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

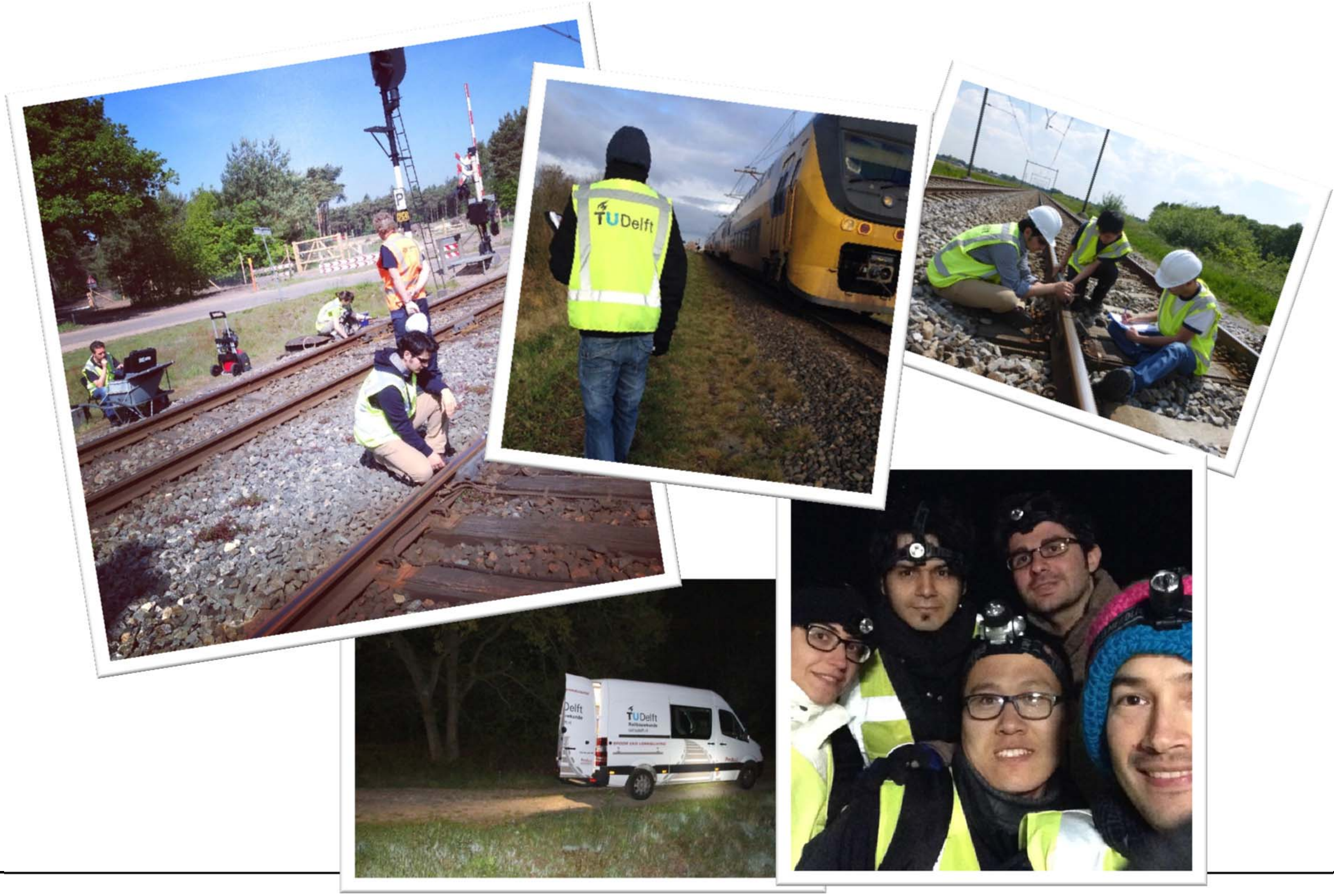
2) Railway infrastructure

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

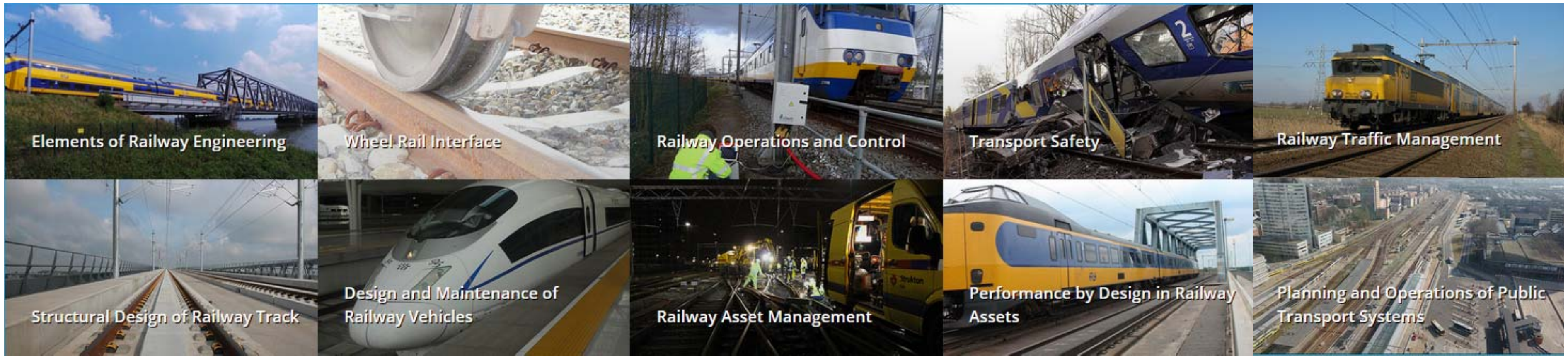
Section of Railway Engineering

- 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

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Home > All Subjects > Engineering > Railway Engineering: An Integral Approach

Railway Engineering: An Integral Approach

Discover the science and complexity behind the exciting world of metro, tram and railway systems.

TU Delft

Starts on October 11, 2017

Enroll Now

I would like to receive email from Delft University of Technology (TU Delft) and learn about other offerings related to Railway Engineering: An Integral Approach.

Teaching

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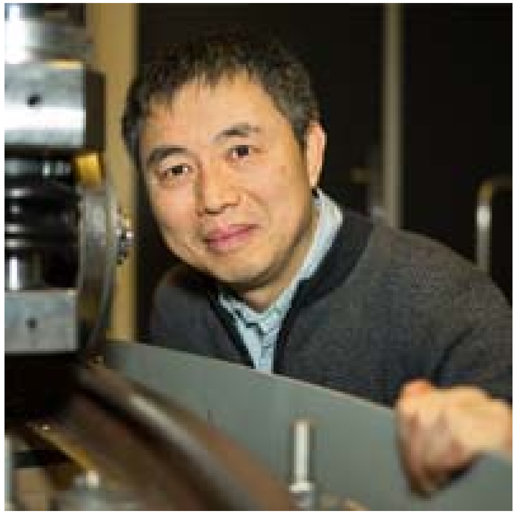
Research

- 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

Foto: Niels Blekemolen

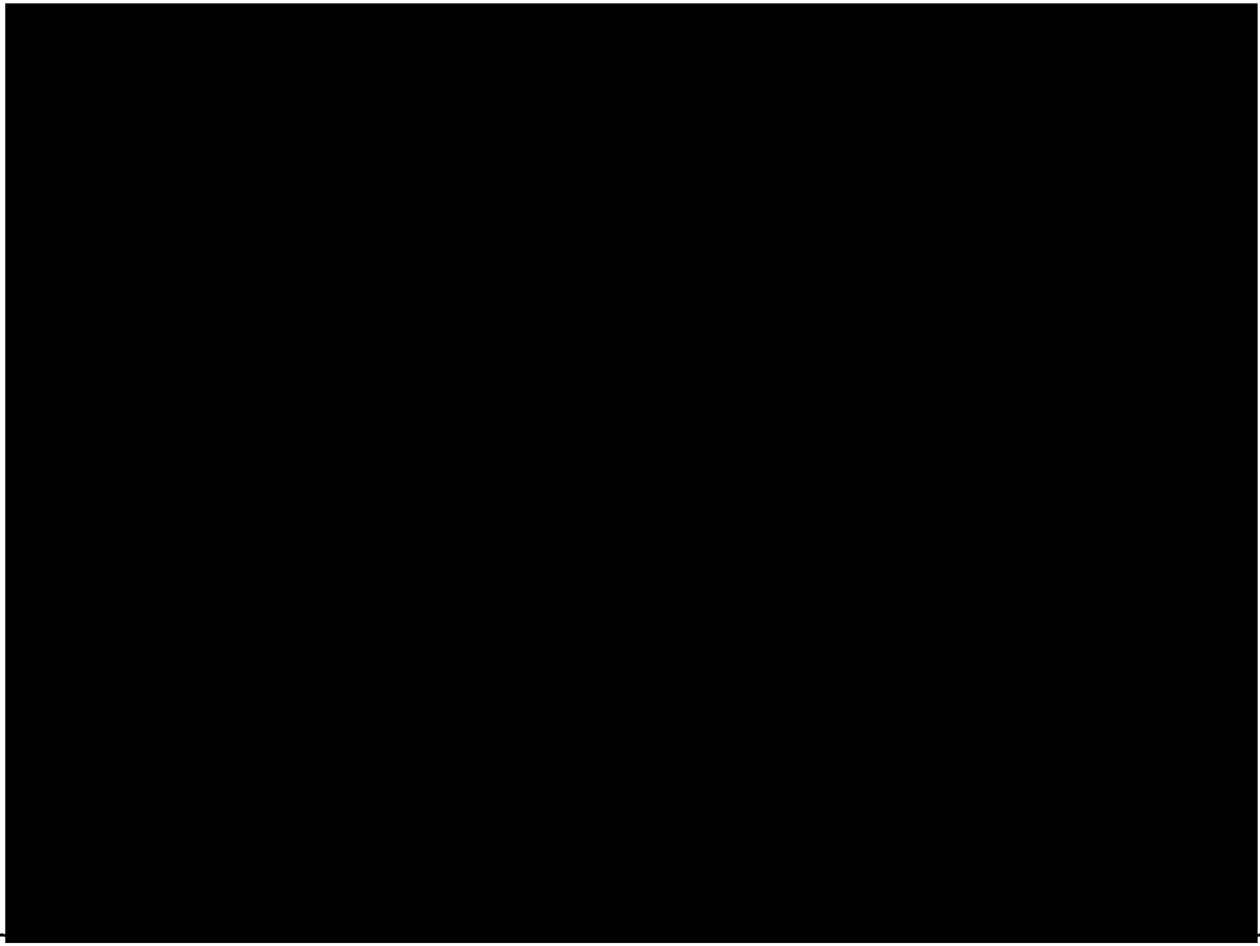
https://www.youtube.com/watch?v=ONJrR8e60aQ

