Application of Machine Learning Methods for Development of Heavy Duty Emission Inventories

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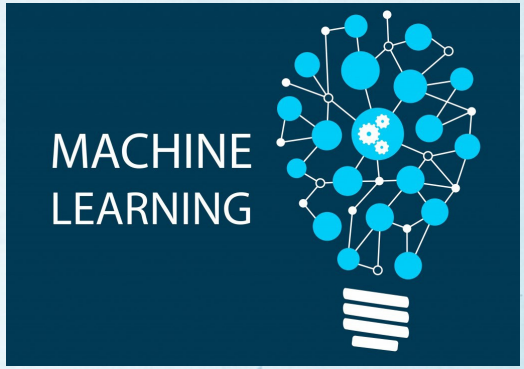
Introduction

- Introduction to Machine Learning (ML)
- Neural Networks
- Emissions Modeling using ML – SCR Temperature
- Results
- Future Work

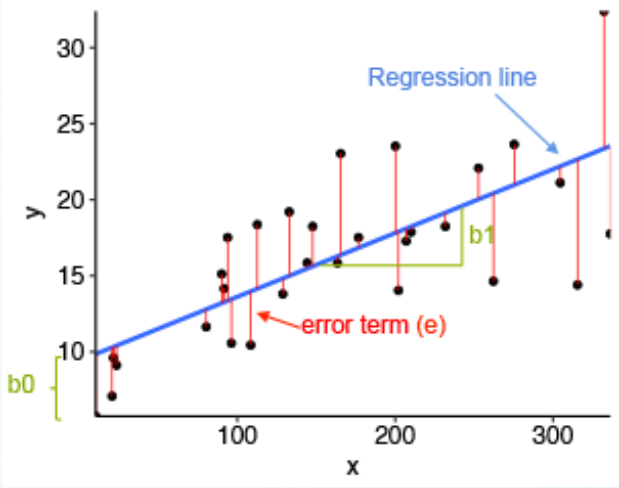
Introduction to Machine Learning (ML)

- What is ML?
- Why ML?
  - Learning
  - Pattern Detection
  - Data driven
  - Self-Programming
- ML use cases
  - Autonomous vehicles and trucks, e.g. Uber
  - Automated recommendations, e.g. by Netflix, Amazon, Facebook
  - Computer vision, e.g. Automated License Plate Readers
  - …



Neural Networks – Simplified

Neural network can be considered as glorified regressions



Linear Regression as a predictive model

$y = ax + b$

where **a** and **b** are selected to minimize sum of error

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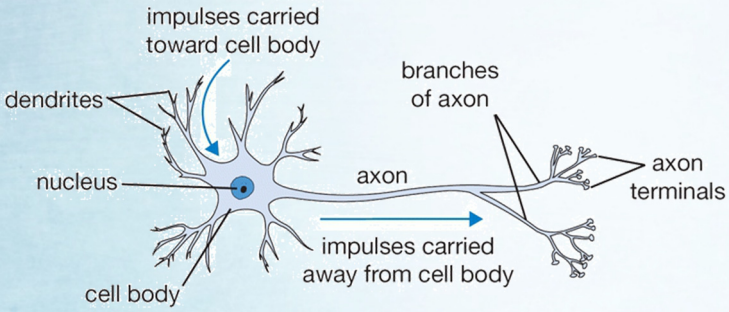
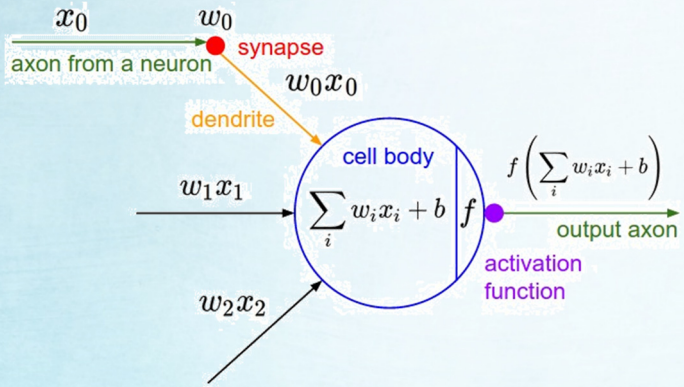
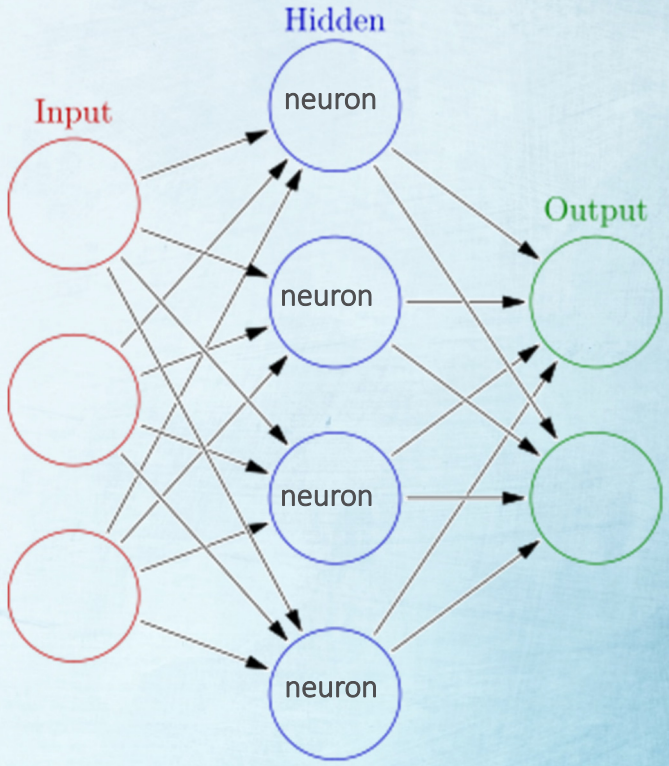
Neuron





