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Evaluation of Two Level Classifier for Predicting Compressor Failures in Heavy Duty Vehicles

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SAIS 2017 workshop, 15 - 16 May

Objective & Motivation

- Predictive maintenance for heavy duty vehicles
  - Predict machine failure
  - On-board sensor data

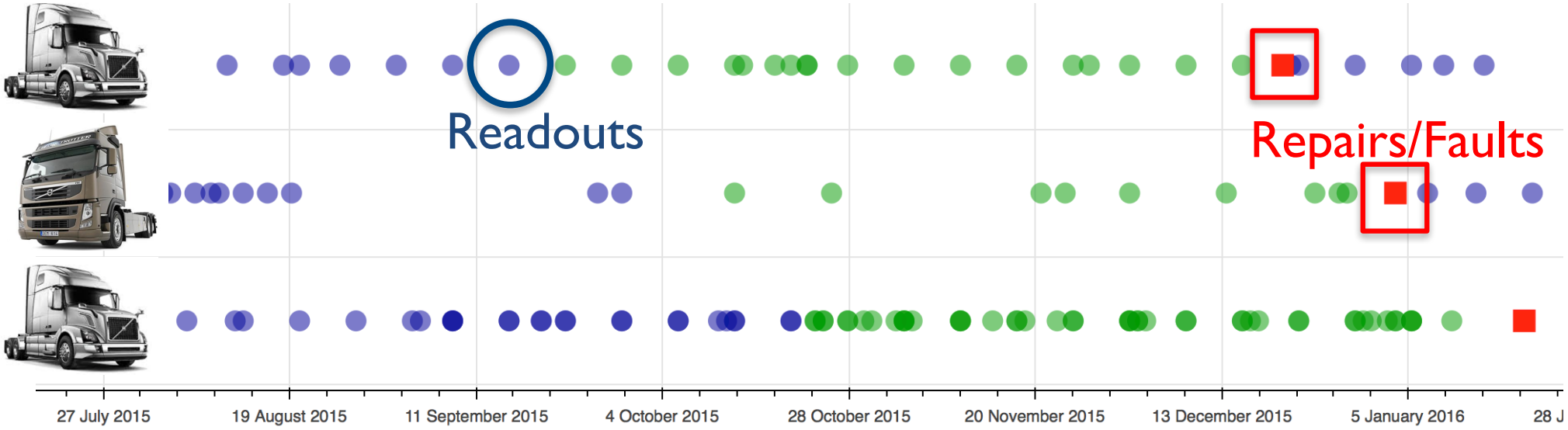
- Avoid unplanned stops
  - Result in extra damage to other components
  - Waiting time in workshop
  - Fail to reach delivery deadline & lose customers/reputation
  - Accident that cause casualties

Overview

- Applied supervised machine learning techniques (a two level classifier) to predict compressor failures in heavy duty trucks
  - Logged Vehicle Data (LVD)
  - Existing resources (data from deployed vehicles)
  - Preliminary results

Data

- Logged Vehicle Data (LVD) – Sensor readouts gathered at service / by Telematics
- Vehicle Service Records (VSR) – Service records of Volvo Vehicles



