KTH ROYAL INSTITUTE OF TECHNOLOGY

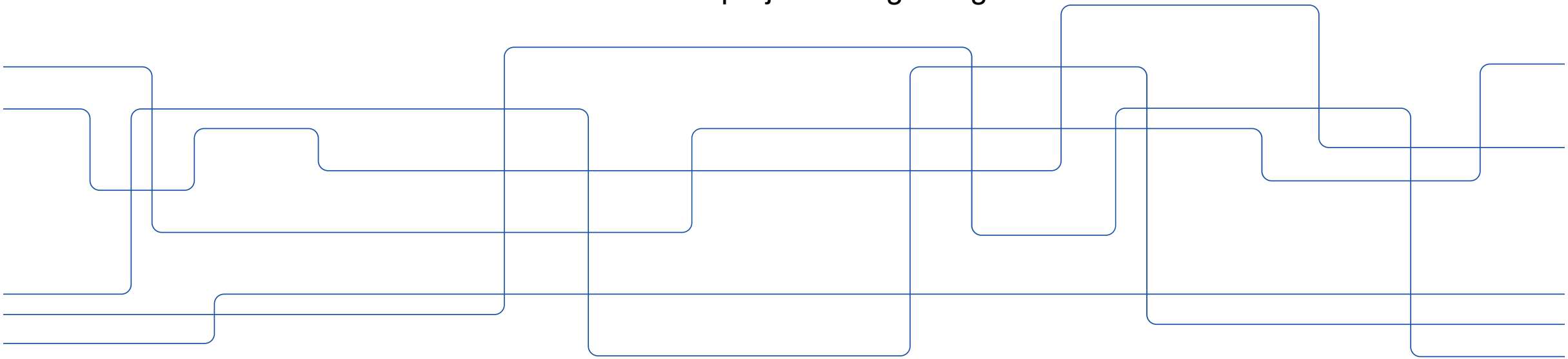
Onboard condition monitoring of vehicle-track dynamic interaction using machine learning

PhD work by Rohan R Kulkarni, KTH

The thesis is available here (June 2023)

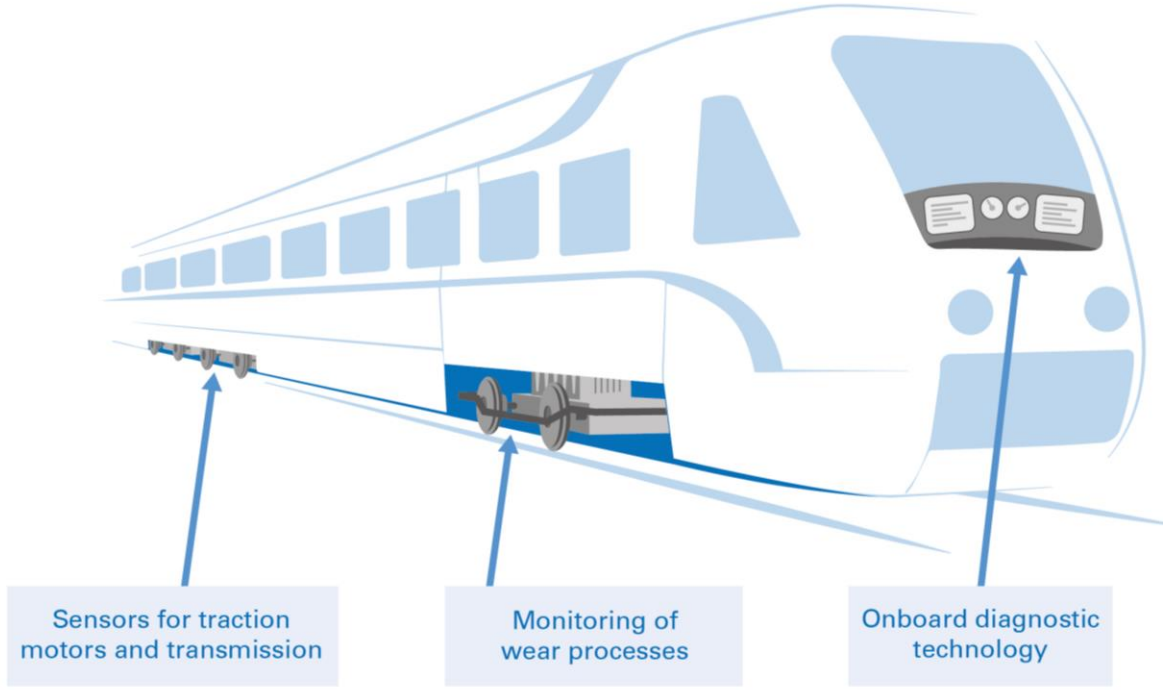
The work is funded by Railway Group, IN2TRACK-2, IN2TRACK-3, PIVOT-2 and Excellency Area 1

