



Using expert review to calibrate semi-automated adjudication of vital sign alerts in Step Down Units

Madalina Fiterau (mfiterau@cs.cmu.edu)

Donghan Wang (donghanw@cs.cmu.edu)

Artur Dubrawski (awd@cs.cmu.edu)

Gilles Clermont (cler@pitt.edu)

Marilyn Hravnak (mhra@pitt.edu)

Michael R. Pinsky (pinsky@pitt.edu)

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Background

- Patients are monitored using non-invasive vital sign (VS) data
- Alerts issued when a VS exceeds predefined thresholds
- Many alerts are artifacts, due to threshold-based issuance
- Artifacts cause **alarm fatigue**
- **Machine Learning** has proven useful in classifying clinical data
- Training data requires laborious **expert annotation**



Objective

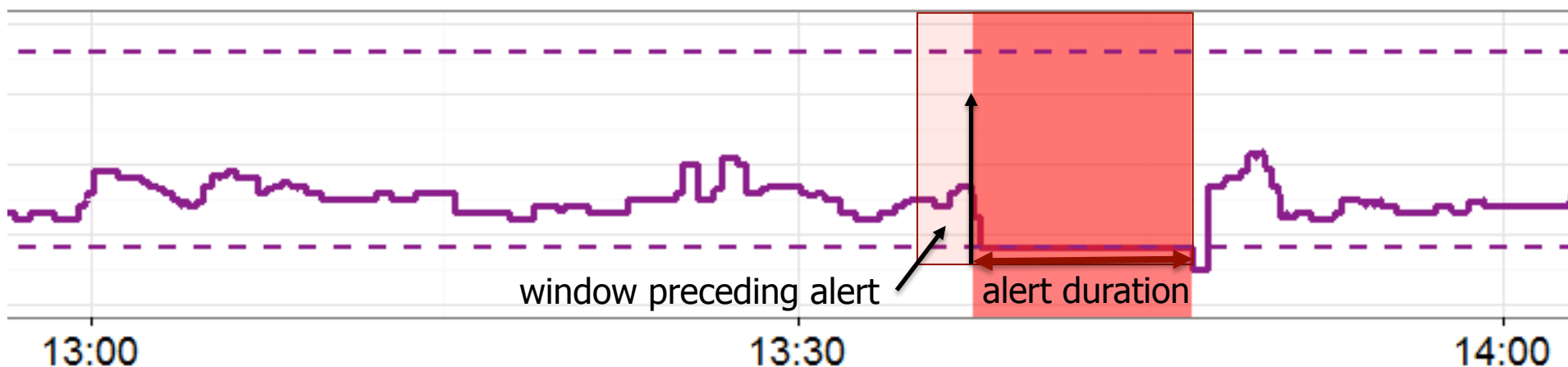
Reduce expert annotation effort through **semi-automatic** adjudication of VS alerts as **real or artifacts**, while maintaining high accuracy.

