VDCA Swedish Vehicle Dynamics Competence Area

Proceedings from 2022 Vehicle Dynamics seminar

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The semniar is held annually. The full title of this year's seminar was "2021 Vehicle Dynamics seminar -- Connected and Electric".

The contents of these proceedings include both **presentations and poster material** and are published at https://research.chalmers.se/en/publication/532686. It will also be available at https://kth.diva-portal.org/ and https://www.sveafordon.com/.

The seminar was arranged by Vehicle Dynamics Competence Area and Swedish Vehicular Engineering Association (SVEA, https://www.sveafordon.com/).

The seminar was very appreciated and held both "in-real life" at LTH in Stockholm and remotely via "Teams". There were 75 registered participants from around 20 organisations, 8 presentations, and 4 poster presentations.

VDCA Swedish Vehicle Dynamics Competence Area

SVEA SWEDISH VEHICULAR ENGINEERING ASSOCIATION
SVERIGES FORDONSTEKNISKA FÖRENING

Contents

Note that the pdf file is generated with these “headings as pdf bookmarks”, so you can also navigate via the “bookmark pane” in your pdf reader.

Announcement of the Seminar

SWEDISH VEHICULAR ENGINEERING ASSOCIATION
SVERIGES FORDONSTEKNISKA FÖRENING

Seminars

2022 Vehicle Dynamics -- Connected and Electric (2022-05-18 09:00)

Seminarie: 2022 Vehicle Dynamics -- Connected and Electric

ENDORSED BY

FISITA

Vehicle Dynamics -- Connected and Electric

Wednesday May 18, 2022, 9-15
Lecture hall (Hörsal) D3, Lindstedtsvägen 9, KTH, Stockholm, Sweden

Hybrid seminar: Both in-real-life and on-line.

Please fill in the registration form to the right. Our appologies for that the registration form is in Swedish:

- "För- och Efternamn" means "First and Last Names"
- "Postadress" means "Mail address"
- "Postnummer" means "Zip code"

- "Stad" means "City"
- "Land" means "Country"
- "Telefonnummer" means "Phone number"
- "E-postadress" means "E-mail address"
- "Jag vill bli medlem" means "I want to apply for membership"
- "Anmäl dig till seminarie" means "Register to seminar"

You will get a confirmation e-mail when you are registered.

Additionally, if you will participate in-real-life, please send an e-mail to info@sveafordon.com. If you do not inform us that you will participate in-real-life, we will assume that you participate on-line.

We will order food (sponsored by SVEA) and send directions to "in-real-lifers".

We will send link to "on-liners".

Note 2022-05-03: We have experienced problems with registration. If you get an error messeage please ask to be registered in an e-mail to info@sveafordon.com. In that case, please remember to also tell if you participate in-real-life.

Purpose with the seminar

- Present and discuss interesting issues within and challenges for **Vehicle Dynamics -- Connected and Electric**
- Develop and increase competence
- Create understanding and interest for vehicle dynamics
- Networking between engineers and organisations and students

SVEAs objectives

- To make vehicular technology's voice heard in an increasingly more challenging debate among different vehicle types and transport modes both domestically and globally.
- To build a network for efficient distribution of technological information
- To attract the next generation of Swedish vehicular engineers

Agenda

[Times stated are in Swedish time]

09:00-09:15 Registration and coffee & Poster session

09:15-09:30 Intro

- *Welcome from SVEA and Vehicle Dynamics Competence Area,*
  Ingemar Johansson & Bengt Jacobson

Moderator: Lars-Gustaf Hauptmann

09:30-10:30 Lecture session 1

09:30-10:30 Lecture session 1

- *Using maps and location data to improve vehicle dynamics*,
  Petter Djerf, HERE Technologies
- *Predictive energy managment for heavy duty vehicles*,
  Olof Lindgärde, AB Volvo
- Micro-presentations of posters, part 1
  - *A study on the energy consumption impact of environmental parameters on heavy vehicles*, Manish Raathimiddi, Chalmers
  - *Heavy duty EPS and its theoretical requirements*, Christopher Essén and David Wikman, KTH and Scania

10:30-10:50 Coffee

10:50-11:50 Lecture session 2

- *Road surface identification and tyre-road property estimation using camera data*,
  Will Midgley, Loughborough University & Volvo Trucks
- *Vehicle as a sensor*, Bas Oremus, Scania
- Micro-presentations of posters, part 2
  - *Variable steering ratio design for steer-by-wire system*, Jakob Roempke and Gustav Lindahl, KTH and Volvo Carsa
  - *Driving Simulator Study on Crosswind Aerodynamics*, Anup Garje Mohan Kumar and Sai Kishan Sawanth, CEVT and Chalmers