Neural Network



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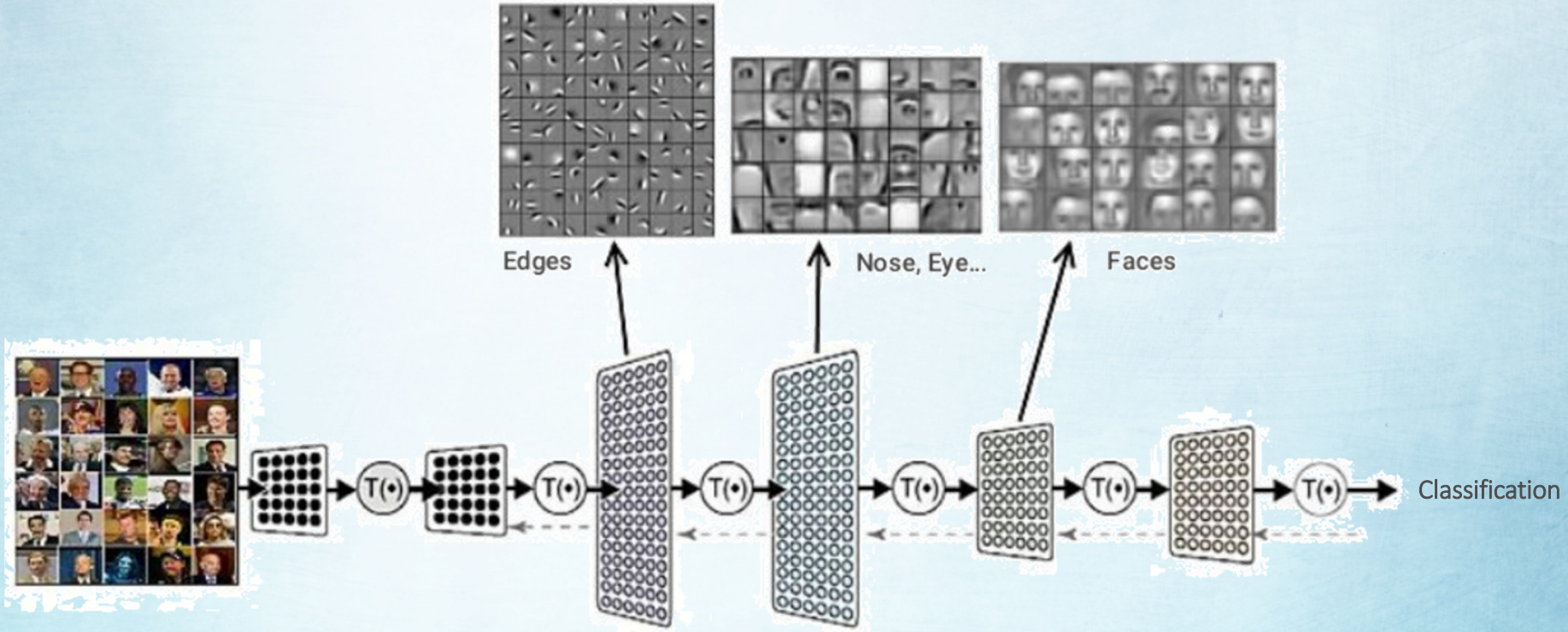
How does it learn?