Data Description



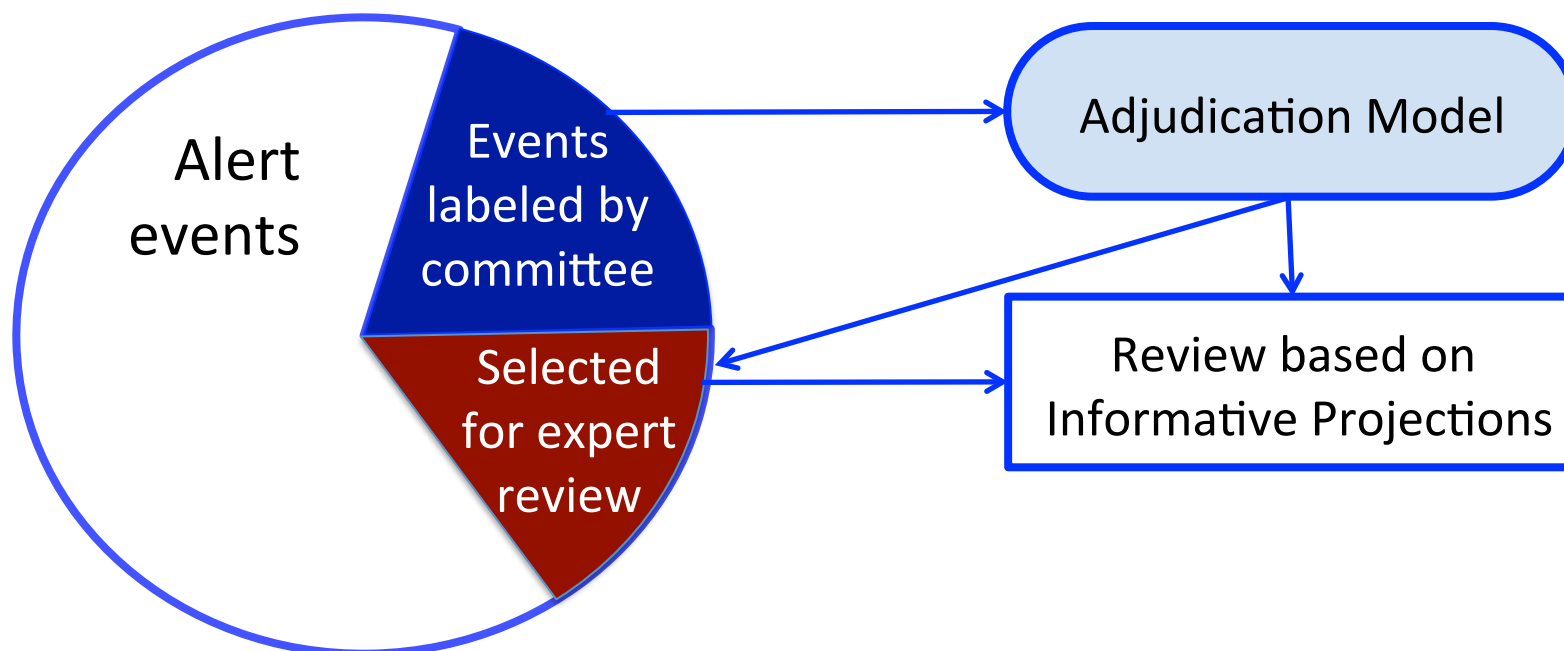
- Heart Rate <40 or >140
- Respiratory Rate <8 or >36
- Systolic Blood Pressure <80 or >200
- Diastolic Blood Pressure >110
- $SPO_2 <85\%$

Alerts
some are *artifacts*,
not *true alerts*



Features computed from time series include common statistics of each VS: mean, stdev, min, max, range of values, duty cycle ...

Expert Review System



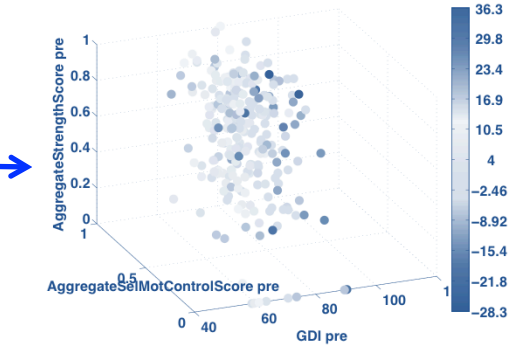
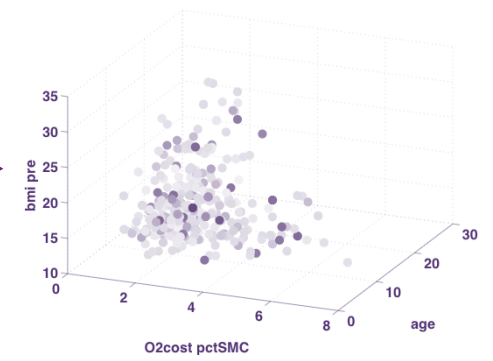
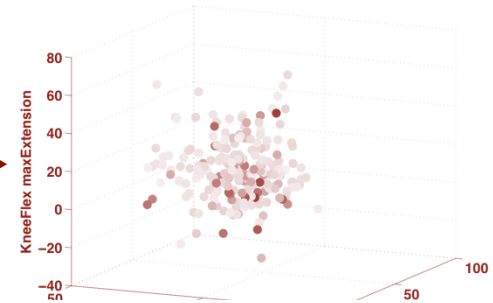
Artifact adjudication models

- **SPO₂** model trained on 91 committee-labeled events
- **RR** model trained on 194 committee-labeled events

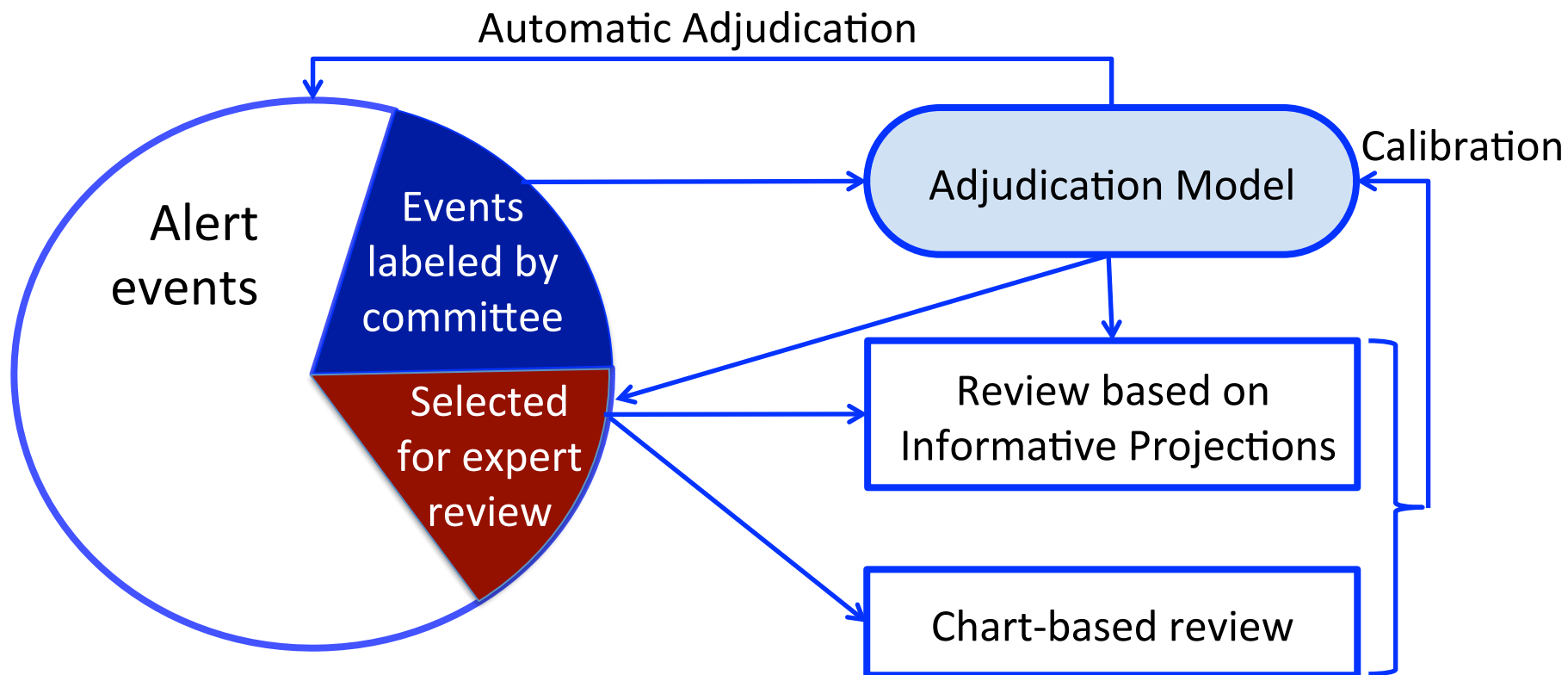
Informative Projections

- Extract **simple projections** of data in which alerts appear as either convincingly correct or easily dismissible

value-SPO2-s	value-RR-slo	value-RR-slo	value-SPO2-s	value-RR-me	value-SPO2-r	value-RR-sd
-0.0029313	4.17E-18	0.00630818	-0.0029313	4.12824428	97.6	1.06706188
0.00136546	0.00182094	0.10504728	0.00247479	6.69565217	94.9565217	4.84527969
-0.0021995	0.00367593	-0.0050222	0.01035002	2.1369863	94.9589041	3.01991109
0.00107737	0.01356958	-0.0711832	-0.0128556	4.70588235	95.0130719	4.58240679
0.00417106	-0.0587037	0.01486003	0.00653597	6.11258278	95.589404	3.90306383
0.00141168	0.00018817	0.01257827	0.00050384	7.06937799	88.8944785	1.38296729
NaN	0.02780576	0.01096782	NaN	7.38402062	NaN	1.14094676
-0.0719377	3.91E-18	0.08264121	-0.0719377	4.45283019	96.0909091	2.40844496
0.02165218	3.31E-18	-0.0483914	0.02165218	6.82539683	97.880597	4.52959423
0.000331	-0.3382077	2.95E-19	-0.0059065	5.66055046	97.2959502	2.3506435
-0.0012807	-0.0199014	0.13292816	0.00608368	9.97692308	96.9384615	7.31406777
-0.022878	-1.82E-18	0.13183775	-0.022878	7.4372093	99.1428571	2.7808611
NaN	0	0	NaN	0	NaN	0
NaN	0	0.03934101	NaN	2.4537037	NaN	4.74860385
0.00330532	-0.0088088	0.22570956	-0.0012042	40.163482	95.522293	7.41396209
NaN	-1.13E-17	0.21905986	NaN	8.49047619	NaN	4.79956186
NaN	0.10475393	0.0196181	NaN	36.4519231	NaN	2.37164306
NaN	1.15751237	0.1057343	NaN	42.173913	NaN	29.3185291
NaN	-0.0588096	-0.0623256	NaN	37.1154734	NaN	18.5174329
NaN	0	0	NaN	0	NaN	0
NaN	-0.0022618	0.03067683	NaN	5.6080402	NaN	5.28931987
0.00085996	-0.017286	0.0713039	0.02119643	4.77429467	98.3291536	2.94378634
-0.0008905	0.01613222	0.05195364	-0.0018359	4.1	98.2666667	2.90514126
0.00028538	0.04655102	0.00519169	0.006475	3.52697842	98.3543166	2.54636124
0.0012656	-0.0161675	-0.0060166	-0.0002526	3.35949765	98.6153846	2.58645329
-0.0042403	0.01048171	0.031308	0.00459974	3.14920635	98.4952381	2.38091356
0.00093348	0.05713114	0.01255181	0.00139109	2.80804954	98.4179567	2.37095459
-0.0002677	0.01437949	0.03630727	0.0019863	4.97345133	98.5271808	3.18231714
0.00062418	0.00445544	0.07044521	-8.14E-05	6.14565005	98.6852395	2.38826595
-0.0002632	-0.0345564	-0.0627989	-0.0032461	4.8875	98.51875	2.69444453
0.00025415	-0.0198156	0.00040705	0.00013692	5.49072012	98.6993319	2.53103089
0.00012693	0.00153996	0.02688751	-0.0037226	6.51566469	98.0736664	2.30050846
0.00052248	0.00170464	0.01674884	-0.004801	5.48423707	98.035309	2.42255108
-1.83E-05	-0.0140705	-0.0002696	-0.0036784	6.19064748	98.0701439	2.67763729
0.00238634	-0.0005541	0.05244581	0.00567888	7.22222222	98.1515152	2.21413437
0.00086189	0.00583861	0.01194609	0.00560662	7.25396825	98.2412698	1.89777088