11:50-12:50 Lunch, mingel

12:50-13:30 Lecture session 3

- *Path following and lateral stability of automated vehicles*,
  Wenliang Zhang, KTH
- *Towards automating High Capacity Transport vehicles*,
  Abhijeet Behera, VTI and LiU

13:30-14:00 Coffee

14:00-14:45 Lecture session 4: Automotive education

- *Vehicle Engineering MSc prog*,
  Mikael Nybacka, KTH
- *Mobility engineering MSc prog*,
  Giulio Bianchi Piccinini, Chalmers
- Questions and discussion about the automotive education

14:45-15:00 Questions and Wrap-up

Poster exhibition

There will be an exhibition of posters. It can be, e.g., master thesis or PhD thesis projects, both concluded and almost concluded such. Please contact Lars Drugge <larsd@kth.se>; or Bengt Jacobson <bengt.jacobson@chalmers.se> if you would like to propose a poster.

Each poster should do a "5 minutes micro-presentation with 2-4 slides". These slides will be printed also on paper and displayed at seminar site.

Proceedings

There will be proceedings from the seminar. This means that the presenters, including poster presenters, are welcome with a paper, or at least a public version of their presentation material. The proceedings will be available as a report on web; at www.sveafordon.com. It will include a list of participants.

Registration

Please fill in the registration form to the right on the top. (Translation in the first section of this page.)

Additionally, if you will participate in-real-life, please send an e-mail to info@sveafordon.com. If you do not inform us that you will participate in-real-life, we will assume that you participate on-line.

We want registration:

- latest Thursday 2022-05-12 (for "in-real-lifers", in order to order food)
- latest Monday 2022-05-16 (for "on-liners", in order to send out link).

Membership in SVEA

If you are not a member, we welcome you as a member.

Member fee in SVEA is 200 SEK/year (free for "junior 26-", 100 SEK for "senior 65+").

Membership application through: http://www.sveafordon.com/bli-medlem/vill-du-bli-medlem/medlemsansokan

Questions via e-mail to: info@sveafordon.com

The seminar is arranged by the Swedish Vehicle Dynamics Competence Area and hosted by SVEA with representatives from:

- *AstaZero*
- *CEVT*
- *Chalmers*
- *KTH*
- *VTI*
- *NEVS*
- *AFRY Automotive*
- *Scania*
- *Volvo Cars*
- *Volvo GTT*

VDCA Swedish Vehicle Dynamics Competence Area

SVEA SWEDISH VEHICULAR ENGINEERING ASSOCIATION

SVERIGES FORDONSTEKNISKA FÖRENING

Plats	KTH, Lecture hall (Hörsal) D3, Lindstedtsvägen 9 Stockholm, Sweden
Pris (medlem)	0 kr
Pris (junior/senior)	0 kr
Pris (ej medlem)	0 kr
Start	2022-05-18 09:00
Slut	2022-05-18 15:00

