Big Data in railway infrastructure

Kivi event, 28th June 2018

Alfredo Núñez Vicencio
Section of Railway Engineering
Delft University of Technology
Delft, The Netherlands
Outline

1) Section of Railway Engineering TUDelft

2) Railway infrastructure

3) Big Data in railway infrastructure

4) Conclusions
Section of Railway Engineering
Delft University of Technology
Our work at TU Delft
Section of Railway Engineering

- 2 Professors
- 3 Assistant professor
- 6 Postdoc and researchers
- 19 + 2 PhD students
- 3 lab researchers and technicians
- 5 visiting researchers
- 1 Secretary
Teaching
Teaching

• Specialization of Railway Engineering
• Starting from academic year 2015 – 2016:
  • Railway operations and control
  • Elements of Railway Engineering
  • Wheel-rail interface & contact mechanics
  • Design & maintenance of railway vehicles
  • Transport safety
  • Railway asset management
  • Mechanical & material engineering for railway
Teaching

https://www.youtube.com/watch?v=qXW4eXT4ydA
Teaching

[Image of a group of people posing together, possibly for a photo related to teaching or an event.]
Research

- Contact mechanics
- Train-track/S&C interaction
- Rolling contact fatigue
- Condition monitoring
- Big Data & asset management
Research

- Contact mechanics
- Train-track/S&C interaction
- Rolling contact fatigue
- Condition monitoring
- Big Data & asset management
Lab facilities

- CTO train
- Train-track interaction test rig
- .... others

https://www.youtube.com/watch?v=ONj rR8e60aQ
Lab facilities

• CTO train
Lab facilities

- Train-track interaction test rig
Railway Infrastructure
Railway Infrastructure

1. Safety system: signal, interlocking
2. Energy System: feeding power supply
3. Communications: Speakers, information board, applications
4. Support: subsoil, cables and wires
5. Crossing: Tunnels, level crossing, fences
6. Guiding: Rail, switches, joints
7. Measurements: Infradata from fixed and on-board sensors
8. Rolling stock: Passengers and freight
9. Transfer: Station, elevators
Railway Infrastructure

Railway Infrastructure

1. Safety system: signal, interlocking
2. Energy System: feeding power supply
3. Communications: Speakers, information board, applications
4. Support: subsoil, cables and wires
5. Crossing: Tunnels, level crossing, fences
6. Guiding: Rail, switches, joints
7. Measurements: Infra data from fixed and on-board sensors
8. Rolling stock: Passengers and freight
9. Transfer: Station, elevators
Big Data in Railway Infrastructure: Some examples
In The Netherlands

Almost no time for monitoring and maintenance 😞
Example 1:
Axle box acceleration
ABA Measuring System

$H_T(x_1) = A$

$H_T(x_2) = C$

Measurements

Track condition

vertical

longitudinal

lateral
Defect detection in rails

- **Initiating squat**
  - Light
- **Moderate**
- **Severe**
- Two squats at a thermite weld

Squats

- Corrugation

Wheel burns

Damaged welds

Bolt tightness

- Insulated joint with plastic surface degradation
ABA at Moderate and Severe Squats

- 200 - 400 Hz (dominant)
- 1000 – 2000 Hz

DOI:10.1109/TIE.2015.2389761
ABA Measurements at Light Squats

- 200 – 400 Hz
- 1000 – 2000 Hz

DOI: 10.1109/TIE.2015.2389761
ABA Measurements at Light Squats

At least 25600 Hz for sampling

Monitoring the entire Dutch railway (more than 7000 km of rails)

Measurements provides a data volume of several terabytes

At least 16 sensors to assure impact, vertical-longitudinal, left-right rail, trailing leading wheel

DOI:10.1109/TIE.2015.2389761
ABA Measurements at Light Squats

At least 25600 Hz for sampling

Monitoring the entire Dutch railway (more than 7000 km of rails)

Measurements provides a data volume of several terabytes

At least 16 sensors to assure impact, vertical-longitudinal, left-right rail, trailing leading wheel

---


**Volume**
- 200 - 400 Hz
- 1000 - 2000 Hz

**Veracity**

BIG DATA
Challenges: grinding and replacement
Challenges: different speeds

Vertical and longitudinal ABA and wavelet power spectrum at a defect, measured at 80 km/h.
Challenges: different speeds

Vertical and longitudinal ABA and wavelet power spectrum at a defect, measured at 200 km/h.
Challenges: massive implementation trains in operation

Locations of the top 75 places where the ABA signal show largest energy variations
Example 2: Video Image processing
Detection of rail defects

Image data

• The dataset consists of 4220 samples, of which 3170 are normal, and roughly 1000 are defects (surface spots, crack initiations, squats, head-checks, etc.)

• We train a convolutional neural network model with 80% of the data, and test with the remaining 20% (in 5 folds). Here is the averaged result of the test:

<table>
<thead>
<tr>
<th></th>
<th>Predicted normal</th>
<th>Predicted defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal samples</td>
<td>635</td>
<td>1</td>
</tr>
<tr>
<td>Defects</td>
<td>10</td>
<td>197</td>
</tr>
</tbody>
</table>

Accuracy = 0.9870
False detections (image data)

False positive

False negative

Images from INSPECTATION
Hits 2 (image data)

True Positive

TU Delft
Hits 3 (image data)

True Positive
Classification of types

- We also tried to classify the defects into 2 categories of spots/light vs. medium/severe.
A big data analysis approach is used to automatically detect squats from rail images.

A Bayesian model is employed to estimate the failure probability.
Example 3:
Video Image processing + ABA + Others

- Video and ABA to detect squats.
- Other signals for influential factors used for modelling.
Other examples:
Integrated systems and Watson
Integrated Big Data for freight trains:
Conclusions
Conclusions

• Big Data is here to stay. “Fancy” algorithms will not perform 100% if the knowledge of the railway system is not included explicitly.

• There is a great potential for using Big Data to facilitate maintenance decisions on Dutch railways. Further research: head-checks, corrugation, wheel-burns, indentations. Self-learning, transfer learning.

• Growth rate of defects should be monitored with appropriate intervals while maintaining the processing load within feasible limits.
Conclusions

• By including predictive and robust capabilities in the decision making, we can give steps towards a maintenance that “anticipates” rather than only “correct”.

• New paradigms for modelling under Big Data conditions are necessary to further develop this decision support method; in order to incorporate, among others, prediction power and robust capabilities in the decision making.

• Many open challenges.
Big Data in railway infrastructure

Kivi event, 28th June 2018

Alfredo Núñez Vicencio
Section of Railway Engineering
Delft University of Technology
Delft, The Netherlands