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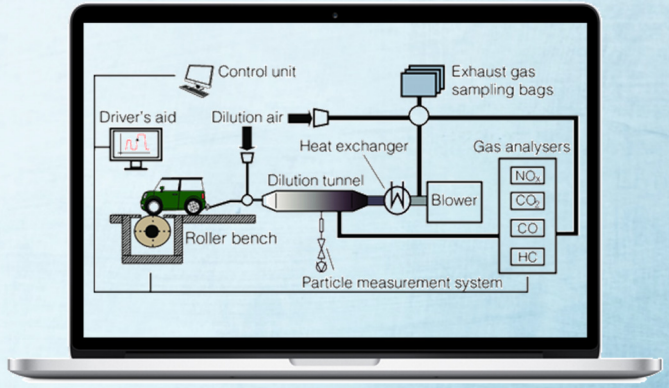
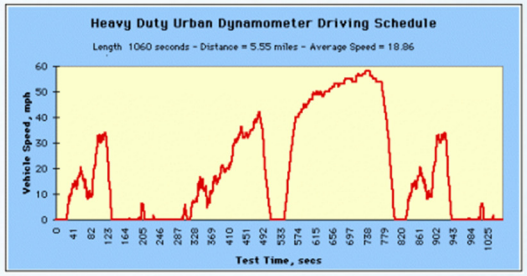
How can ML help us?

- Development of modal emissions models
  - Virtual Emission Testing Laboratory
  - Development of drive cycles
  - In-use compliance
- Emission Inventory Development



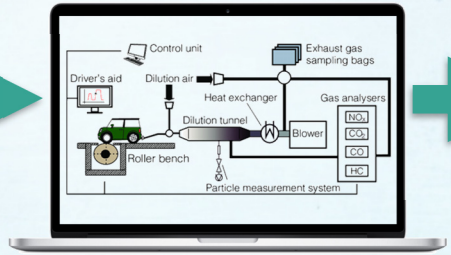
Virtual Emissions Testing Laboratory

Destination cycle (e.g. UDDS) - Velocity and power traces



PEMS testing – Source cycle

Virtual Chassis Dyno Lab



Simulated Cycle and Modal Emissions Data (e.g. for UDDS)

Inventory Development

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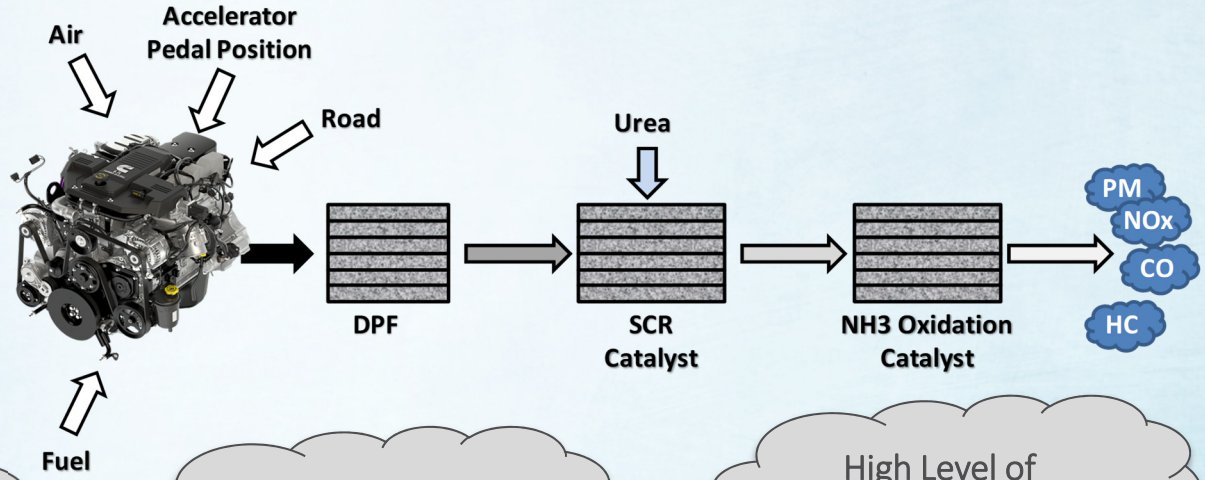
FROM CHAOS TO ORDER

Emissions Modeling using ML - Modeling SCR Temperature

Challenges of Emissions Modeling



Non-Linear System

Sophisticated Technologies

High Level of Noise

Lot of Parameters

Time Delays

Variability across OEMs

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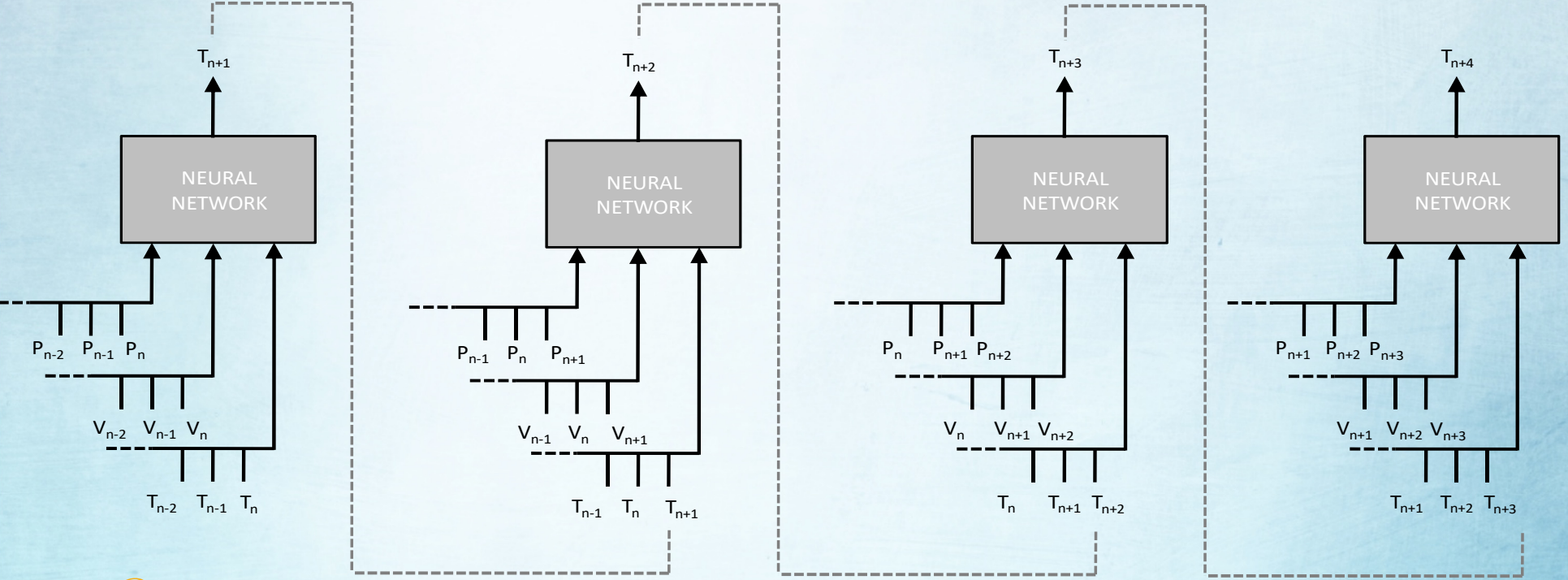
Solution Architecture