Anmälan

För- och Efternamn

Postadress

Postnummer

Stad

Land

Telefonnummer

bengt.jacobson@chalmers.se

Jag vill bli medlem

Anmäl dig till seminarie

SVEA
c/o L-G Hauptmann
Färåsvägen 14
428 37 KÅLLERED

Tel 031-169985
info@sveafordon.com

Registered participations

75 registered

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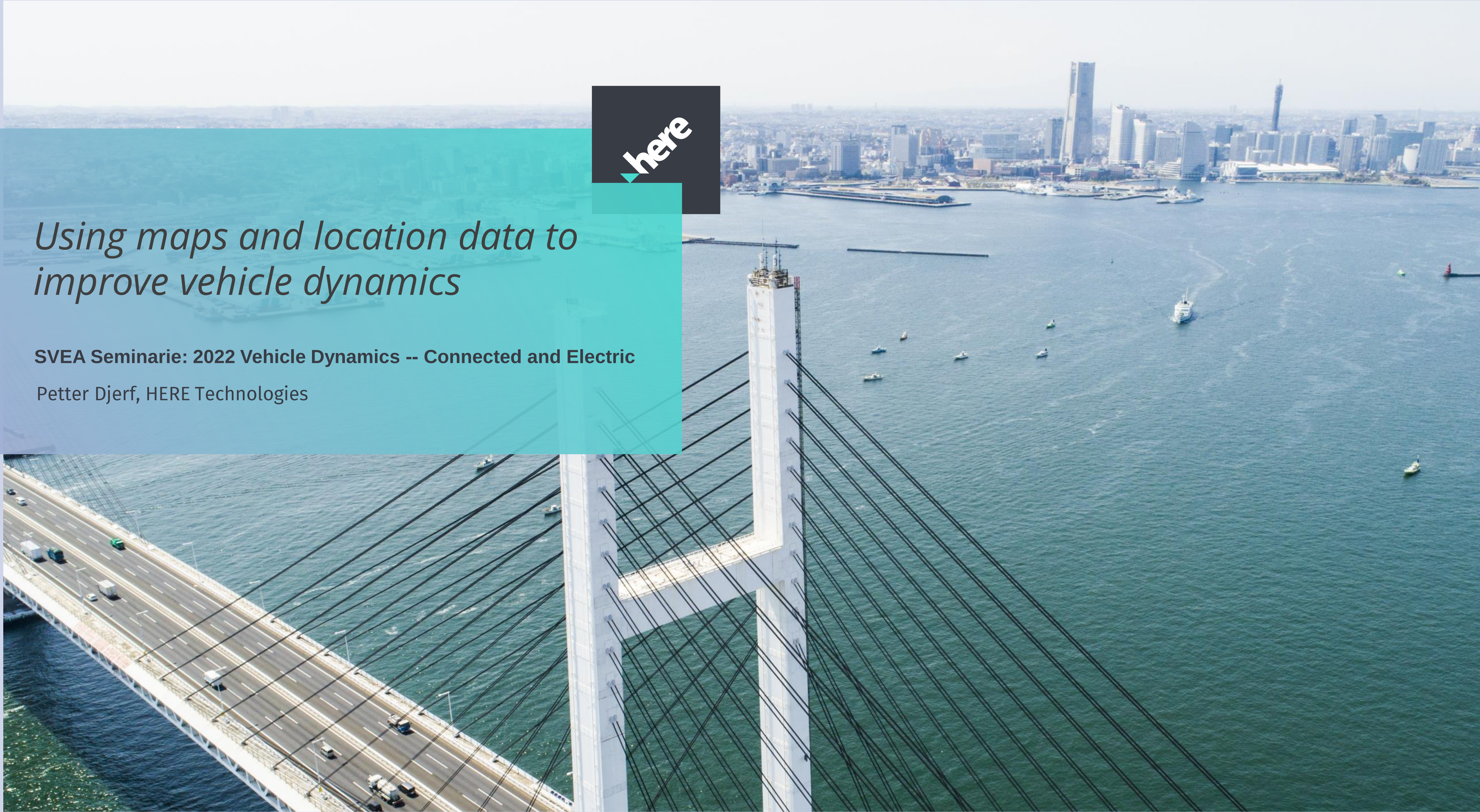
Presentation:

Using maps and location data to improve vehicle dynamics,

Petter Djerf, Here Technologies



Using maps and location data to improve vehicle dynamics

SVEA Seminarie: 2022 Vehicle Dynamics -- Connected and Electric

Petter Djerf, HERE Technologies

Global trends in Location Technology today…

AI & Machine Learning

Increasing **Regulations & Public Scrutiny**

Converging **Industries**

Transport & Mobility Revolution

Changing **Consumer Demands**

Platform Scale

Creating a DIGITAL REPRESENTATION of the PHYSICAL WORLD

35+
Years in mapmaking

#1
Location platform in analyst evaluations[1]

