NTNU

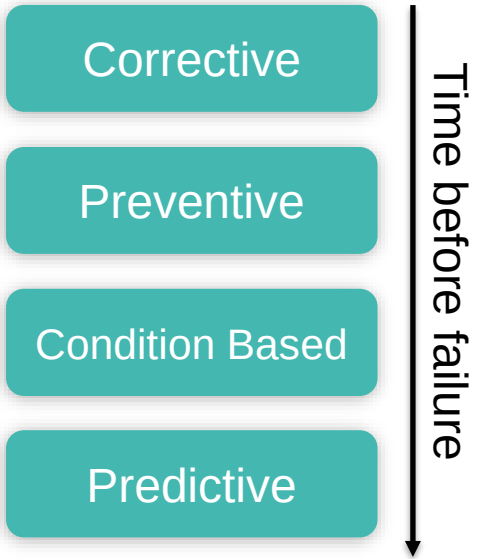
Norwegian University of Science and Technology

Systematic Mapping Review on Railway Track Condition Monitoring 2016-2021

2022.06.22

1. Introduction

- Track condition monitoring: better economy and safety



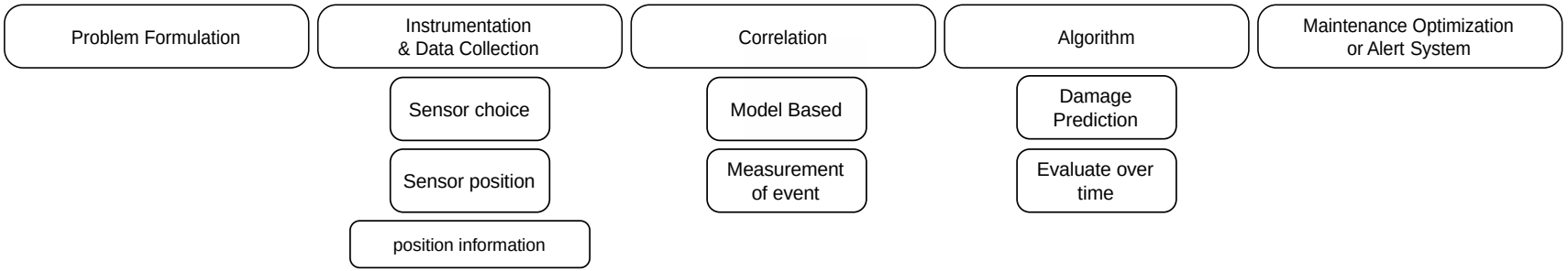
Categories from [1]

- Earlier detection means less interruptions in traffic
- Planning especially important on lines with high complexity and without double tracks for minimized costs [2]
- Several methodologies, including track following trolleys and vehicles, as well as discrete sensor placement along the track

1. Introduction

- Previous literature reviews
  - Xie et. al: data-driven models for predicting track maintenance needs [1]
  - Farkas: measurement of railway track geometry, comprehensive review of common sensors and limits and possibilities [3]
  - Weston et al: specifically the use of instrumented in-service vehicles [4]

