Reduction of Transient Particulate Matter Spikes with Decision Tree Based Control

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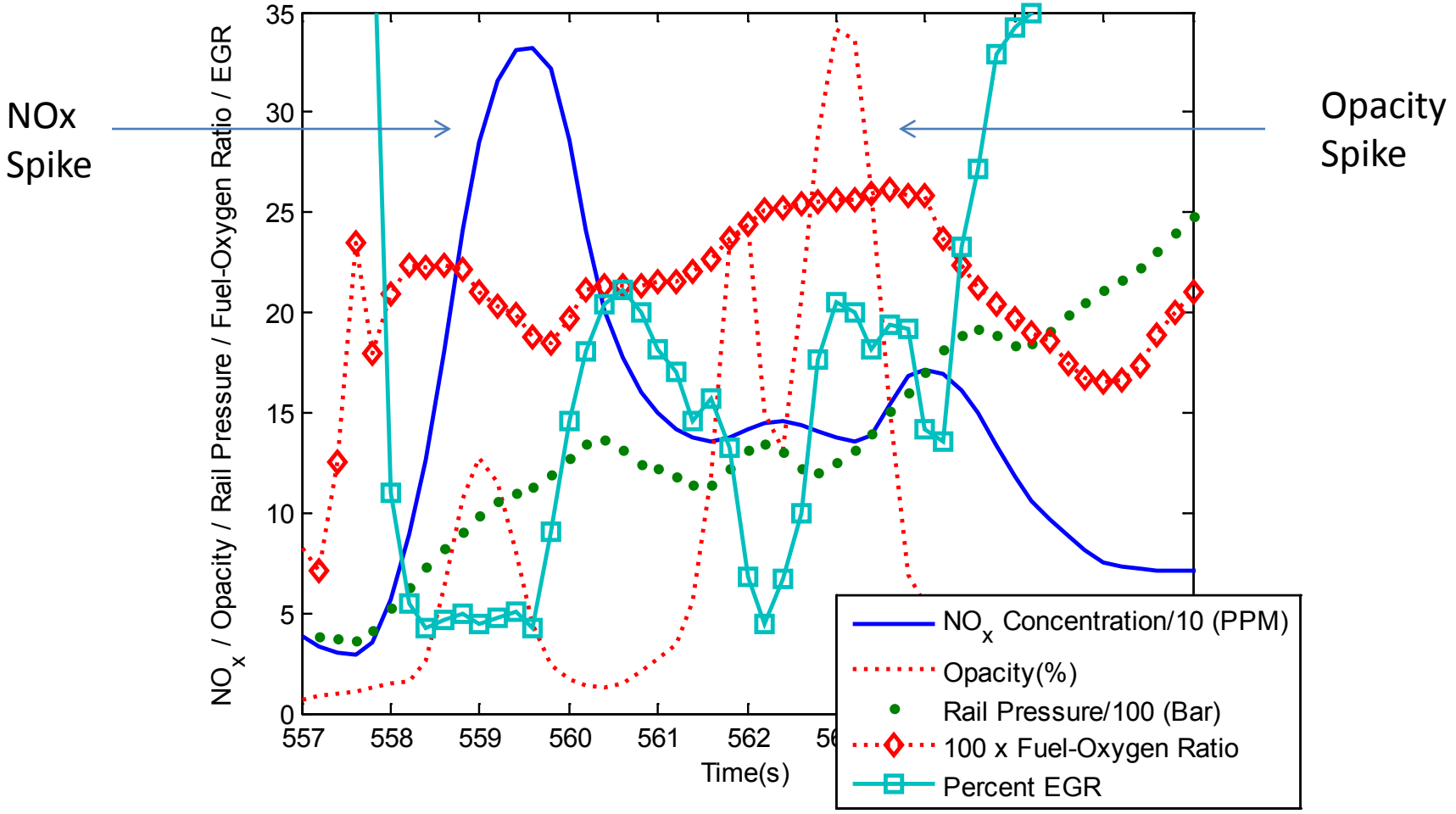
Outline

- Motivation
- The Difficulty in Predicting PM Spikes
- Decision Tree Based Detection
- Possible Applications

Motivation

Targeted PM Reduction: To control PM spikes during the turbocharger lag period with minimum impact on NO_x spikes , by targeting exclusive regions



