Archetyping Artifacts in Monitored Noninvasive Vital Signs Data

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Disclosures

Disclaimer: no Commercial Conflict of Interest

- No private funding as used for this research and this work is not commercially biased

Introduction

- False alerts in monitored patients cause alarm fatigue in clinical staff and can adversely impact medical outcomes

- We used an informative clustering approach to identify human interpretable archetypes of false alerts

- Automatic detection used as a preliminary step to a corrective action plan

- The validity of the identified artifactual patterns was confirmed by expert clinicians

Methods: Data Acquisition

- Prospective longitudinal study recruited admissions over 8 weeks in a 24 bed trauma stepdown unit (SDU)

- Noninvasive vital sign (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 (SpO_2) by finger plethysmography

- Collected at 1/20 Hz frequency

Methods: Data Processing

- VS data analyzed beyond local instability threshold values:
    - HR<40 or >140; RR<8 or >36;
    - SBP <80 or >200; DBP>110, SpO_2<85%
    - Each alert associated with a category indicating the leading abnormal VS
- 1582 abnormality episodes of 4 types: HR, RR, SpO_2, BP
- Adjudication by committee of 4 expert clinicians:
    - 1115 real alerts, 318 artifacts
    - 149 could not be adjudicated due to expert disagreement

Methods: Data Processing

- Features computed, for each VS signal, during span of each alert, and a short window of 4 minutes preceding alert onset

- Features include common statistics of each VS: mean, standard deviation, minimum, maximum, gradients, min and max of first order differences, duty cycle etc.

- Artifacts were clustered on low-dimensional projections for easy interpretation

- Automatic system runs an optimization over a set of nearest-neighbor measures to identify an optimal set of low-d clusters

- Patterns were validated by expert clinicians

Methods: Projection Recovery

- **Aim:** Find a few simple projections of data in which alerts appear as cohesive clusters; find areas of a greater data density in low-d projections

- **Challenge:** There are many candidate projections to choose from
  - If we are considering pairs of the n features, there are n(n-1)/2 projections

- **Solution:** Machine Learning algorithm called RIPR: Regression-based Informative Projection Recovery [1,2]

