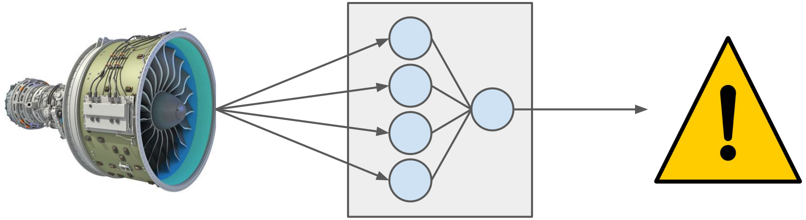
Shifeng for FieldBox.ai

Intelligent Turbofan Failure Warning System

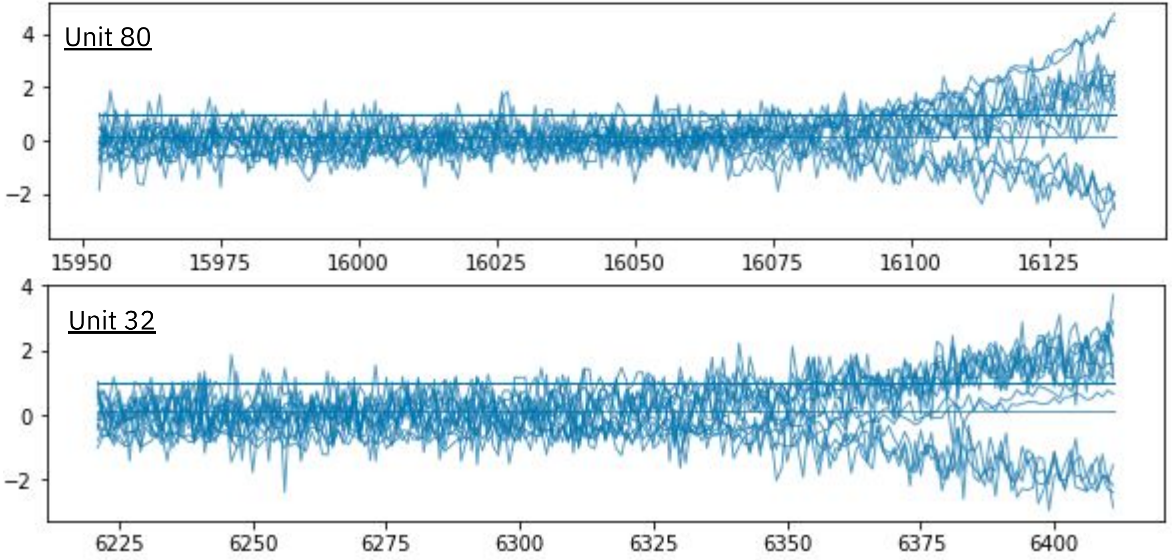
Predicting operational failure of turbofan with a deep learning classifier.



Data Sources

- 100 simulation runs of turbofan operation done until failure
- Corresponding measurements of 21 sensors, until failure

Sensor Measurements (normalized time-series data)



Objective

- Predict failure <u>15 cycles</u> before it happens
- Minimize missed detection
- Minimize false alarm

Methodology

- Sliding window
- Neural network classifier
    - 1 hidden layer
    - Sigmoid output

Requirements

- Python 3.5+
    - Pandas, Torch, Numpy
- Jupyter

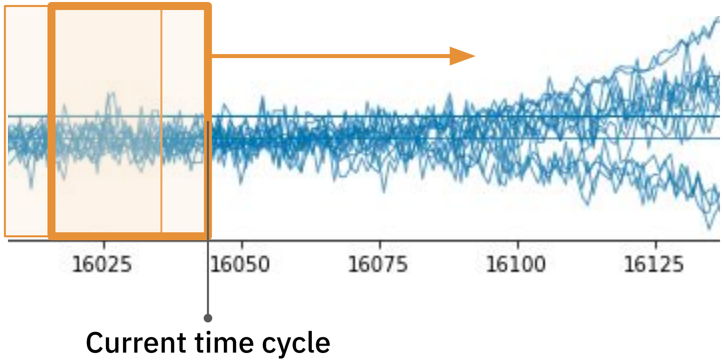
Data Processing & Algorithm

Preparing data and developing predictor.

Preprocessing

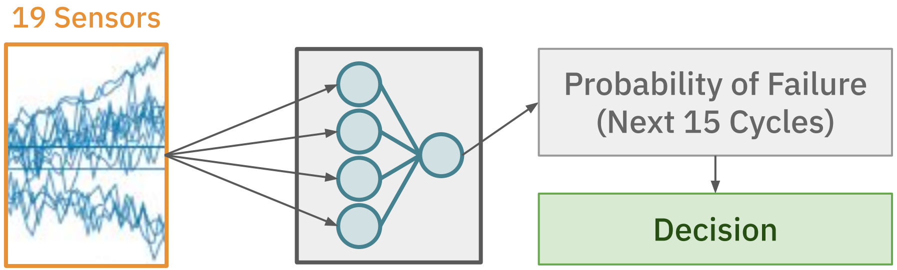
- Data is noisy generally acceptable
- 2 sensors with no data removed
- Sensor signals are normalized & rescaled
- Sliding windows of signals are created

Overlapping “windows” of sensor measurements are analyzed at the current time cycle to determine the status of the turbofan throughout its operation.



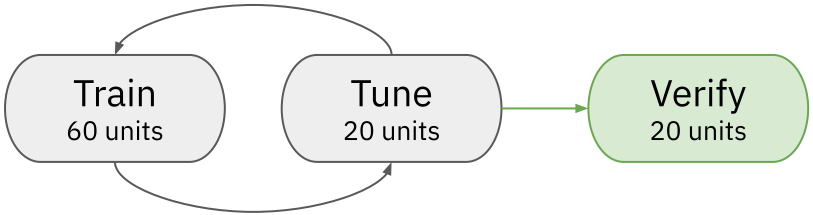
Deep Neural Network Classifier

- 4 hidden neurons with non-linearity
- Final sigmoid neuron to predict probability



Development Process

- Parameters are trained/tuned with 60+20 units
- Performance is verified using 20 units
    - the algorithm has never seen these 20 units

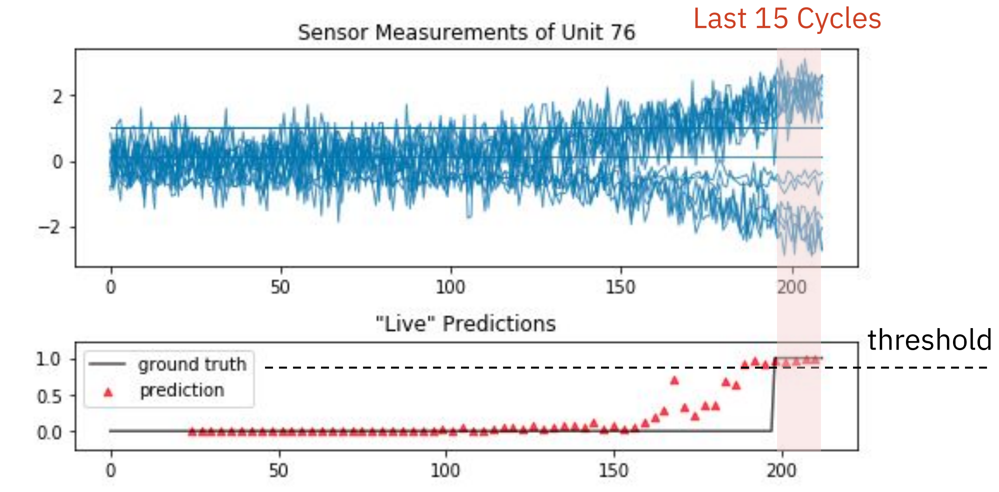


Verification of Results

A demonstration of the classifier in deployment.

