Fault Detection & Diagnosis of Spark Plugs using Machine Learning

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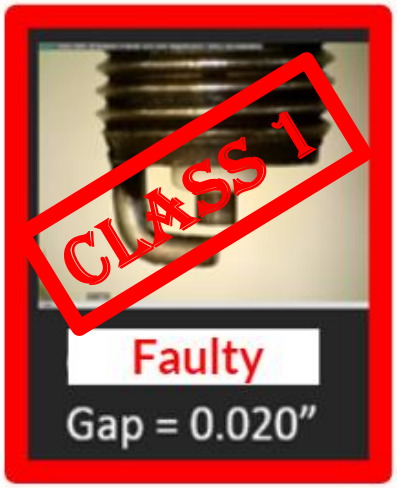
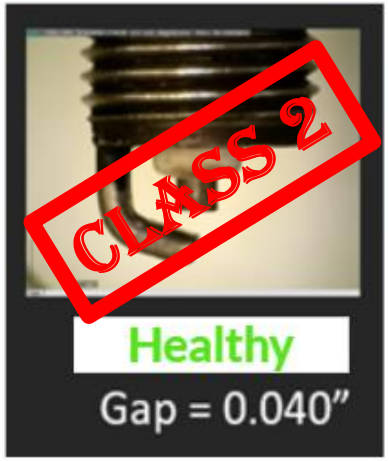
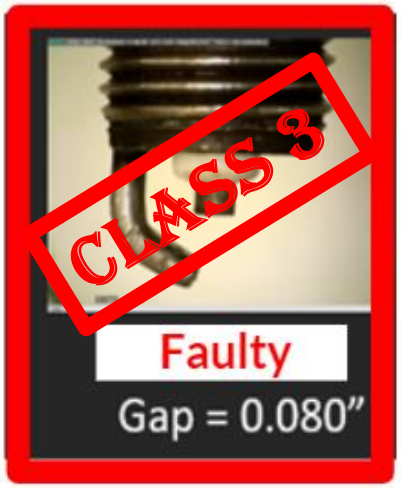
Problem Statement



- Short Spark
- Early & weak ignition
- Low engine performance
- Low efficiency
- High Fuel Consumption





- Wide Spark
- Late ignition (or None)
- Low engine performance
- Low efficiency
- High Fuel Consumption

Objective(s)

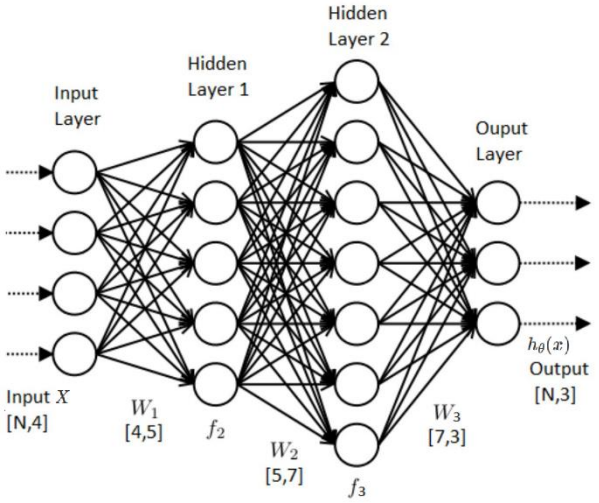
- Create a FDD model that:
  - Detect engine failure due to spark plug.
  - Classify Healthy / Small / Large spark plug gaps.

Tasks/Plan

- Collect data from engine sensors.
- Build a ML model.
- Train the ML model with the engine data.
- Test the model with verification data.
- Compare different ML models.