  - RIPR selects a small set of projections in such that all alerts are covered

  - Each alert requires only one projection to be clustered

  - Low-dimensional projections allow easy interpretability

[1] M. Fiterau, A. Dubrawski, A Unified View of Informative Projection Retrieval, ICMLA 2013
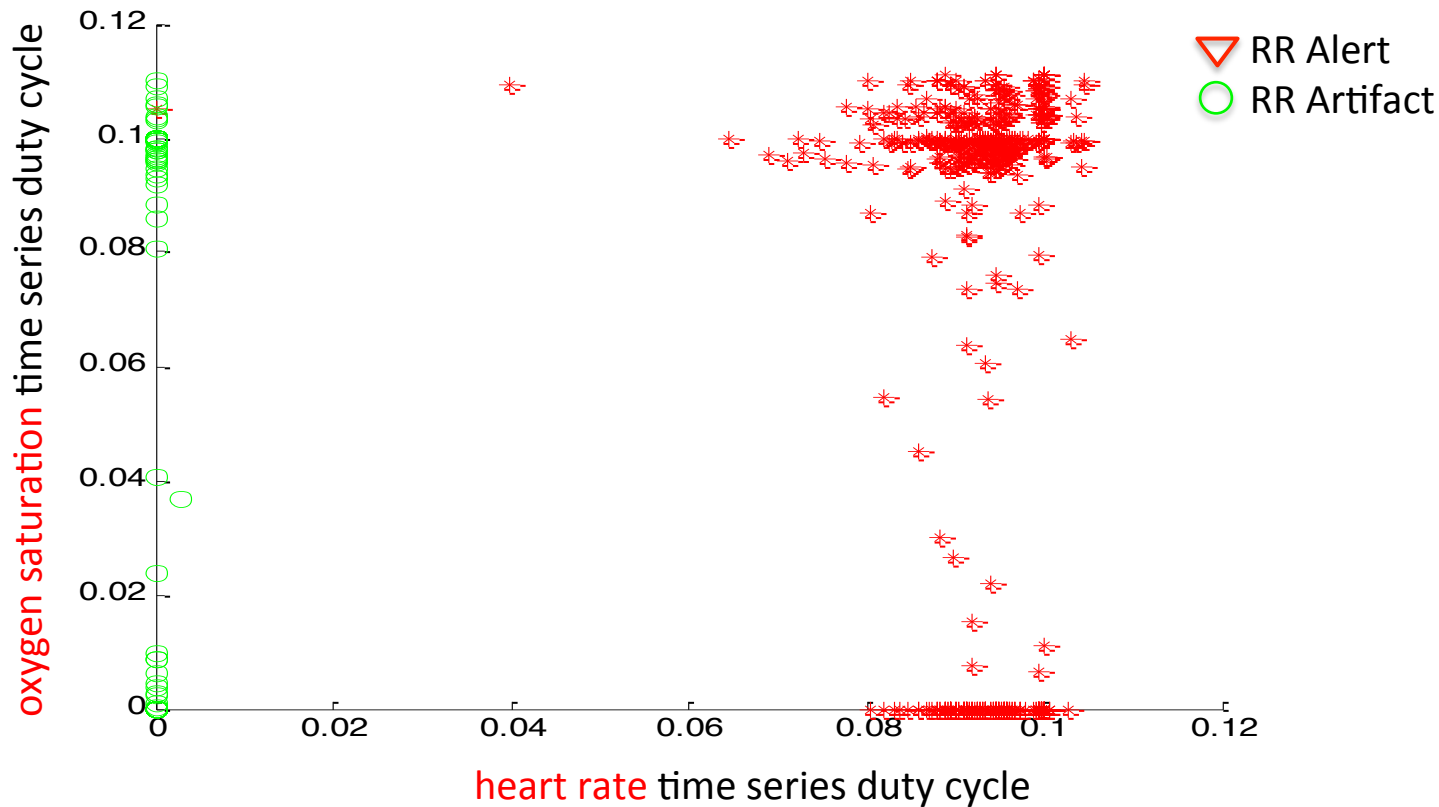[2] M. Fiterau, A. Dubrawski, Informative Projection Retrieval for Classification, NIPS 2012
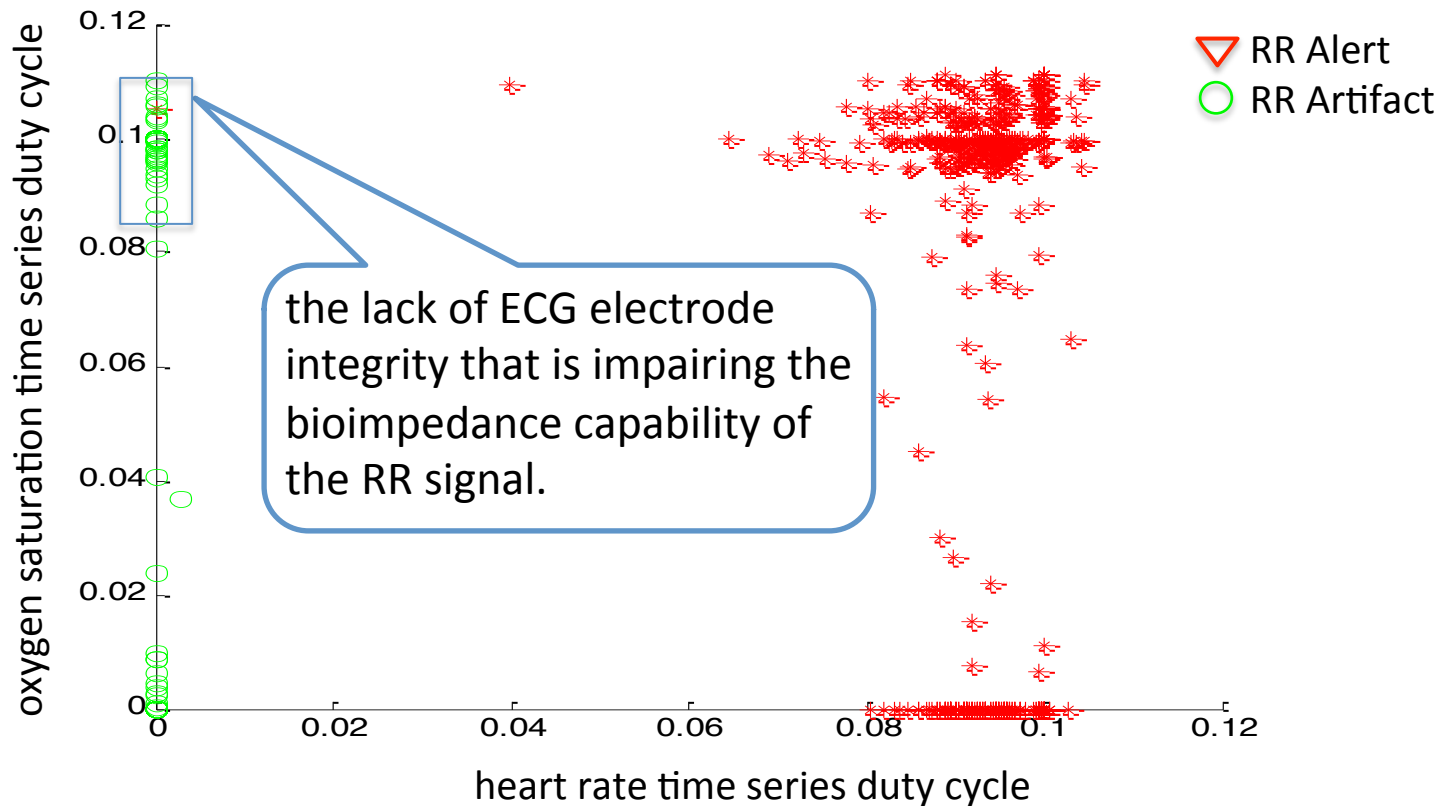
RESULTS