8,000
Employees

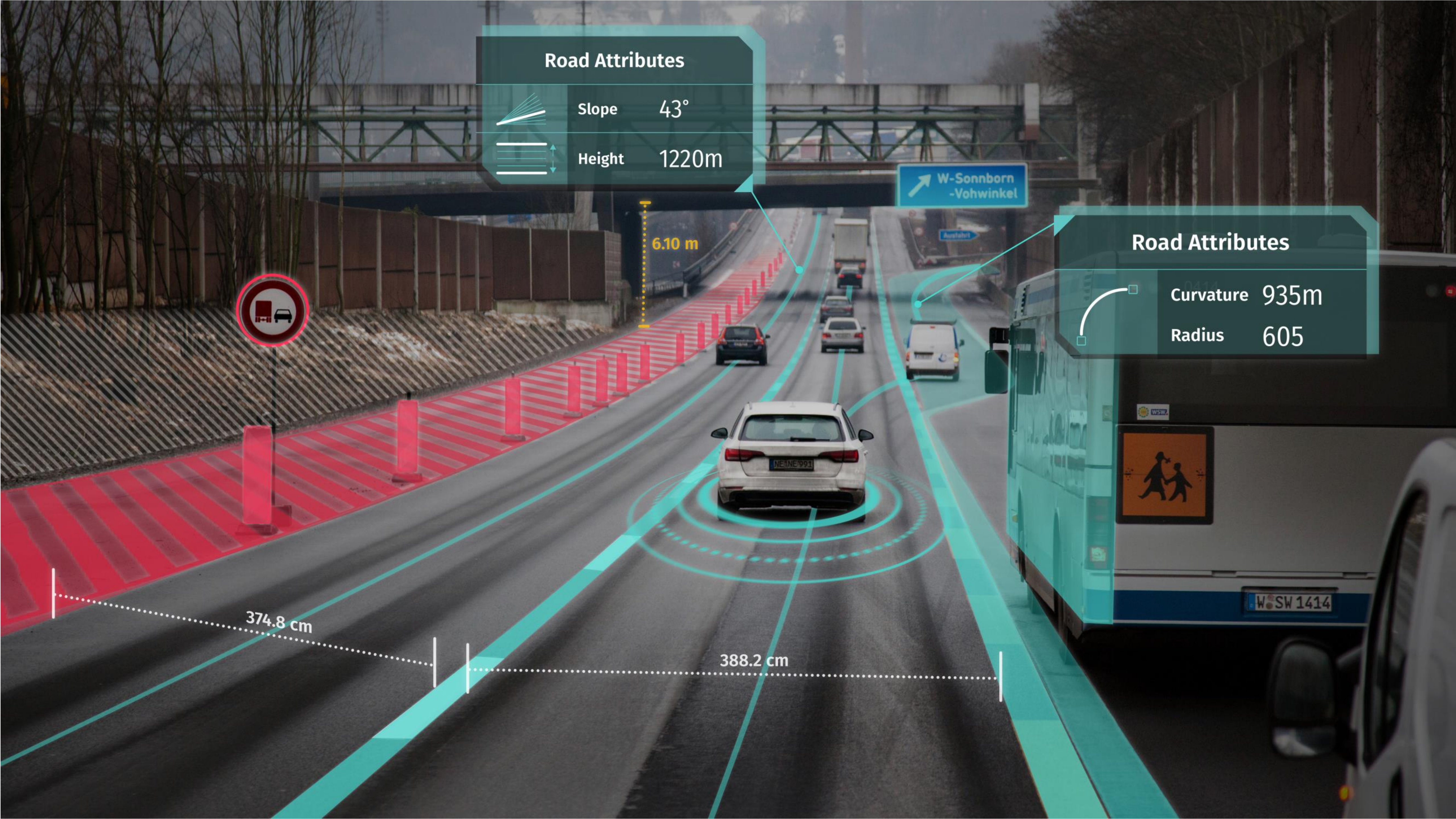
2m+
Developers in our ecosystem

190+
Countries & territories for which we provide data

160m+
Vehicles with HERE on board

200m+
Points of interest

15b+
Real-time probe data points ingested daily



Road Attributes
Slope 43°
Height 1220m
W-Sonnborn
-Vohwinkel
6.10 m
Road Attributes
Curvature 935m
Radius 605
374.8 cm
388.2 cm
W SW 1414


Where to?
When the World ...
Superclusive
Phone
Comfort doors
Massage
AUTO
Climate menu
AUTO
NW
W
N
SW
NE
300
330
SE