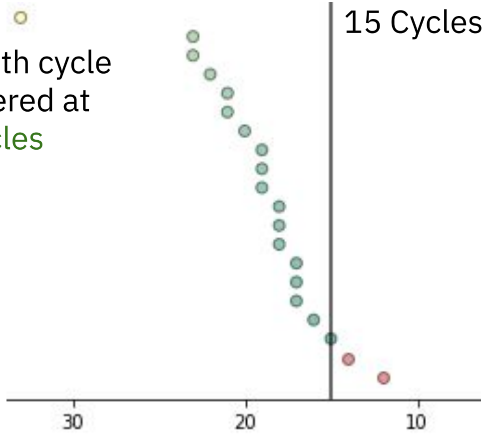
Classifier Features

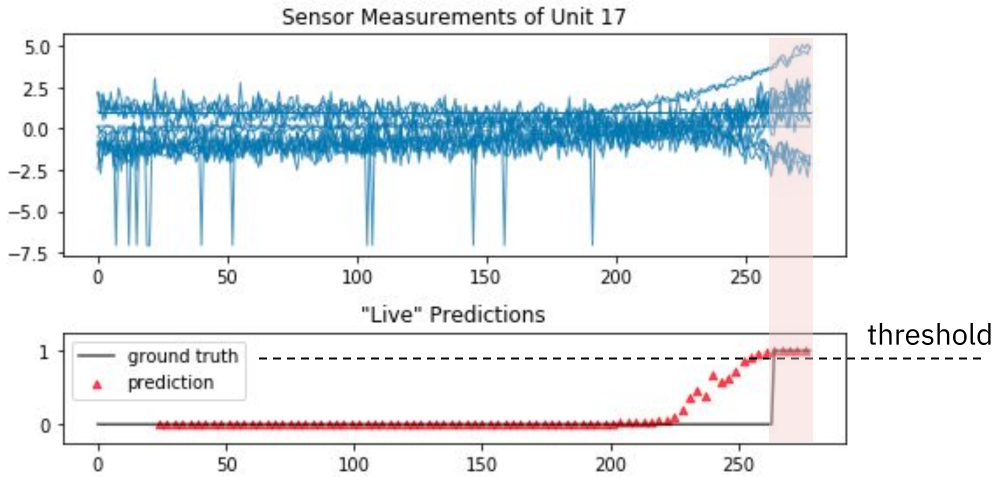
- Starts to detect probability of failure 60 cycles in advance.
- Is able to predict failure in the next 15 cycles with a high probability (close to 1)



Overall results

- 1 outlier at 35th cycle
- Warning triggered at 19.4 ± 4.2 cycles





Customization

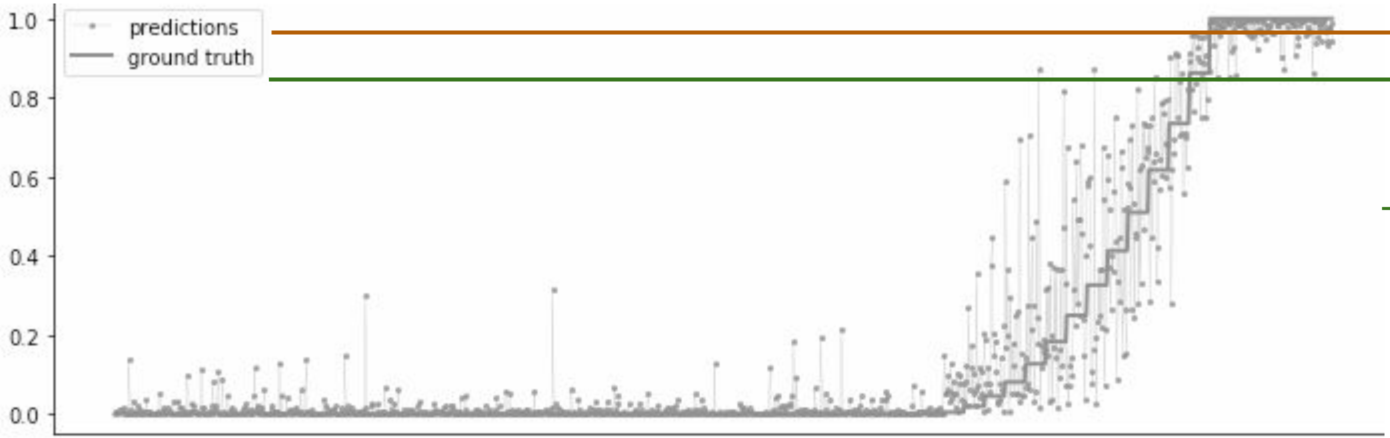
Adjustable threshold and usage on new turbofans/sensors.

Optimal Threshold

- The threshold is tuned in order to minimize the *cost of a warning*.
- It is indirectly controlled by setting these variables:
    - *Early warning cost* - the cost incurred for every cycle the warning is early
    - *Late warning cost* - the cost incurred for every cycle the warning is late
- High relative late warning cost will push threshold lower to detect warnings less selectively, hence earlier

Selective Threshold

- Only picks up warnings within the last 15 cycles
- More likely to warn late



Safest Threshold

- Picks up more warnings
- More likely to warn early