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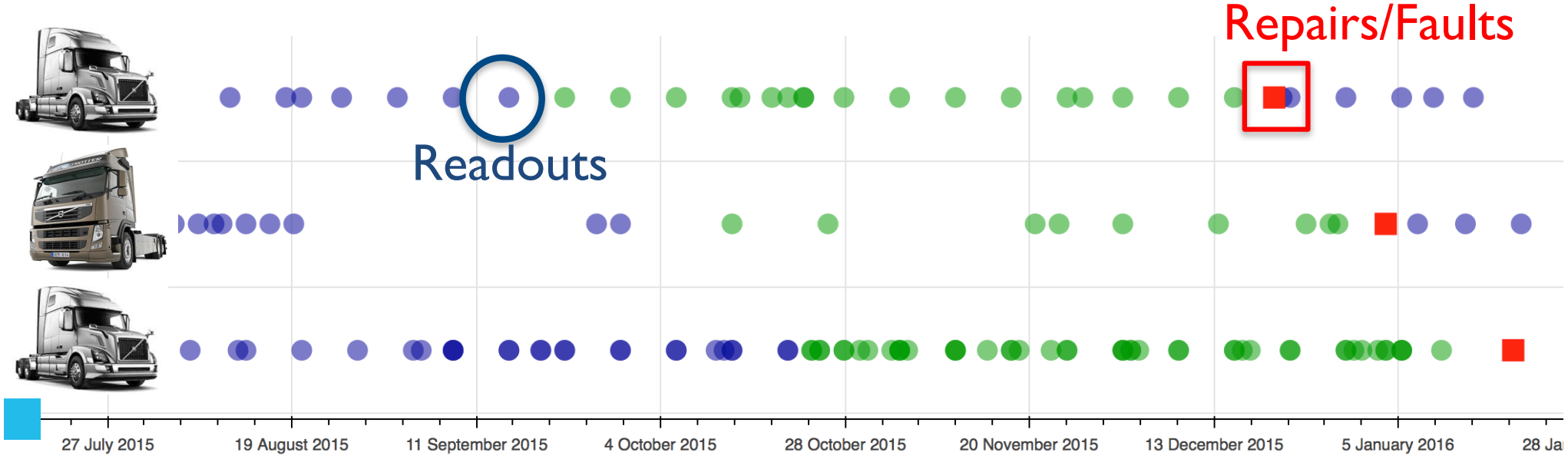
LVD (1046 Trucks, 169 features, 2yrs)

- Configuration & specification (93 categorical)
- Aggregated sensor readings (76 numerical)
  - Mean & accumulated values
    - Vehicle (truck) level: Mileage, speed statistics
    - Component level: average duty cycles



Challenges

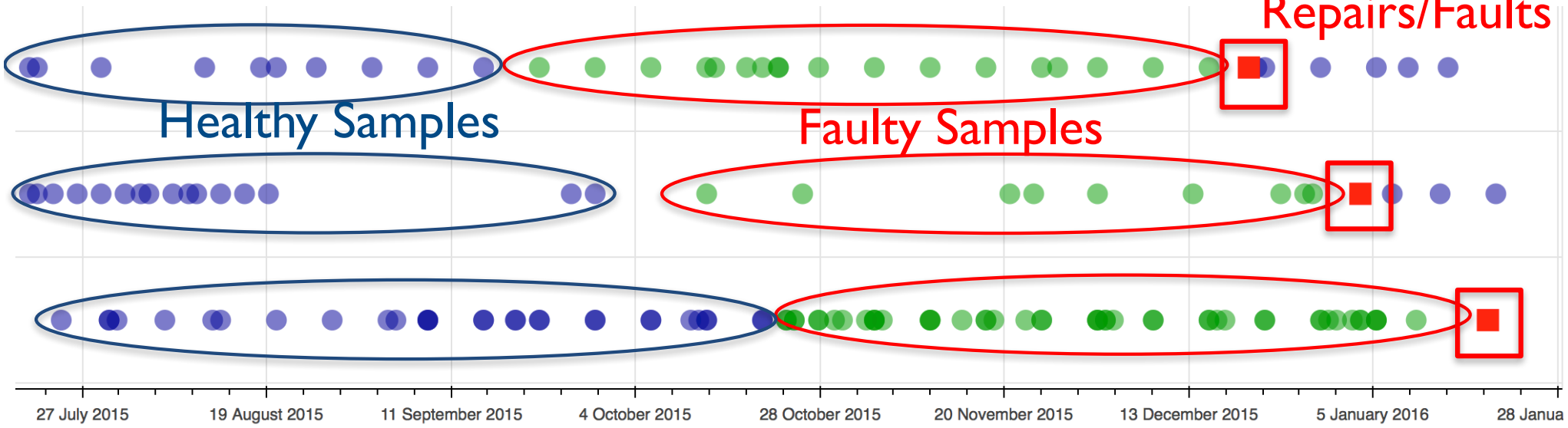
- Missing values
  - Aggregated data: More than 80%
    - Workshop visit (up to 76 parameters)
    - Telematics (up to 10 parameters)
  - Categorical data (configuration): 3.2%
    - Heterogeneous fleet
    - E.g. Cruise control, Contract type
- Unbalanced data set
  - 115 (out of 1046) vehicles with compressor failures
  - 10% vehicles are faulty
- Uneven time intervals of readouts