Lab facilities

- **CTO train**

Lab facilities

- **Train-track interaction test rig**

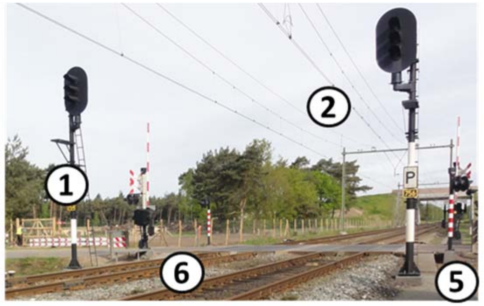


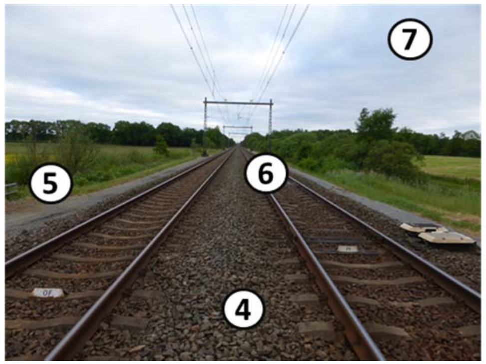
Railway Infrastructure

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





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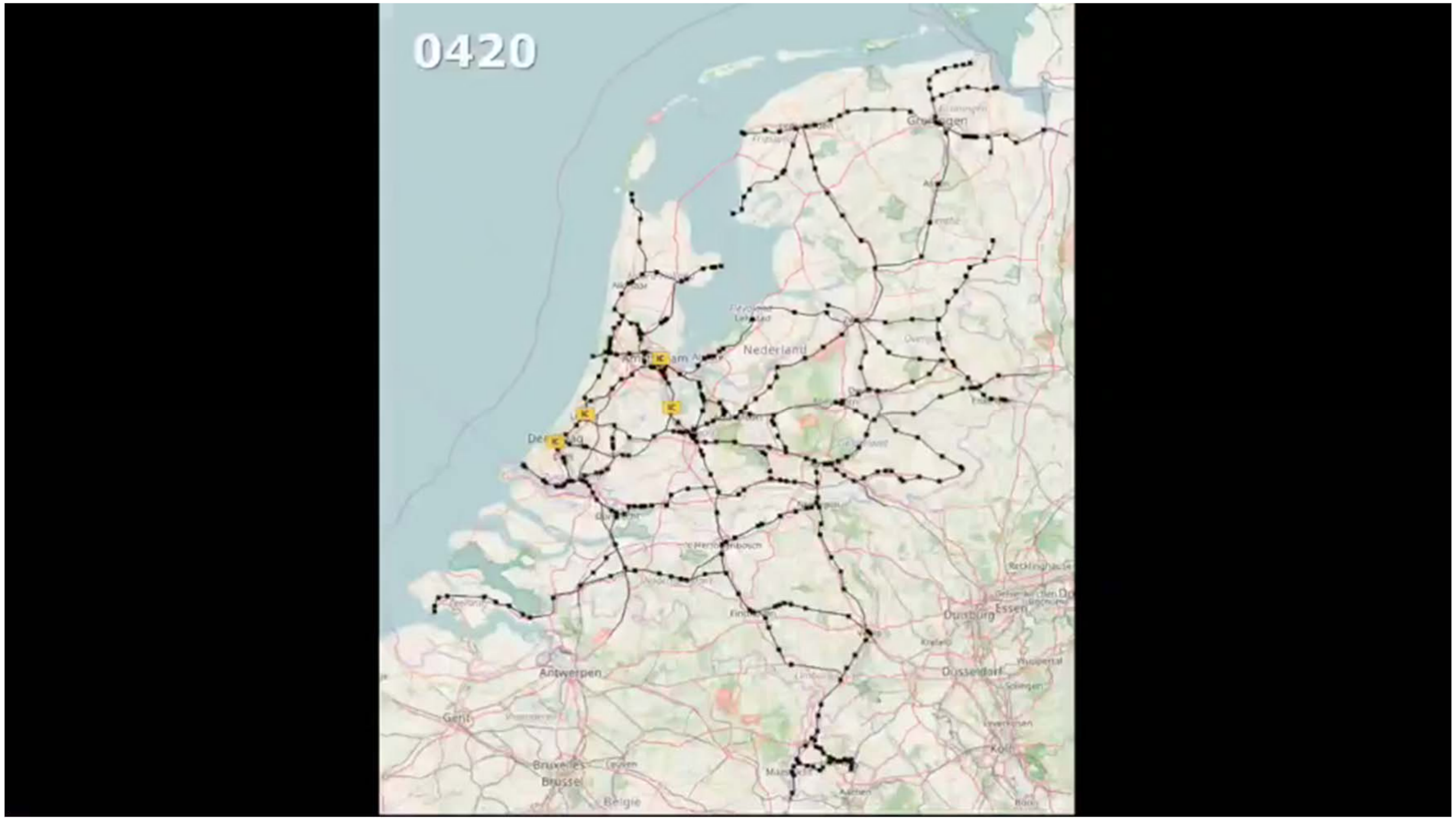
Big Data in Railway Infrastructure: Some examples