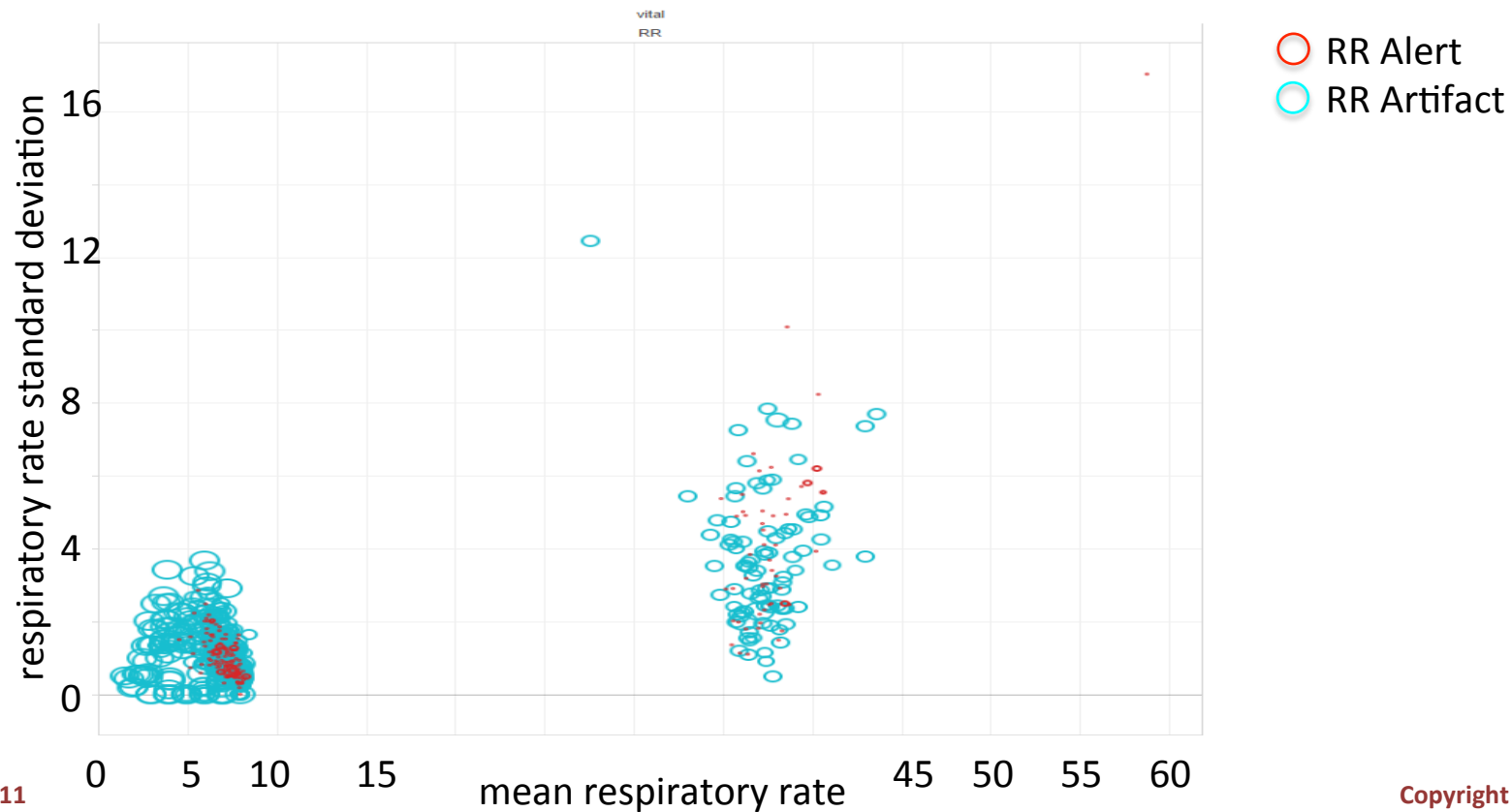## Clinician Interpretation of Discovered Archetypes
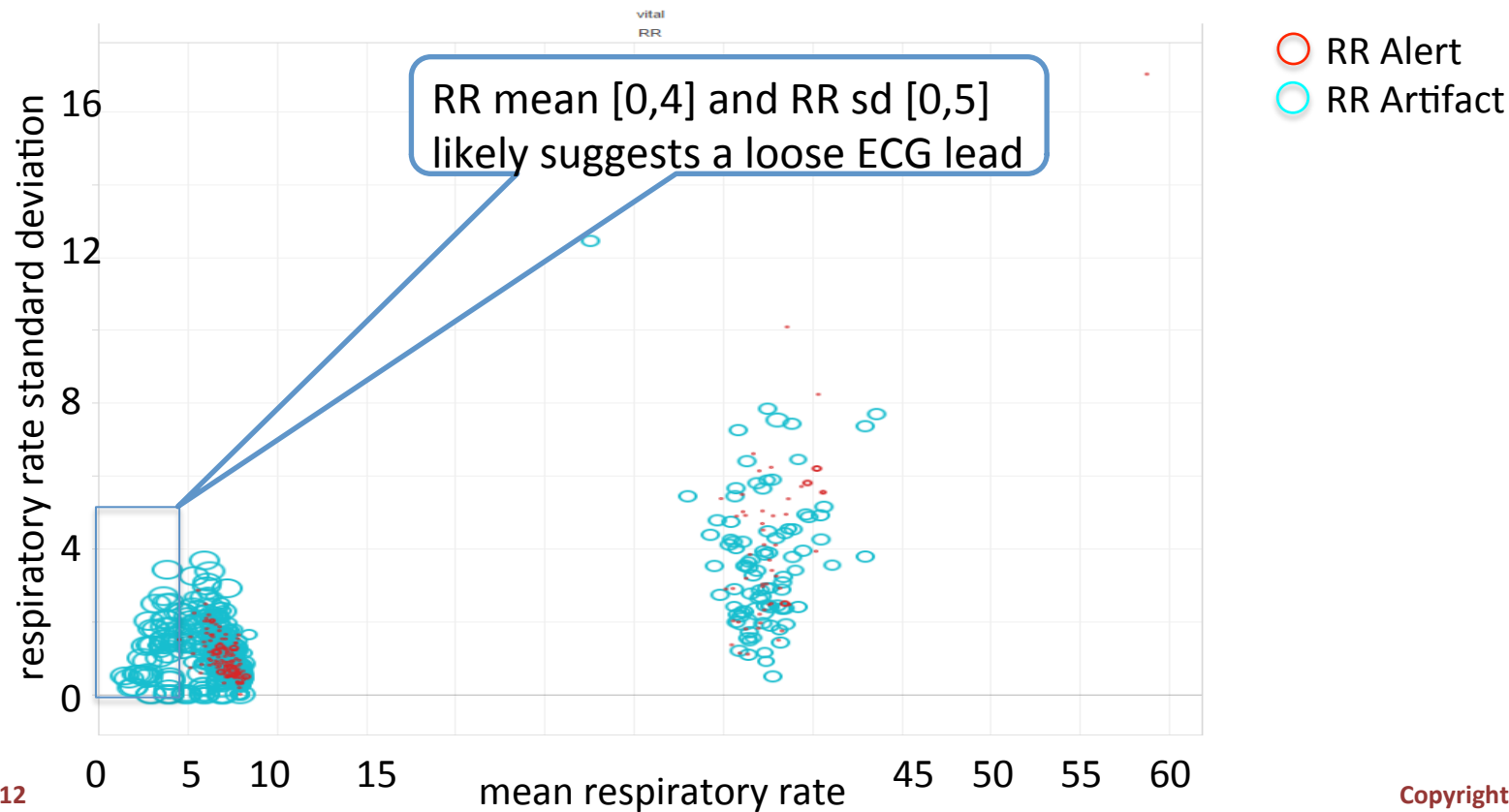
Results: RR Archetypes

