Objectives

• Noninvasive vital sign (VS) data collected in a Step-Down Unit
• Alerts issued when a VS exceeds predefined thresholds
• Many alerts are artifacts, causing alarm fatigue
• Need to dismiss these artifacts

Outcomes

• Machine Learning improves alert adjudication accuracy, precision, and recall
• Visualizable results
• Models confirm clinicians’ insights regarding alerts
• Clinicians can derive new alert adjudication rules from informative low-dimensional projections of complex data

Approach

• Regression-based Informative Projection Recovery (RIPR) enables alert adjudication
• Highly multivariate analysis
• Results presented in a human-understandable form

This work has been partially funded by the National Science Foundation (awards 0911032, 1320347) and the National Institutes of Health (R01NR013912)
Alert Artifact Identification
Fiterau, Dubrawski, Chen, Hravnak, Clermont, Pinsky

Data Description

- Prospective longitudinal study recruited admissions over 8 weeks in a 24 bed trauma stepdown unit all with noninvasive VS monitoring:
  - Heart Rate (HR) from 5-lead ECG
  - Respiratory Rate (RR) from ECG bioimpedance
  - Systolic (SBP) and Diastolic (DBP) Blood Pressure (oscillometric)
  - Peripheral arterial oxygen saturation (SpO₂) by finger plethysmography

- VS data analyzed beyond local instability threshold values:
  - HR<40 or >140; RR<8 or >36; SBP <80 or >200; DBP>110, SpO₂<85%
  - Each alert associated with a category indicating the leading abnormal VS
  - 812 alerts of 3 types: RR, SpO₂, BP
  - Features computed, for each VS signal independently, during span of each alert, and a short window (4 minutes) preceding alert onset
  - Features include common statistics of each VS: mean, standard deviation, minimum, maximum, and range of values
Alert Artifact Identification  
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**Approach: Finding Informative Projections of Data**

- **Aim:** Find a few simple projections of data in which alerts appear as either convincingly correct or easily dismissible
- **Challenge:** There are many candidate projections to choose from
- **Solution:** Machine Learning algorithm called RIPR: Regression-based Informative Projection Recovery [*]

  - RIPR selects a manageably small number of projections that jointly explain multiple alerts
  - Each alert requires only one projection to be explained
  - Low-dimensional projections allow easy interpretability
  - RIPR also enables automated adjudication (classification) of alerts

[*] M. Fiterau, A. Dubrawski, A Unified View of Informative Projection Retrieval, ICMLA 2013
Cross-Validation Results Separate True From False Alerts

The retrieved few low-dimensional projections make it possible for domain experts to quickly validate the assigned alert labels.

<table>
<thead>
<tr>
<th>Alarm Type</th>
<th>RR</th>
<th>BP</th>
<th>SPO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2D</td>
<td>2D</td>
<td>3D</td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.98</td>
<td>0.833</td>
<td>0.885</td>
</tr>
<tr>
<td>Precision</td>
<td>0.979</td>
<td>0.858</td>
<td>0.896</td>
</tr>
<tr>
<td>Recall</td>
<td>0.991</td>
<td>0.93</td>
<td>0.958</td>
</tr>
</tbody>
</table>

*data density = number of readings over time units: a low value indicates high sparseness
Confirmatory Results and Outlier Detection

- According to experts, lack of HR signal indicates an RR artifact. The model validates expert intuition by correctly selecting HR data density as the most important dimension in RR artifact classification.

- Example shown includes two alert episodes that would be classified as non-artifacts. Both have continuous streams of RR data, but the RR signals are irregular – an uncommon artifact. Investigation has shown that instances like these can be identified using variance of signal.

- RIPR also highlight potentially mislabeled alerts allowing clinicians to reconsider their judgments.
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Deriving Artifact Identification Rules (Example: SpO₂)

Conclusion: (1) RIPR models show high accuracy, precision, and recall or alert adjudication, while presenting results in an easy to understand form; (2) Retrieved projections confirm clinicians’ insights and highlight potential mislabelings; (3) Informative low-dimensional projections make it easy for clinicians to derive new alert adjudication rules.