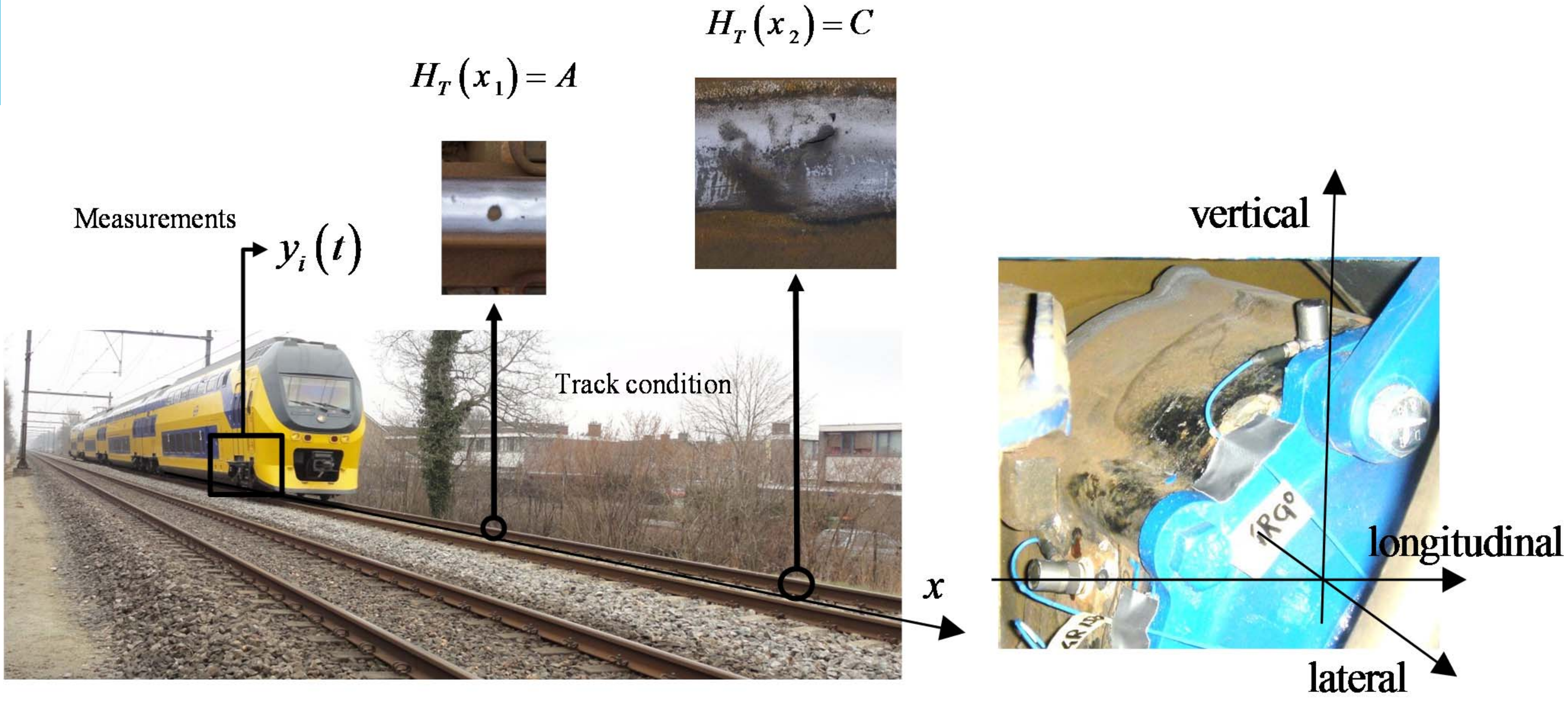
In The Netherlands

Almost no time for monitoring and maintenance ☹

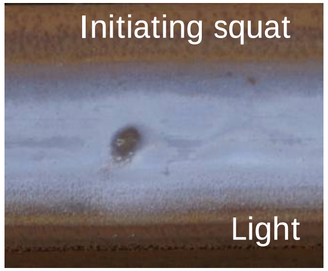


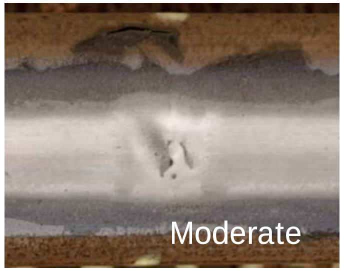
Example 1:
Axle box acceleration

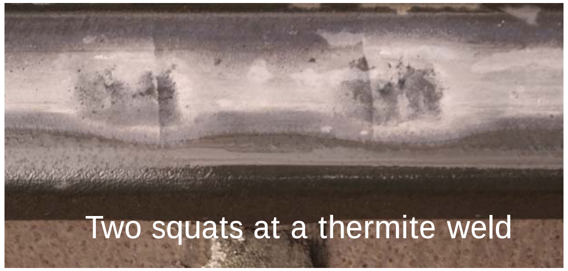
ABA Measuring System



Defect detection in rails

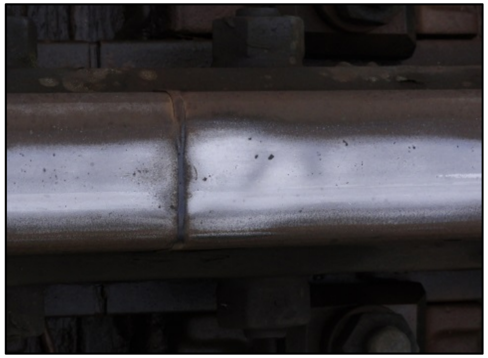






Squats

Corrugation



Insulated joint with plastic surface degradation

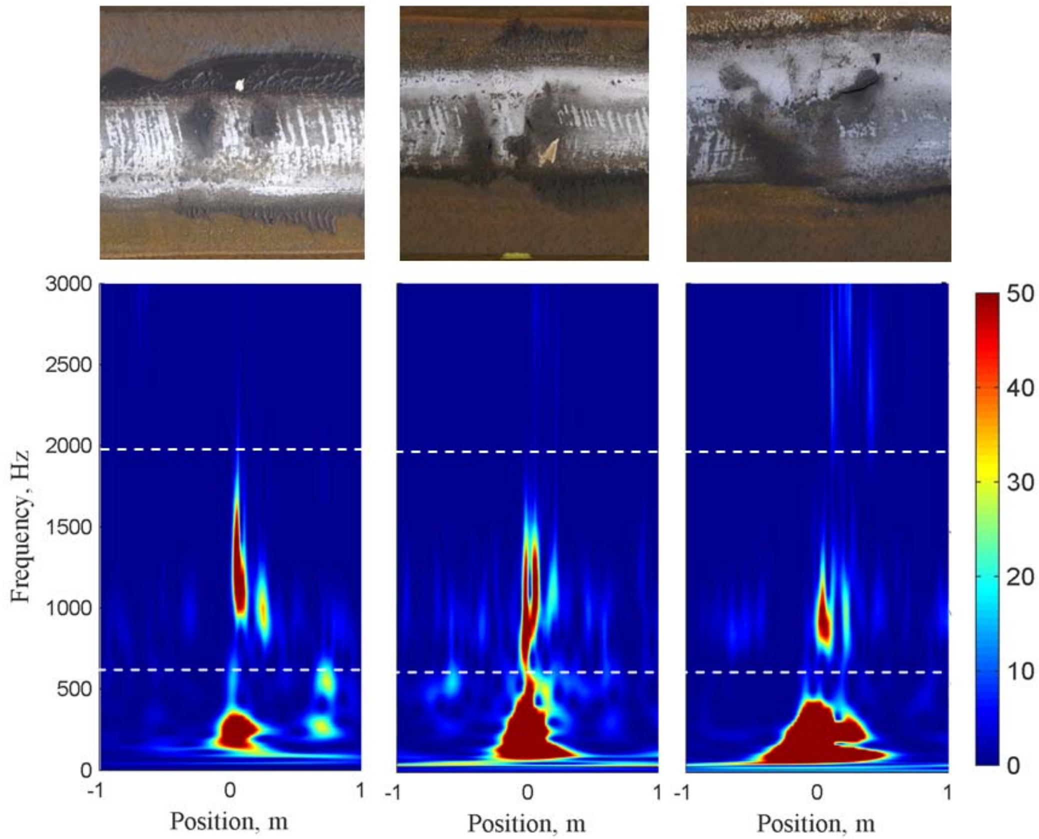
Wheel burns

Damaged welds

Bolt tightness

.....

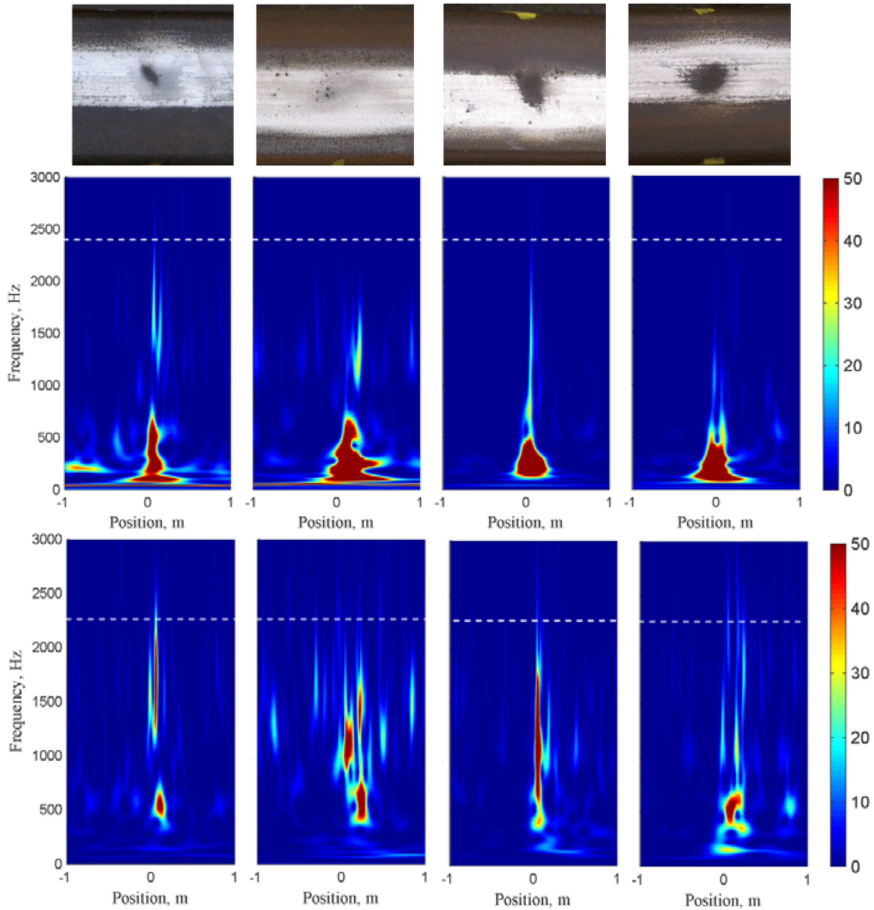
ABA at Moderate and Severe Squats



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

Z. Li, M. Molodova, A. Núñez, and R. Dollevoet, “Improvements in axle box acceleration measurements for the detection of light squats in railway infrastructure”. IEEE Transactions on Industrial Electronics 62(7): 4385-4397, 2015. DOI:10.1109/TIE.2015.2389761

ABA Measurements at Light Squats



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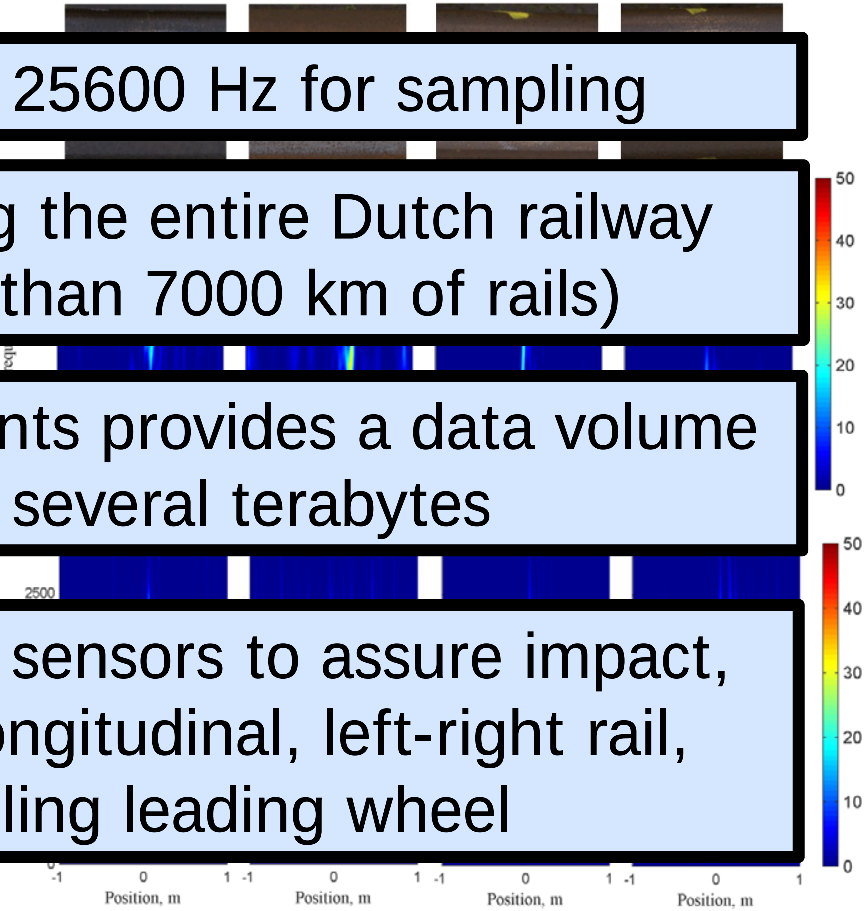
ABA Measurements at Light Squats

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

Z. Li, M. Molodova, A. Núñez, and R. Dollevoet, “Improvements in axle box acceleration measurements for the detection of light squats in railway infrastructure”. IEEE Transactions on Industrial Electronics 62(7): 4385-4397, 2015. DOI:10.1109/TIE.2015.2389761