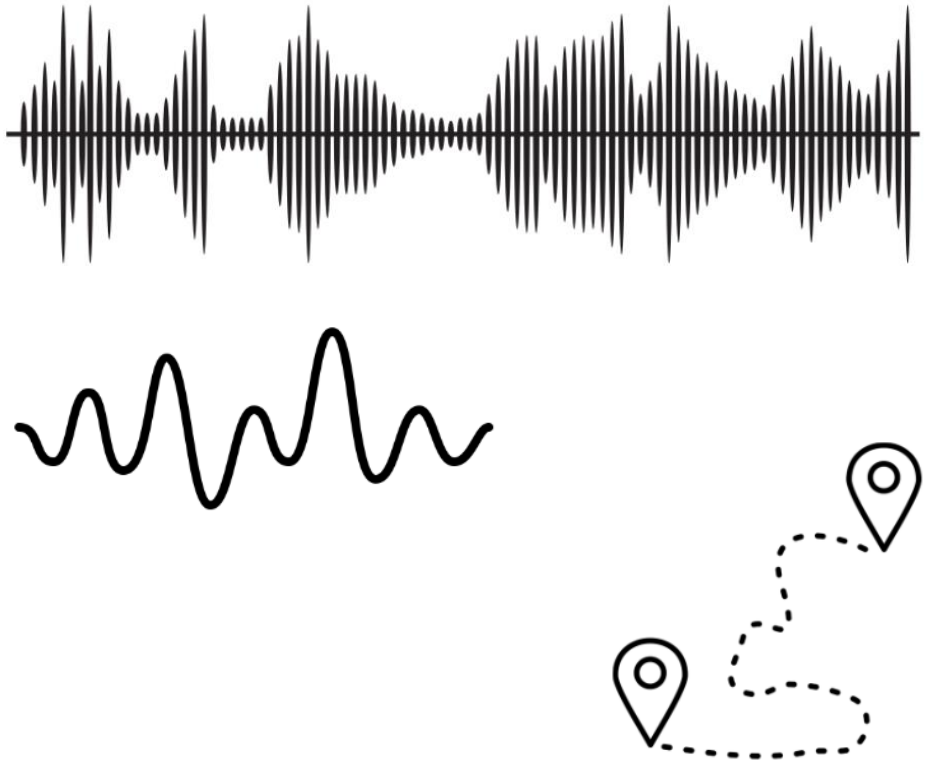
The work is also related to the national project ”Dålig Gång”