The Difficulty in Predicting Transient PM Spikes

Particulate Rate (PM) predictions over 8 test cycles	Average 100*σ/μ over all cycles	Worst 100*σ/μ over any cycle	Cumulative % Error over 8 cycles	Worst % error over any cycle
1. Global Regression	112%	183%	27.99%	46.45%
2. Neural Networks	146%	190%	43.88%	74.22%
3. Two-Zone Regression	113%	169%	26.46%	40.20%
4. Localized Regression	123%	181%	29.70%	47.93%
5. Robust Regression	120%	191%	30.52%	51.44%

-No empirical method could predict PM **point-by-point** in a satisfactory manner

-This was particularly true when test data originated from a transient calibration that was different than the transient calibration used to generate training data

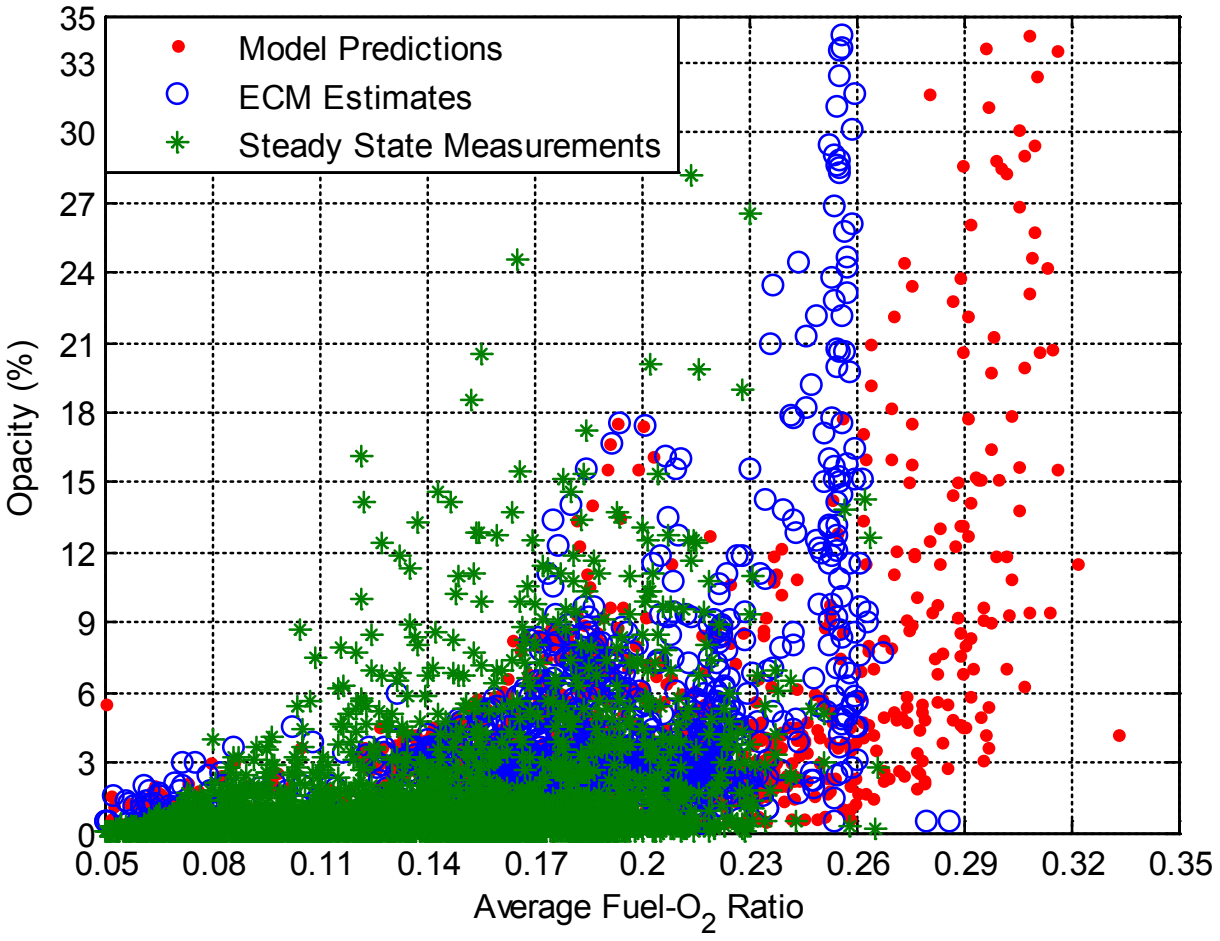
-Point by Point results become worse as number of parameters are increased