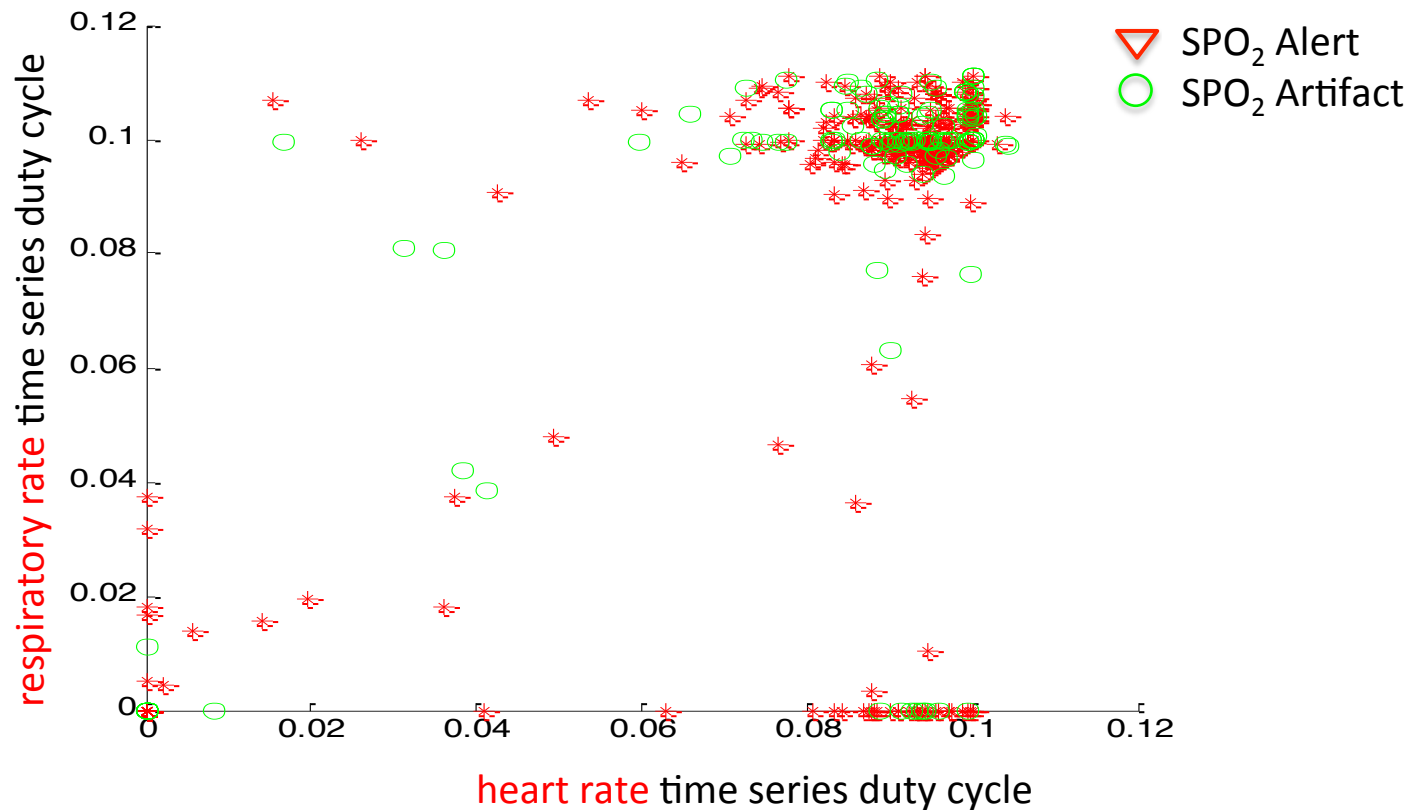# Results: RR Archetypes

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vital
RR

○ RR Alert
○ RR Artifact

respiratory rate standard deviation

mean respiratory rate

Results: RR Archetypes

RR mean [0,4] and RR sd [0,5] likely suggests a loose ECG lead

○ RR Alert
○ RR Artifact

respiratory rate standard deviation

mean respiratory rate

Results: RR Archetypes

RR mean [0,4] and RR sd [0,5] likely suggests a loose ECG lead

RR mean [33,40] and RR sd [0,10] is likely due to insufficient bioimpedance

○ RR Alert
○ RR Artifact

respiratory rate standard deviation

mean respiratory rate
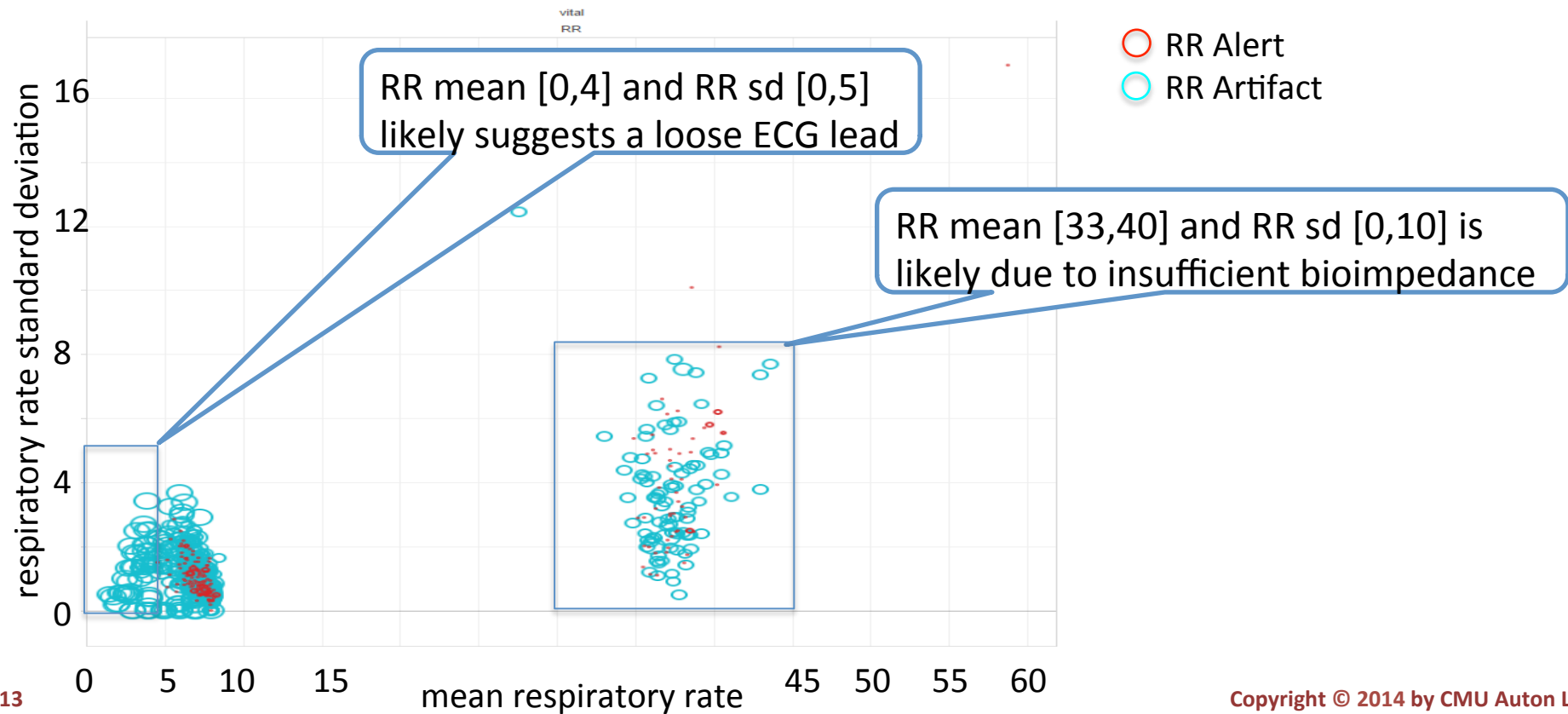
Results: SPO$_2$ Archetypes