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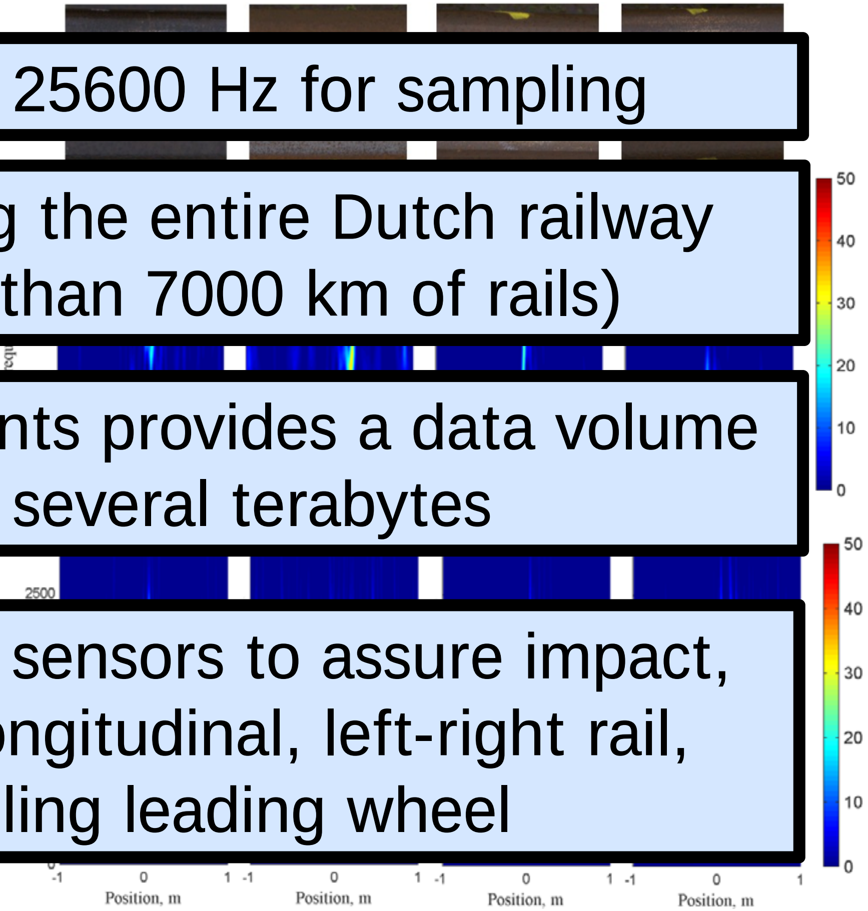

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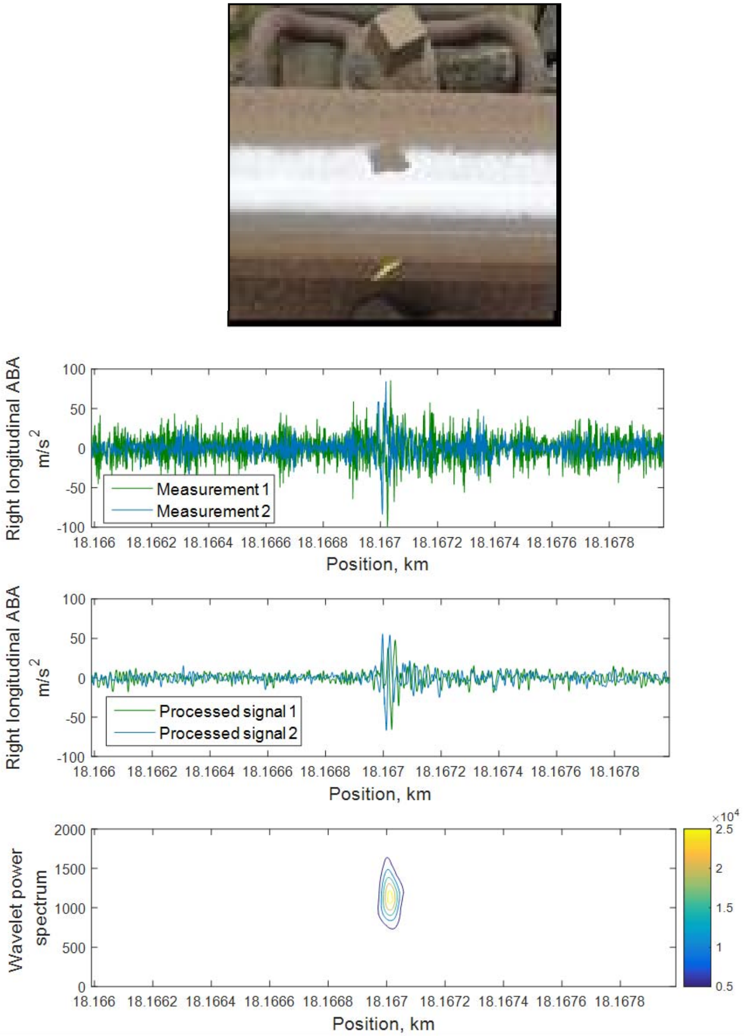
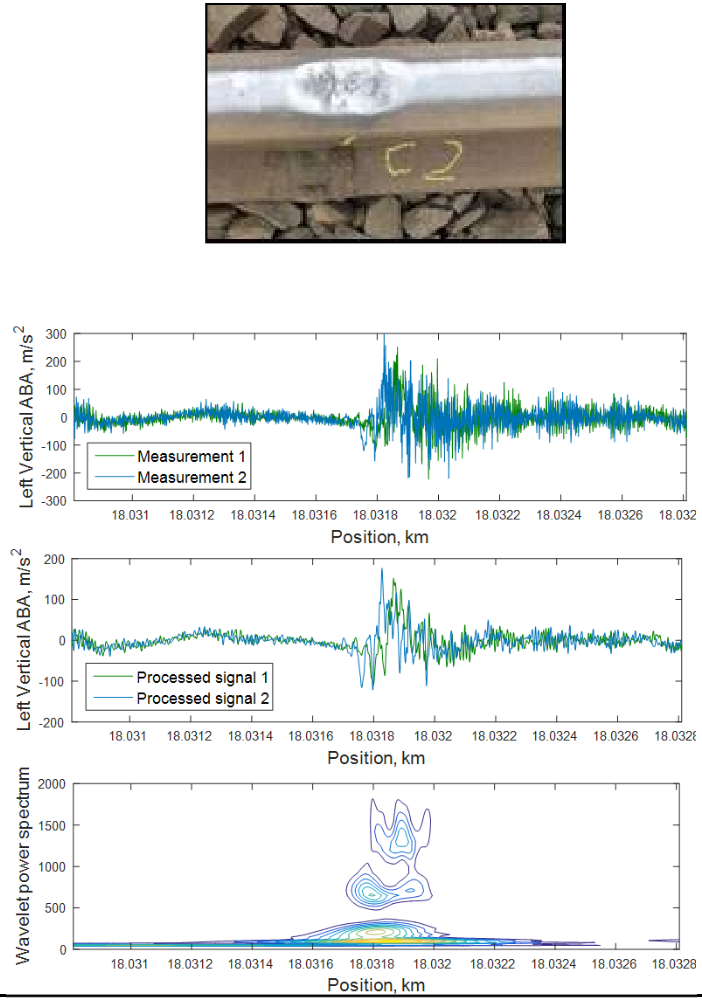
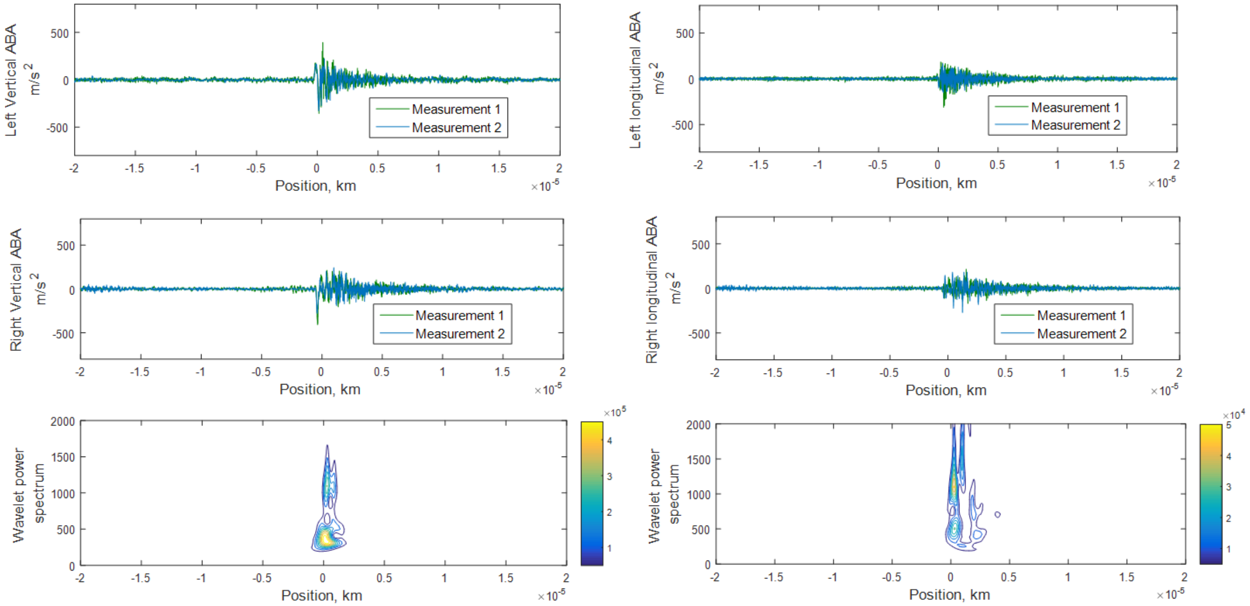
BIG DATA