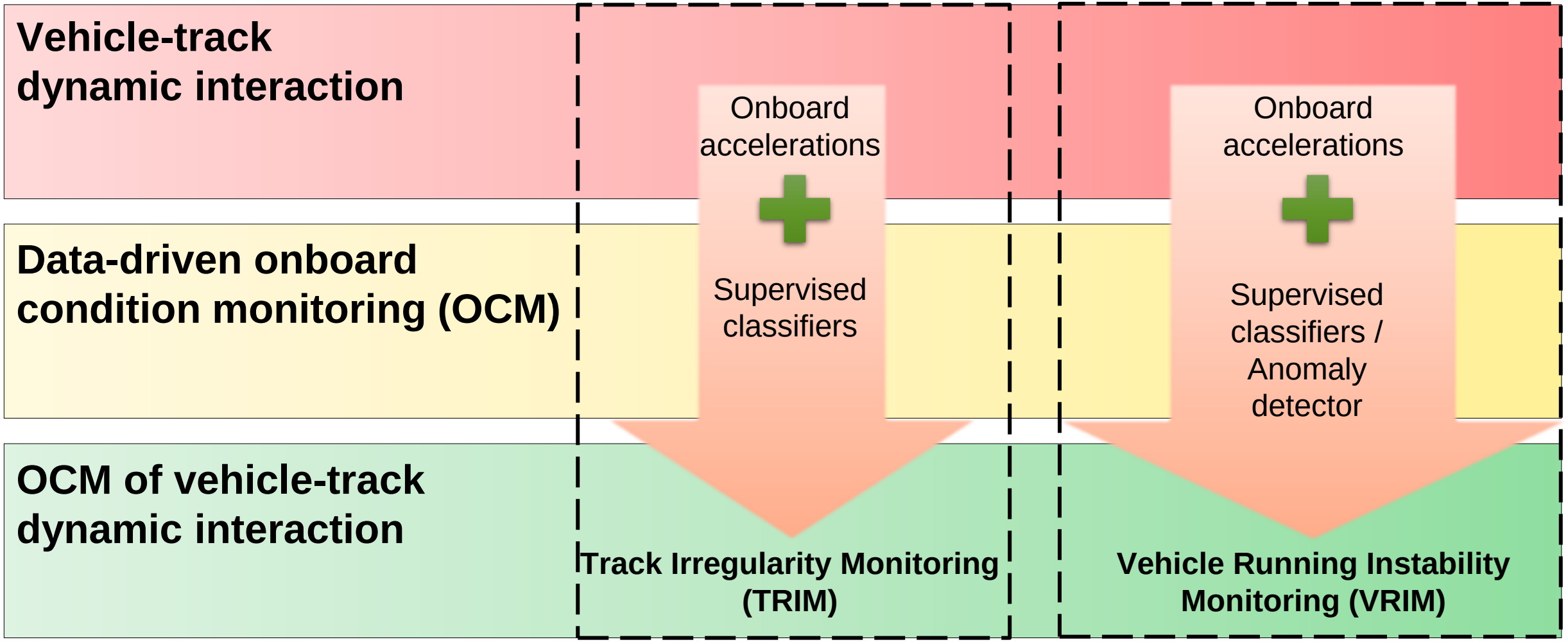
Introduction

Onboard condition monitoring of vehicle–track dynamic interaction from in-service vehicles



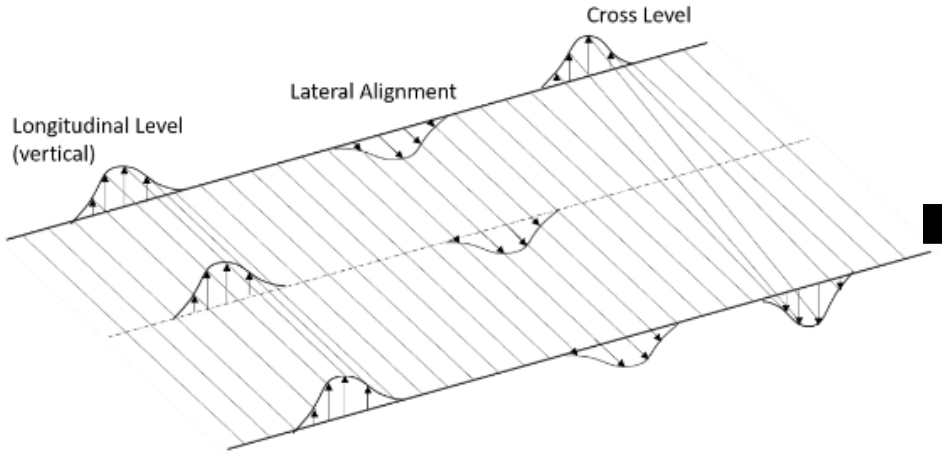


Introduction: Research Framework

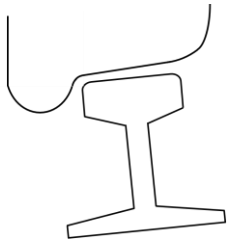


TRIM – Introduction

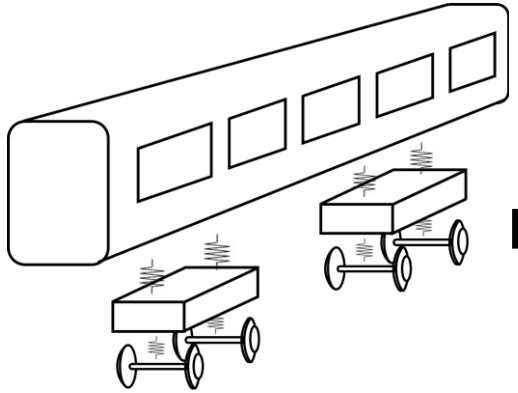
- Track irregularities excite the vehicles as the vehicles run along the track



