Predictive Maintenance Using Deep Learning

Sudheer Nuggehalli  Rachel Johnson
Listen carefully. Which compressor has a faulty bearing?
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Predictive Maintenance Using Deep Learning

Sudheer Nuggehalli  Rachel Johnson
Key Takeaways for Predictive Maintenance

- Small gains can yield big rewards. Try different approaches, including deep learning.
- You need AI and domain expertise. MATLAB helps you do both.
- MATLAB can automate your entire workflow.
Journey 1: *Do you speak air compressor?*

Journey 2: *Data, data, everywhere*

Fault Isolation with Acoustic Data

Anomaly Detection with Vibration Data
Meet Rachel*

- Mechanical Engineer at Membrane Manufacturing**
- Responsible for a fleet of industrial machines
- New company AI initiative
- No deep learning experience

*Rachel is an actor who works at MathWorks
**Not a real company
Predictive Maintenance Workflow

DATA PREPARATION

- Data access and preprocessing
- Simulation-based data generation
- Feature engineering
Predictive Maintenance Workflow

**DATA PREPARATION**
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**AI MODELING**
- Model design and tuning
- Hardware-accelerated training
- Model exchange across frameworks
Predictive Maintenance Workflow

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DEPLOYMENT
- Embedded Devices
- Enterprise Systems
- Edge, cloud, desktop

ITERATION & REFINEMENT
Journey 1: Do you speak air compressor?
# Journey 1: Do you speak air compressor?

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<td><strong>Fault detection:</strong> Identify specific faults to enable maintenance staff to respond more quickly</td>
<td><img src="image" alt="Image of compressor and waveform" /></td>
<td><img src="image" alt="Image of waveform" /></td>
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**Journey 1: Do you speak air compressor?**

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| Acoustic time series data from sensors | Labeled faults from maintenance logs | | 1. Healthy  
2. Leakage Inlet Valve fault  
3. Leakage Outlet Valve fault  
4. Non-Return Valve fault  
5. Piston Ring fault  
6. Flywheel fault  
7. Rider Belt fault  
8. Bearing fault |
**Journey 1: Do you speak air compressor?**

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Access data with datastore

Extract features with Audio Toolbox

Train and validate LSTM

Generate C code for edge deployment
Air Compressor Data Classification

Part 1: Data Preparation

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Air Compressor Data Classification
Part 1: Data Preparation
  Create Datasstore
  Split Into Training and Validation Sets
  Data Preparation
    Human Insight
  Generate Training Features
  Normalize Training Features
  Generate and Normalize Validation Features
  Generate MATLAB function compatible with C/C++ Code Generation
Journey 1: Do you speak air compressor?

- Successfully identified faults with 95% validation accuracy

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Journey 1: Do you speak air compressor?

- Successfully identified faults with 95% validation accuracy
**Journey 1:** Do you speak air compressor?

**Poll:** How could we improve the results?

- Collect more data
- Tune network hyperparameters
- Try a different feature set
- Try a different algorithm
- Buy more GPUs
Journey 1: Do you speak air compressor?

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Journey 1: Do you speak air compressor?

- What’s Next?

Deploying AI to Embedded and Production Systems
Journey 2: Data, data, everywhere…
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- **Anomaly Detection**: Detect when the machine deviates from normal operation.
- Avoid surprises. Address anomalies before catastrophic failure occurs.

**Currently**
- Routine monthly maintenance
- Not many failures
- But when failures do happen…
Journey 2: Data, data, everywhere…

- Vibration data from 3-axis accelerometers

- Labeled “before” and “after” maintenance
  - “After” data = Normal ✓
  - “Before” data = Not sure ?

- Some data tagged as “abnormal” by maintenance crews
**Journey 2: Data, data, everywhere…**

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Journey 2: Data, data, everywhere…

**Goal**

**Data**

**Approach**

**Result**

Autoencoder

Input data

Encoded data

Reconstructed data

Encode

Decode
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<td>Extract and rank features with Diagnostic Feature Designer App</td>
<td>Train autoencoder on normal data</td>
<td>Deploy algorithms to the cloud</td>
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**Journey 2: Data, data, everywhere…**
Part 1: Data Preparation and Feature Extraction

*Industrial Machinery Anomaly Detection*

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Load Data
Visualize Data Before and After Maintenance
Extract Features with Diagnostic Feature Designer App

Load Data

```matlab
load("IndustrialMachineData.mat")
```

Visualize Data Before and After Maintenance

Visualize data before and after maintenance across channels for one member of the ensemble
Journey 2: Data, data, everywhere…

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Reconstruction Error on Abnormal Validation Data
Mean Error: 1.68

Reconstruction Error on Normal Validation Data
Mean Error: 0.09
Journey 2: Data, data, everywhere…

- What’s Next?

MATLAB EXPO

DevOps for Software and Systems: Putting Algorithms and Models in Operation
Six months later…
Six Months Later

- Increased uptime by 10%
- Want to expand to entire fleet, multiple locations
- Next project: Predict Remaining Useful Life (RUL)
- Got a promotion! 😊
Companies are succeeding with MATLAB for Predictive Maintenance

- **Airbus** detects defects in aircraft pipes with semantic segmentation
- **Siemens** develops health monitoring system for distribution transformers
- **RWE Renewables** detects anomalies in wind turbine bearings using neural networks
- **Mondi** develops and deploys algorithms to predict plastic production machine failures
LG Energy Solution used Deep Learning for Predictive Maintenance on industrial cutter

Challenge
Maintenance of equipment in the factory also depends on the site engineer’s opinion, and sometimes those are a bit conservative.

Solution
Developed a condition monitoring system and deployed standalone executable which can acquire raw data from NI device directly, make a prediction and display the result in GUI.

Advantages of using MATLAB and Simulink
- Interactive Apps for generating features and training various AI models
- Capabilities of entire workflow from data acquisition to deployment
- Leveraged MathWorks engineer’s support for fast prototyping

“3 advantages of MATLAB that lead our project to success: App-based AI development workflow, compatibility with 3rd party hardware and short test cycle with rapid prototyping.”

Junghoon Lee, LG Energy Solution

>> MATLAB for deep learning
Key Takeaways for Predictive Maintenance

Small gains can yield big rewards. Try different approaches, including deep learning.

You need AI and domain expertise. MATLAB helps you do both.

MATLAB can automate your entire Predictive Maintenance workflow
Thank you