Data preprocessing

- Imputation for aggregated data
  - Linear interpolation
    - E.g. Date, mileage
- Categorical data
  - Transform into binary features
- Vehicle has compressor failures
  - Keep data until first failure occurs

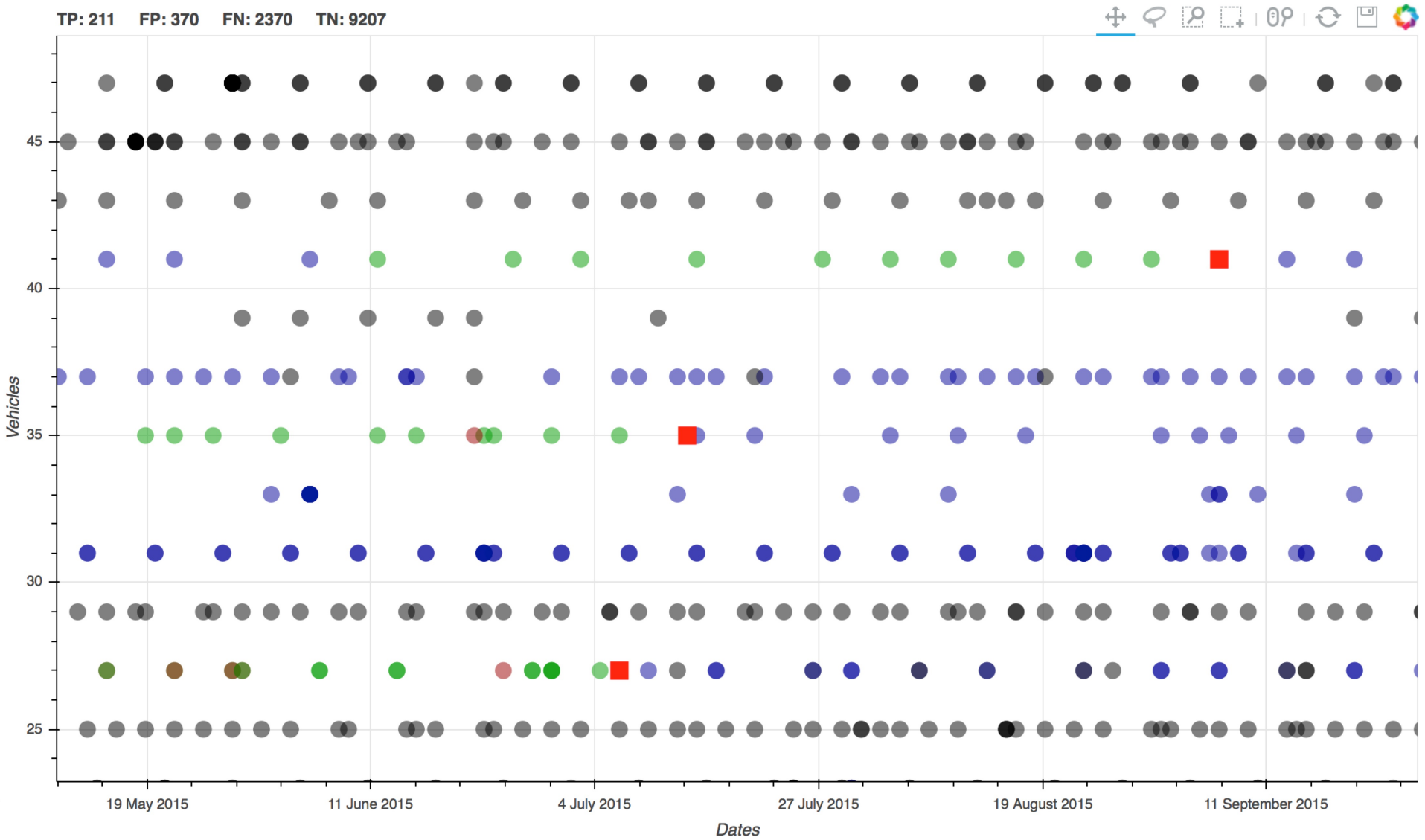
Classifier developed by Prytz et al. [1,2]