Expert Review System



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Review based on projections

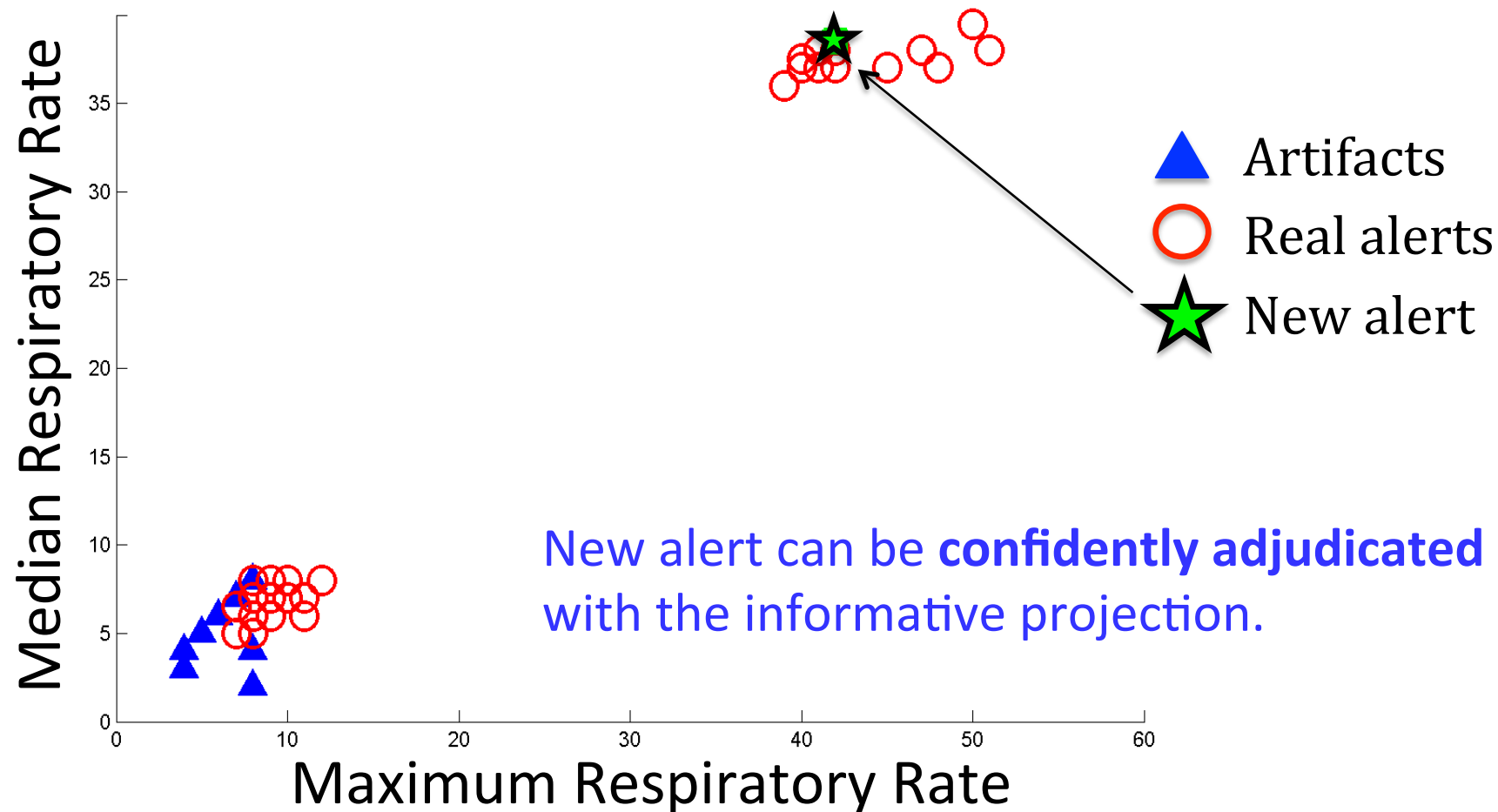
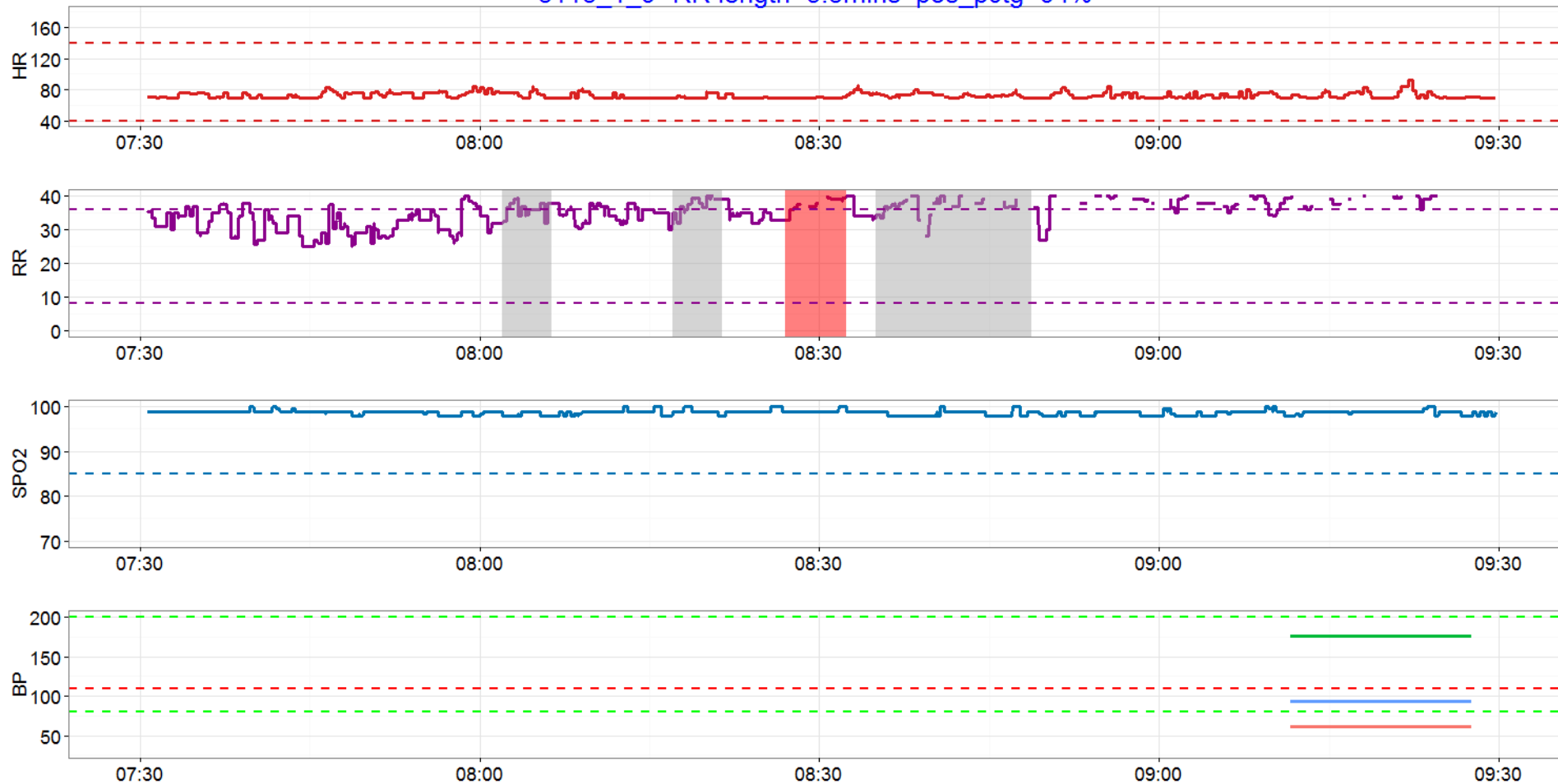