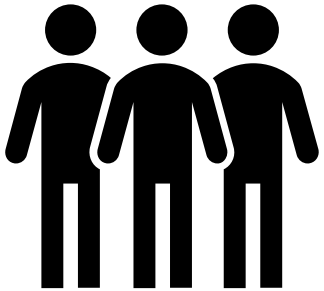
Track irregularities
(Track curves and S&C)
(Wheel out-of-roundness)



Wheel–rail contacts,
wear and fatigue



Vehicle dynamic response
Safety and fatigue



Safety and comfort
(Freight damage)

TRIM – Introduction

ETR 500 Dia.Man.Te

- Occasionally acquired
- Dedicated train → service interruption
- Sophisticated and expensive sensors (laser optical sensors)

Freccia rossa

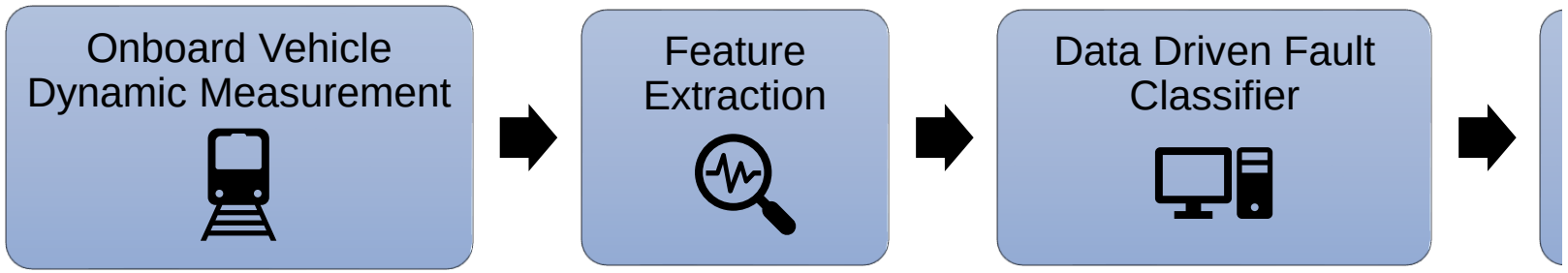
- Every day
- In-service trains
- Simple and inexpensive sensors (accelerometers)

Collaboration with Politecnico di Milano

TRIM – Proposed Methodology

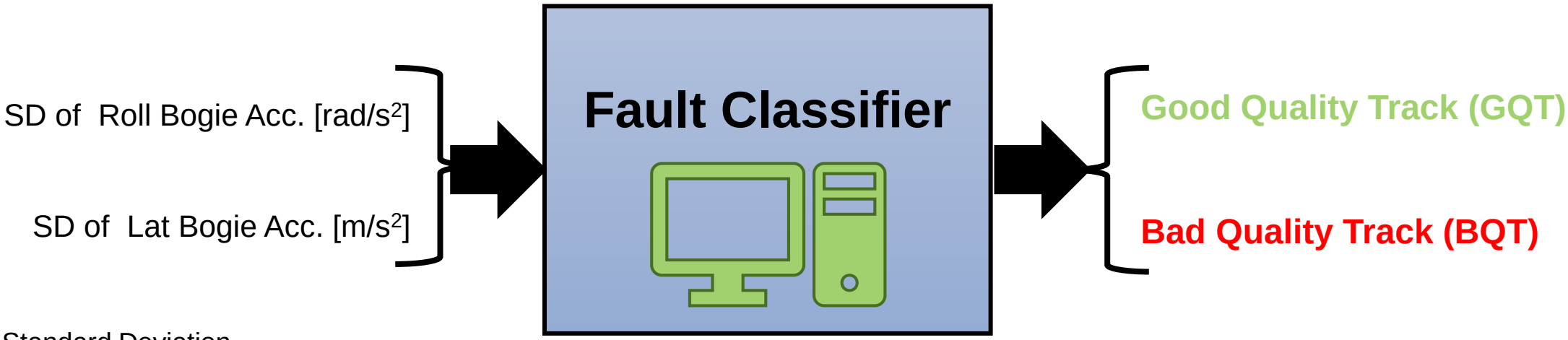
- Research Question 1 (RQ1)
  - OCM algorithms for qualitatively assessing track irregularities via bogie frame accelerations
  - Optimal decision boundaries in the vehicle response space?