Challenges: grinding and replacement



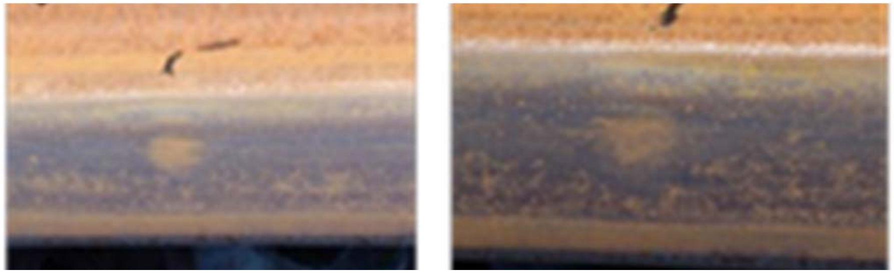


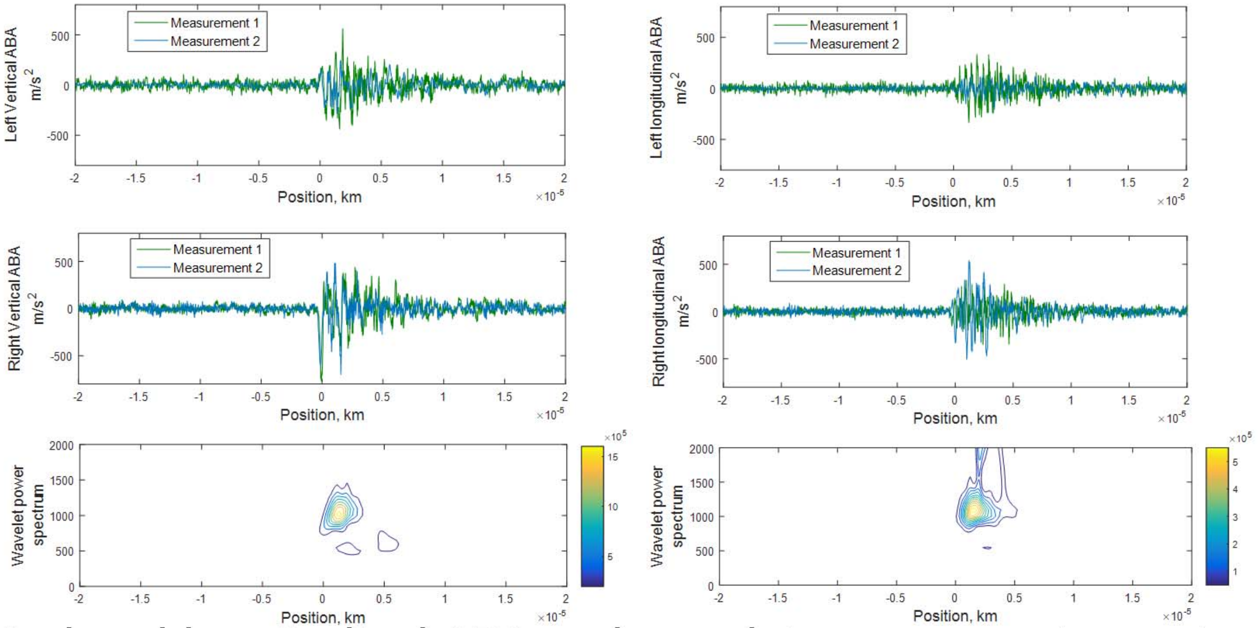
Challenges: different speeds



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.


ESC
MENU
CTRL
ENTER
ILUM +
RESET
ILUM -
199
140
TEST
SOFTRONIC - CV
SOFTRONIC
km/h
195

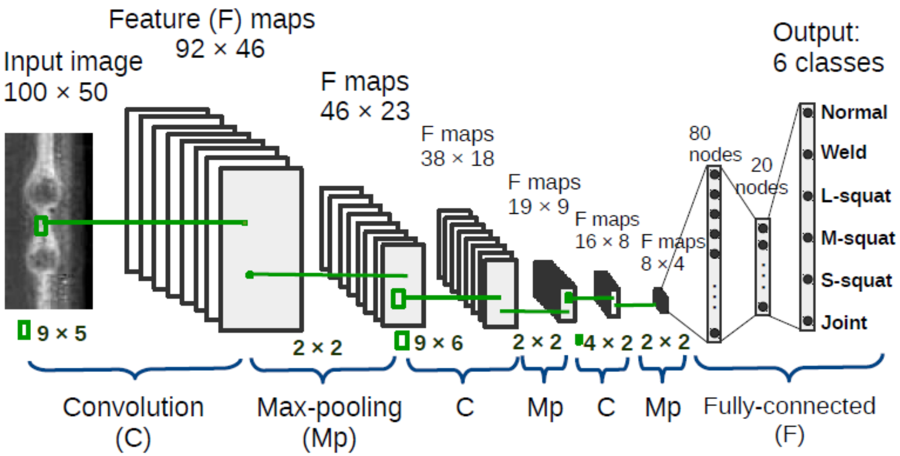
Challenges: massive implementation trains in operation

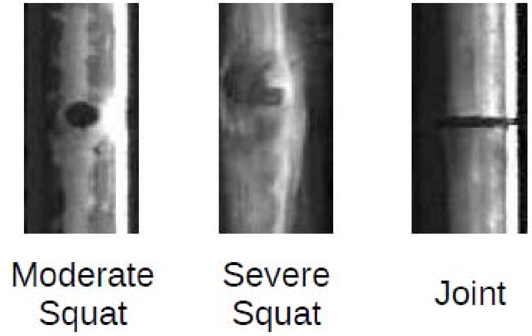
Locations of the top 75 places where the ABA signal show largest energy variations

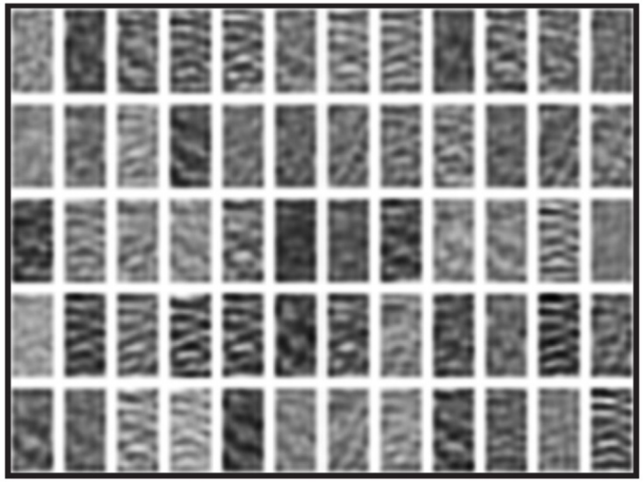
Example 2:

Video Image processing

Detection of rail defects







S. Faghih-Roohi, S. Hajizadeh, A. Núñez, R. Babuska, and B. De Schutter, "A deep learning approach for detection of rail defects". Proceedings of the IEEE World Congress on Computational Intelligence, IEEE WCCI 2016, 2016 International Joint Conference on Neural Networks (IJCNN), Vancouver, Canada, 25-29 July, 2016, pp. 2584-2589.

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:

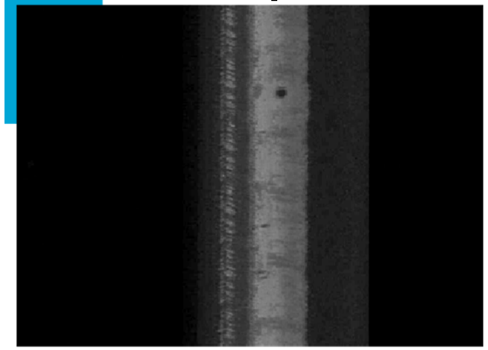
	Predicted normal	Predicted defect
Normal samples	635	1
Defects	10	197

Accuracy = 0.9870

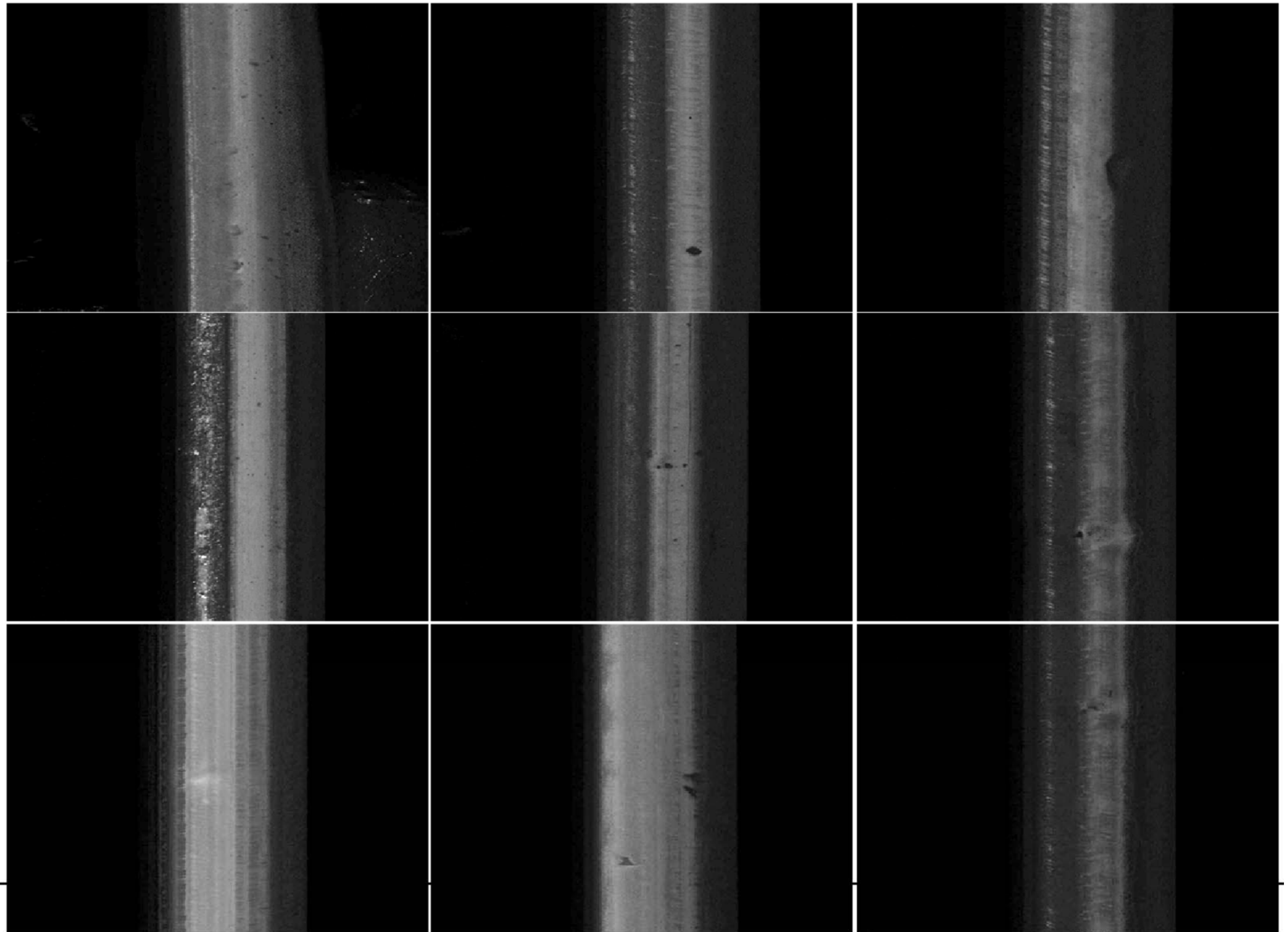
TU Delft

False detections (image data)