The Difficulty in Predicting Transient PM Spikes

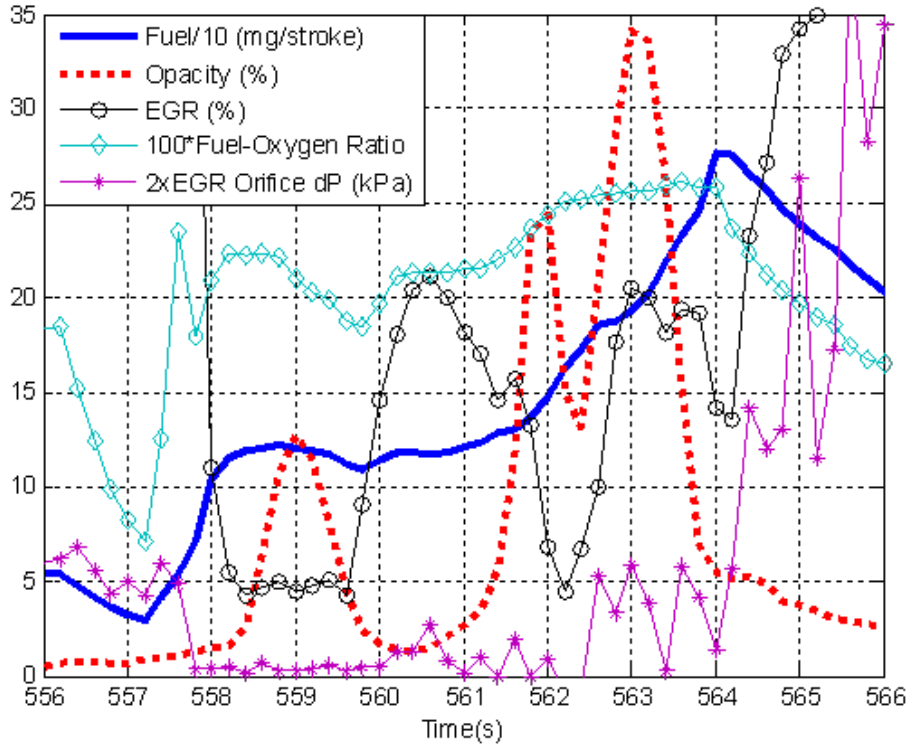
Primary Reasons

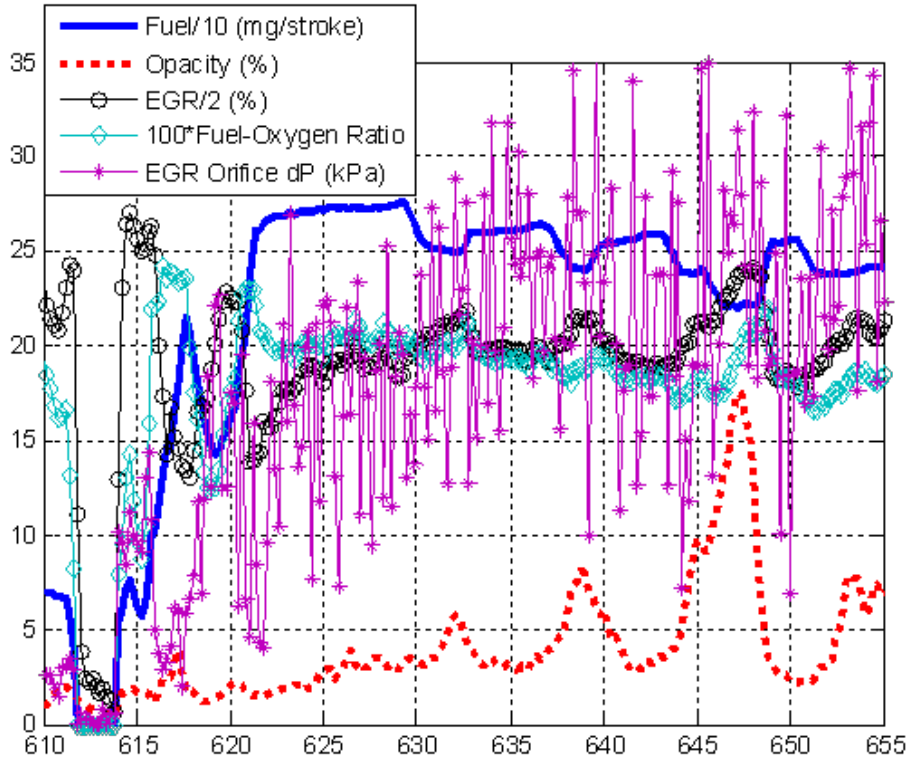
-Inaccurate Fuel-Oxygen ratio estimation during transients