Topics within research field



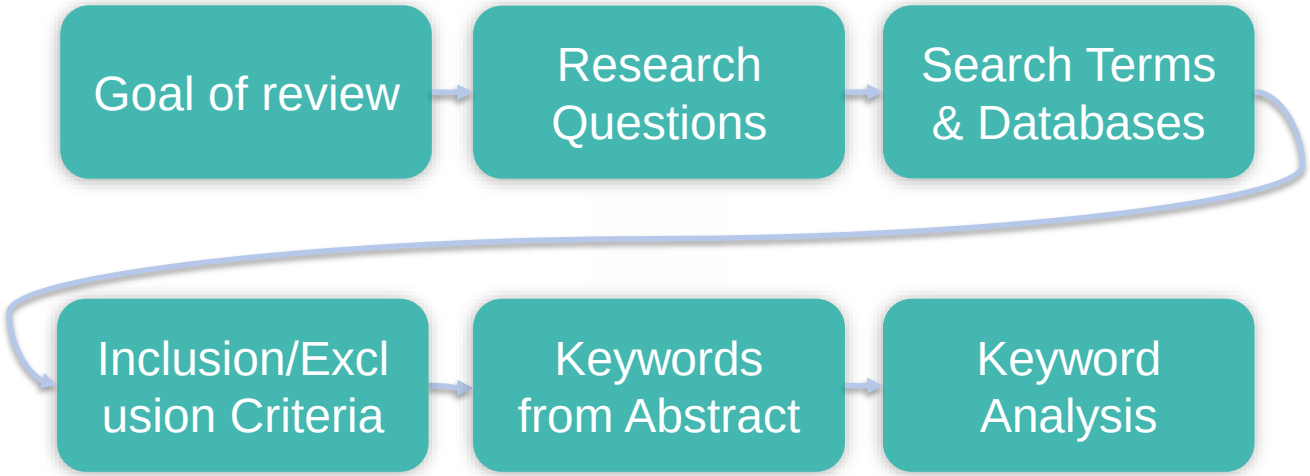
Advantages of systematic mapping

- Scope a research field [5]
- Generalize a large number of research papers [6]

- Systematic, and therefore repeatable

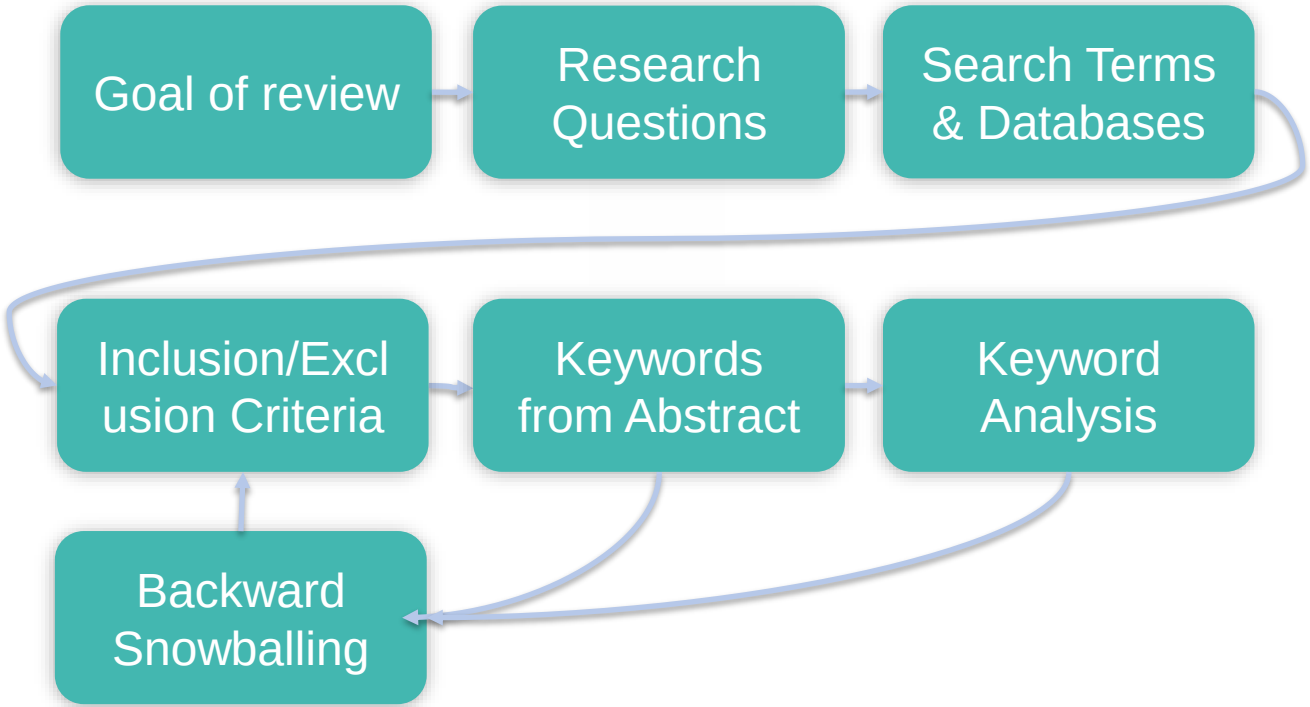
2. Method

- General method of systematic mapping



2. Method

- General method of systematic mapping



2. Method

- Implementation of method in this study
  - Research questions:
    - What are popular methods of track condition monitoring – including sensor choice and position?
    - What trends within railway track condition monitoring are there?
    - What are the research gaps in the field
  - Search terms: PICO method

Literature Search

Population	Intervention	Control/Compare	Outcome
Railway track	measurement	n/a	condition, status, track health