- Prediction Horizon & data labeling
- Vehicle-wise cross-validation
  - Per vehicle basis



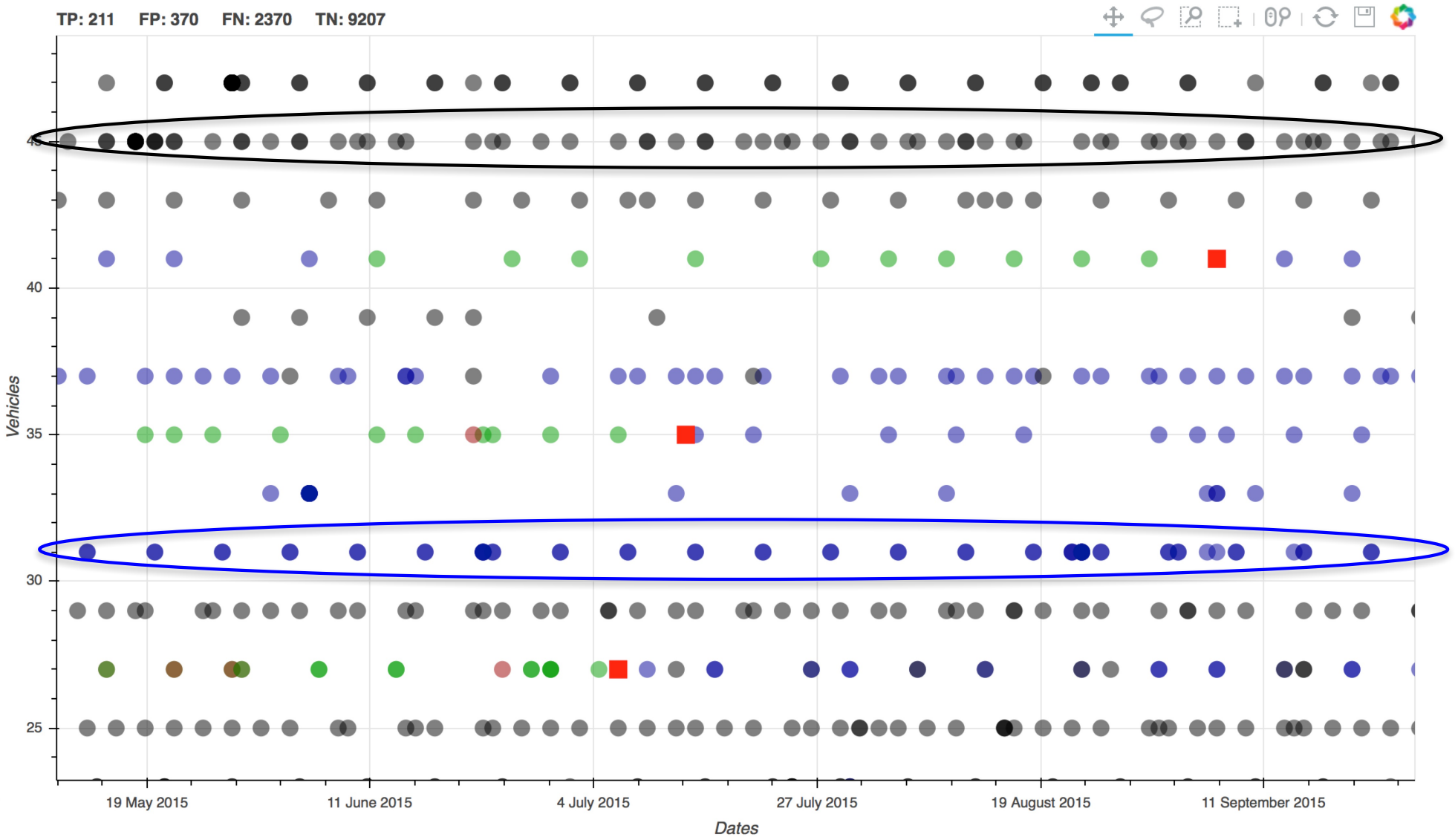
[1] Rune Prytz. Machine learning methods for vehicle predictive maintenance using o-board and on-board data. Licentiate thesis, Halmstad University Press, 2014.
[2] Rune Prytz, Slawomir Nowaczyk, Thorsteinn Rögnvaldsson, and Stefan Byttner. Predicting the need for vehicle compressor repairs using maintenance records and logged vehicle data. Engineering applications of articial intelligence, 41:139{150, 2015.