-Inaccurate EGR Fraction estimation during transients



EGR Fraction Estimation During Transients

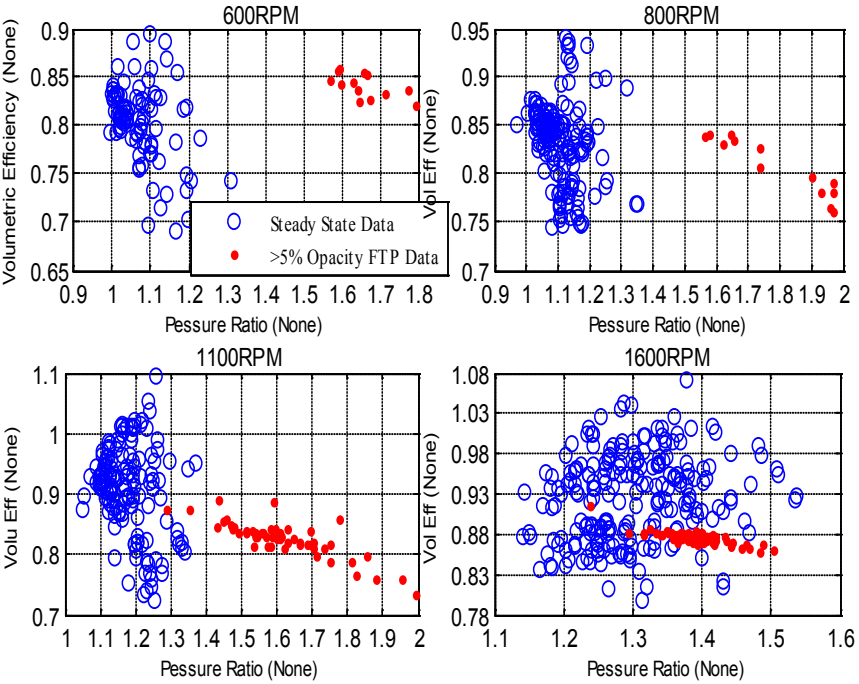




For Orifice Based Estimation: Inaccurate and noisy at low EGR flow rates during turbo lag period

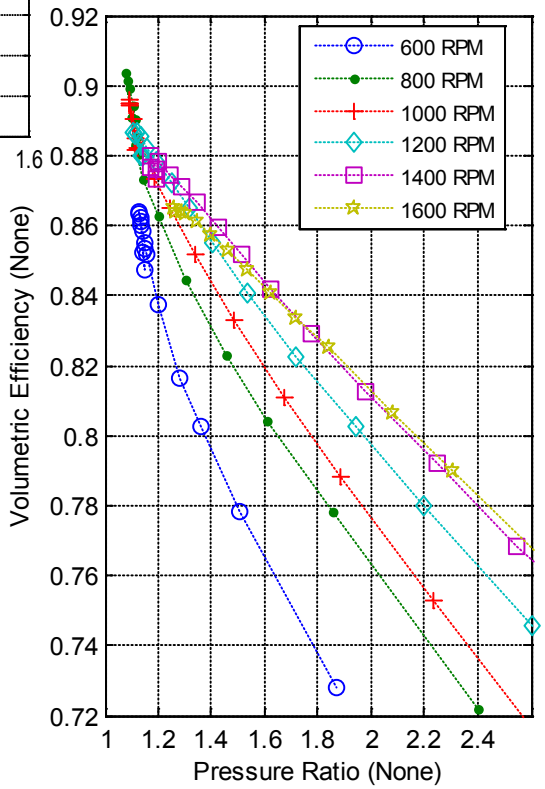
For MAF Based estimation: Volumetric Efficiency estimates inaccurate at high pressure ratios seen during turbo lag period

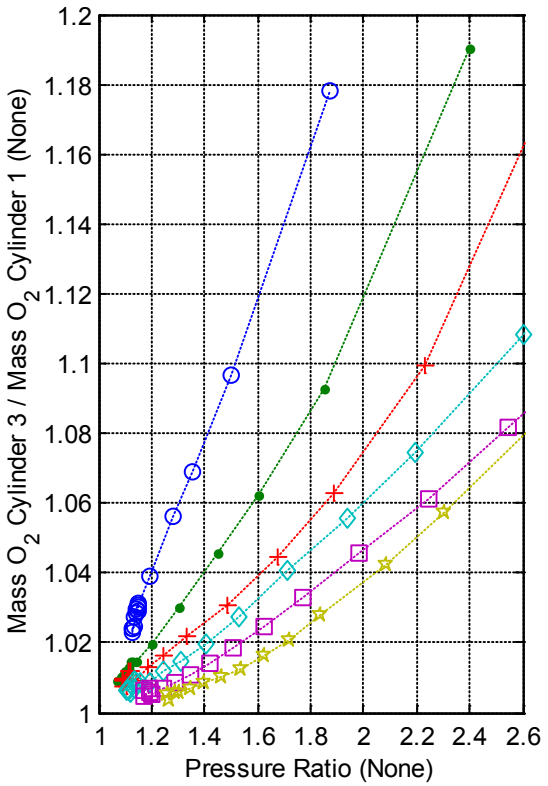
Volumetric Efficiency Estimation During Transients



