Fault Prediction and Failure Detection of drives using real-time signal processing and machine learning techniques

KNIME Spring Summit 2017 Berlin, Germany
Jürgen Walter & Stefan Weingaertner
Unknown unknowns

“There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know.”

Donald Rumsfeld
In complex shop floor environments relevant data is not integrated and still locked away

- To identify unknown unknowns all relevant data sources need to be unlocked and correlated.
- However - with every new data source the number of combinations is growing exponentially.
- That’s where Machine Learning comes into play.
Machine Learning drives autonomous and automated driving

- Google is a pioneer in integrating machine learning technologies into smart business processes.
- Google's self-driving cars process and correlate each second millions of measurements and make more than 20 driving decisions.
- For shop floors the approach can be adapted to
  - know where you are going
  - see where you are going
  - get where you are going
Datatroniq synchronizes industry data for superior machine learning applications

By applying
• Anomaly Detection
• Root-Cause Analysis
• Predictive Analytics
we create value services for
• Increased Performance
• Improved Availability
• Higher Quality
• Reduced Costs
Identifying and increasing Maintenance Maturity Level

Efficiency
Effectiveness
Performance
Availability
Quality

Advanced Analytics
Machine Learning Algorithms

Predictive
Condition-based

Here?
Yet here?

Performance & Effectiveness
- Predict evolution of asset condition
- Detect unknown anomalies
- Keep running longer
- Lean Maintenance

Monitor actual condition
- Detect known anomalies
- Understand root causes
- Avoid down time
- Optimize maintenance schedules

Operations Efficiency
- Based on hours, run-hours, mileage, counters
- Follow vendor’s schedule
- Operator care tasks
- Unforeseen breakdown
- Repair after failure

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Datatronicq Solution Overview

- Sensors
- Smart Data Hub
- MES, ERP, BI etc.

- Machinery & Equipment

• Machine Learning
• Data Archival
• Datatronicq-Application

• Notifications – alerts, warnings, progress
• Anomalies, Root-Cause Analysis, Predictions
• KPIs (e.g. OEE)
• Guided problem determination and resolution

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Overview and interplay with KNIME

Access to DATATRONIQ’s Industrial Data Universe
- Raw & sampled signals
- PLC data
- Anomaly vectors
- Compressed signal features
- ...
Access to Datatrontiq’s Industrial Data Universe
Easy exploration of sensor data
# Vibration Anomaly Detection (Drive End Bearing) Failure Reasons

<table>
<thead>
<tr>
<th>Component</th>
<th>Imperfection</th>
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<tbody>
<tr>
<td>Outer Raceway</td>
<td>Waviness</td>
</tr>
<tr>
<td></td>
<td>Discrete Defect</td>
</tr>
<tr>
<td>Inner Raceway</td>
<td>Eccentricity</td>
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<tr>
<td></td>
<td>Waviness</td>
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<tr>
<td></td>
<td>Discrete Defect</td>
</tr>
<tr>
<td>Rolling Element</td>
<td>Diameter Variation</td>
</tr>
<tr>
<td></td>
<td>Waviness</td>
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<tr>
<td></td>
<td>Discrete Defect</td>
</tr>
</tbody>
</table>

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Types of Vibration and Sound in Bearings

• **Structural Vibration**
  • Race noise
  • Click noise
  • Squeal noise
  • Cage noise
  • Rolling element passage vibration

• **Vibration related to bearing manufacturing**

• **Vibration due to improper handling**
  • Flaw noise
  • Contamination noise

• **Other vibration and sound**
  • Acoustic Emission
Loudness range of race noise

Power level (dB)

Sound Output (watts)

10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^1 10^2 10^3 10^4

Whispering
Regular Conversation
Piano
Pneumatic Hammer
Jet Plane

Bearings
race noise

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Condition Monitoring – where it all started...
Raw Signal Drive End Bearing

- Normal Condition?

- Failure?
Anomalies – Display changes over time
Challenges in Vibration Signal Analysis

• Most sample-based approaches miss the fault, e.g. acoustic emission cracks
  • Data sampling vs. real-time data

• Real-time signals produce extreme data volumes
  • A 3D-vibration sensor with sample rate of 12.000Hz delivers 36.000 data points per second – for each channel

• Characteristic frequency might get lost in the noise
  • An efficient de-noising technique is required

• Real-time decisioning
  • Is a vibration anomaly critical or a false alarm?
Advanced Analytics Process

Drive & Vibration Sensor

Digital Signal Processing & Machine Learning

Anomalies, Root-Cause Analysis & Predictions
KNIME Digital Signal Processing Nodes (donated by AI.Associates)
Frequency Domain Features

From each window, a vector of features will be obtained by calculating variables from the frequency domain.
Anomalies – Display changes over time
Anomalies – Quantification
4. Root Cause Analysis - Decision Tree
Root Cause Analysis of single alerts
Upcoming Events - KNIME Meetup in Stuttgart (3rd April 2017)

An evening on Industry 4.0 & the Industrial Internet of Things...and Analytics!

• 18.00 Welcome and Introductions
• 18.05 KNIME Open Source Story
• 18.20 What’s new in KNIME Analytics Platform
• 18.45 Condition Monitoring Use Cases with KNIME Analytics Platform
• 19.30 Industrial Data Space: A New Idea for Sharing Data
• 20.15 – 21.00 Panel Discussion: Industry 4.0 and Smart Manufacturing - Challenges & benefits of the data-driven shop floor
• 21.00: Networking & tasting of regional wines

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