Classification results



Prediction of all Readouts from the same vehicle are highly correlated

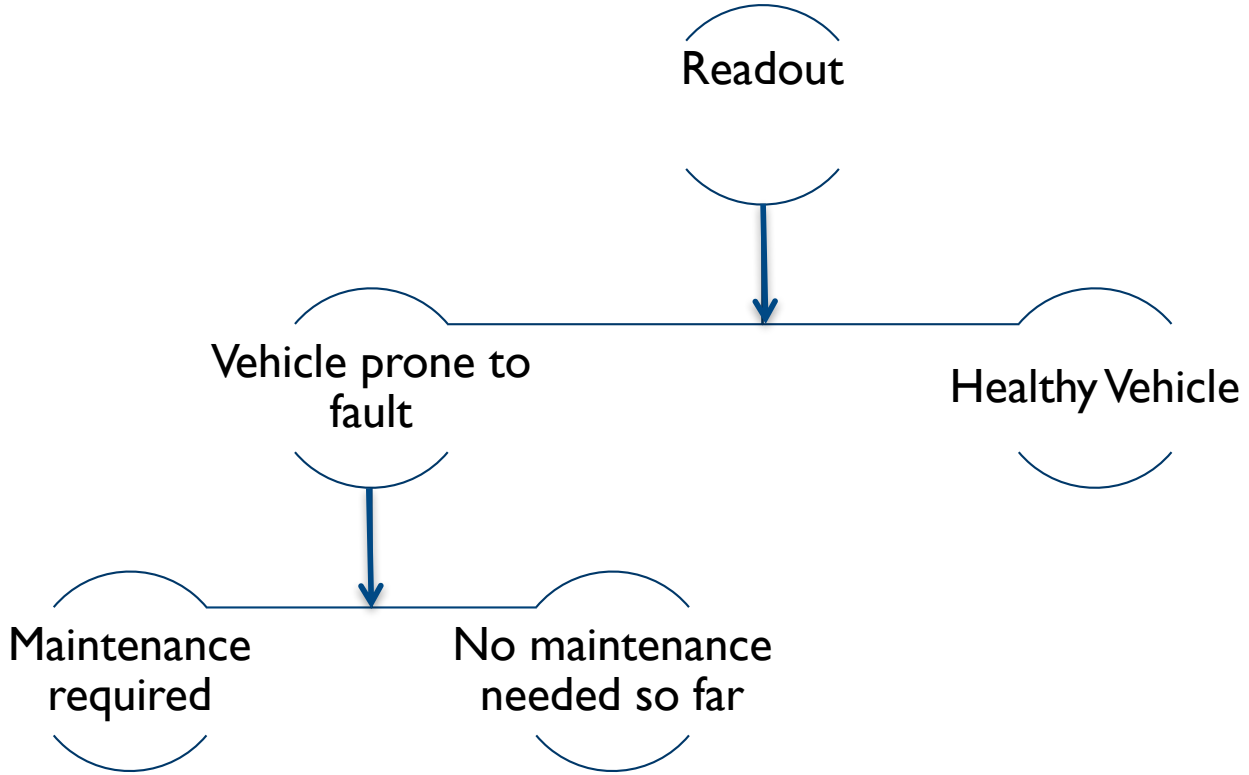
Classification results



Prediction of all Readouts from the same vehicle are highly correlated

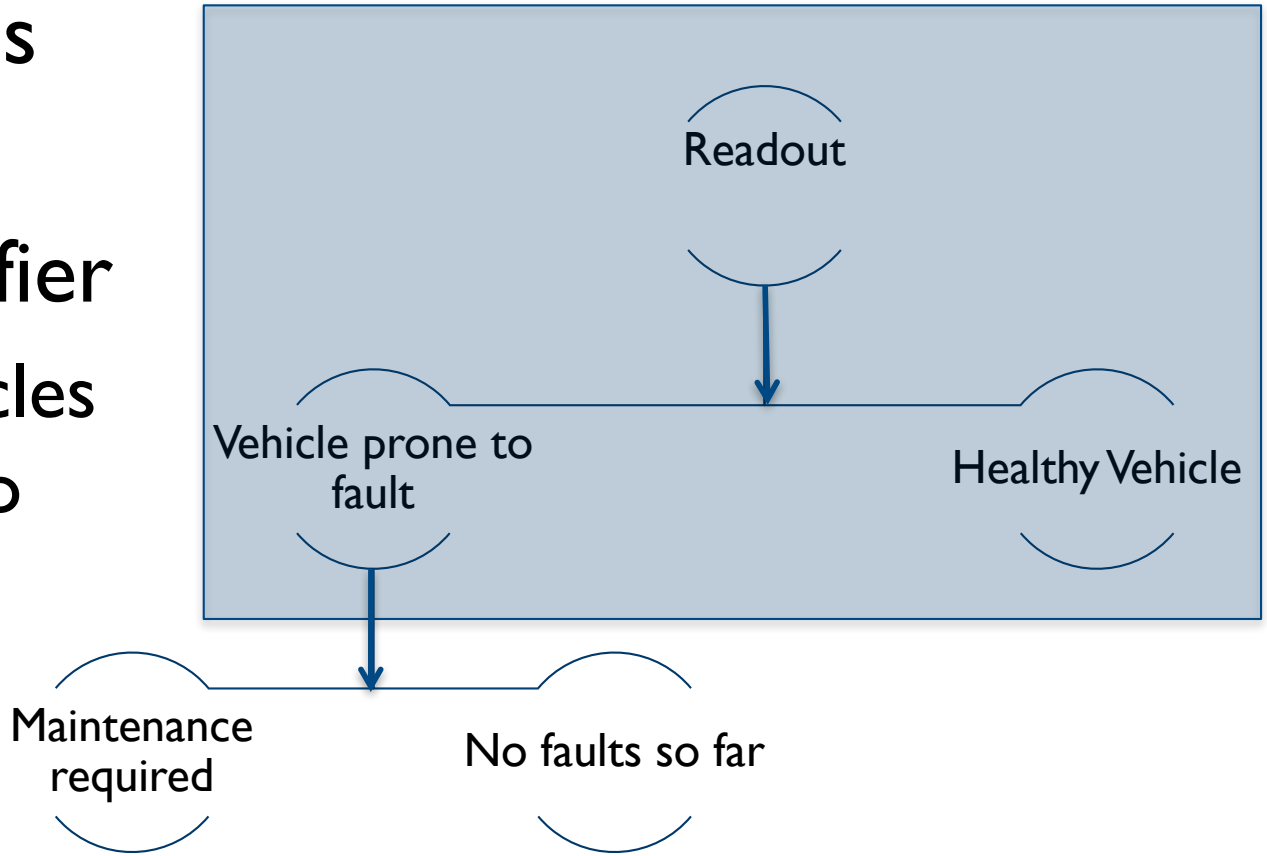
Hierarchical classification

- Two level class hierarchy



Hierarchical classification

- Two level class hierarchy
- 1st level classifier
  - Identify vehicles that prone to failures