- A data-driven OCM algorithm is proposed for qualitative asse irregularities



TRIM – Proposed Methodology

- A data-driven OCM algorithm is proposed for qualitative assessment of track irregularities



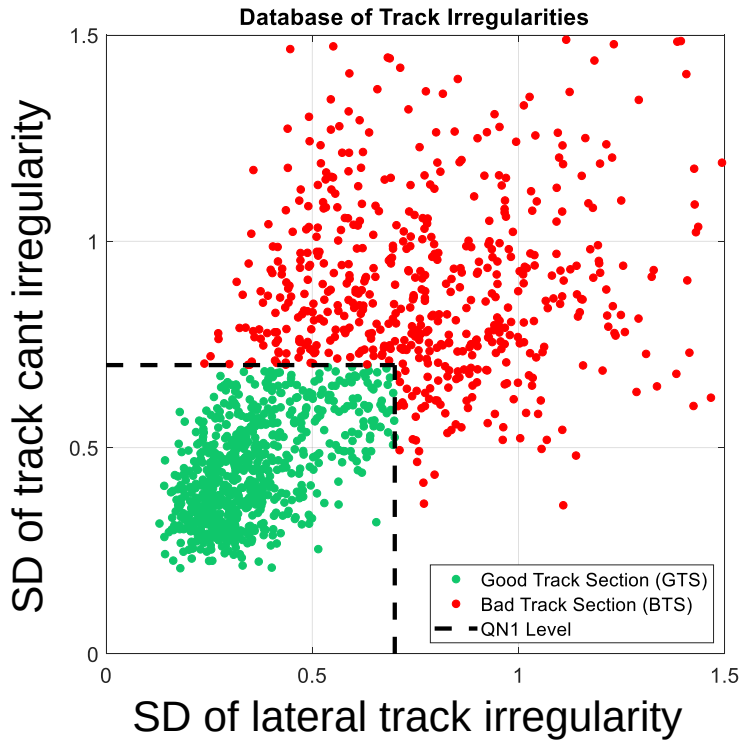
SD = Standard Deviation

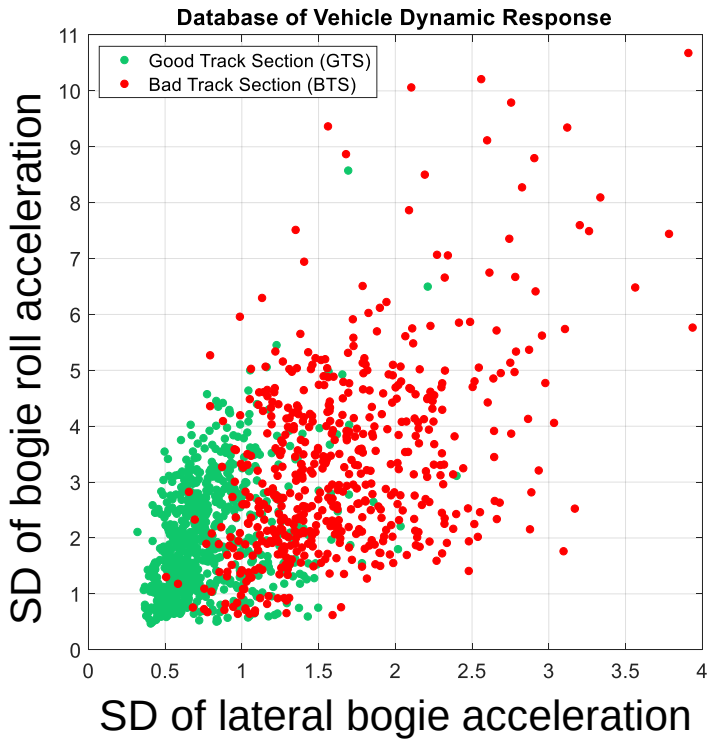
– Machine Learning model **trained with numerical simulations**

– Machine Learning model **tested on field measurements**

TRIM – Results

- Training by multibody dynamics simulations





- Testing by Dia.Man.Te measurements (improved accuracy)