False positive



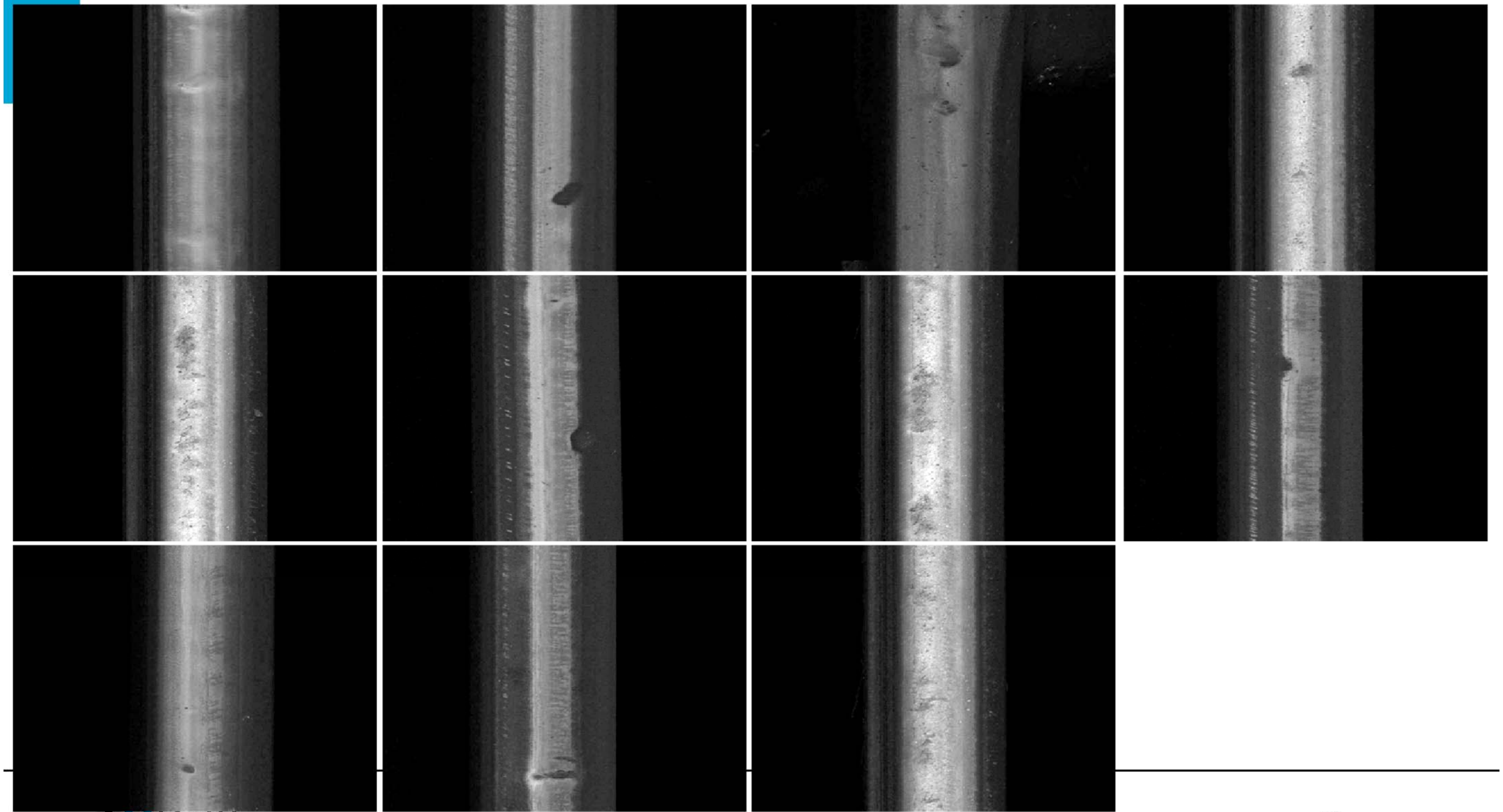
False negative



Images from INSPECTATION

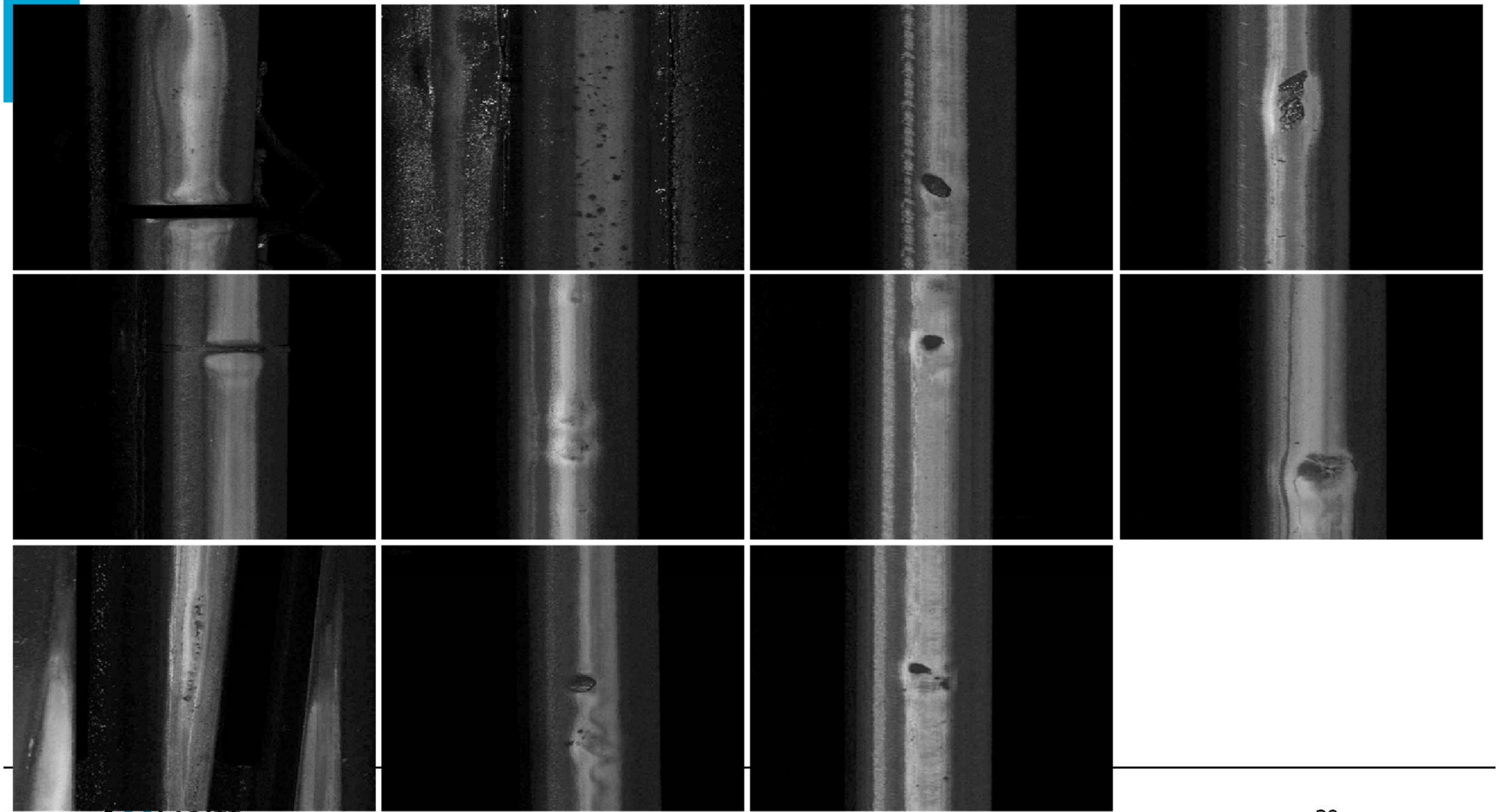
Hits 2 (image data)

True Positive



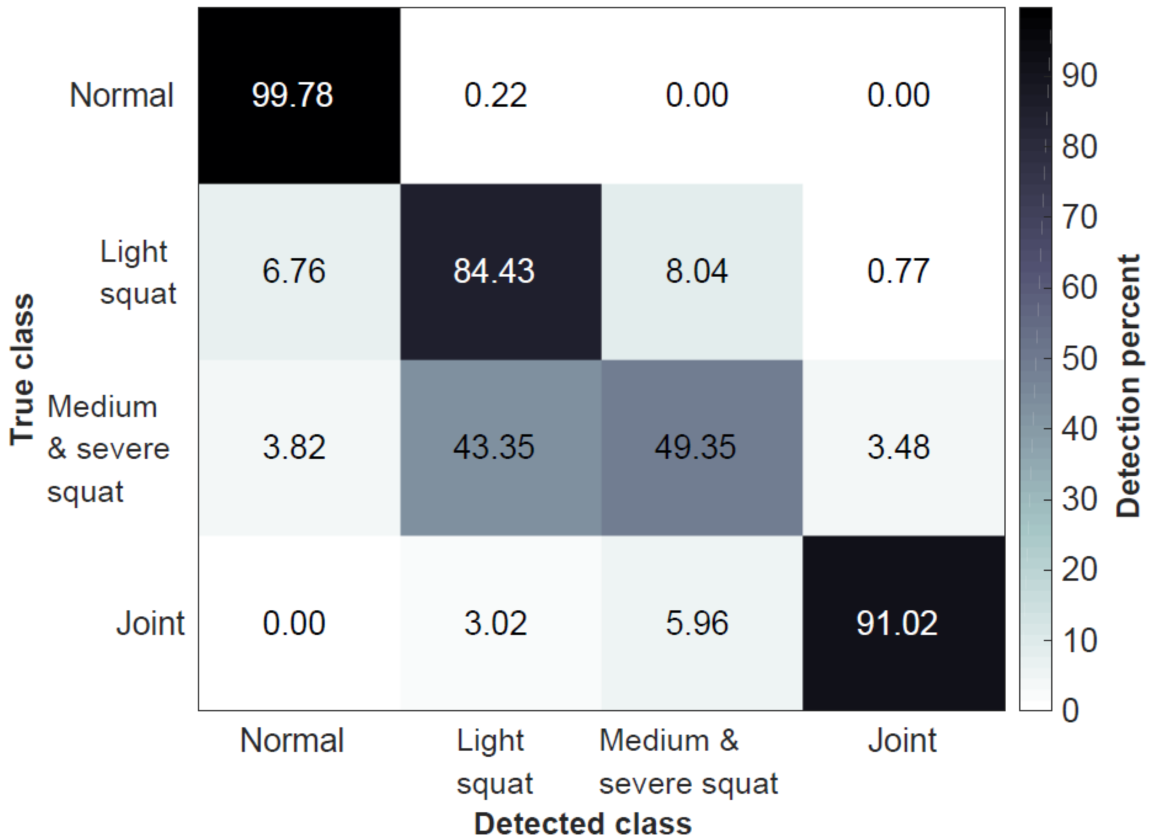
Hits 3 (image data)