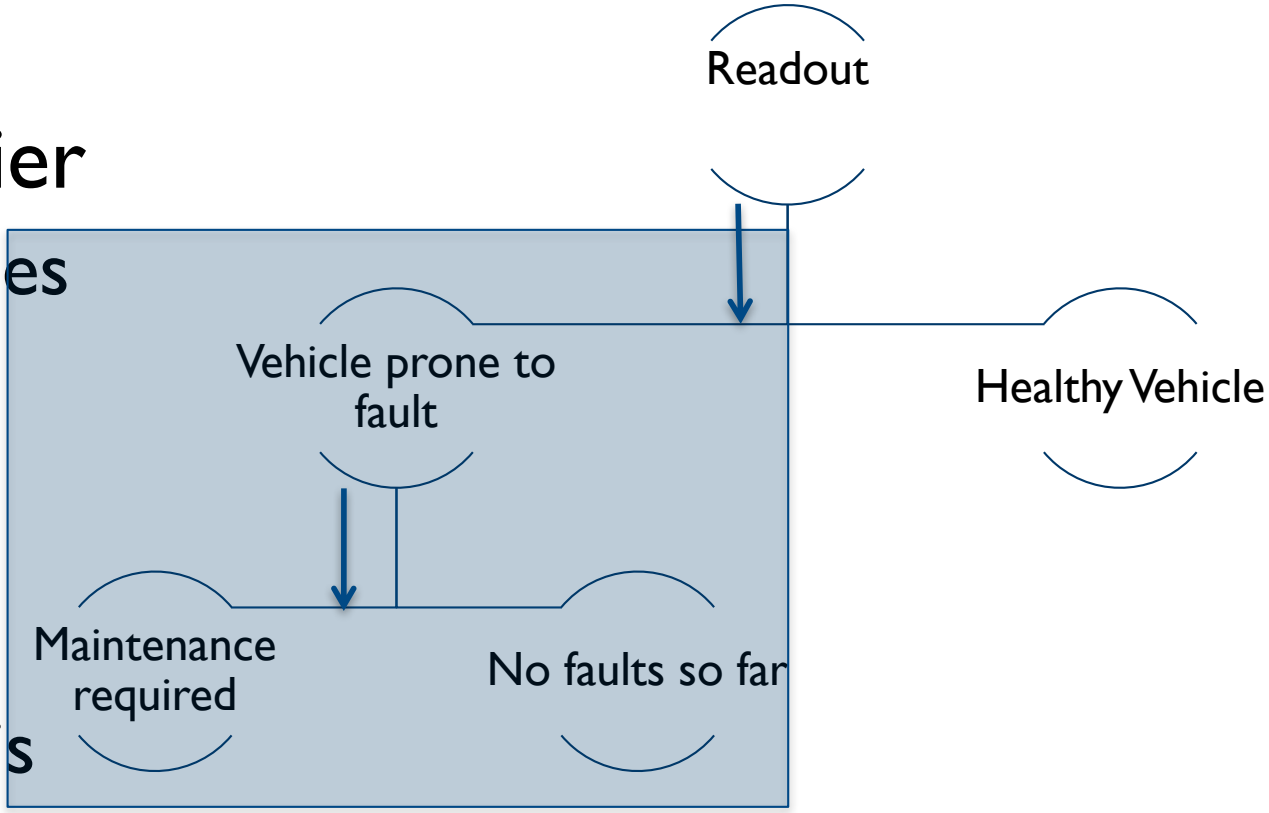
1st level classifier

- Readouts were labeled based on whether a vehicle had compressor faults

- Predict whether a vehicle is prone to compressor faults
  - Based on prediction outcome of all readouts from target vehicle
    - Warning
    - Majority voting