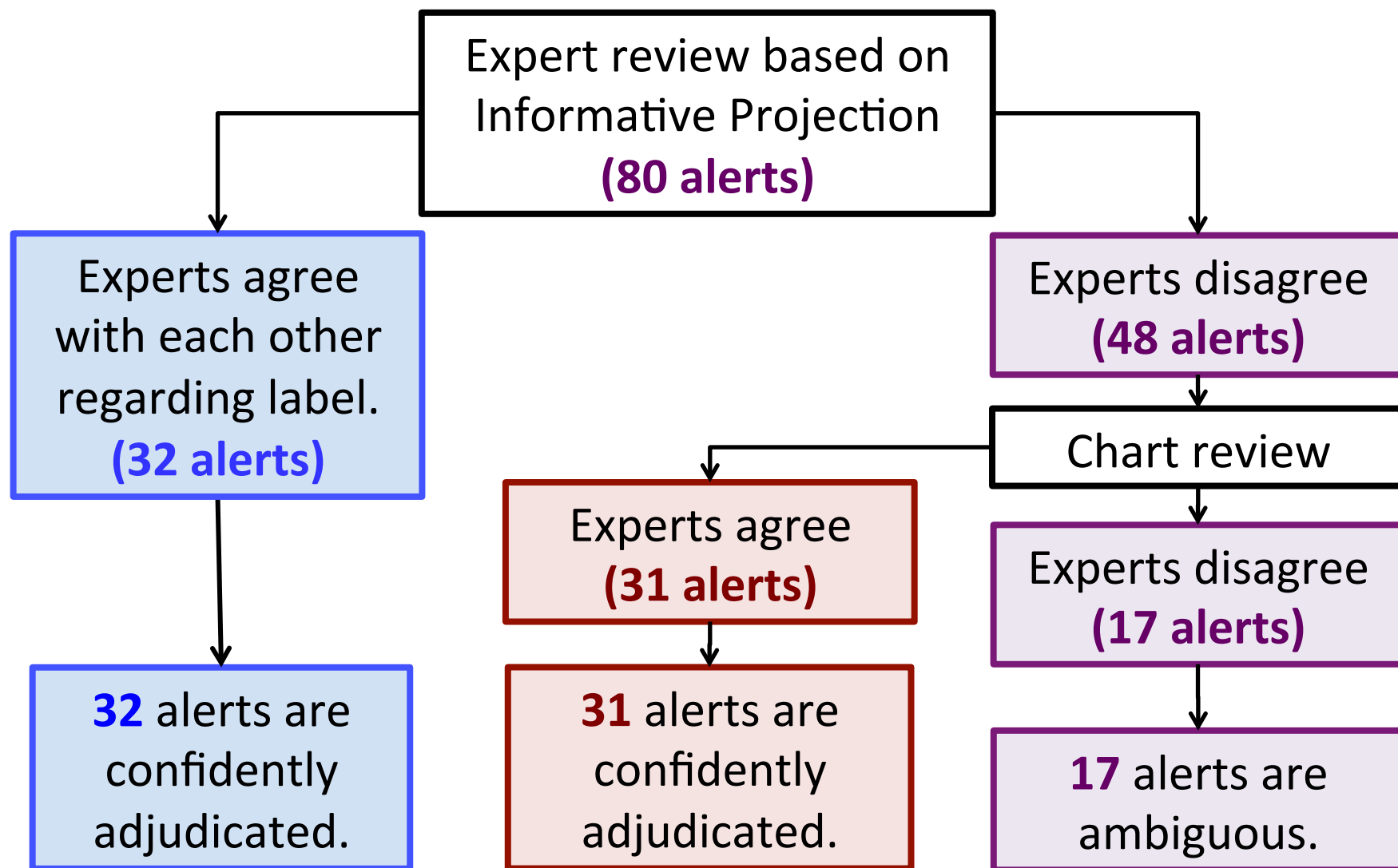
Chart-based review

3113_1_9--RR length=5.3mins pos_pctg=94%



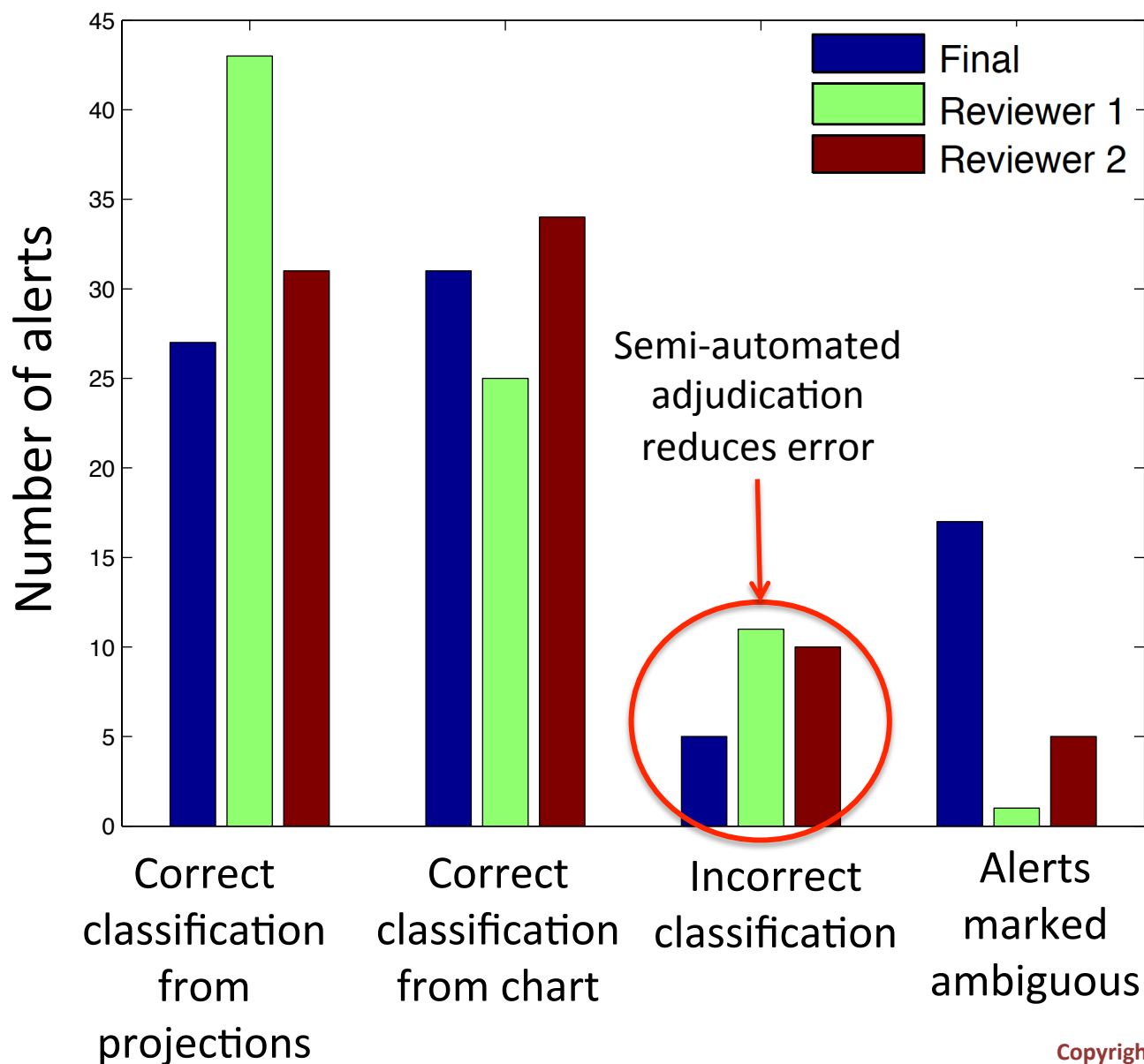


Study Results





Adjudication error





Conclusions

- Half of alerts that can be classified are **handled automatically**
- **3 ways** ML reduces expert labeling effort
 - Use of **ML models** for semi-automatic adjudication
 - Active **sample selection** for expert review
 - Threshold adjustment maximizes **confident adjudication**
- 1/5 of alerts **could not be classified** by system or reviewers
- Semi-automated adjudication model filters out **artifactual alerts**, helping to reduce **alarm fatigue**