Simulation of SCR Inlet Temperature

TensorFlow
By Google Brain Team



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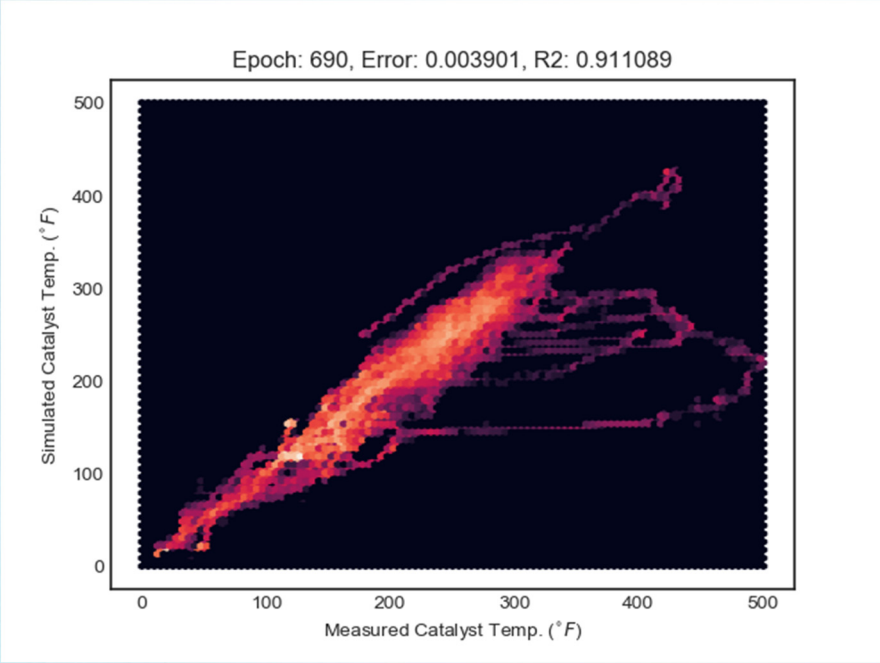
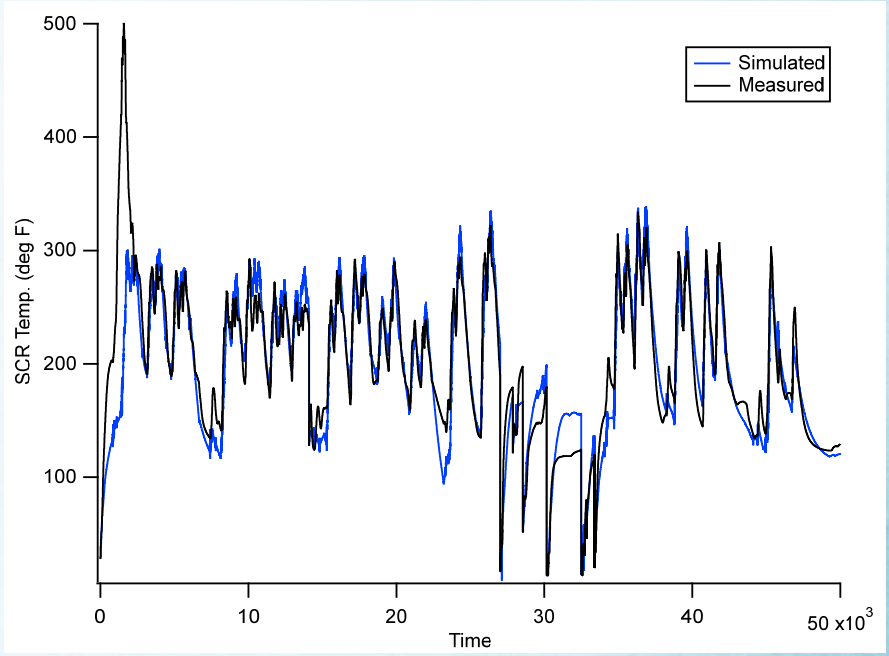
Shuttle Bus, MY2012