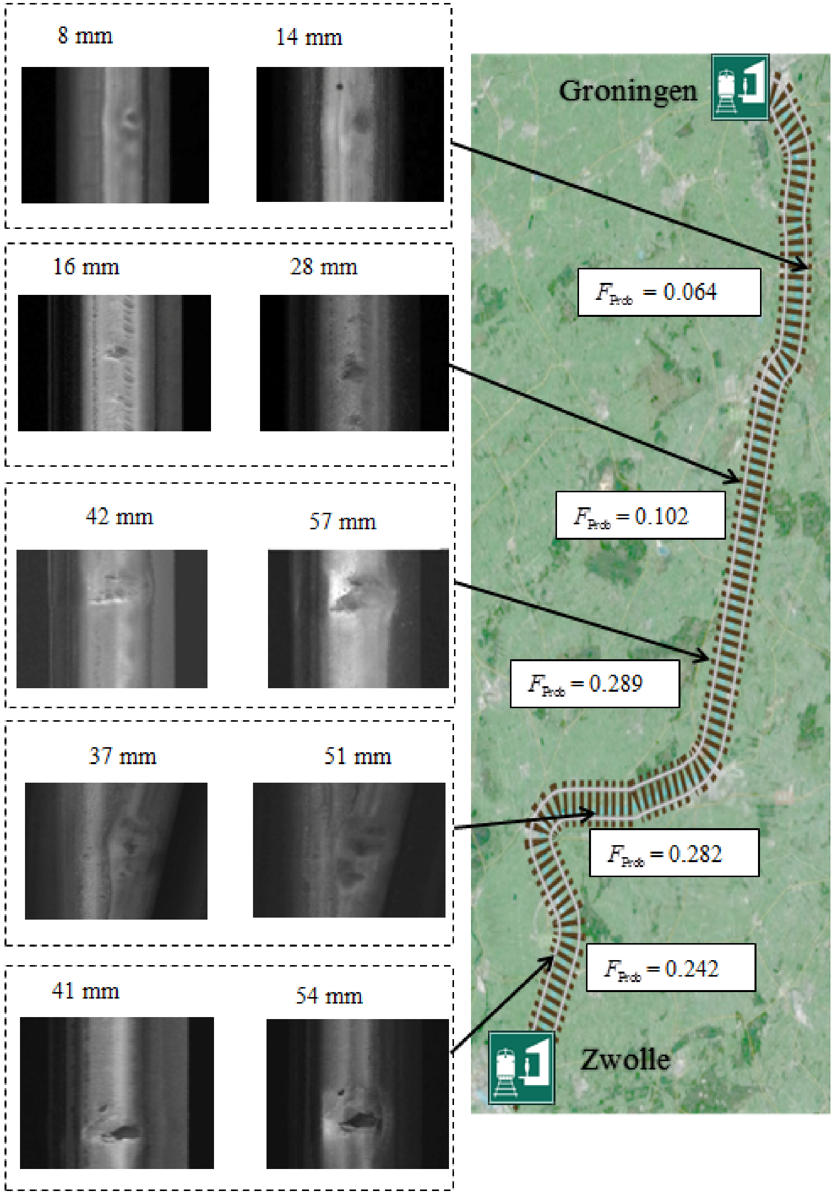
True Positive



Classification of types

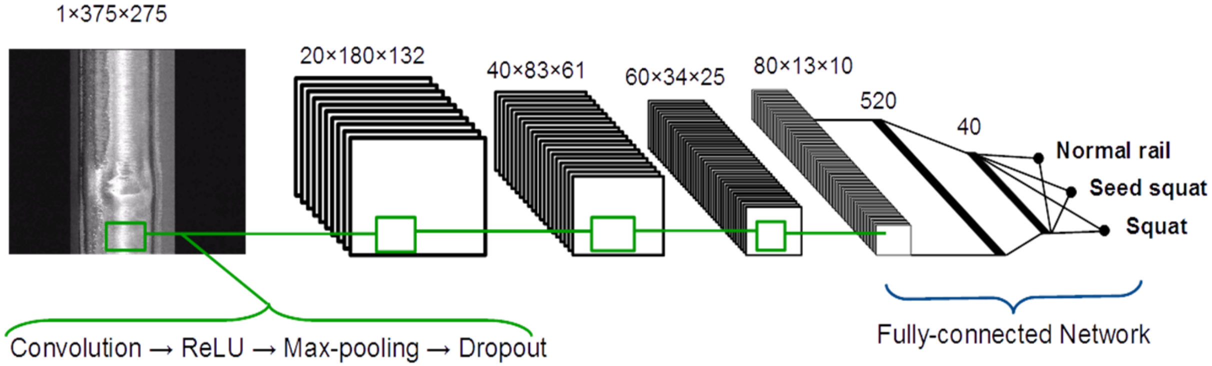
- We also tried to classify the defects into 2 categories of spots/light vs. medium/severe.



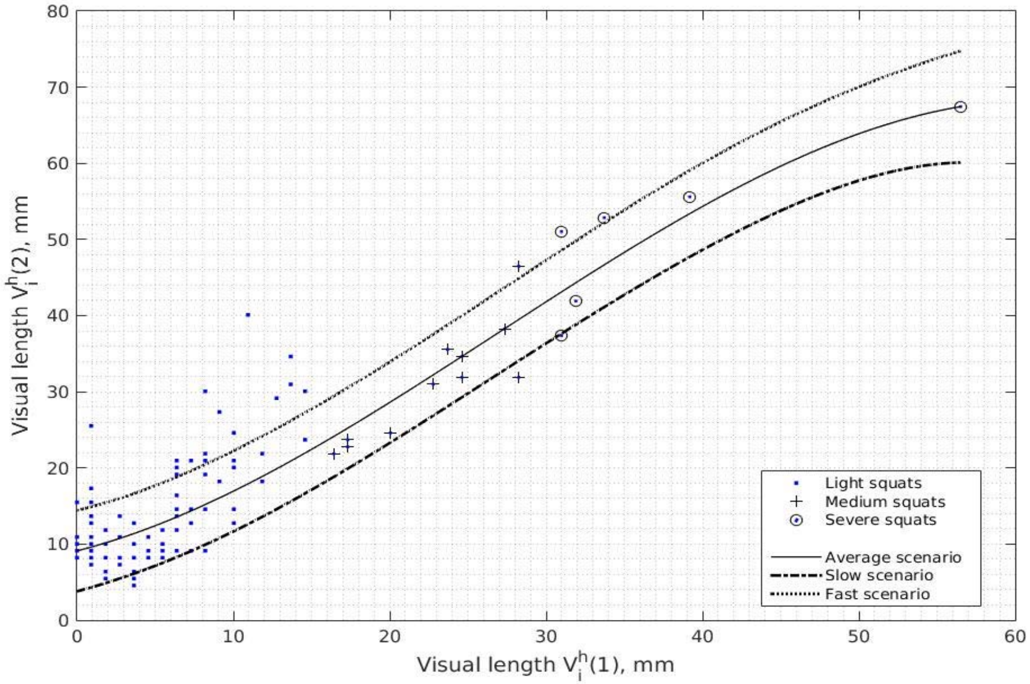


- ❖ A big data analysis approach is used to automatically detect squats from rail images.
- ❖ A Bayesian model is employed to estimate the failure probability.

A. Jamshidi, S. Faghih-Roohi, S. Hajizadeh, A. Núñez, R. Babuška, R. Dollevoet, Z. Li and B. De Schutter, “A big data analysis approach for rail failure risk assessment”. Risk Analysis, Volume 37, Issue 8, August 2017, Pages: 1495-1507. DOI: 10.1111/risa.12836