Expected Outcome & Deliverables

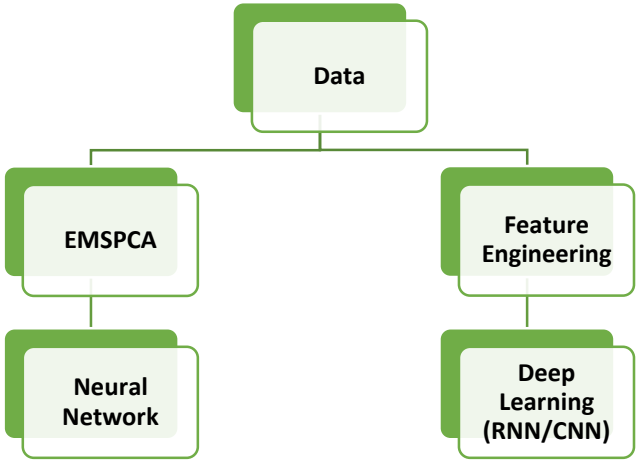
- Structured database that includes engine data of healthy and defective spark plugs.
- 3-output classifier that indicates the engine status.



Data Acquisition

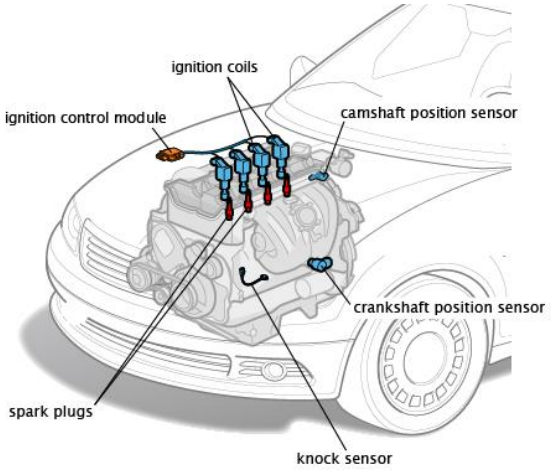
- 7 Engine Sensors
  - 4 knock sensors
  - 2 accelerometers
  - 1 Speed Sensor
- Cloud Database

FDD Model



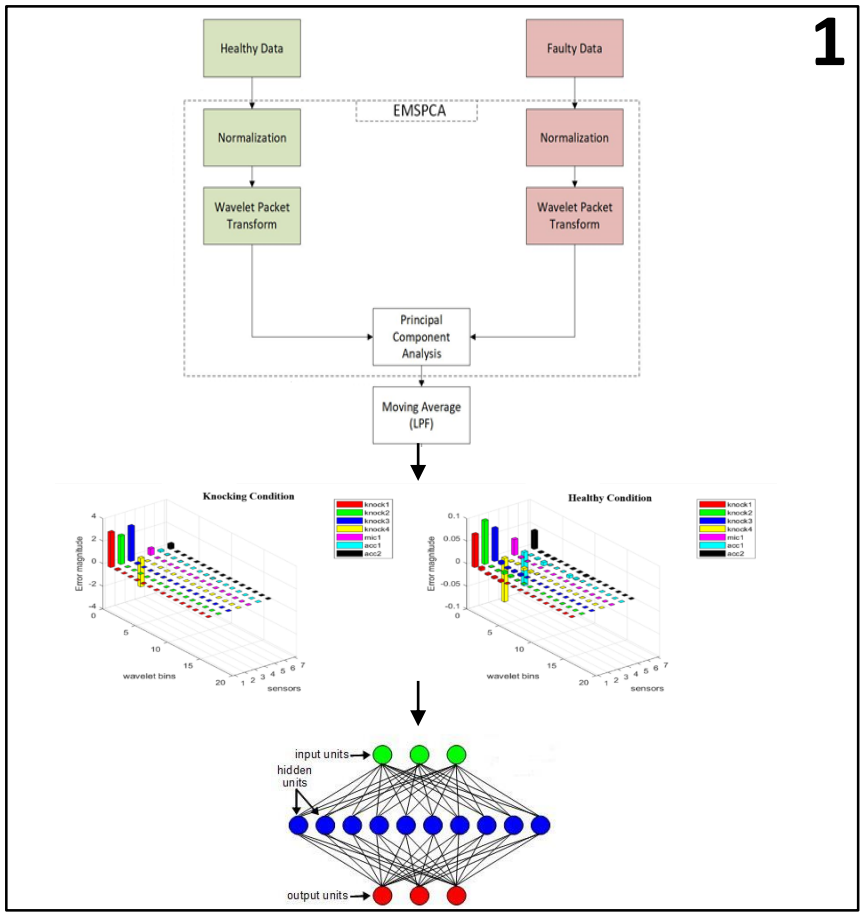
Train/Test/Validation

- 3 Classes (Healthy/Small/Large)
  - 200 cycles (per sample)
  - 7 features (per sample)
  - = 10M data points (per sample)
  - Hundreds of samples
- 60% Train, 20% Test, 20% Validation

