Detecting system failure: Signal Processing + Machine Learning on LEM dataset

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Abstract

In this project, we partnered with Lightning eMotors (LEM) to develop a prediction model for early detection of a system failure. LEM is an automotive research and manufacturing company that develops zero-emission all-electric powertrains. The company provided of a data set with over 9 million unique observations for 19 different variables across different vehicle units gathered in the timeframe between November 29, 2020 and February 7, 2022. Using this dataset, we developed a method to predict system failure with Signal Processing and Machine Learning techniques. The predictive model yielded outstanding results and we believe it can be utilized commercially as an early detection mechanism for system failure.

Methodology

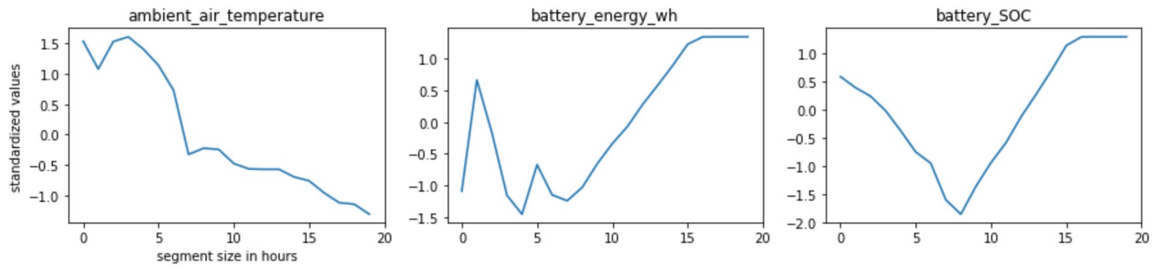
Our proposed solution has four steps:

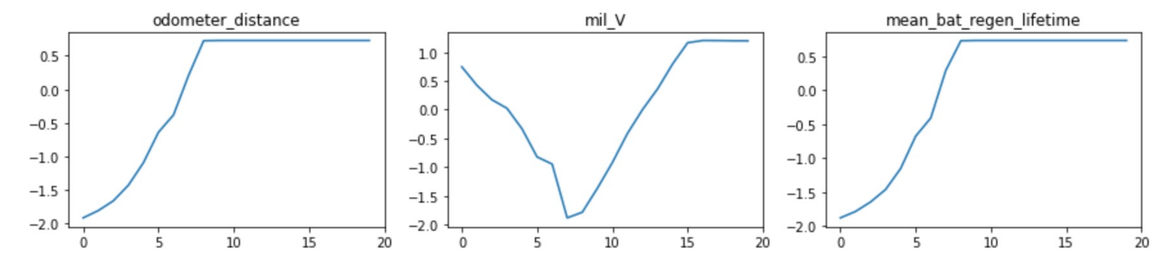
1. Data Preprocessing
2. Operationalization of “system failure”
3. Signal Processing with Continuous Wavelet Transform(CWT)
4. Convolutional Neural Network on scaleograms

First, we extracted the sequential 20-hour long signals from the provided dataset and processed them using Continuous Wavelet Transform, which is a Signal Processing technique. The output of this step was then used as input for Convolutional Neural Network that was trained to discriminate between “good” and “bad” signals.

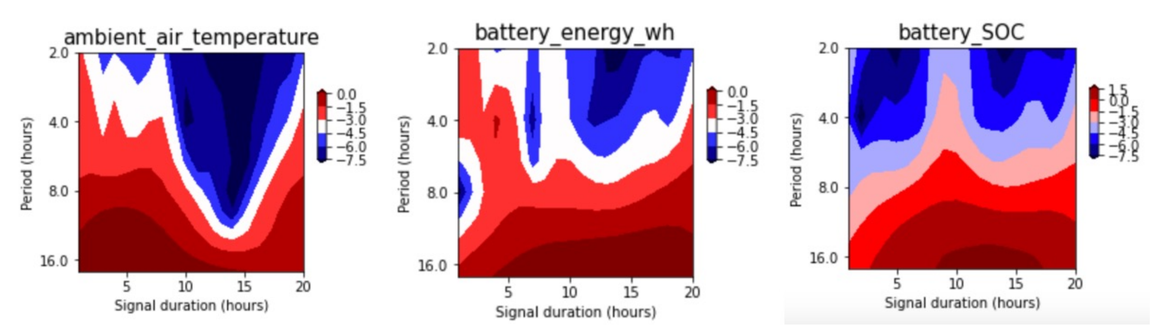
The operationalization of "bad" signals that might lead to a system failure was done based on 50 mV threshold for the cell divergence between min and max cells in millivolts. The 50-mV threshold was chosen because most consumer orientated Lithium ion batteries charge to a voltage of 4.2 volts per cell and this has a tolerance of around ± 50 mV per cell.

The examples of signals used as input for Signal Processing are provided below:



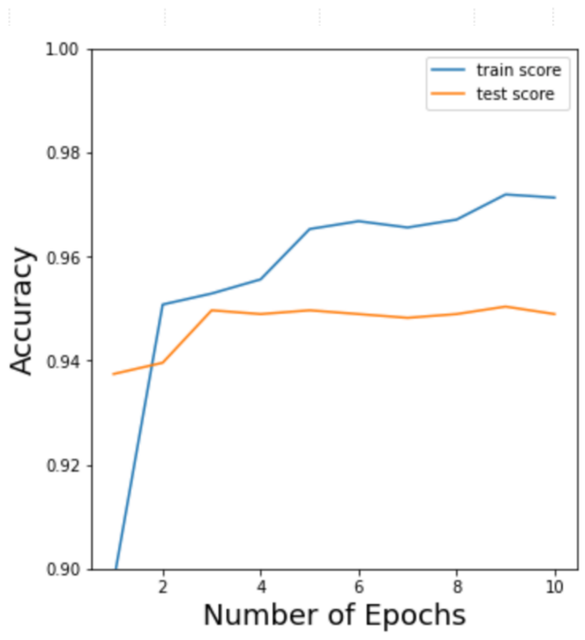


The examples of scaleograms used as input for CNN are provided below:



Results and Evaluation

Because our neural network is shallow, the training didn’t take up much time. Even with the shallow neural network, we were able to achieve 0.95 accuracy score on test data.



Conclusion

Detecting system failure in electric vehicles can help the industry prevent accidents and save costs on repair and maintenance.

The proposed method for detecting system failure through Signal Processing and Convolutional Neural Network yielded excellent results.

The solution is fully automated in Python and the preprocessing decisions, including operationalization of “system failure”, can be easily modified as per new requirements.

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