Predictive Maintenance with MATLAB
A data-driven approach

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Why perform predictive maintenance?

- Example: faulty braking system leads to windmill disaster
  - [https://youtu.be/-YJuFvjtM0s?t=39s](https://youtu.be/-YJuFvjtM0s?t=39s)

- Your equipment can cost millions of dollars

- Failures can be dangerous

- Maintenance also very expensive and dangerous
Types of Maintenance

- **Reactive** – Do maintenance once there’s a problem
  - Example: replace car battery when it has a problem
  - Problem: unexpected failures can be expensive and potentially dangerous

- **Preventive** – Do maintenance at a regular rate
  - Example: change car’s oil every 5,000 miles
  - Problem: unnecessary maintenance can be wasteful; may not eliminate all failures

- **Predictive** – Forecast when problems will arise
  - Example: certain GM car models forecast problems with the battery, fuel pump, and starter motor
  - Problem: difficult to make accurate forecasts for complex equipment
What Does Success Look Like?
Safran Engine Health Monitoring Solution

- Monitor Systems
  - Detect failure indicators
  - Predict time to maintenance
  - Identify components

- Improve Aircraft Availability
  - On time departures and arrivals
  - Plan and optimize maintenance
  - Reduce engine out-of-service time

- Reduce Maintenance Costs
  - Troubleshooting assistance
  - Limit secondary damage

http://www.mathworks.com/company/events/conferences/matlab-virtual-conference/
Predictive Maintenance of Turbofan Engine

Sensor data from 100 engines of the same model

Predict and fix failures before they arise
- Import and analyze historical sensor data
- Train model to predict when failures will occur
- Deploy model to run on live sensor data
- Predict failures in real time

Data provided by NASA PCoE
http://ti.arc.nasa.gov/tech/dash/pcoe/prognostic-data-repository/
Modeling Approaches

First Principles Modeling

- Simulink
- Simscape
- System Identification Toolbox
- Simulink Design Optimization

Data-Driven Modeling

- Statistics and Machine Learning Toolbox

Tools for Modeling Dynamic Systems
Challenges

1. Data – Do you have enough/correct data?
   A failure might be a rare occurrence – how do you develop an algorithm if you don’t know what a failure looks like

2. How do you find the best possible algorithm?

3. How do you deploy your algorithm into production?
Overview – Machine Learning

Type of Learning

- **Supervised Learning**
  - Develop *predictive model* based on both input and output data

- **Unsupervised Learning**
  - Group and interpret data based only on input data
Using Unsupervised Machine Learning to Detect Deterioration of an Engine
Generating Datasets for Model Training Through Simulation

- If you don’t have real data available, consider generating data through simulation
- Model your system in Simulink, introduce errors (e.g. clogged hydraulics line), log the output of the simulation
- Use the generated dataset to develop a model to predict e.g. remining useful lifetime
Generating Datasets for Model Training Through Simulation
Predictive Maintenance of Turbofan Engine

Sensor data from 100 engines of the same model

Scenario 2: Have failure data
- Performing scheduled maintenance
- Failures still occurring (maybe by design)
- Search records for when failures occurred and gather data preceding the failure events
- Can we predict how long until failures will occur?

Data provided by NASA PCoE
http://ti.arc.nasa.gov/tech/dash/pcoe/prognostic-data-repository/
How Data was Recorded

<table>
<thead>
<tr>
<th>Engine</th>
<th>Initial Use/ Prior Maintenance</th>
<th>Recording Starts</th>
<th>Failure</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine1</td>
<td>?</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Engine2</td>
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<tr>
<td>Engine200</td>
<td>?</td>
<td>✔</td>
<td></td>
<td>✗</td>
</tr>
</tbody>
</table>
Overview – Machine Learning

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Categories of Algorithms

- Regression
- Classification
Challenges

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   A failure might be a rare occurrence – how do you develop an algorithm if you don’t know what a failure looks like

2. How do you find the best possible algorithm?
   There are dozens of modeling techniques

3. How do you deploy your algorithm into production?
Identifying the Best Classifier Using Classification Learner App
Challenges

1. Data – Do you have enough/correct data?
   A failure might be a rare occurrence – how do you develop an algorithm if you don’t know what a failure looks like

2. How do you find the best possible algorithm?
   There are dozens of modeling techniques

3. How do you deploy your algorithm into production?
   Manually translating MATLAB into other languages can be error prone, and building a production-quality back-end from scratch is expensive
Integrate Analytics with Your Enterprise Systems

MATLAB Compiler and MATLAB Coder
Building a MATLAB-based service

Equipment

Databases

Streaming

MATLAB Analytics

Dashboards

Algorithm development
Demo: Predictive Maintenance Analytics in the Cloud
Performing RUL Classification in the Cloud
Key Takeaways

- Frequent maintenance and unexpected failures are a large cost in many industries.

- MATLAB enables engineers and data scientists to quickly create, test and implement predictive maintenance programs.

- Predictive maintenance:
  - Saves money for equipment operators
  - Increases reliability and safety of equipment
  - Creates opportunities for new services that equipment manufacturers can provide.
Predictive Maintenance with MATLAB

- Stop by at the "Data Analytics" demo station to learn more