Literature Search

"railway track" AND (condition OR status OR quality OR health) AND (monitoring OR detection OR measurements)

Database	Search results
Engineering Village	525
IEEExplore	114
ProQuest	132
ScienceDirect	72
Scopus	308
tot	1151

Data Selection

- Inclusion/exclusion criteria
  - Papers specifically on the monitoring of railway track superstructure using measurements (published between 2016 and 2021)
  - Excluding foreign objects, electric components, bridges, ballast subgrade, wheel, vehicle damage
  - Lit reviews included for reference of previous publications, excluded from mapping text analysis
- 251 articles included, 11 lit reviews
  - Analysis from abstracts, keywords, fulltext when needed/possible

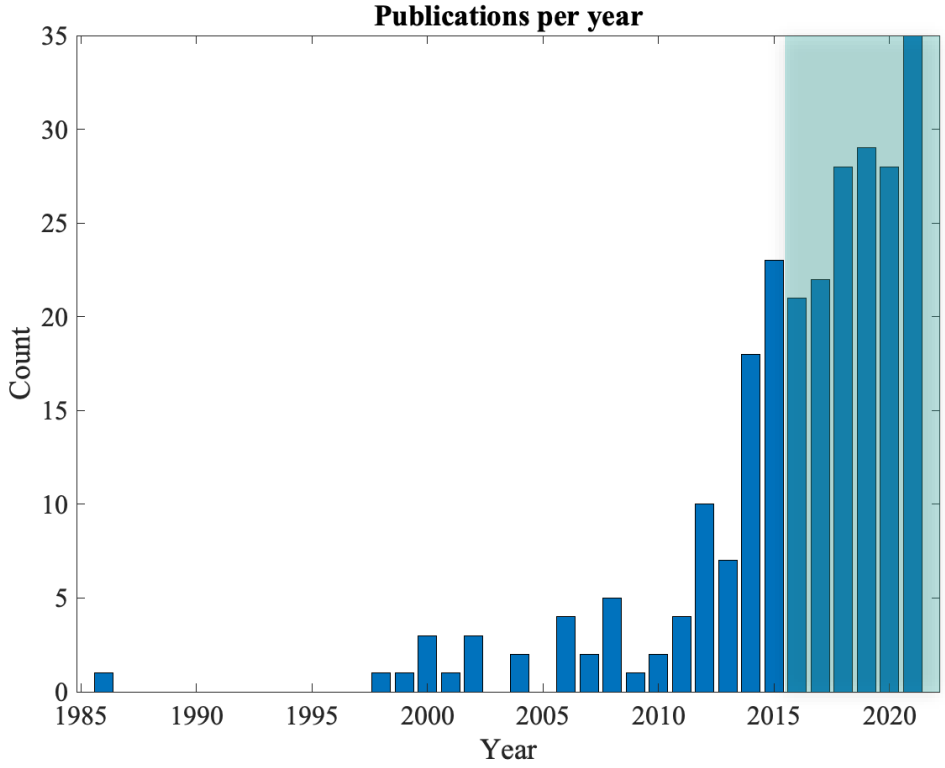
Keyword separation

	A	B	E	I	J	K	M	N	Q	R
1	No.	Title	Year	Detecting what	Sensor	Trackside vs Track followi	Position on Vehic	Vehicle Type	Algorithm	algorithm, simplify
88	92	Method for automatic railway track surface defect classification and evaluation using a laser-based 3D model	2020	surface defect	laser (laser-based images)				multi-class classifiers	supervised
89	93	A Method to Monitor Railway Tracks' Foreign Body Invasion Based on Phase Sensitive Optical Fiber Sensing Technology	2017	"events"	fiber-optic acceleration (optical fiber, vibration)				auto-regressive model	statistic
90	94	MFL sensing based NDE technique for defect detection of railway track	2016	local damage	magnetic (magnetic flux leakage)					
91	95	A Model Comparison Method In Digital Inspection Of Railway Track Wear	2016	track wear	vision (structured light scanner)				segmentation algorithm, Euclidean clustering, random sample consensus	deep learning,unsupervised
92	96	Monitoring bolt tightness of rail joints using axle box acceleration measurements	2017	bolt tightness rail joint	acceleration	track following, vehicle	axle-box	in-service		
93	97	MUHAFIZ: IoT-Based Track Recording Vehicle for the Damage Analysis of the Railway Track	2021	squats, turnout frogs, dip angles, drainage, broken rail, corrugation	acceleration	track following, trolley	axle box	trolley		
94	98	A multi-sensor fusion framework for detecting small amplitude hunting of high-speed trains	2018	small amplitude hunting	other (multi-sensor)				probability support vector machine	supervised
95	99	Multi-target Defect Detection of Railway Track Based on Image Processing	2020	surface defects, fasteners	vision (images)				image recognition, feature extraction, SVM	supervised
96	100	Multi-target defect identification for railway track line based on image processing and improved YOLOv3 model	2020	surface defects, fastener position	vision (images)				deep learning, YOLOv3	deep learning
97	101	Multiphysical system of operational monitoring of the condition of the railway track	2019		na					
98	102	A new approach for inspection of selected geometric parameters of a railway track using image-based point clouds	2018	track gauge, cant	vision (image (DSLF camera))					
99	103	A new device for stress monitoring in continuously welded rails using bi-directional strain method	2018	rail stress CWT	strain					

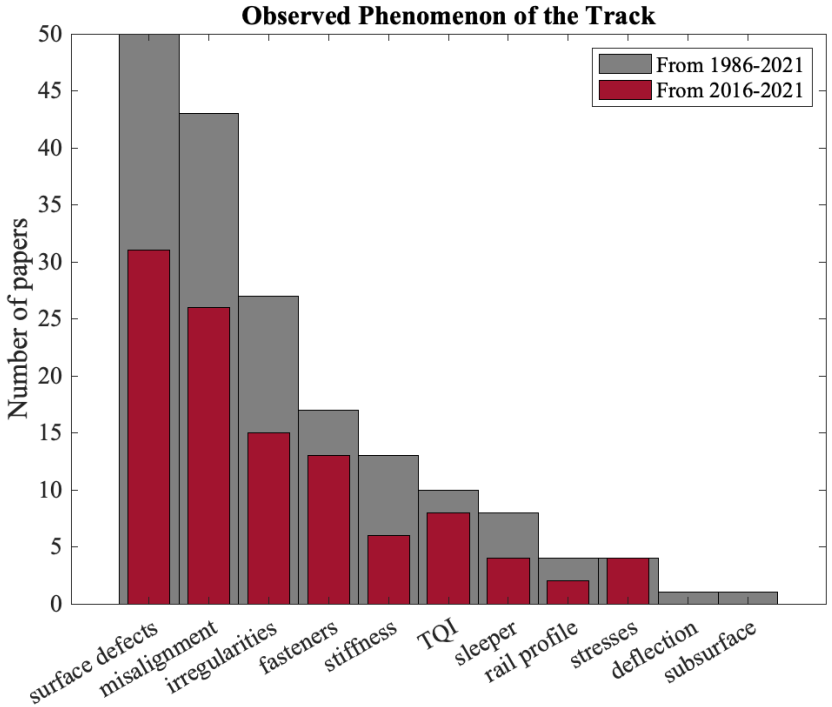
3. Results

- Publication trends
- Observed phenomenon
- Sensors, and position
- Overview of vehicle based methods
- Overview of algorithm choices

