Live Road Assessment (LiRA)

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RESEARCH, TECHNOLOGY & GROWTH

Background

Standard road measures have been developed to assess road conditions and optimize maintenance strategies focusing on (DRD costs 5 million DKK per year – do not include emissions):

- Safety
- Comfort
- Durability
- Environmental Emissions (noise and CO_2)

Limitations

1) Costs
2) Weather
3) Road Geometry
4) Not always objective
5) Frequency

between 1 to 3 years


Project idea$_{1/2}$

Are there alternative way to monitor maintain and manage the roads?

Modern cars are equipped with many sensors which also provide additional valuable data (e.g. energy consumption).

Can car sensors data be used to measure road conditions?

Project idea$_{2/2}$

What do we need?

CAR SENSING platform

1) *Connected fleet of vehicles*
2) *Modern vehicles*
3) *Access to CAN bus data*
4) *Customized Additional hardware*

STANDARD road measures

1) *Roughness & Rutting*
2) *Cracking and potholes*
3) *Friction*
4) *Noise and RR*

Data processing and Software engineering

1) *BYG (Physical models)*
2) *Compute (software engineering)*
3) *Compute (machine learning)*

Management system

1) *Implement live road measures*
2) *Maintenance strategies*

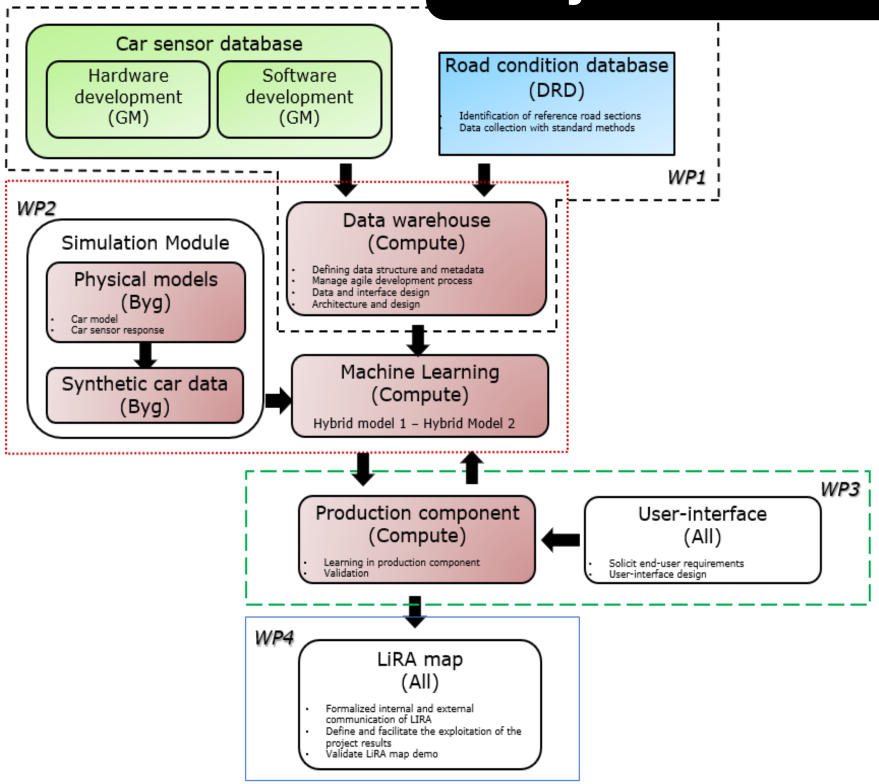
Live Road Assessment (LiRA)$_{1/2}$

DURATION: 3.5 years (started 1st of February)

MOTIVATION:
→ **harness the technological development in the car industry – give value to new available data**

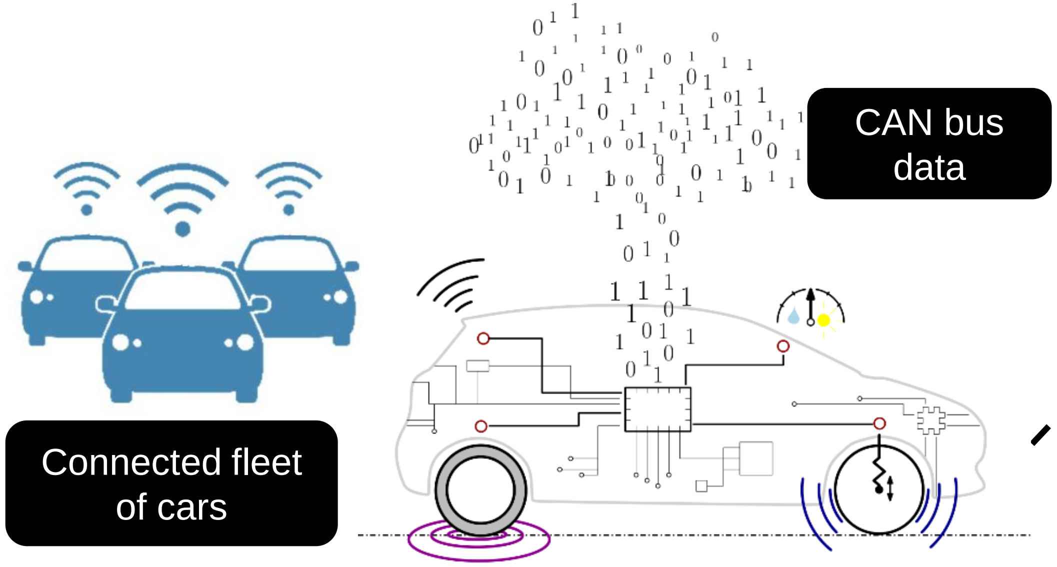
OBJECTIVE:
→ **performing road condition surveys using data collected by a connected fleet of vehicles**

Project structure



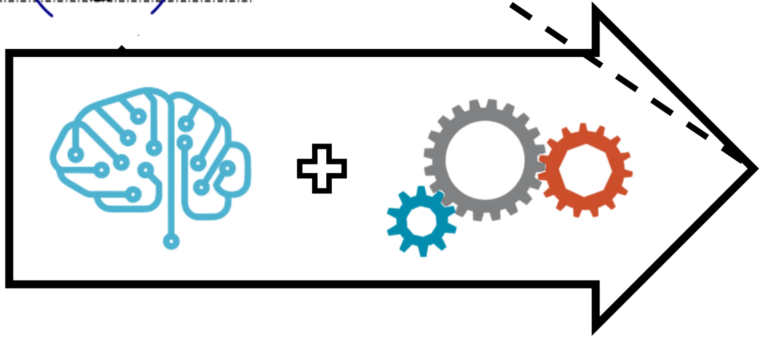
PARTNERS: Vejdirektoratet Danish Road Directorate, SWECO, DTU, GreenMobility

Live Road Assessment (LiRA)$_{2/2}$



- Noise emissions
- Energy consumption
- Other relevant road measures

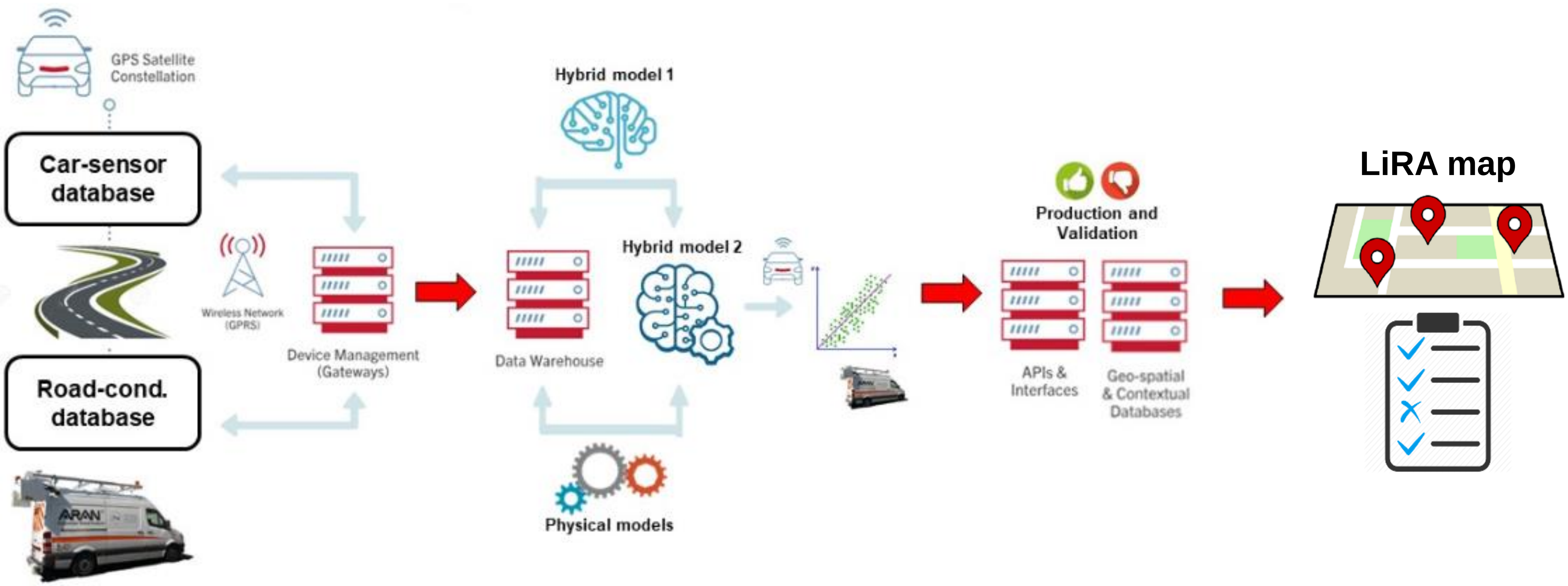
METHOD: **bigdata and machine learning**



- Training (supported by physical models)
- Validation & Testing (Copenhagen)

CHALLANGES: Hardware customization, software customization, Database: data flow and data processing

Project plan and organization



Data collection

Modelling

Software development

Hardware customization

The hardware has an embedded Raspberry Pi:

- runs a full Linux operating system,
- alongside with demanding applications.

new possibilities provided by AutoPi.io (https://www.autopi.io/).

AutoPi Dongle

The flexibility offered by this system enable LiRA team to:

1. CUSTOMIZE the connected SENSORS (possible new tasks, considering to add gyro and microphone on a prototype version);
2. CUSTOMIZE the DATA PROCESSING (new tasks – tweaking software to the LiRA needs);
3. Can rise the frequency of acquisition of ACCELEROMETER UP TO 800 Hz

Software customization

Currently 56 relevant sensors are used

- A total of 373 sensors available.
- Existing library (open source) for the Renault Zoe utilized.

Raw data stream from AutoPi / GM car

1F8#0204FFEFFE00000D
5DE#0000000001000040
17A#FFFFFFAA00F031A3
42E#4E3FD0DC6405C039
17E#FFFFFF00FF4000FF
130#00486FFE009FFEAD
186#00003203200020
12E#C77FFC7FD0FFFF00
242#0200FFEFFE000C

AutoPi / CanZE library

ID (hex)	startBit	endBit	resolution	offset	decimals	unit	options (hex	see MainActivity for definit
0c6	0	15	1	32768	1	°	ff	Steering Position
0c6	16	31	1	32768	1	°/s	ff	Steering Acceleration
0c6	32	47	1	32768	1	°	ff	SteeringWheelAngle_Offse
12e	0	7	1	198	0		ff	LongitudinalAccelerationProc
12e	8	23	1	32768	0		ff	TransversalAcceleration
12e	24	35	0.1	2047	1	deg/s	ff	Yaw rate
130	20	31	1	4094	0	Nm	ff	ElecBrakeWheelsTorqueRequest
130	44	55	-3	4094	0	Nm	ff	DriverBrakeWheelTq_Req
17a	48	63	0.5	12800	1	Nm	ff	Estimated Wheel Torque
186	0	15	0.125	0	2	rpm	ff	Engine RPM
186	16	27	0.5	800	1	Nm	ff	MeanEffectiveTorque

Different Frequencies
Most of OBD2 data
- 5 Hz
- 0.5 Hz
- 0.05 Hz
- Accel up to 800 Hz

GM car data

GM cloud database

LiRA data warehouse

Database: Data flow and processing

How do we manage and structure a different road data flow?

TODAY – DRD measures a road (e.g., once per year) and then data goes into the database

FUTURE or LIRA situation

Everyday new data
come into the database

It could be 1 – 10 or
100 cars per day

HOW DO WE
ASSEMBLE DATA?

Daily

Repairing
Winter maintenance

Yearly

Pavement
management system

DRD – measurement plan

Road condition database (DRD)

Identification of reference road sections
Data collection with standard methods

Section Type	Number or Direction	Length
Trial 1 – DTU*	1 loop	4 km
Trial 2 – M13**	2 – North and South	22 km
Motorways and rings	7	179.6 km
Copenhagen	More than 100	More then 140.0 km

- ARAN9000
- Friction
- Noise
- P79

Car sensors

Renault ZOE (in-vehicle):

- Yaw rate (°/s), speed (km/h), odometer (km), temperature (°C), tire pressure (mbar), energy consumption (kW), safety belt, wipers..
- Sampling rate 0.05-0.5 Hz

AutoPi (external)