Hierarchy classification

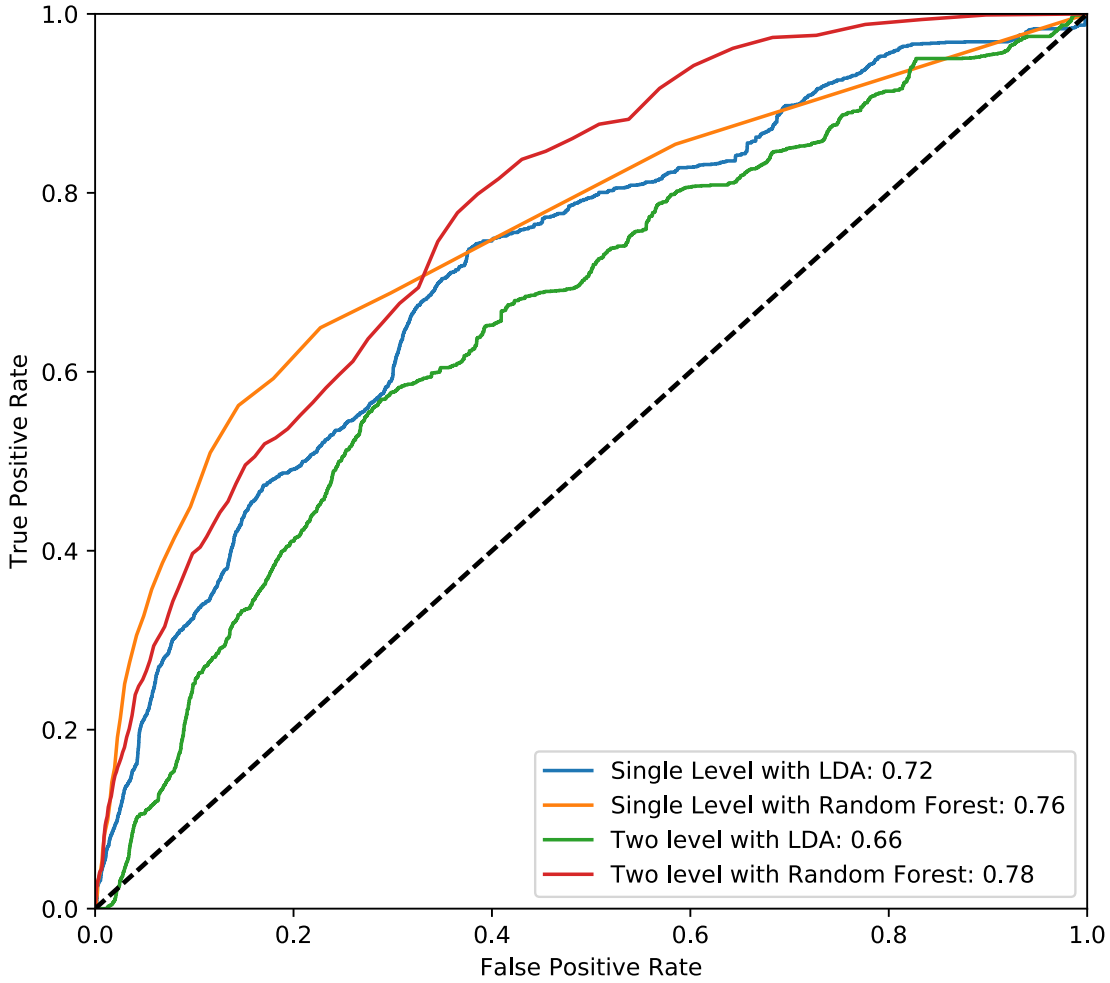
- Two level class hierarchy
- 1st level classifier
  - Identify vehicles that prone to failures
- 2nd level
  - Predict when maintenance is needed



2nd level classifier

- Trained using readouts only from Vehicles with compressor failures
  - Prediction Horizon of 90 days
- Predict when maintenance is needed for vehicles that are prone to faults

Preliminary Results (AUC)



	Single level approach	Two level approach
LDA	0.72 ± 0.10	0.66 ± 0.12
Random Forest	0.76 ± 0.10	0.78 ± 0.08

Conclusion & Future Work

- The AUC of proposed two level classifier is similar to the single level classifier
- Future work
  - Construct features
    - Representation learning: e.g. Capture aggregation patterns of numerical parameters for 1st level classifier
  - Balance the dataset
    - Oversampling the minor class (in feature space)
  - Improve Imputation method
    - Expert knowledge based models
  - Evaluation method for predictive maintenance

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