Results





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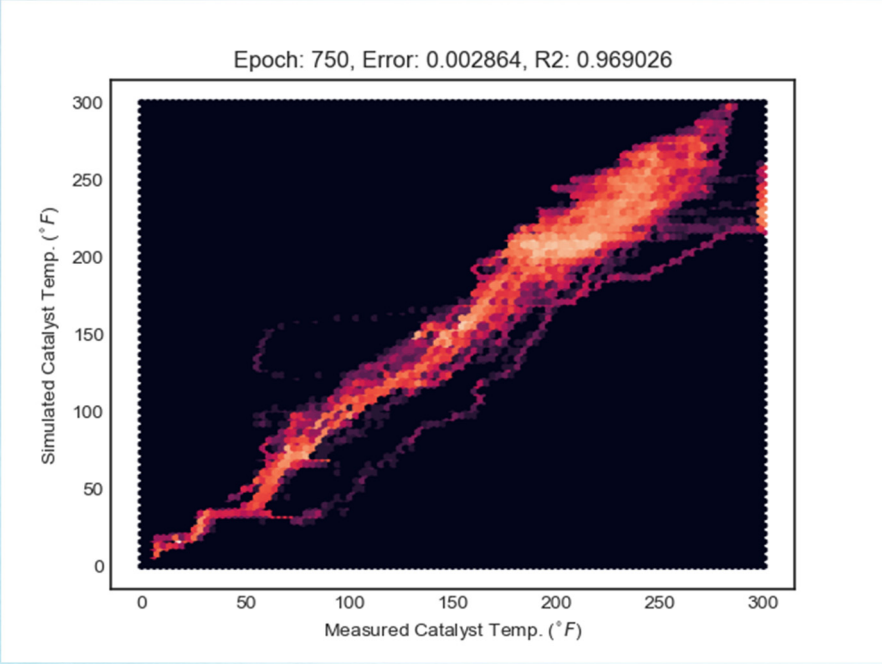
Results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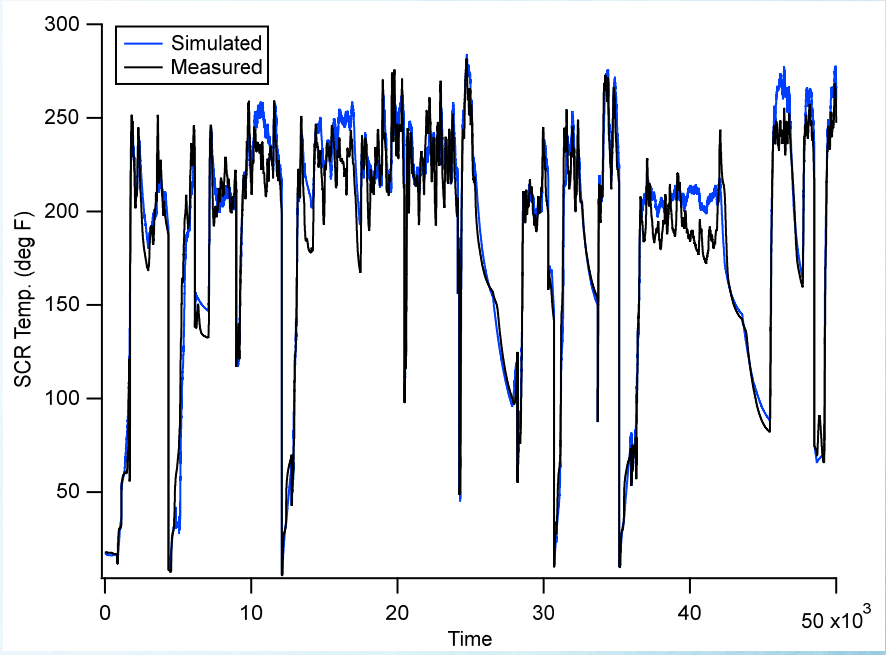
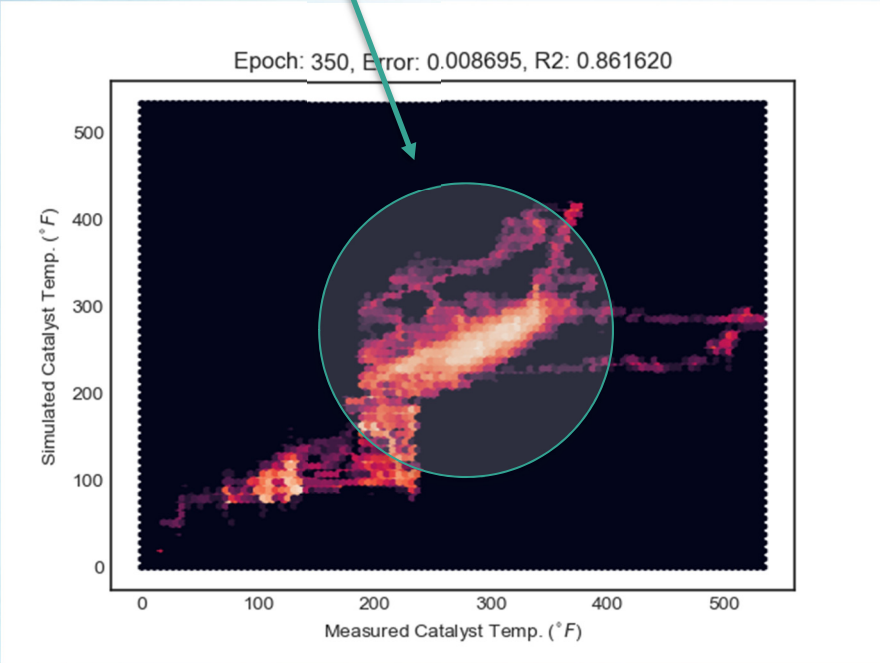
Simulated Catalyst Temp. (°F)
Measured Catalyst Temp. (°F)
0
50
100
150
200
250
300