Phase	Classifier	Accuracy
Testing Phase	L SVM	95.8±0.3%
	G SVM	95.6±0.2%
	MAP NB	95.9±0.2%

TRIM – Research Question 1 (revisit)

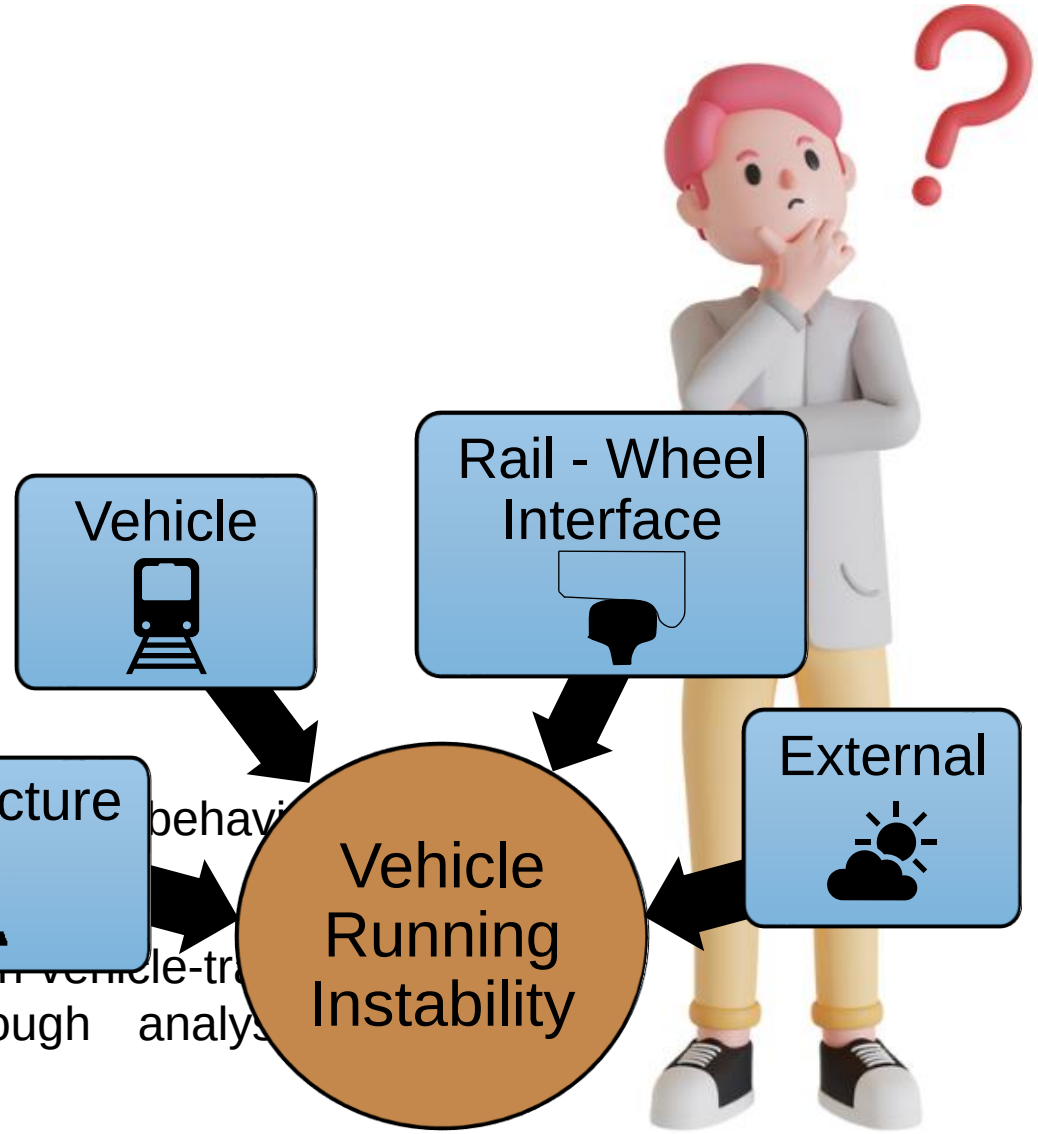
- RQ1
  - OCM algorithms for qualitatively assessing track irregularities via bogie frame accelerations
  - Optimal decision boundaries in the vehicle response space?