Results: SPO$_2$ Archetypes

decreases in both HRdd and RRdd seems to be more likely associated with artifact and might suggest overall problem with signal pickup in both spo2 and the ecg/rr sensors
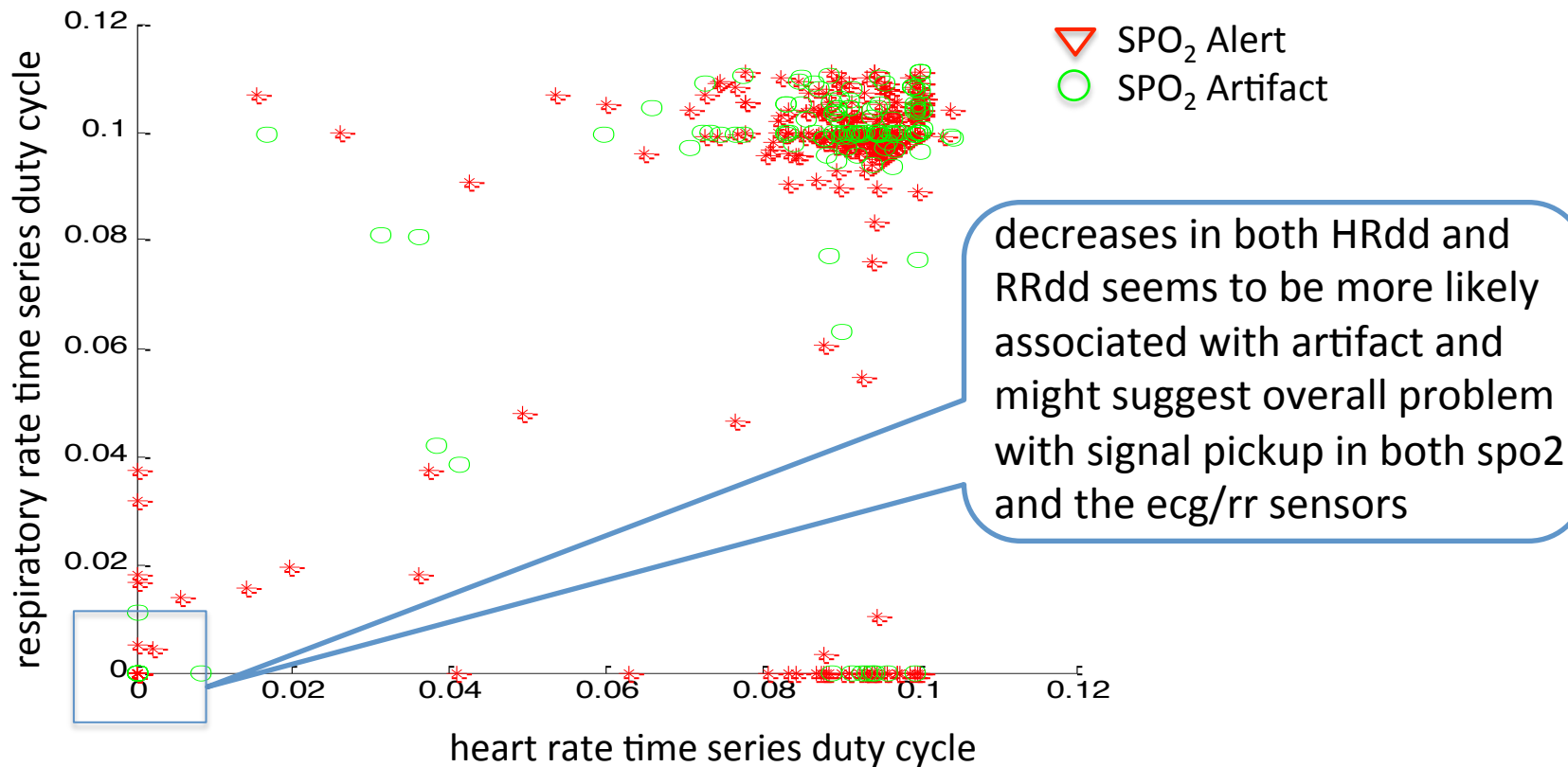
Conclusion

- Informative clustering techniques support automated interpretation of artifacts in VS monitoring data streams
- Notable outcome: even though the system was not given labels, the discovered clusters (archetypes) illustrate crucial differences between true alerts and artifacts
- The archetypes of automated clustering can be used to improve alert adjudication accuracy, precision, and recall
- Archetypes have the potential to reduce annotation effort and to be useful in guiding corrective actions