-Ratio of Exhaust to Intake Pressure (Pressure Ratio) is much larger for transient data

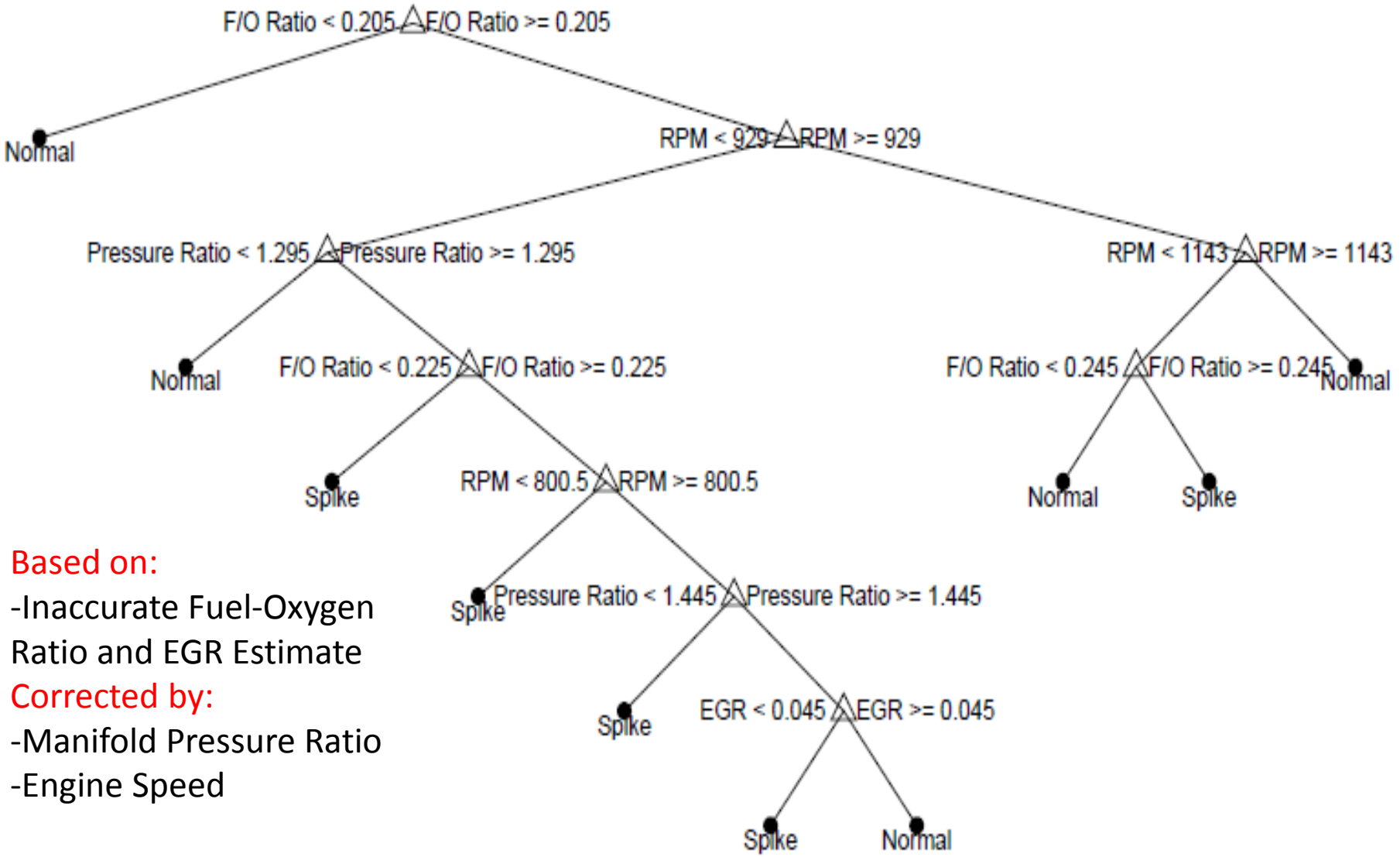
-However volumetric efficiency correlations are usually based on steady state data