- Conclusions
  - OCM method is proposed
  - Multiple data driven classifiers
  - Data driven OCM method outperforms linear correlation analysis method

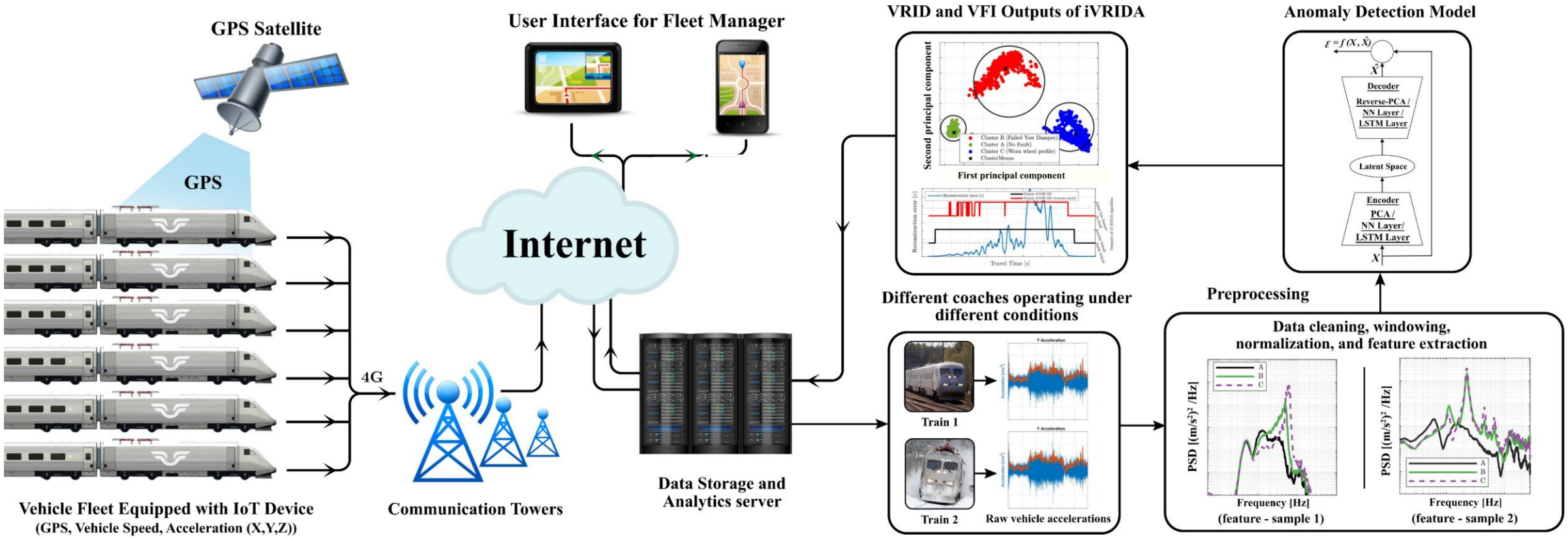
- Future work
  - Extending the dataset to incorporate curve sections
  - Hybrid method (Model based + data driven)
  - Use of smartphone accelerometers for TRIM

VRIM – Introduction

- The task is challenging
  - Nonlinear dynamics of wheelset – track interaction
  - Multiple components may trigger running instability
  - Scarcity of running instability occurrence
- Research questions
  - RQ2
    - > Effect equivalent conicity function's nonlinearit… behavi…
  - RQ3
    - > OCM algorithm for detecting and diagnosing anomalies in vehicle-tr… explicitly focus on vehicle running instability through analys… accelerations?



VRIM – *iVRIDA* Methodology



Collaboration with Trafikverket, SJ and Perpetuum

VRIM – Research Question 3 (revisit)

- RQ3
  - OCM algorithm for detecting and diagnosing anomalies in vehicle-track interaction, explicitly focus on vehicle running instability through analysing carbody accelerations?

- Conclusions
  - A sporadic phenomenon, i.e., an anomaly of vehicle-track interaction.
  - Anomaly detection (AD) framework, referred to as *iVRIDA,*
  - Tested and validated on onboard measurements of two high-speed vehicles

- Future work
  - Diversification of data sources
  - Incorporation of advanced generative models such as VAE, CAE and GAN models.

Acknowledgements

- Financial supporters:

Järnvägsgruppen

- Industrial and academic collaborators: