Real life examples of early warnings in railways

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4 September 2018
Treasure hunting

- Trend: extra sensors for detection and diagnosis
- However: already many available sensors

- $10^7$ weighing in motion records per year
- $10^6$ axle bearing temperatures per year
- $10^5$ maintenance records per year
- $10^{10}$ train records per year

- A wealth of information is hidden in it!
Real Time Monitoring

- These data contain a wealth of information!
- With advanced analytics → even more!
Real Time Monitoring
Overview

- Low adhesion
  - Traction, braking, velocity, GPS

- Toilet
  - Water reservoir sensors

- Air supply
  - Compressor switch on and switch off times

- Door problems
  - Notifications of door obstruction

- Axle bearings
  - Hotbox

- Location dependent disturbances
  - Train diagnosis, GPS

- Train imbalance
  - Gotcha: wheel imbalance and load detection

- Bogie springs
  - Gotcha
Overview

- Axle bearings
- Hotbox
- Air supply
- Compressor switch on and switch off times
- Bogie springs
- Gotcha
Example 1: Springs in bogie

Nick Oosterhof, Margot Peters

Springs in bogie: Question

- Damage to springs
  - unbalanced train
  - higher derailment probability
- Currently visual inspection
- Sometimes difficult to see
- Can we see it from data?
Springs in bogie: Available data

- Possible to use existing data?
- Weighing in motion
  - Cumulative load infra
  - Wheel flatness
  - Wheel load measurements
  - Wheel load differences
- Physics:
  - Damage causes imbalance
  - Damage occurs suddenly
Springs in a bogie: Method

Real life examples of early warnings in railways

Likely something broke
Likely something is repaired
Likely something is wrong
Non-parametric test with median
Springs in a bogie: Detect and *diagnose* suspension defects

Three types of suspension imbalance:

- Single axle imbalance  →  diagnosis unknown
- Bogie diagonal imbalance.   →  likely primary suspension issue
- Coach diagonal imbalance.  →  likely secondary suspension issue
Springs in a bogie: Results

- 8 maintenance records
- All detected by algorithm
  - 2 incorrect diagnosis

<table>
<thead>
<tr>
<th>True Type of issue</th>
<th>True Suspension</th>
<th>Anomalous event</th>
<th>Model Suspension</th>
<th>Model Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1 defect</td>
<td>primary</td>
<td>yes</td>
<td>secondary</td>
<td>Wrong type of defect</td>
</tr>
<tr>
<td>Case 2 defect</td>
<td>secondary</td>
<td>yes</td>
<td>secondary</td>
<td>OK</td>
</tr>
<tr>
<td>Case 3 defect</td>
<td>secondary</td>
<td>yes</td>
<td>secondary</td>
<td>OK</td>
</tr>
<tr>
<td>Case 4 defect</td>
<td>primary</td>
<td>yes</td>
<td>primary</td>
<td>Wrong axles</td>
</tr>
<tr>
<td>Case 5 defect</td>
<td>secondary</td>
<td>yes</td>
<td>secondary</td>
<td>OK</td>
</tr>
<tr>
<td>Case 6 set</td>
<td>secondary</td>
<td>yes</td>
<td>secondary</td>
<td>OK</td>
</tr>
<tr>
<td>Case 7 set</td>
<td>secondary</td>
<td>yes</td>
<td>secondary</td>
<td>OK</td>
</tr>
<tr>
<td>Case 8 set</td>
<td>primary</td>
<td>yes</td>
<td>primary</td>
<td>OK</td>
</tr>
</tbody>
</table>

Example 2: Air leakage detection

Wan-Jui Lee
International Journal of Prognostics and Health management
Vol 8, No 020 (2017)

Inge Kalsbeek
Implementation
Air leakage detection: Question

- 1½ leakage / train / year
- Every year:
  - 1/30 trains strand due to air
  - 1/10 trains have delays due to air
- Auditory inspection
- Can we see it from data?
Air leakage detection: Available data

- Real Time Monitoring
  - Switch on time
  - Switch off time
Air leakage detection

- **Physics of leakage**
  - Air is consumed faster
  - Decrease in idle time
  - Gradual change

Real life examples of early warnings in railways
Air leakage detection: Method

 Idle time: 10-20 min

 Run time: ~5 min

 Leakage detectable

 Bad situation

 Repair
Air leakage detection

- Calculation of threshold
  - Automatic
  - Train specific
  - Classification

- Detection of leakage
  - Automatic
  - Clustering
Air leakage detection: Results

- Algorithm testing historic data:
  - > 1 year, >250 work orders
    - 66% clearly detected
    - 17% possible detected
    - 27% not detected

- Since implemented in February:
  - 6 trains taken out of service
  - All had air leakage

Example 3: Axle bearings

Margot Peters

Annual Conference of the prognostics and Health Management Society Vol 17 No 041 (2017)
Axle bearings: Question

- Axle bearings safety critical
- Many safety nets:
  - Inspection
  - Temperature stickers
  - Hotbox: $T > 115^\circ C \rightarrow$ train immediately out of service

- Very disturbing for timetable

- Can we get an early warning from the data?
Axle bearings: Data

- 24 measuring sites
- Temperature axle bearings
Axle bearings: Method

Bearing 7 has higher temperature

Bearing 7 broken
Axle bearings

Side difference of temperature: good feature → early warnings

Decision tree: Severity of warning
Axle bearings: Results

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>True label</th>
<th>False</th>
<th>No failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure</td>
<td>Alarm</td>
<td>Correct result: 6x</td>
<td>False positive: 1x</td>
</tr>
<tr>
<td></td>
<td>No alarm</td>
<td>False negative: 5x</td>
<td>Correct result</td>
</tr>
</tbody>
</table>

Margot Peters, Annual Conference of the prognostics and Health Management Society Vol 17 No 041 (2017)
Challenges

■ Available data
  • Not meant for the new purpose
  • Not always well calibrated
  • Not always complete
■ Clear maintenance records
■ Rare failures
■ Feedback from maintenance depot
■ Company Culture
Conclusion

- Available data (train, way side) contain a wealth of information
- Treasure hunting with Advanced analytics
- Philosophy: combine
  - knowledge from physics
  - Smart algorithms

Real life examples of early warnings in railways:
Thank you!

Wan-Jui Lee

Air supply
Compressor switch on and switch off times

Inge Kalsbeek

Axle bearings
Hotbox

Margot Peters

Bogie springs
Gotcha

Nick Oosterhof