Simulations suggest that the decrease in volumetric efficiency and increase in cylinder-to-cylinder variation is difficult to estimate with current techniques

PM Spike Detection With Decision Trees



Based on:

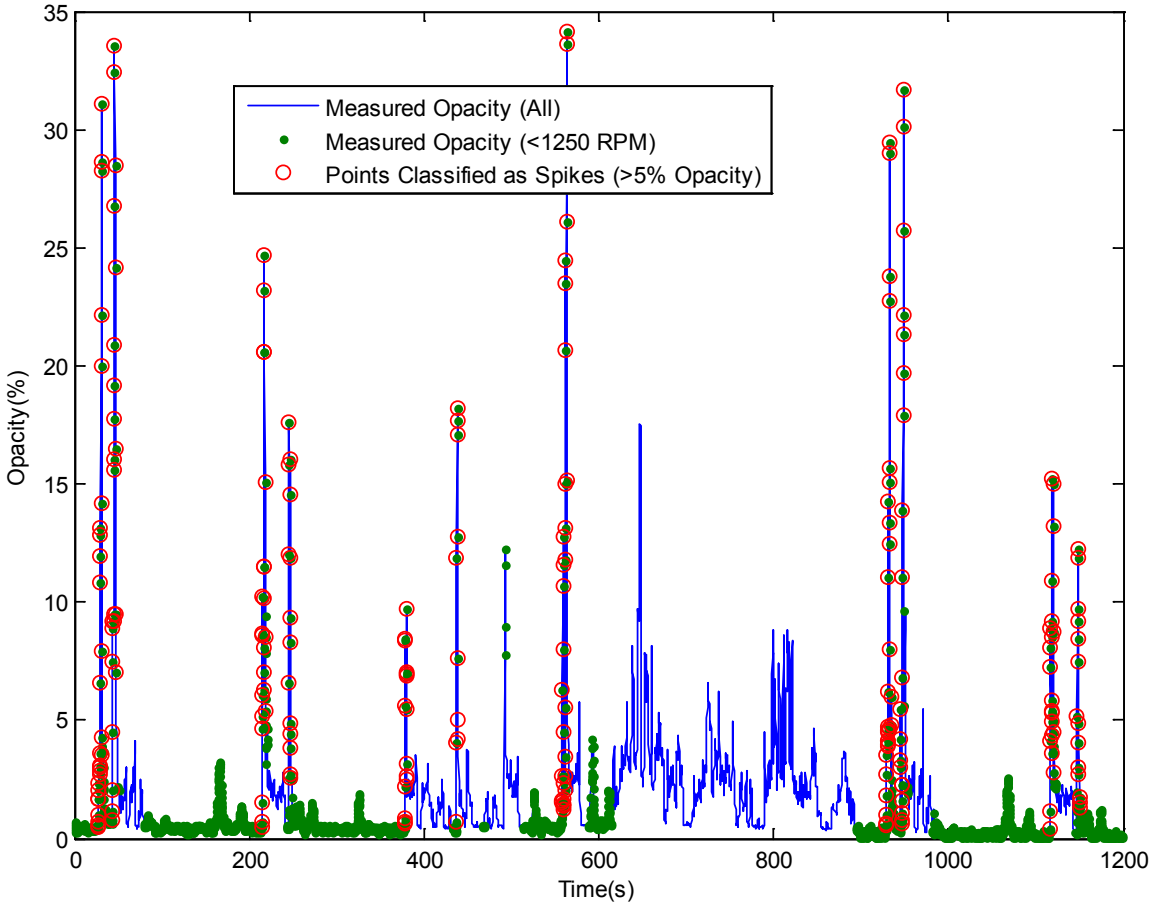
-Inaccurate Fuel-Oxygen Ratio and EGR Estimate

Corrected by:

-Manifold Pressure Ratio

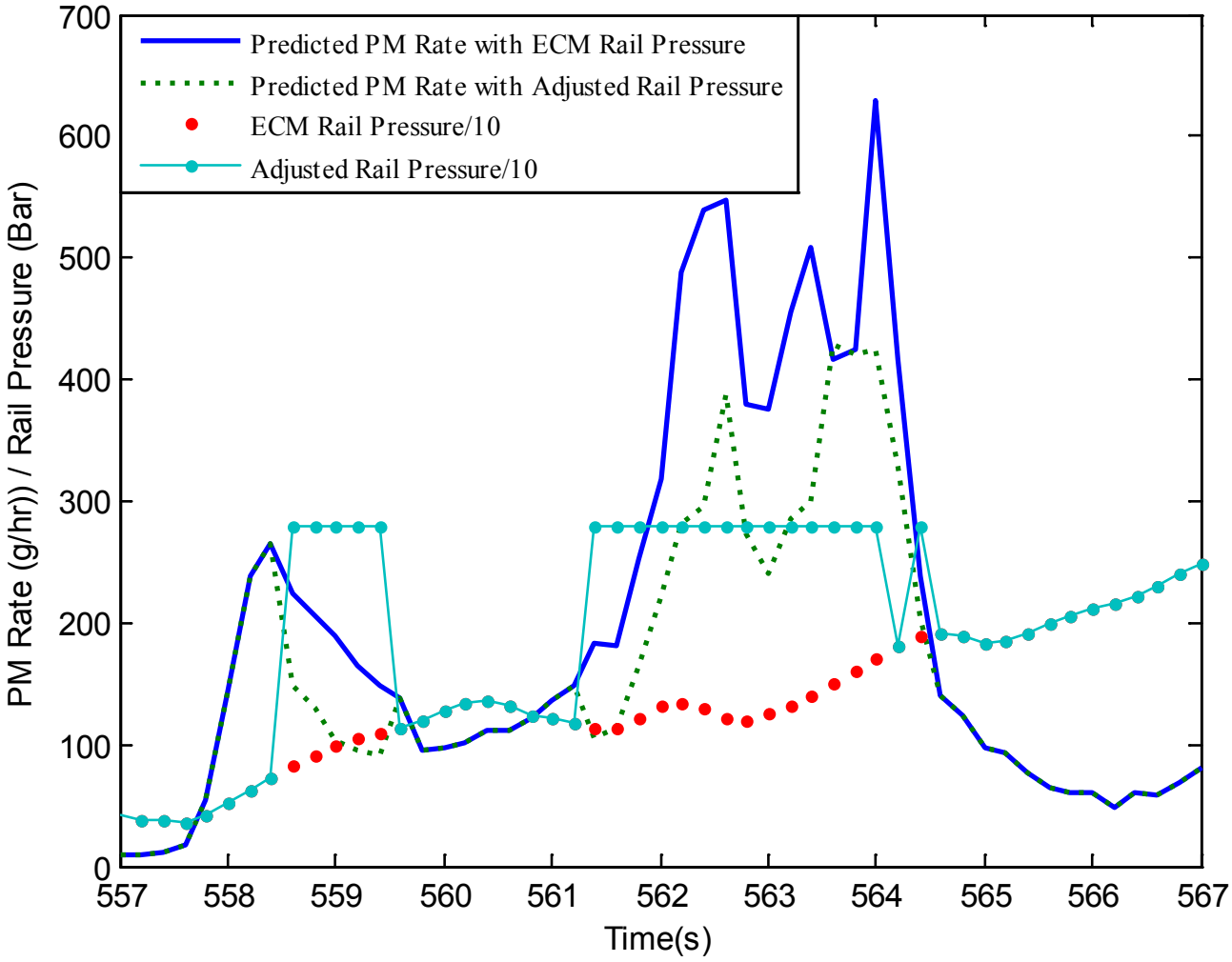
-Engine Speed

PM Spike Detection With Decision Trees



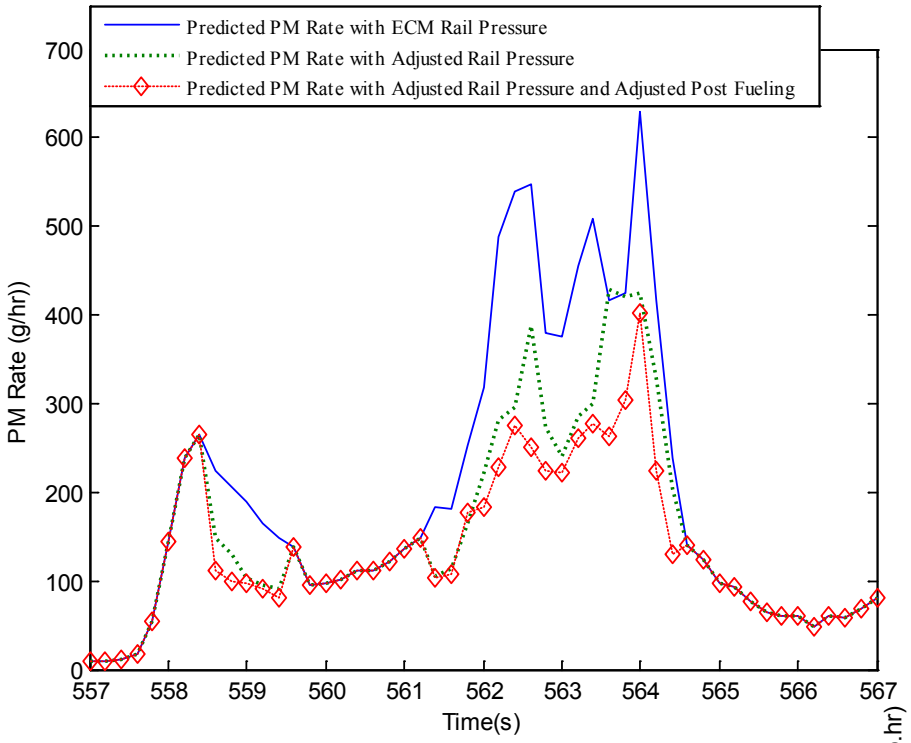
Decision trees trained with snap throttle transients could detect about 94% of the high opacity points during the turbocharger lag periods of the heavy duty FTP cycle, while falsely classifying about 3% of normal points as high opacity points.

Adjusted Rail Pressure Strategy: GT-Power Simulation Over Selected Segment

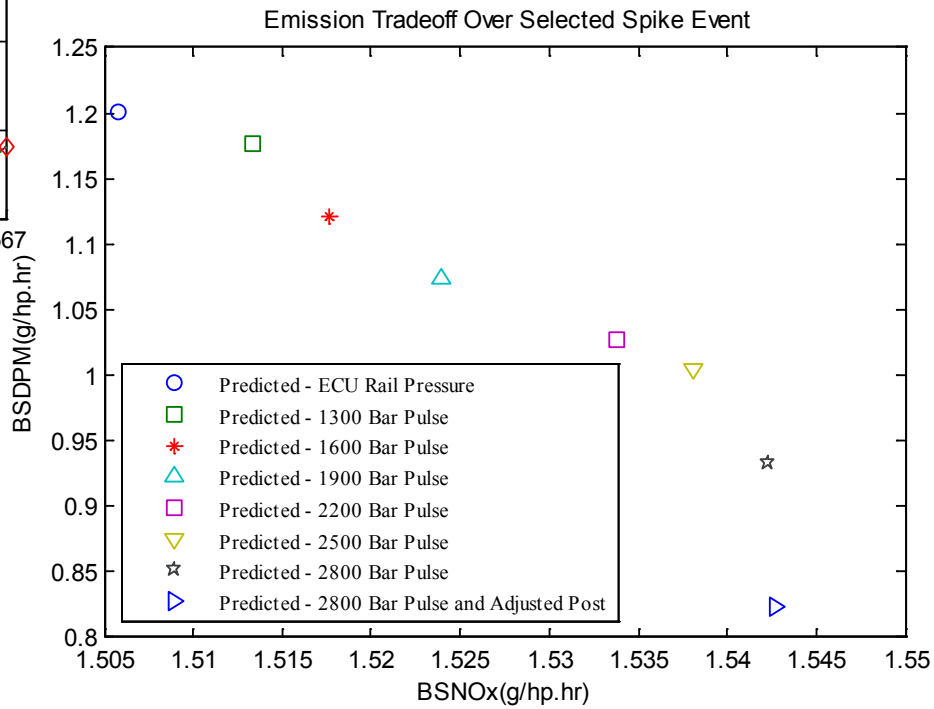


Integrated PM reduced by 22% over the baseline integrated mass, while integrated NO_x mass increased by only 2.4%

Adjusted Rail Pressure and Post Injection Strategy: GT-Power Simulation



Integrated PM reduced by 31% over the baseline integrated mass



Conclusions

- It is difficult to predict transient PM point-by-point with parametric models
- This is because it is difficult to estimate volumetric efficiency, EGR fraction and cylinder-to-cylinder variation in real time during the turbo lag period
- A non-parametric decision tree approach could correctly identify 94% of high opacity spikes while incorrectly classifying 3% of ‘normal’ points.
- Because PM and NOx spikes often occur such that there are relatively large exclusive areas, accurate classification could be used to take targeted action to reduce PM without affecting NOx

References

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