Architecture of the proposed DCNN model



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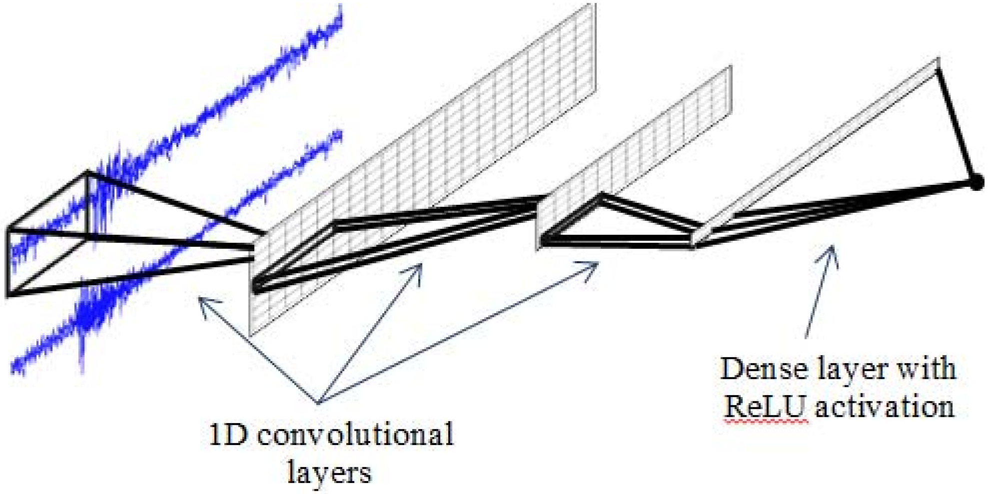
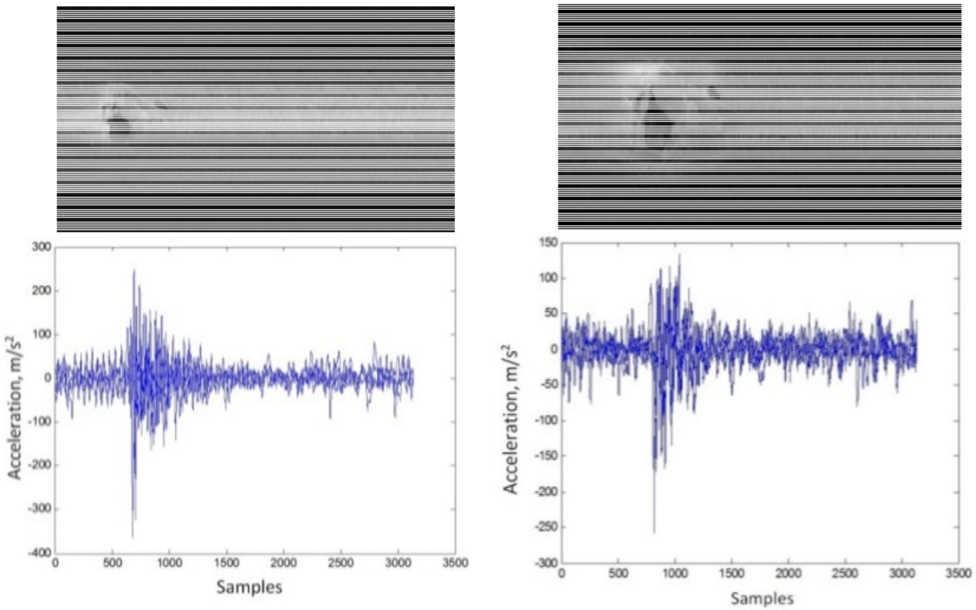
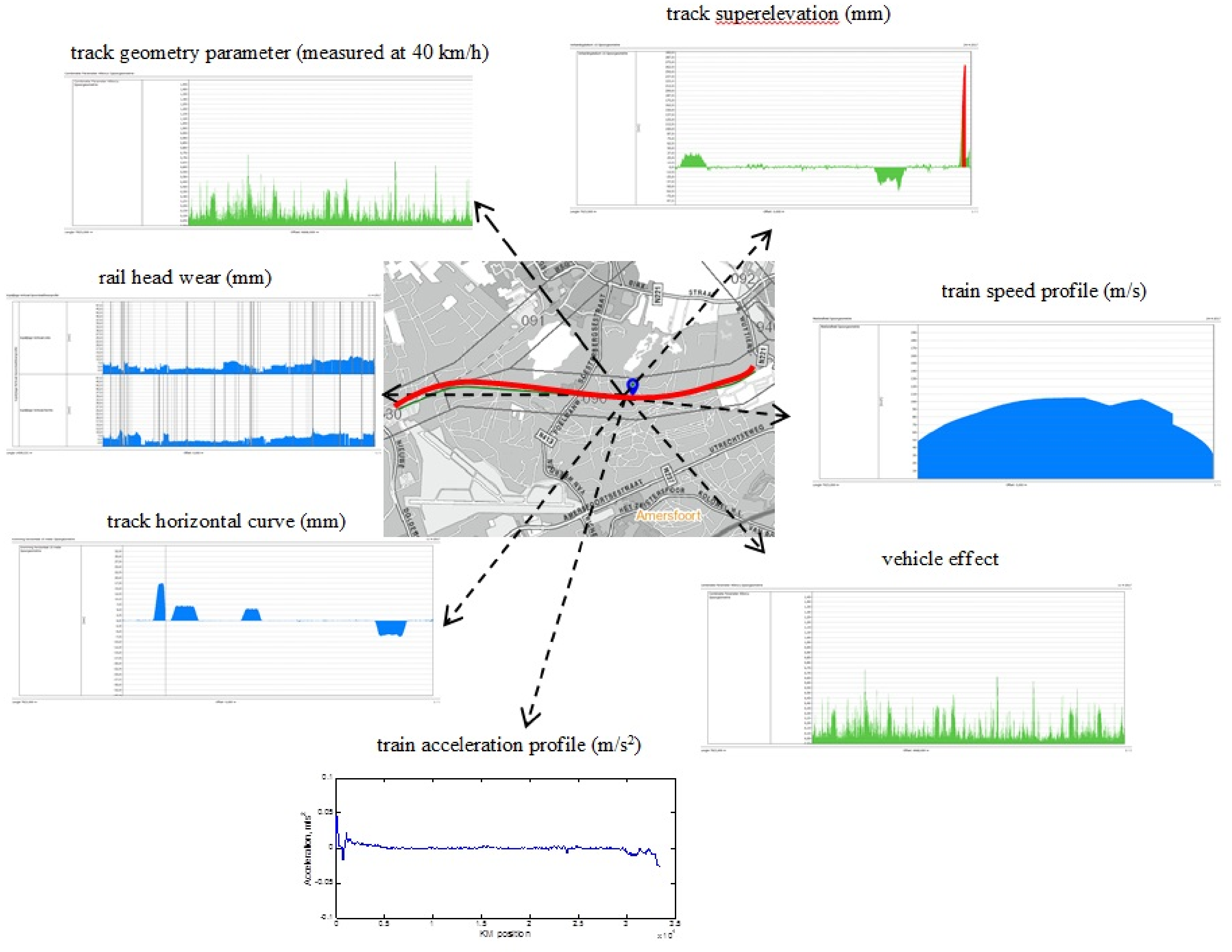
Example 3:
Video Image processing + ABA + Others





- ❖ Video and ABA to detect squats.
- ❖ Other signals for influential factors used for modelling.

A. Jamshidi, S. Hajizadeh, Z. Su, M. Naeimi, A. Núñez, R. Dollevoet, B. De Schutter, and Zili Li, “A decision support approach for condition-based maintenance of rails based on big data analysis”. Under review.



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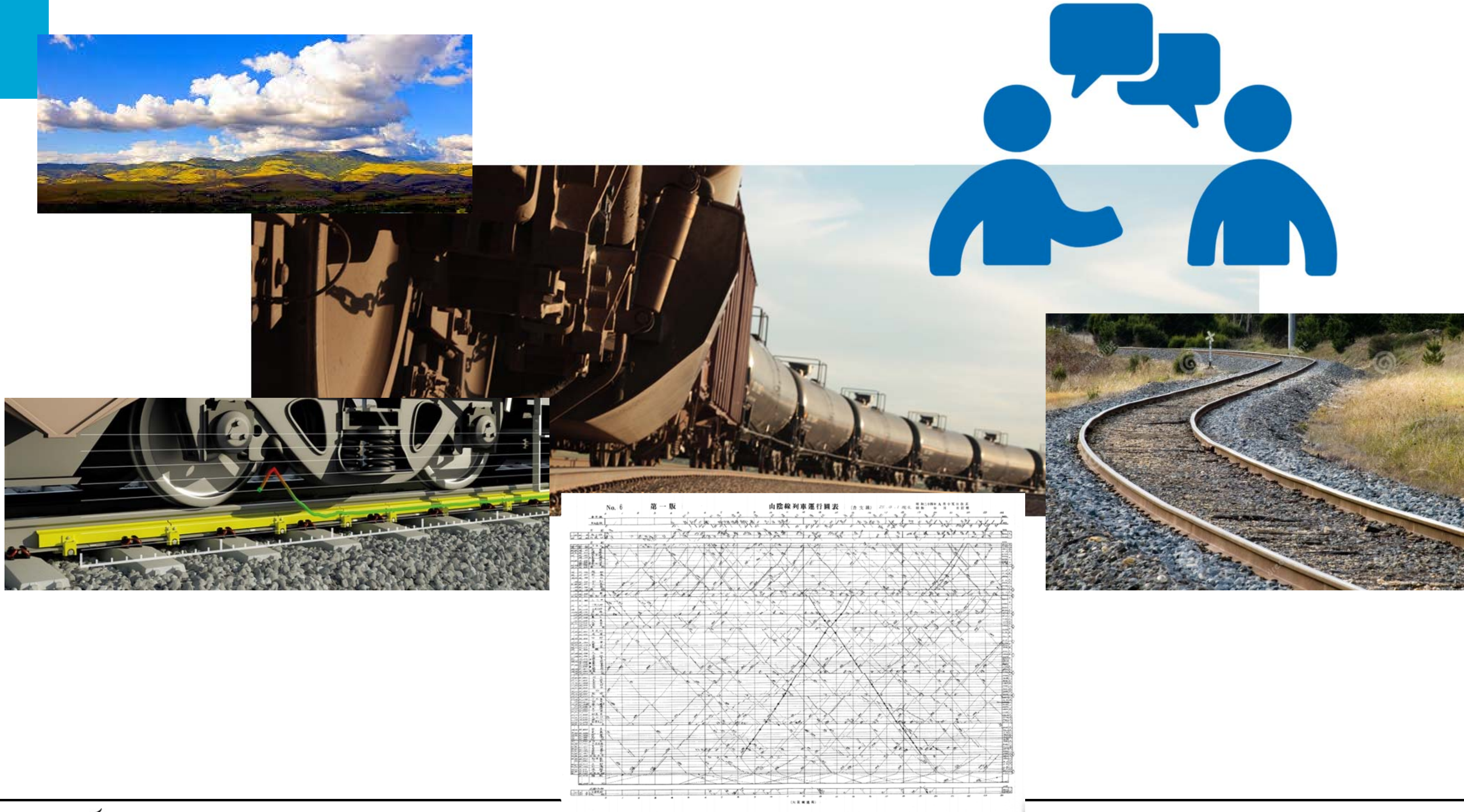
Other examples:
Integrated systems and Watson

Integrated Big Data for freight trains:



https://www.aar.org/report/Pages/R1C2S1.aspx

IBM Watson

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

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