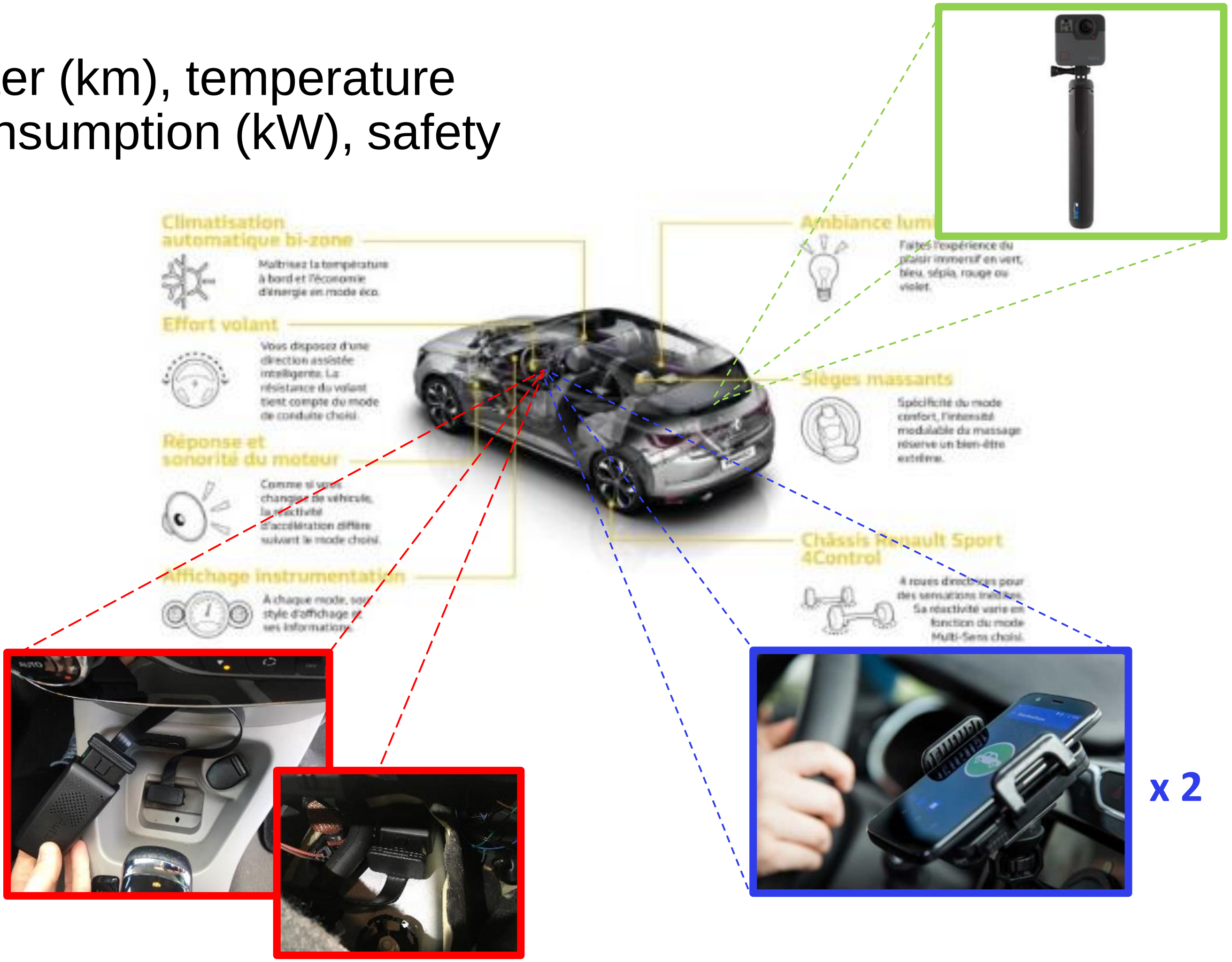
- 3D accelerometer
- Sampling rate 50 Hz

Mobile Phones (external)

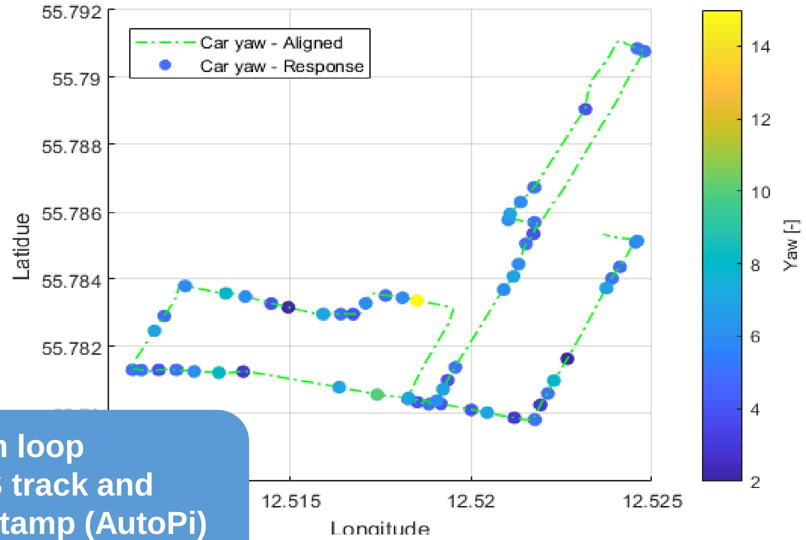
- 3D accelerometer and gyroscope
- Sampling rate 150 Hz

GoPro (external)

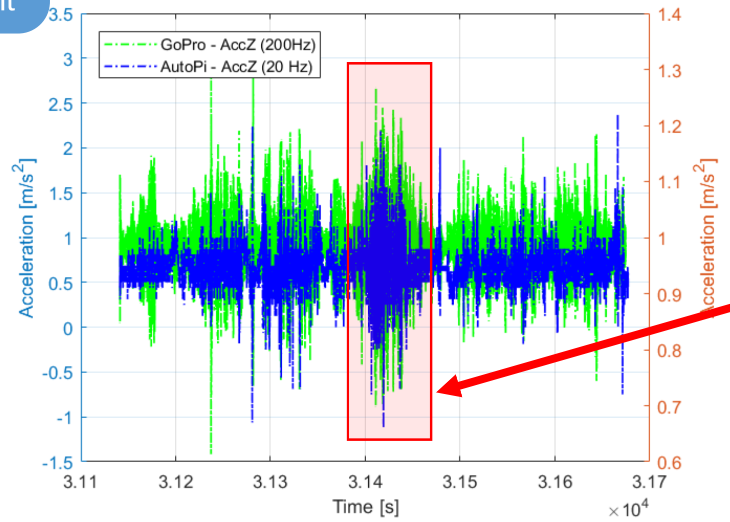
- 3D accelerometer and gyroscope
- Sampling rate 200 Hz

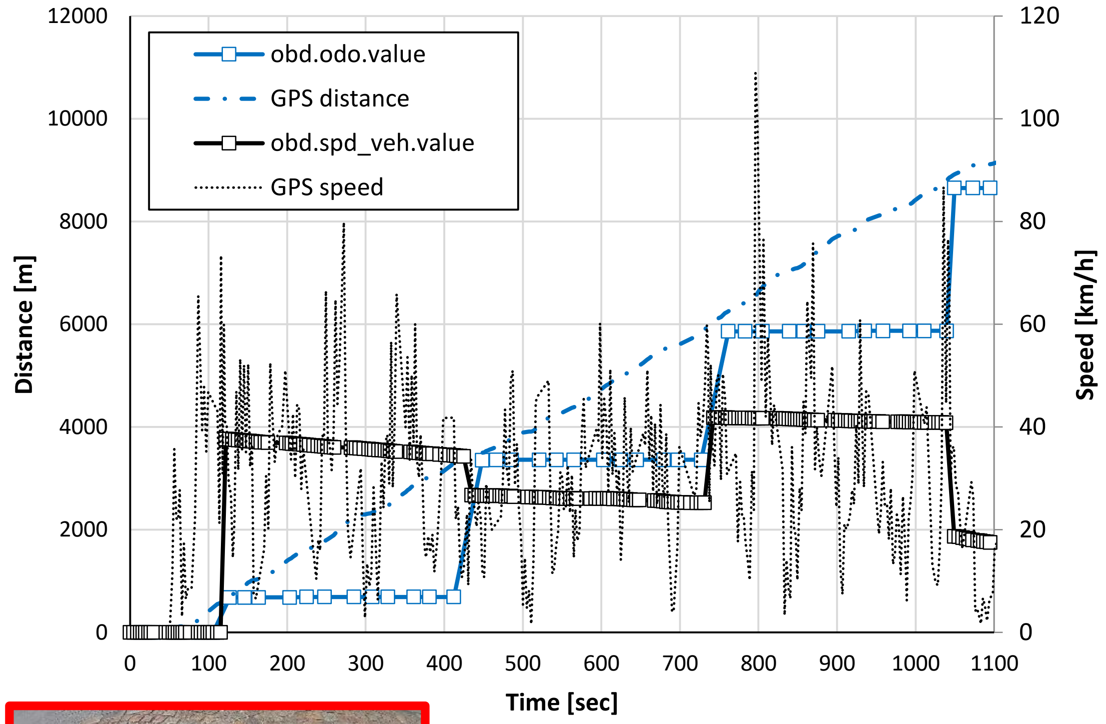


Validation of car data



- 4 km loop
- GPS track and timestamp (AutoPi)
→ car data alignment





Standard devices

ARAN9000 – LCMS 2.0

- Structural distress: Potholes, Ravelling (disintegration), Cracks (length, width and depth), Bleeding
- Serviceability: Roughness (IRI), Mean Profile Depth (surface macro texture), Rutting, Bleeding
- 10 m sub-sections

P79

- 3D road profile (m) / sampling rate ~1000 Hz
- Rutting and Mean Profile Depth / 10 m sub-sections

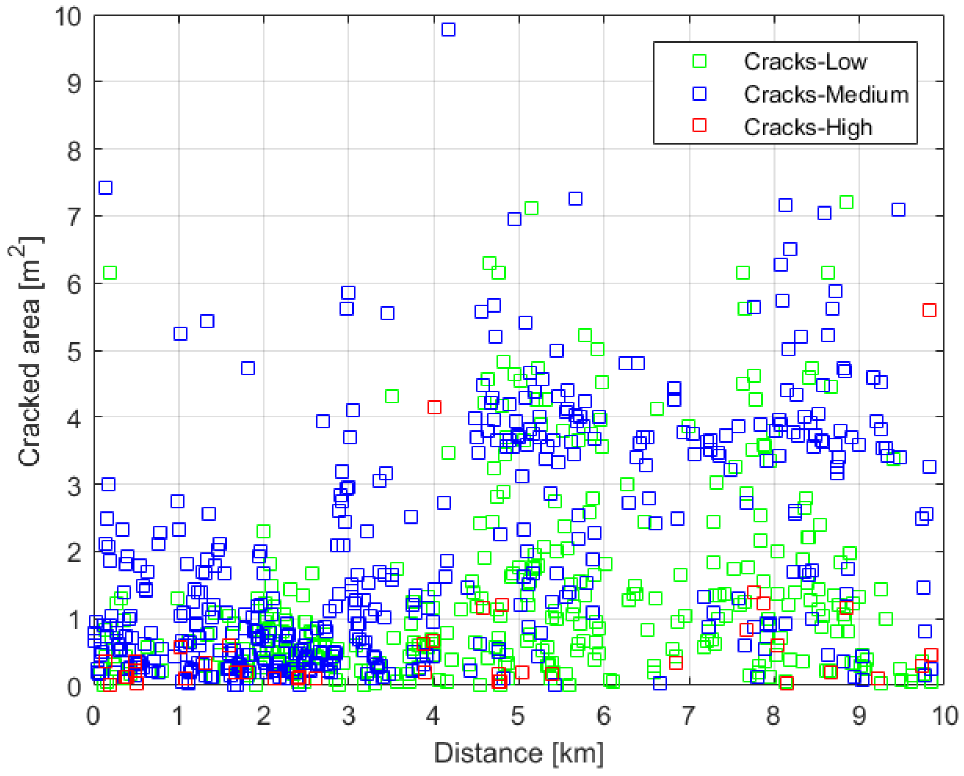
CPX

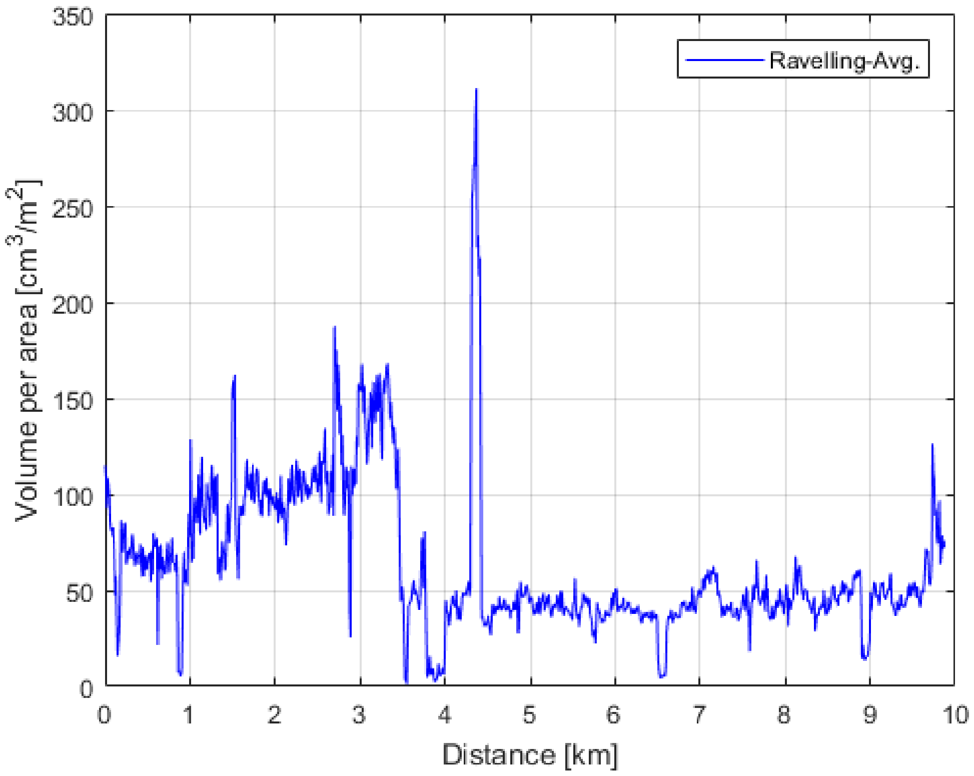
- Noise measurements (dB) / 10 m sub-sections

FRIKV

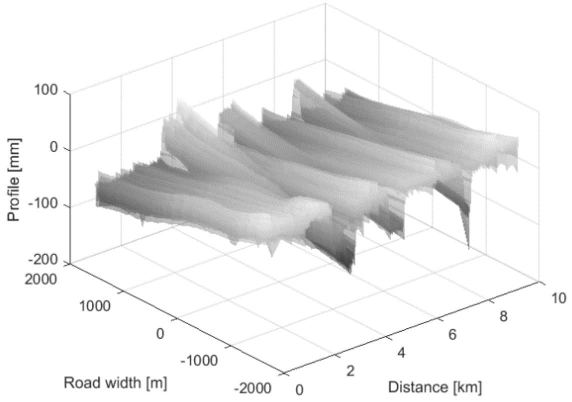
- Friction measurements (slip in %) / 5 m sub-sections

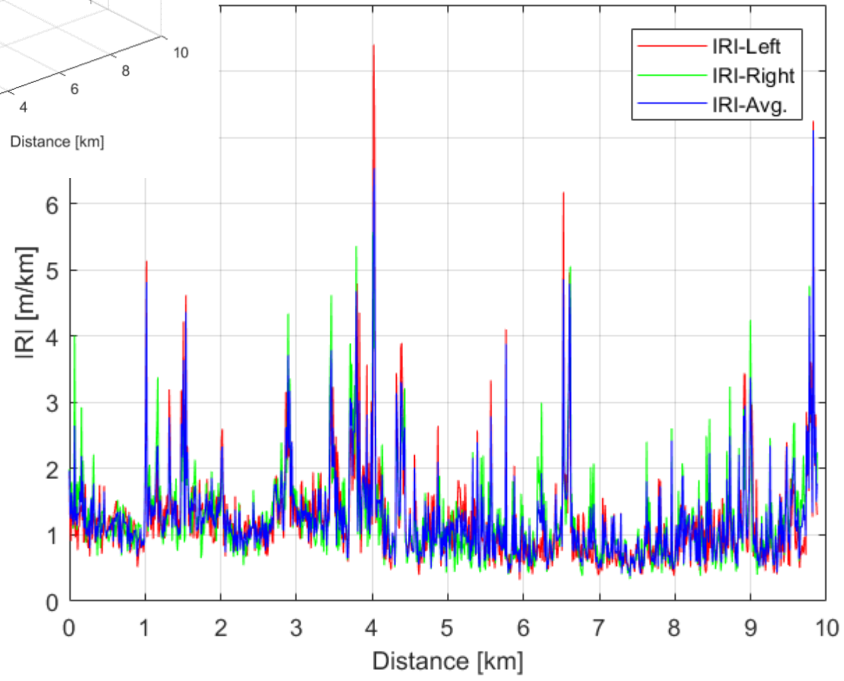
Cracks and Raveling (M13)

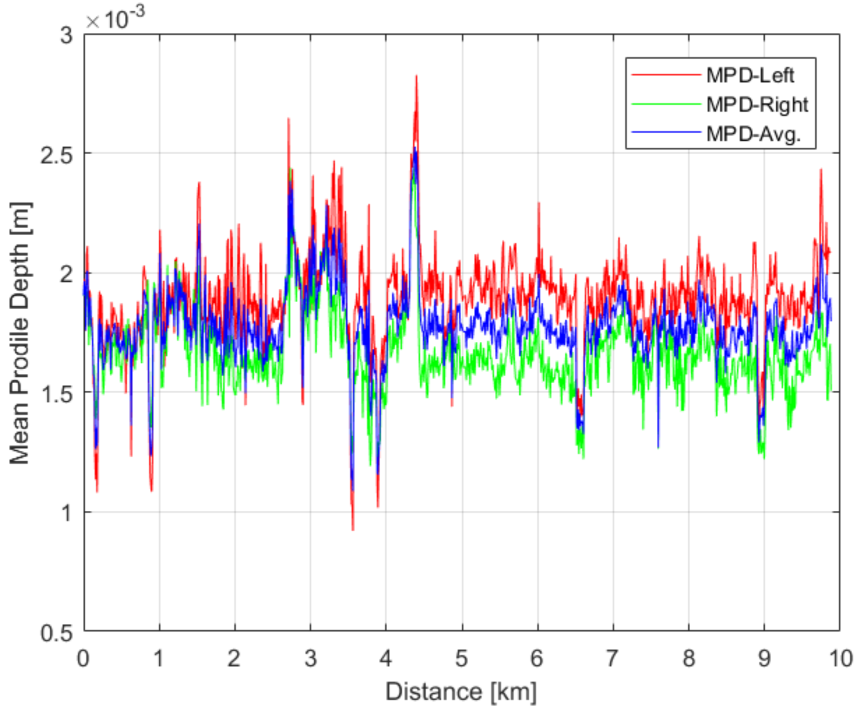




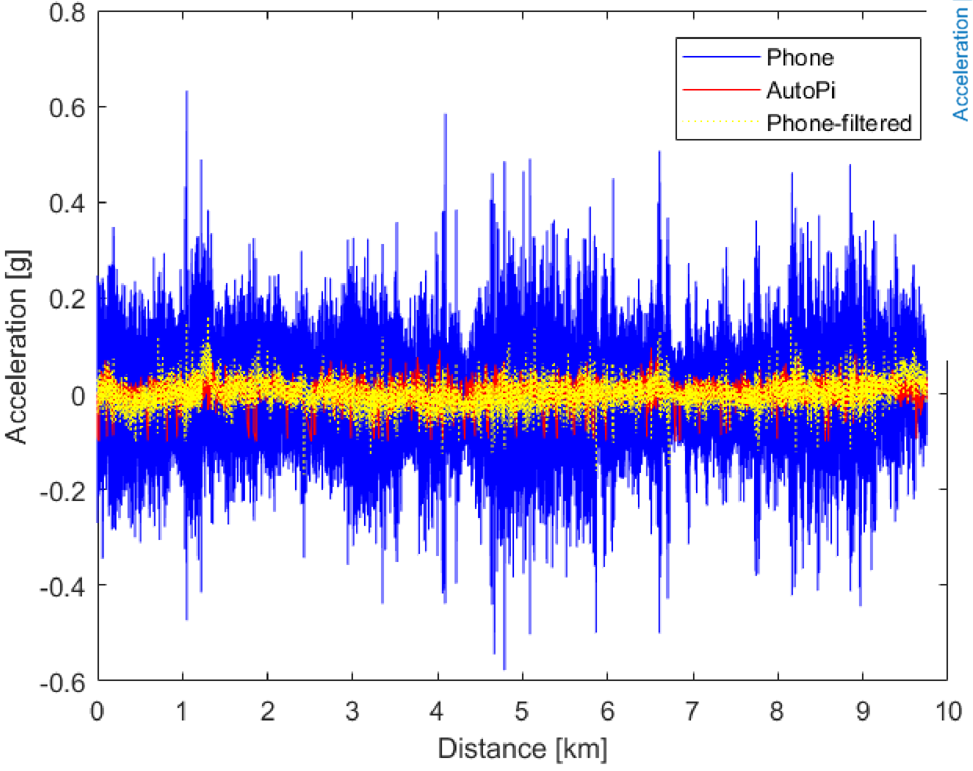
Profile, IRI and MPD (M13)

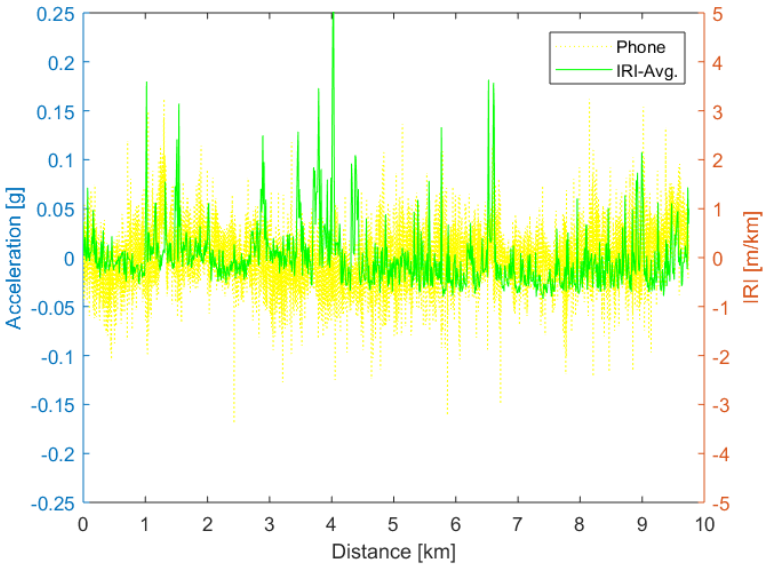


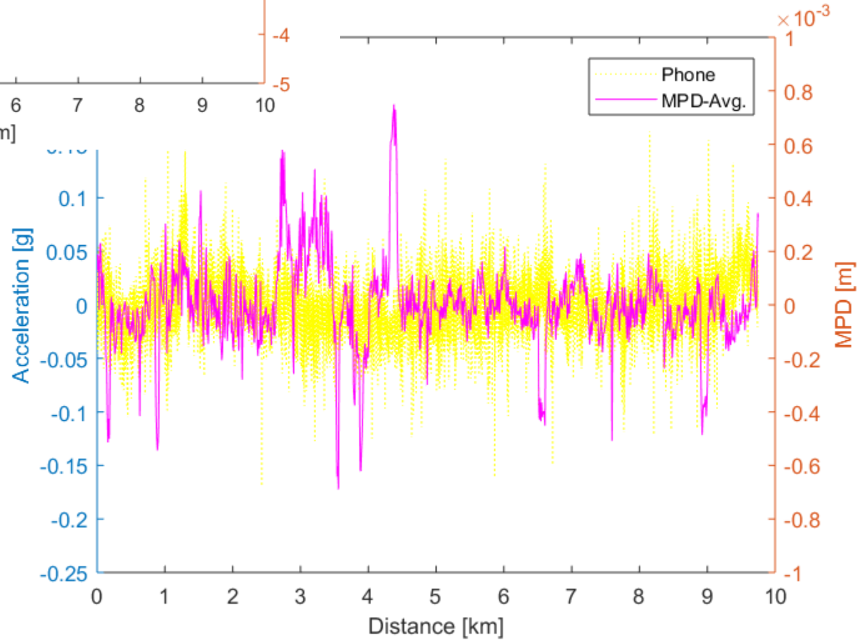




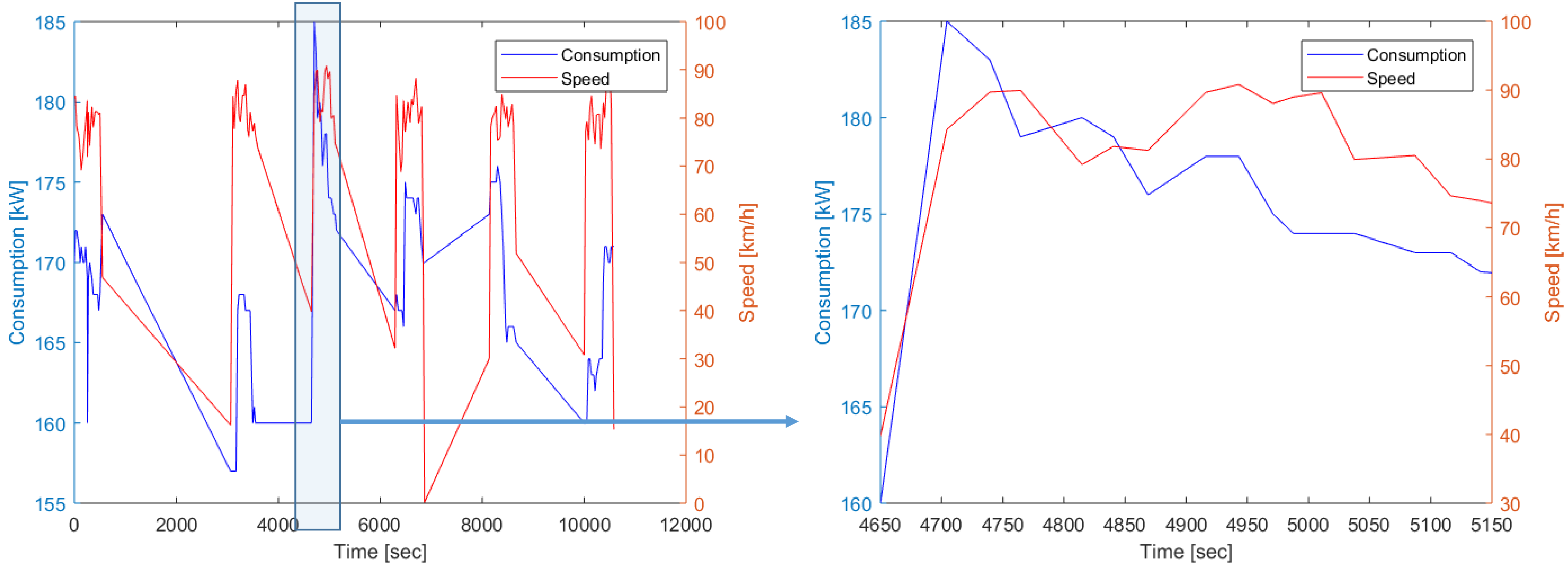
Accelerations, IRI and MPD (M13)



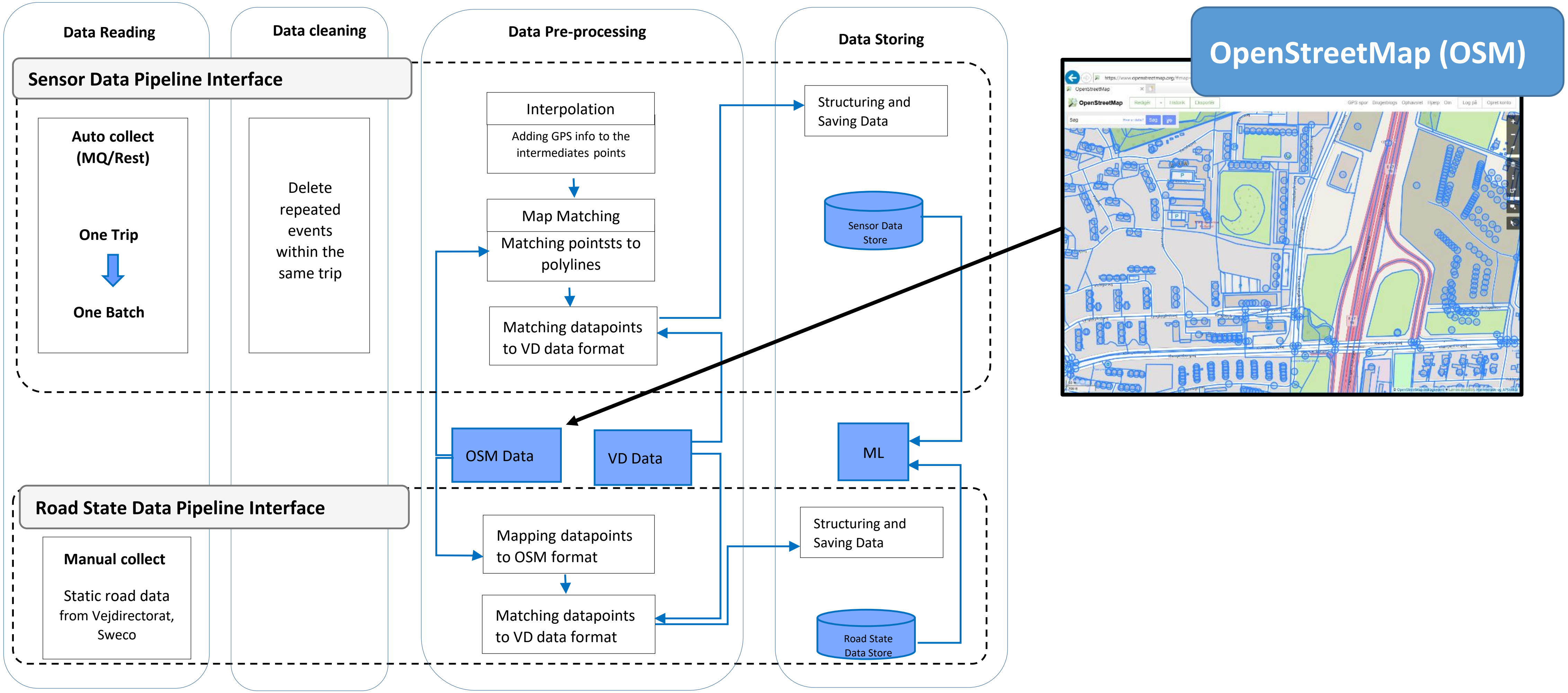




Energy consumption (M13)



Data Pipeline Interface

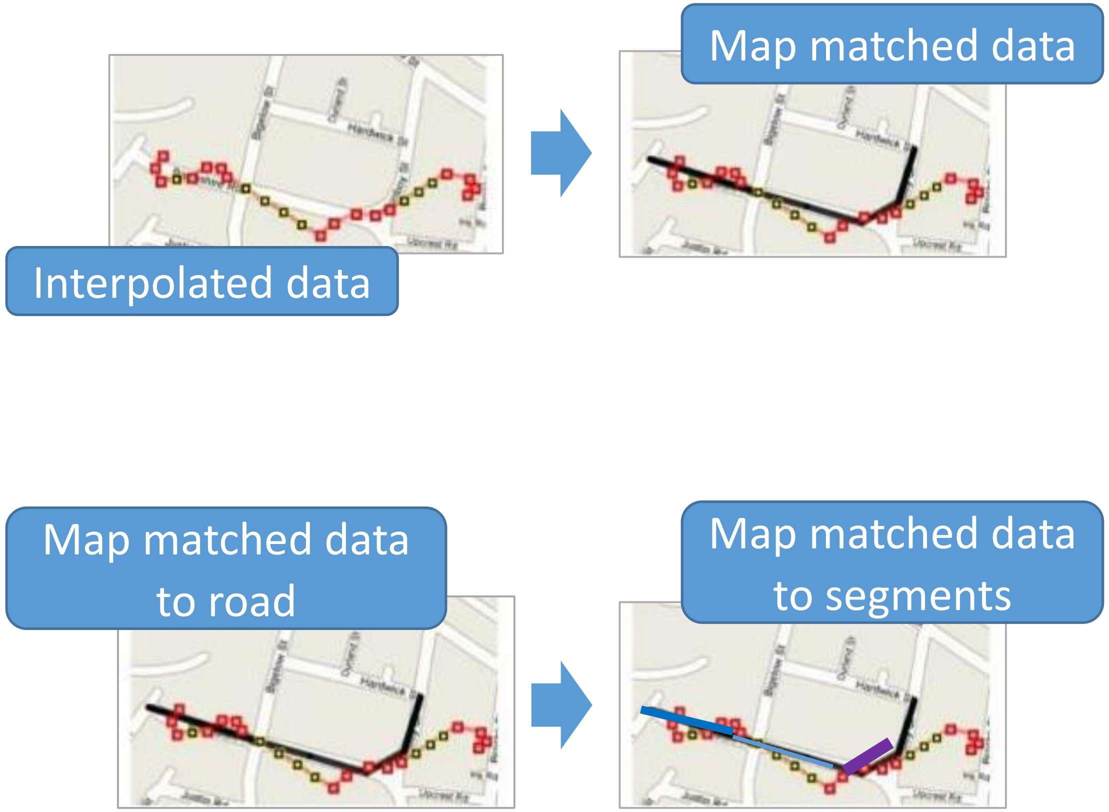


Pre-Processing: Map Matching

- Map-matching is the process of aligning a sequence of observed user positions with the **road** network on a digital map.
- Hidden Markov Model Map matching

  (Paul Newson and John Krumm, 2009)

- Map Matching Service from OSRM library
  - from Open Source Routing Machine(OSRM)
  - It matches/snaps given GPS points to the road network



Physical modelling$_{1/2}$

The idea of implementing physical modelling in the project is twofold:

a) Road event classification based on physical models

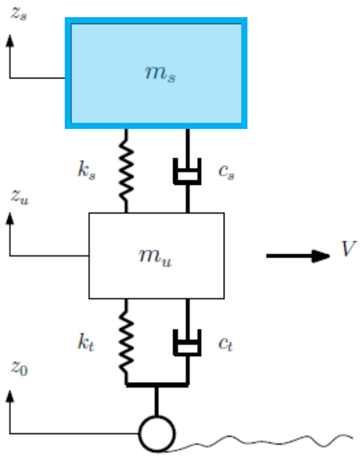
b) Road event classification based on hybrid machine learning models

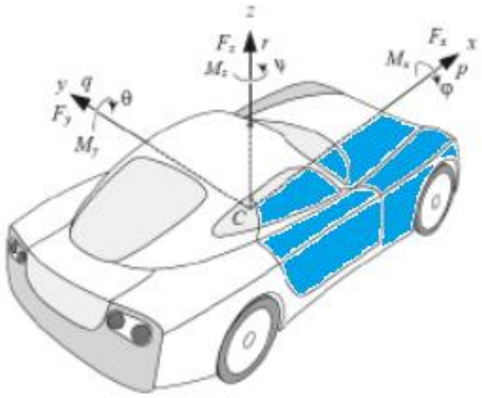
Related research questions to b):

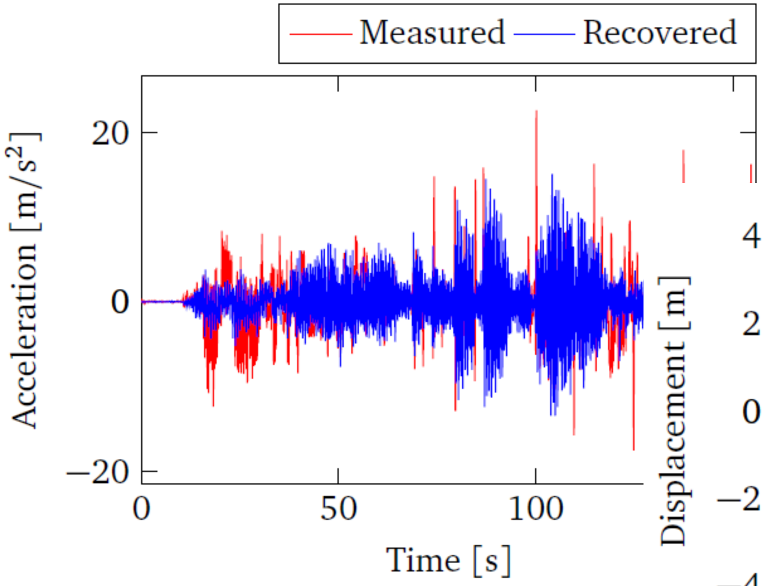
- To what level of detail can we classify and describe single road events
- Can single events be recognized when combining these events?
- What is the influence of noise in data (realistic scenario)?
- Can a physical models help improve efficiency or accuracy?

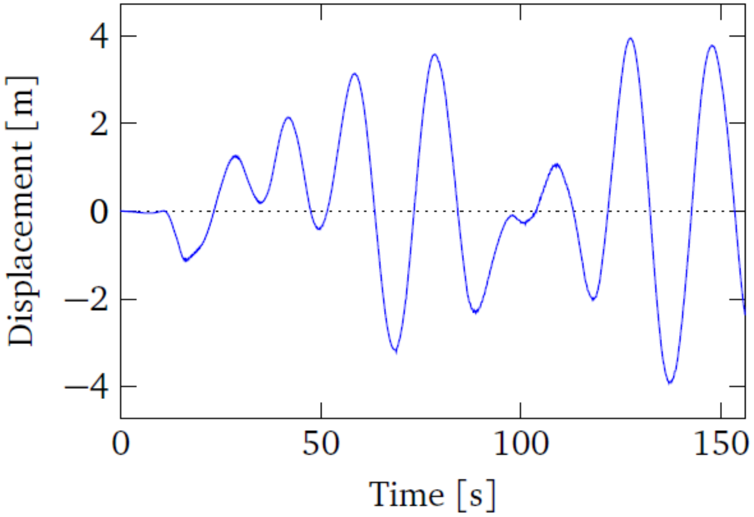
Physical modelling$_{2/2}$

- A quarter-car model is selected.
- The model includes the major dynamic effects.
- Input to this system is the road profile z_0 and vehicle velocity *V*.





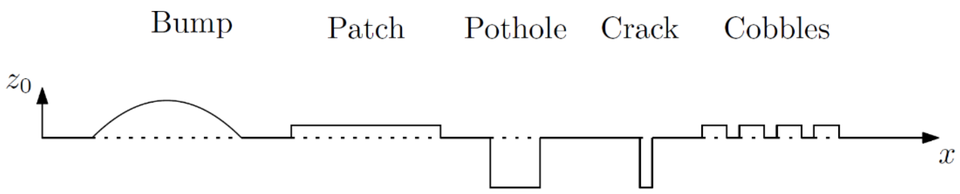


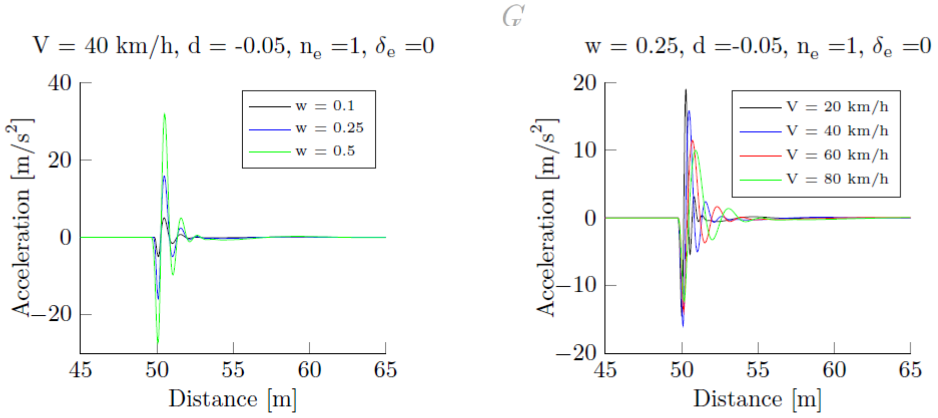


Application related to road condition, e.g.,

← **Recovery of road profiles**

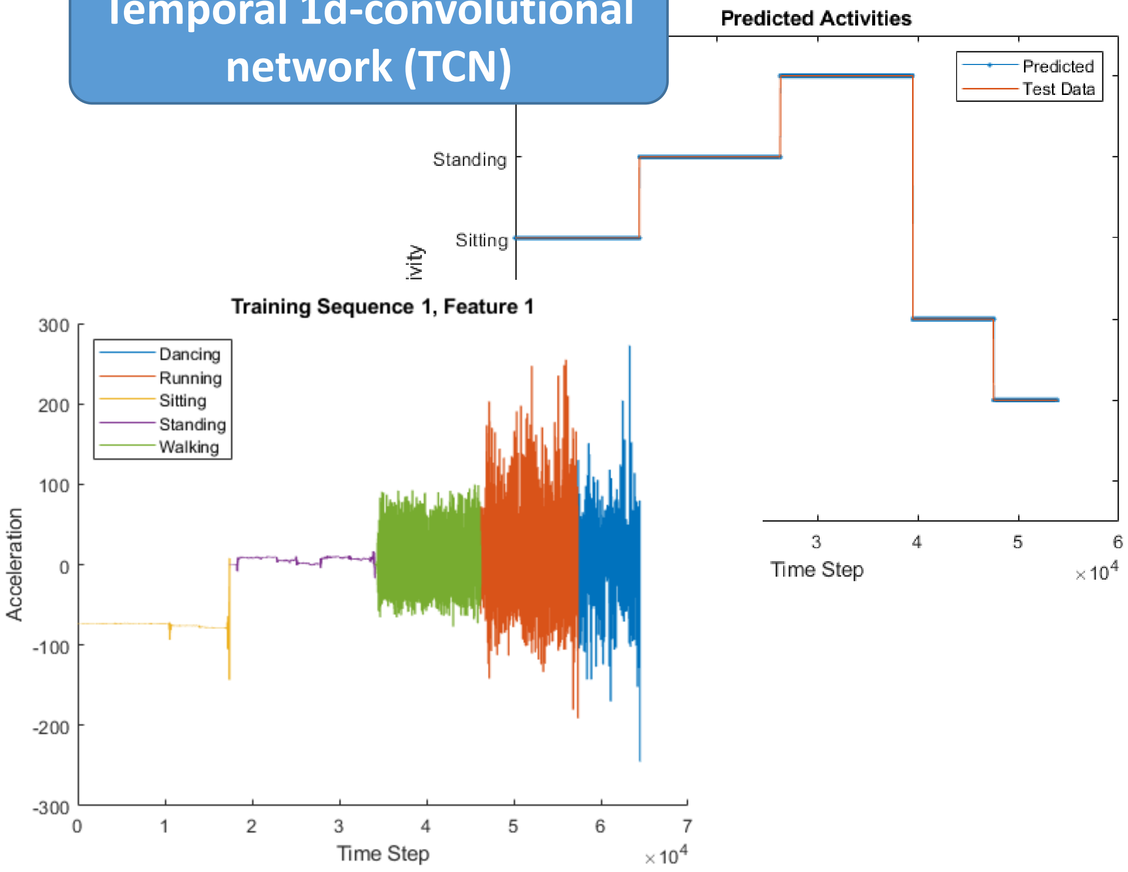
Machine learning





Synthetic data (simulation)

Temporal 1d-convolutional network (TCN)



Success criteria

1. **Operative road assessment system** based on the sensors in a homogenous car fleet;
2. **LiRA map** Demo (like VEJMAN but LIVE);
3. **Reliable algorithms** and models used to calculate road measures from car sensors data. 6 road measures of the 10 listed above should have an **accuracy higher than 80%**;
4. Hardware Configuration and **Set-up implementable on other cars** supported by validated calibration procedure;
5. **Guidelines** to develop a Live Road Assessment system.
6. Publications on national and international journals.

1. Friction
2. Cracking density
3. Potholes
4. Noise
5. IRI
6. Energy Expenditure
7. Patched area
8. Unevenness
9. Rutting depth
10. Texture depth