Publications per year



Observed Phenomenon



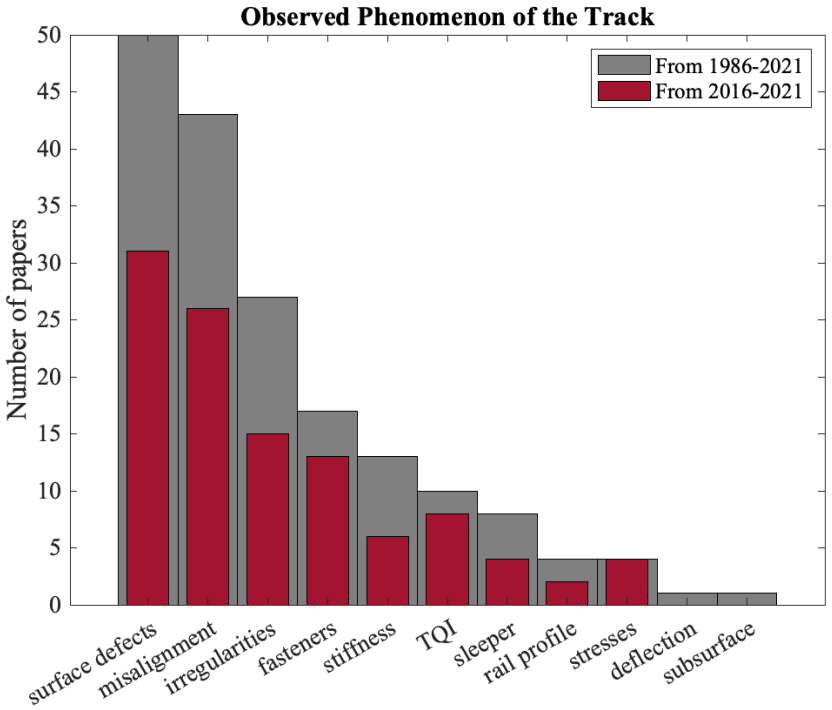
Observed Phenomenon

Cracks 16

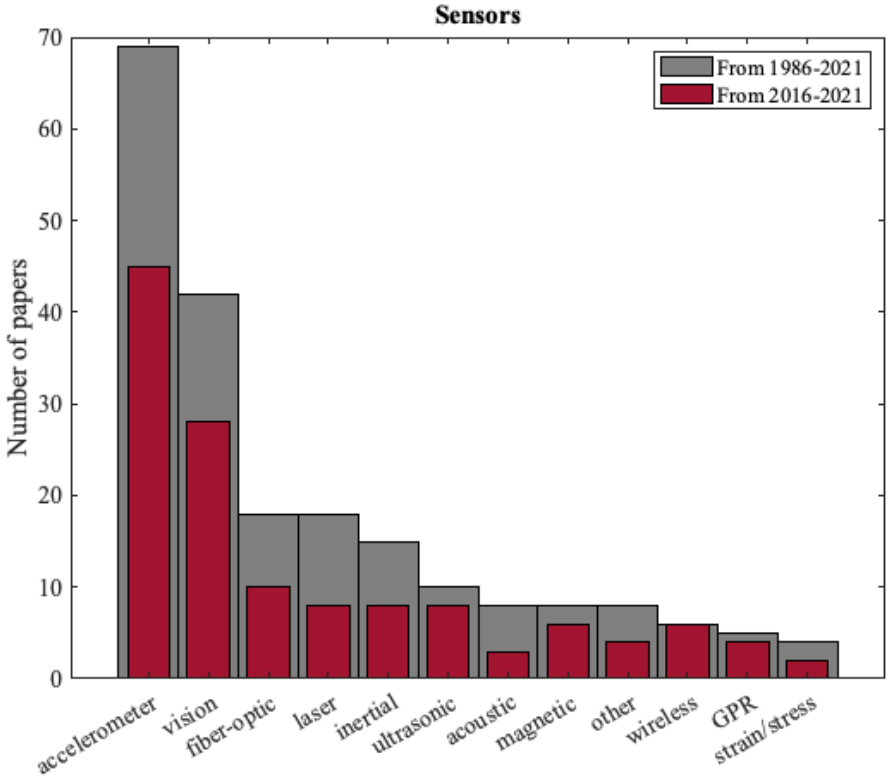
Corrugation 11

Squats 10

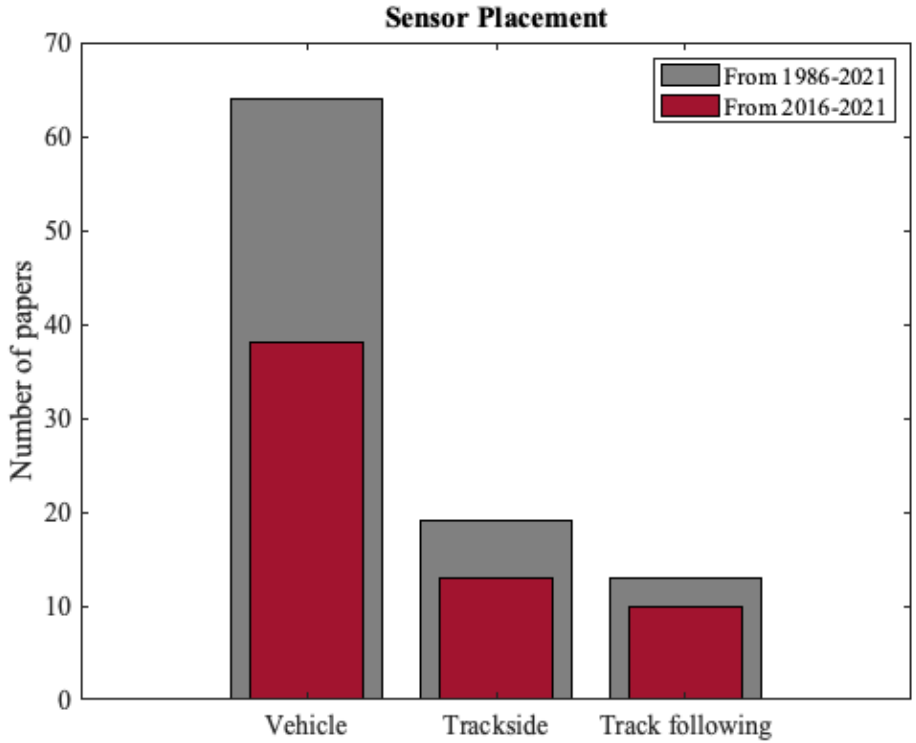
Other 4

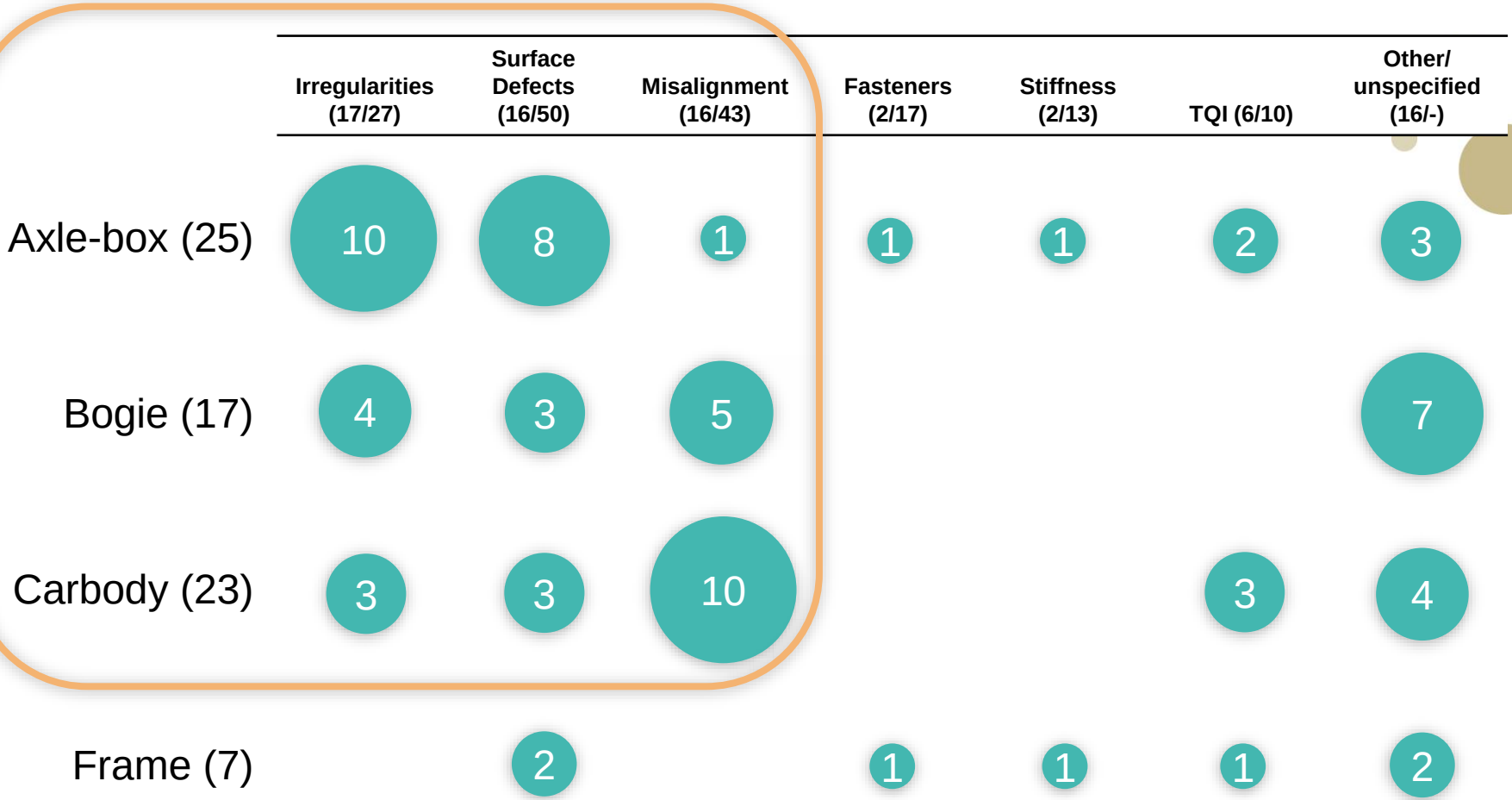


Sensor choice

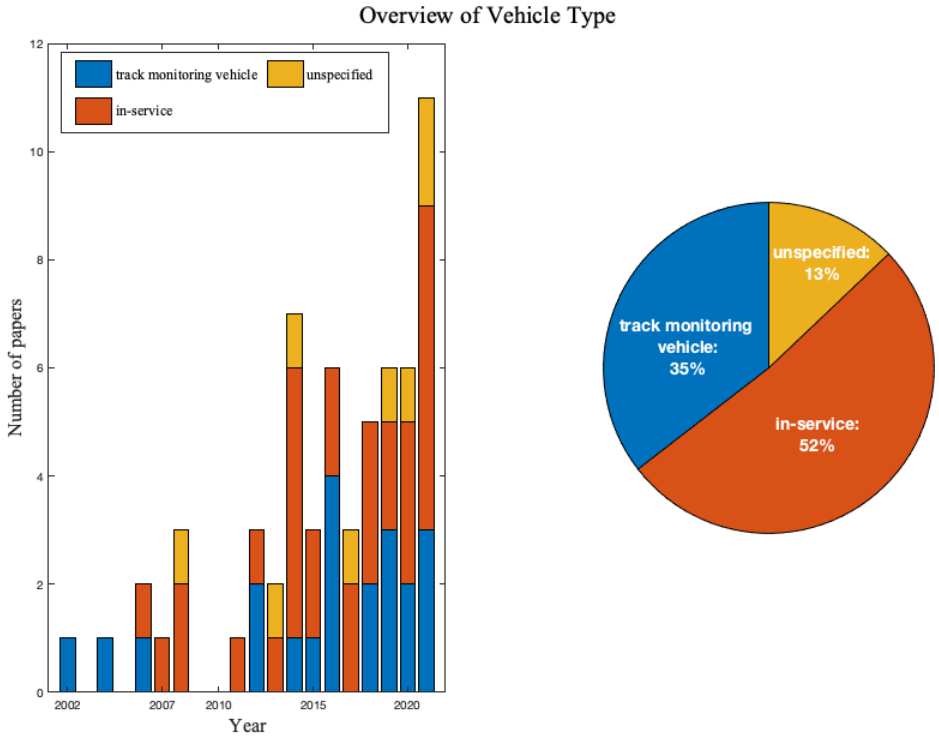


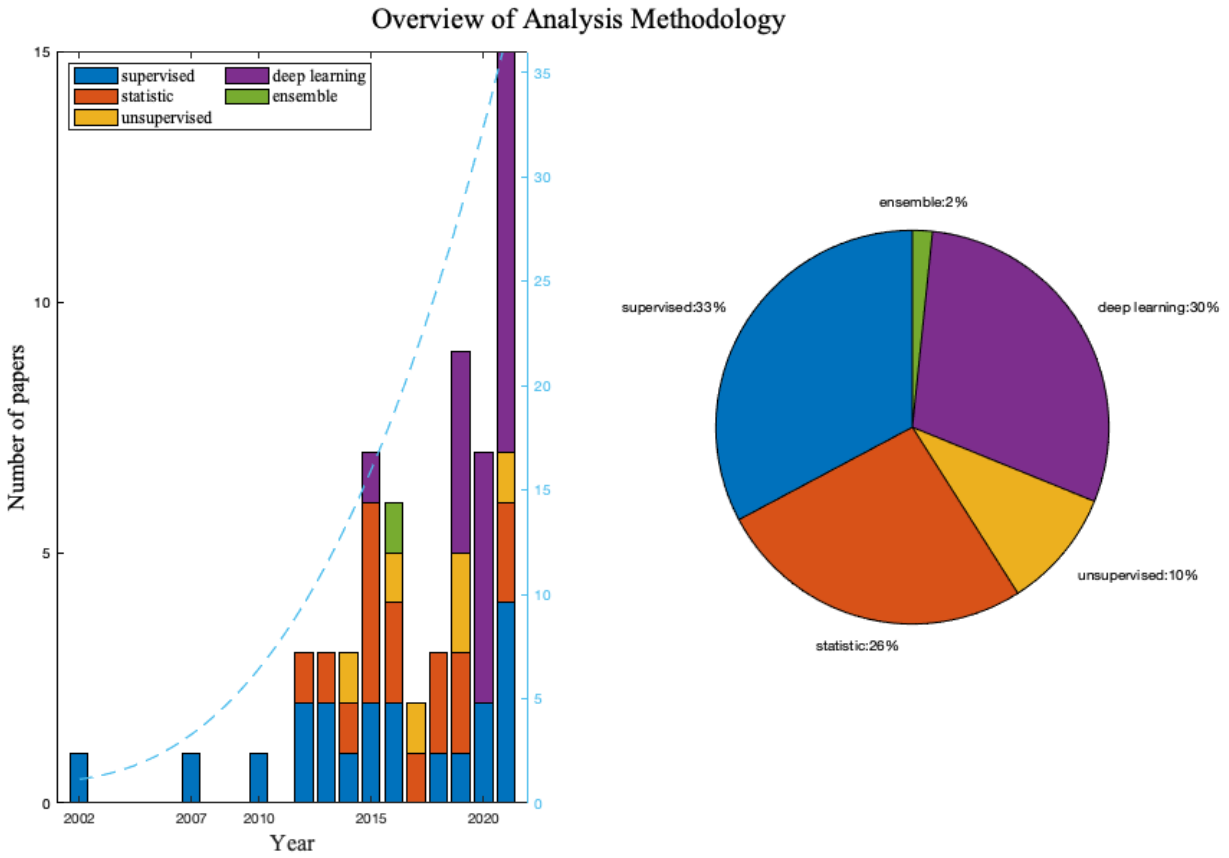
Sensor Placement




Irregularities (17/27)
Surface Defects (16/50)
Misalignment (16/43)
Fasteners (2/17)
Stiffness (2/13)
TQI (6/10)
Other/ unspecified (16/-)
Axle-box (25)
10
8
1
1
1
2
3
Bogie (17)
4
3
5
7
Carbody (23)
3
3
10
3
4
