suprasternal Indrawing’
  - Retractions in our dataset mapped to ‘Scalene Retractions’ in PRAM
  - Exp Wheeze and Insp Wheeze (two attributes in our dataset) mapped to one PRAM attribute, ‘Wheezing’
  - Air Entry in our dataset has 2 values but PRAM ‘Air Entry’ has 4 possible values
  - SAO2 in our dataset maps to PRAM ‘Oxygen Saturation’

- All mappings approved by ED physician
Rules to Compute PRAM Scores

- RETRACTIONS=absent, AIR_ENTRY=good --> 0
- RETRACTIONS=absent, AIR_ENTRY=reduced --> 1
- RETRACTIONS=absent, AIR_ENTRY=? --> 1
- RETRACTIONS=present --> 2

- EXP_WHEEZE=absent, INSP_WHEEZE=absent --> 0
- EXP_WHEEZE=present, INSP_WHEEZE=absent --> 1
- EXP_WHEEZE=present, INSP_WHEEZE=present --> 2
- EXP_WHEEZE=absent, INSP_WHEEZE=present **** Undefined

- AIR_ENTRY=good --> 0
- Class=mild, AIR_ENTRY=reduced --> 1
- Class=other, AIR_ENTRY=reduced --> 3

- SAO2=ge_95 --> 0
- SAO2=ge_93_lt_95 --> 1
- SAO2=ge_88_lt_93 --> 2
- SAO2=lt_88 --> 3
Dataset as Divided by PRAM Scores

Original and Complete Dataset: 362

PRAM Incorrect: 9

PRAM Instances: 147

Non-PRAM Instances: 180

PRAM Borderline: 26
Computing Missing Values using PRAM – Experimental Design

- Extracted complete and correct PRAM cases
- Attempted to mine rules from these examples with which to perform substitution of other PRAM values
- Tried association rules, but were either empty (none) or involved too many attributes (very few examples to sufficiently support the rules)
- Therefore, used simple logical (rule-based) classifiers for substitution
- Re-ran original classifiers on substituted data
- Substitution, however did not significantly improve results
Using PRAM Scores for Classification

- Observation from applying PRAM scores:
  - PRAM is a very reliable identifier of ‘typical’ cases
  - How about using PRAM as a classifier?
Two Set Approach

- Inspired by Two-Tiered Approach:

- Set is partitioned based on concept representation where the first set captures explicitly basic concept properties, and second set characterizes allowable concept modifications
Two Set Approach – Our Dataset

- PRAM complete and correct cases are ‘typical’ and correspond to the first set (PRAM set)
- All other cases (PRAM incomplete and PRAM incorrect) are ‘atypical’ and correspond to the second set (Non-PRAM set)
- Build a classifier for each outlined set
- For each new case must decide which set to assign it to (achieved by a meta-classifier)
Two Set Approach – Our Dataset

Strategy is: Leave one out cross validation
## Two Set Approach – PRAM Set

- All classifiers work well on PRAM set

<table>
<thead>
<tr>
<th>Classifier</th>
<th>Cases</th>
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<th>Spec (BL)</th>
<th>Acc (BL)</th>
<th>Auc (BL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB</td>
<td>147</td>
<td>88 (73)</td>
<td>71 (70)</td>
<td>89 (72)</td>
<td>97 (79)</td>
</tr>
<tr>
<td><strong>J48</strong></td>
<td><strong>147</strong></td>
<td><strong>93 (71)</strong></td>
<td><strong>96 (57)</strong></td>
<td><strong>95 (65)</strong></td>
<td><strong>98 (59)</strong></td>
</tr>
<tr>
<td>NBT</td>
<td>147</td>
<td>86 (72)</td>
<td>92 (65)</td>
<td>89 (69)</td>
<td>96 (73)</td>
</tr>
<tr>
<td>(LWL_{NB})</td>
<td>147</td>
<td>90 (73)</td>
<td>88 (70)</td>
<td>89 (72)</td>
<td>96 (78)</td>
</tr>
</tbody>
</table>
Two Set Approach – Non-PRAM Set

- Much bigger variation among classifiers

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<tbody>
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<td>74 (73)</td>
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<td>74 (72)</td>
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<td>69 (73)</td>
</tr>
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<td>LWL_{NB}</td>
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<td>76 (73)</td>
<td>60 (70)</td>
<td>69 (72)</td>
<td>71 (78)</td>
</tr>
</tbody>
</table>
Ongoing Work

- Aiming to improve results on the Non-PRAM set
  - In particular focusing on methods to improve Specificity
  - Clustering, Automatic and Expert Feature Selection
  - Contextual Normalization

- Implementation of Meta-Classifier
  - Simplest based on presence/absence of PRAM values
  - May also consider voting and ranking mechanisms
Conclusions

- Retrospectively collected clinical data provides many difficulties for data mining and machine learning.
- Our approach has been to apply Secondary Knowledge Sources (PRAM) to preprocess data for classification.
- Employ a two set approach based on concept representation for data partitioning.
- Approach will be tested on new data that is prospectively collected in ED.

To learn more about the research: [http://www.mobiledss.uottawa.ca](http://www.mobiledss.uottawa.ca)