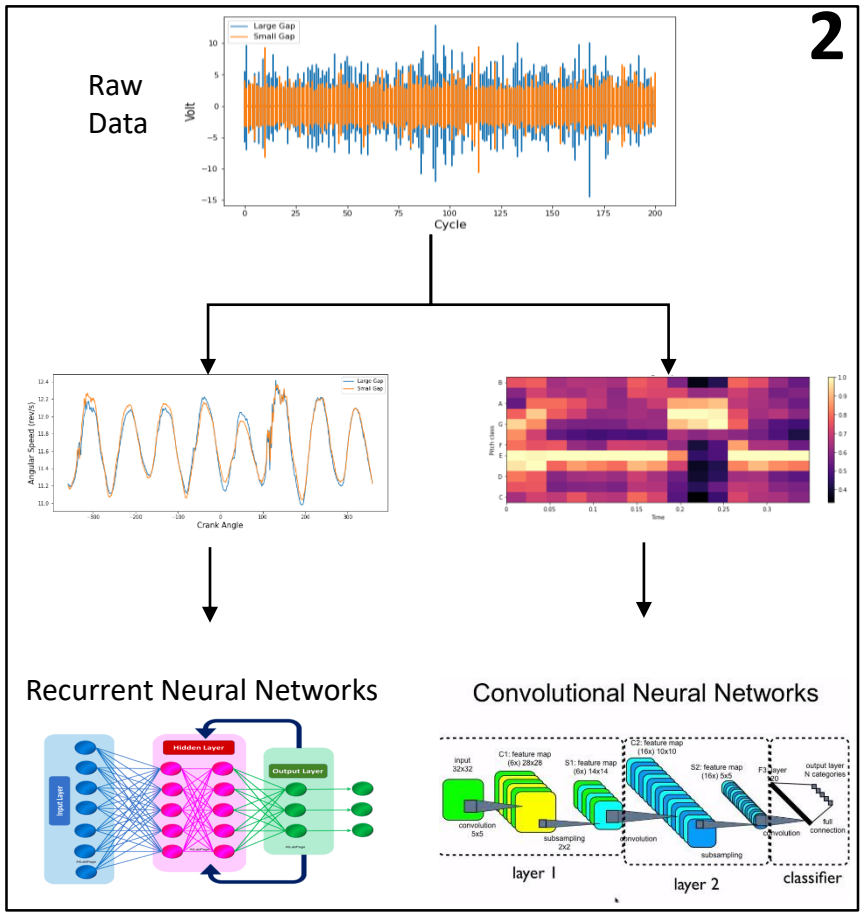


ML Models

1


Healthy Data
Faulty Data
EMSPCA
Normalization
Normalization
Wavelet Packet Transform
Wavelet Packet Transform
Principal Component Analysis
Moving Average (LPF)
Knocking Condition
Healthy Condition
Error magnitude
wavelet bins
sensors
knock1
knock2
knock3
knock4
mic1
acc1
acc2
input units
hidden units
output units

2


Raw Data
Large Gap
Small Gap
Volt
Cycle
Angular Speed (rev/s)
Crank Angle
Recurrent Neural Networks
Hidden Layer
Output Layer
Convolutional Neural Networks
input 32x32
C1: feature map (6x) 28x28
S1: feature map (6x) 14x14
C2: feature map (16x) 10x10
S2: feature map (16x) 5x5
output layer N categories
convolution 5x5
subsampling 2x2
convolution
subsampling
full connection
layer 1
layer 2
classifier

Progress & Results

- Cloud database was built and currently migrating.
- EMSPCA was trained and tested with 2% 4 levels of wavelets.
- Recurrent Neural Network was trained and tested.
- Convolutional Neural Network was trained and tested.

Average Detection Rate (Validation Accuracy)

EMSPCA + MLP (wavelet Level = 4)	**Deep RNN**	**Deep CNN**
100%	98.81%	98.5%