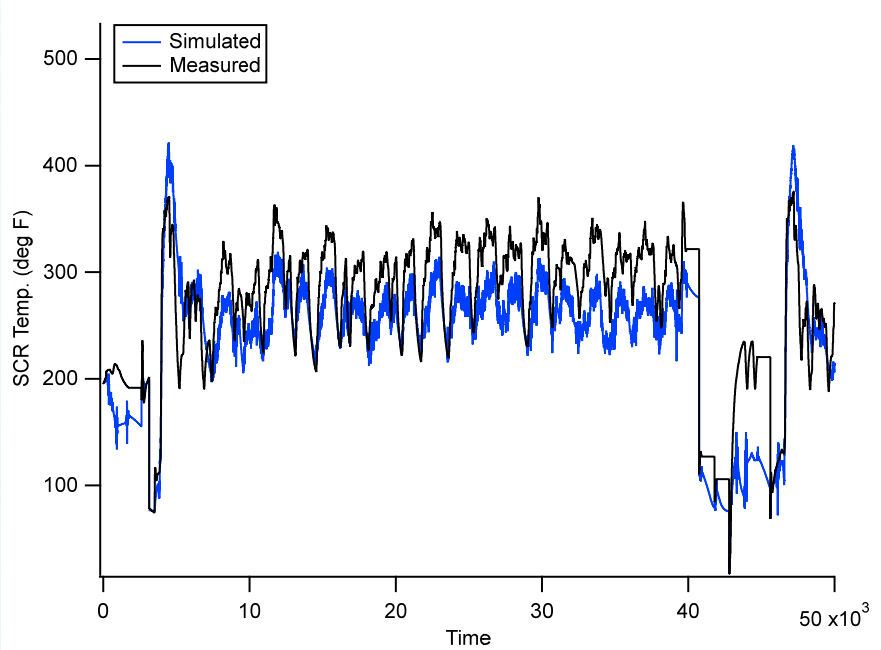

Simulated
Measured
SCR Temp. (deg F)
Time
50 x10^3
0
10
20
30
40
50
100
150
200
250
300

