빅데이터 분석을 통한
자동 고장 진단 및 예측 유지보수 시스템 개발

Application Engineer
엄 준 상 과장
Why perform predictive maintenance?

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

- Wind turbines 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

- Scheduled – 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
Benefits of Predictive Maintenance

- Increase “up time” and safety
- Minimize maintenance costs
- Optimize supply chain

Reliability
Cost of Ownership
Reputation
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/
Predictive Maintenance of Turbofan Engine

Sensor data from 100 engines of the same model

Scenario 1: No data from failures
- Performing scheduled maintenance
- No failures have occurred
- Maintenance crews tell us most engines could run for longer
- Can we be smarter about how to schedule maintenance **without** knowing what failure looks like?

Data provided by NASA PCoE
http://ti.arc.nasa.gov/tech/dash/pcoe/prognostic-data-repository/
Machine Learning
Characteristics and Examples

- **Characteristics**
  - Too many variables
  - System too complex to know the governing equation (e.g., black-box modeling)

- **Examples**
  - Pattern recognition (*speech, images*)
  - Financial algorithms (*credit scoring, algo trading*)
  - Energy forecasting (*load, price*)
  - Biology (*tumor detection, drug discovery*)
  - Engineering (*fleet analytics, predictive maintenance*)
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.
Principal Components Analysis – what is it doing?
Example Unsupervised Implementation

<table>
<thead>
<tr>
<th>Round 1</th>
<th>Round 2</th>
<th>Round 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Use/Prior Maintenance</td>
<td>Engine1</td>
<td>Engine1</td>
</tr>
<tr>
<td>125 Flights</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>135 Flights</td>
<td>✔️</td>
<td>✔️</td>
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</table>
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/
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

Categories of Algorithms

- Regression
- Classification
How Data was Recorded

Initial Use/ Prior Maintenance

- Engine1
  - Recording Starts
  - Failure

- Engine2
  - Recording Starts
  - Failure

- Engine100
  - Recording Starts
  - Failure

- Engine200
  - Recording Starts
  - Maintenance

Historical

Live

Time (Flights)
Integrate analytics with your enterprise systems

MATLAB Compiler and MATLAB Coder
MathWorks Services

- Consulting
  - Integration
  - Data analysis/visualization
  - Unify workflows, models, data
  
  www.mathworks.com/services/consulting/

- Training
  - Classroom, online, on-site
  - Data Processing, Visualization, Deployment, Parallel Computing
  
  www.mathworks.com/services/training/
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
MATLAB Differentiators

1. Analytics that increasingly require **both business and engineering data**
   - DATA
     - Engineering, Scientific, and Field
     - Business and Transactional

2. Developing **embedded systems** which have increasing analytic content

3. Deploying applications that run on **both traditional IT and embedded platforms**

4. Enable **Domain Experts to do Data Science**

Data Analytics

Business Systems

Smart Connected Systems