Frame (7)
2
1
1
1
2

Vehicle Based Methods




Overview of Analysis Methodology
supervised
statistic
unsupervised
deep learning
ensemble
Number of papers
Year
0
5
10
15
0
5
10
15
20
25
30
35
2002
2007
2010
2015
2020
ensemble:2%
supervised:33%
deep learning:30%
unsupervised:10%
statistic:26%

4. Discussion

- No one method for all
- Vision based methods becoming more popular
- Deep learning requires large amounts of data… not always better
- Advantages and limitations of chosen method
  - Generalization requires that the reader can make correct assumptions regarding the implications of certain wordings:

    Ex: some of the papers that conducted “measurement” according to abstract did not actually perform measurement

Thank you!

Sources

[1] J. Xie, J. Huang, C. Zeng, S.-H. Jiang, and N. Podlich, “Systematic Literature Review on Data-Driven Models for Predictive Maintenance of Railway Track: Implications in Geotechnical Engineerin,” *Geosciences,* vol. 10, 2020.

[2] UIC, “Key Cost Drivers in Railway Asset Management”, 2015.

[3] P. Weston, C. Roberts, G. Yeo and E. Stewart, “Perspectives on railway track geometry condition monitoring from in-service railway vehicles,” *Vehicle System Dynamics,* vol 53, pp. 1063-1091, 7 2015.

[4] A. Farkas, “Measurement of Railway Track Geometry: A State-of-the-Art Review,” *Periodica Polytechnica Transportation Engineering,* vol 48, pp. 76-88, 10 2019.

[5] K. Petersen, S. Vakkalanka, and L. Kuzniarz, “Guidelines for conducting systematic mapping studies in software engineering: An update,” *Information and Software Technology,* vol. 64 pp. 1-18, 8 2015.

[6] K. Petersen, R. Feldt, S. Mujtaba, and M. Mattson, “Systematic Mapping Studies in Software Engineering,” *Proceedings of the 12th International Conference on Evaluation and Assessment in Software Engineering,* vol 17, 5 2008.