Urban Bus, MY2014

Results

Most of the data points are accumulated here





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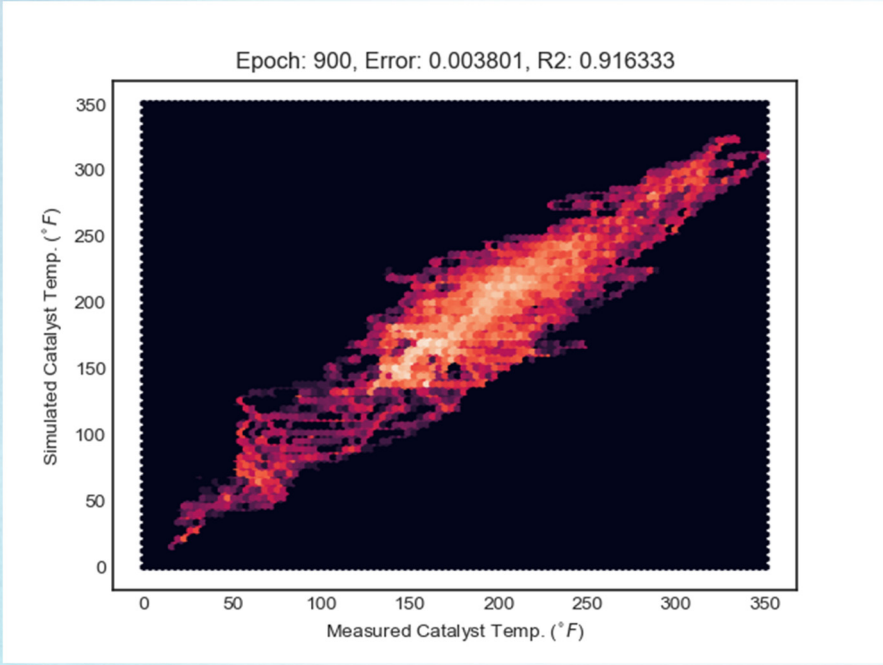
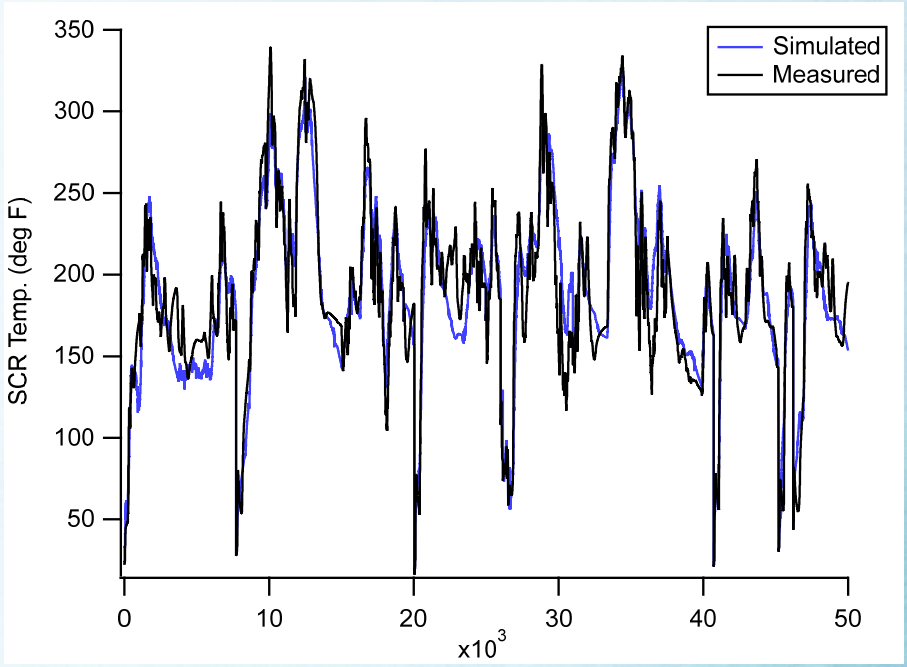
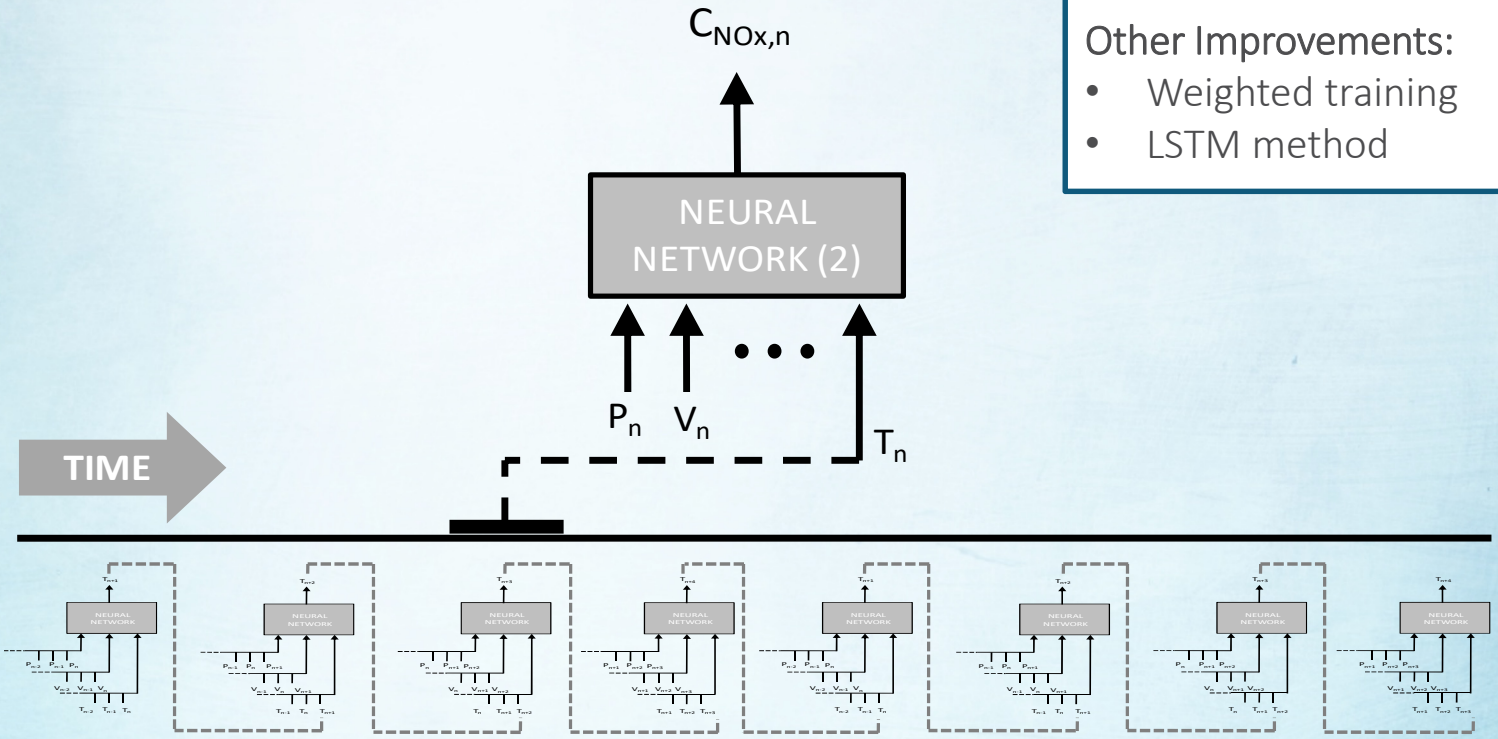
Results


Epoch: 900, Error: 0.003801, R2: 0.916333
Simulated Catalyst Temp. (°F)
Measured Catalyst Temp. (°F)
0
50
100
150
200
250
300
350


Simulated
Measured
SCR Temp. (deg F)
x10^3
0
10
20
30
40
50
50
100
150
200
250
300
350

Future Work: NOx Prediction



Other Improvements:

- Weighted training
- LSTM method

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Summary

- Neural networks seem to be a promising method for modeling SCR temperature as a function of vehicle speed and power.
- Weighted training is necessary due to non-uniform distribution of training data.
- Simulation of modal NOx emissions will open new possibilities such as virtual dyno labs, development of emission inventories and new drive cycles, and in-use compliance.

Thank you!

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