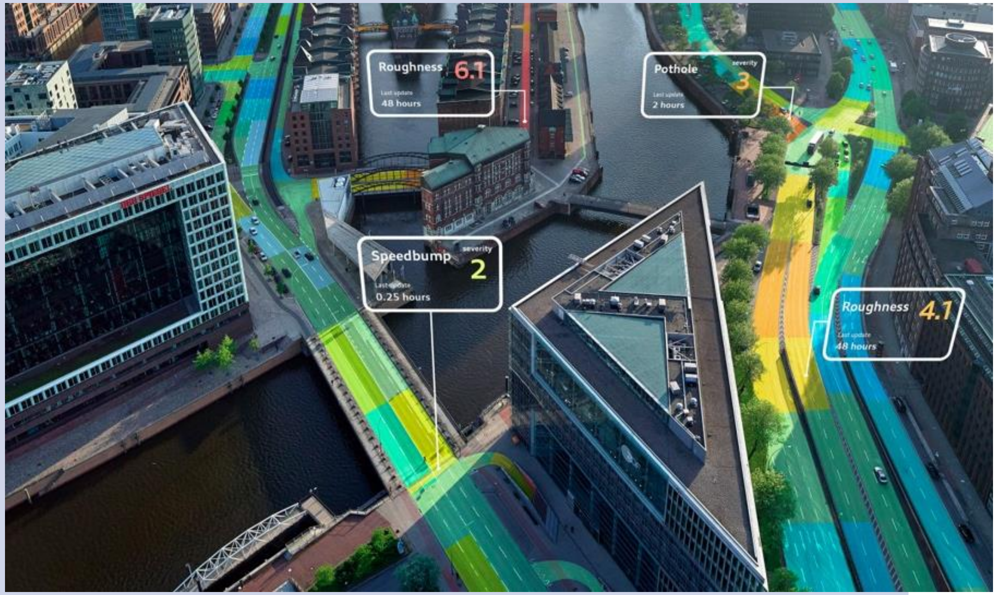
Daimler became the first customer to provide access to vehicle sensor data via HERE Neutral Server

- Vehicle Door Status
- Vehicle Electric Range
- Vehicle Fuel Status
- Vehicle Lights Status
- Vehicle Mileage
- Vehicle Window Status
- Safety related traffic
- Vehicle Battery Status
- Vehicle Odometer

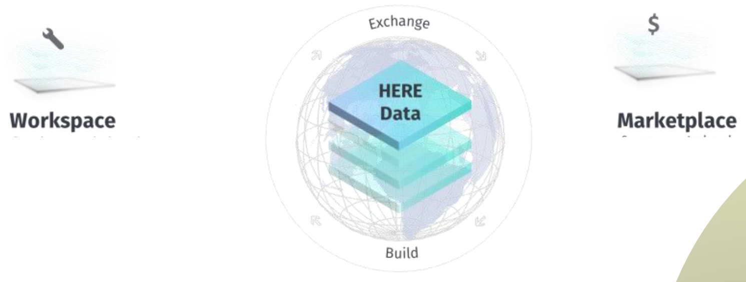
Examples of services,”virtual” sensors & use cases

- Road speed
- Probe data
- EV
- Friction / Grip
- Roughness
- Speedbump
- Pothole
- Aquaplaning
- Road resistance
- …

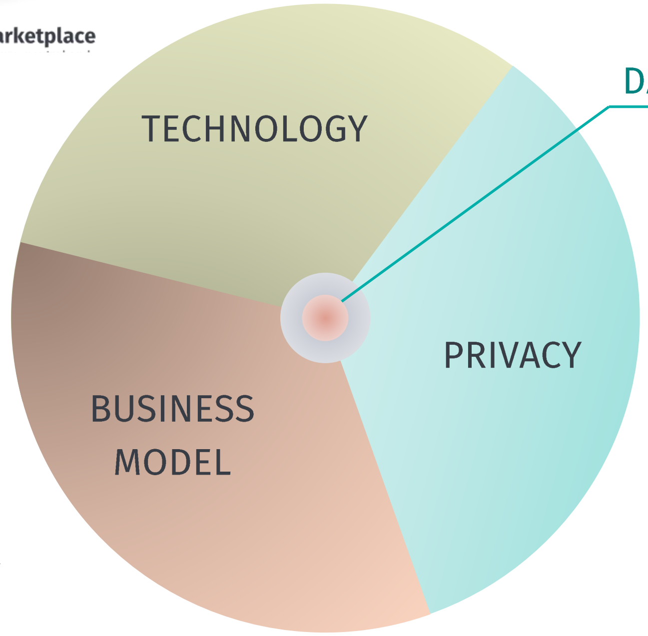
- Speed assist
- ADAS all kinds
- Traffic info
- Parking services
- Truck parking
- EV
- Friction alert
- Road hazards
- …



Overview vehicle dynamics – digital challenges



DATA DRIVEN VEHICLE DEVELOPMENT



How to enter a new market
How to protect the product
How to set the right price

Consent in time
Consent technology
Anonymization
Safety regulations

THANK YOU!

Petter Djerf

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Presentation:

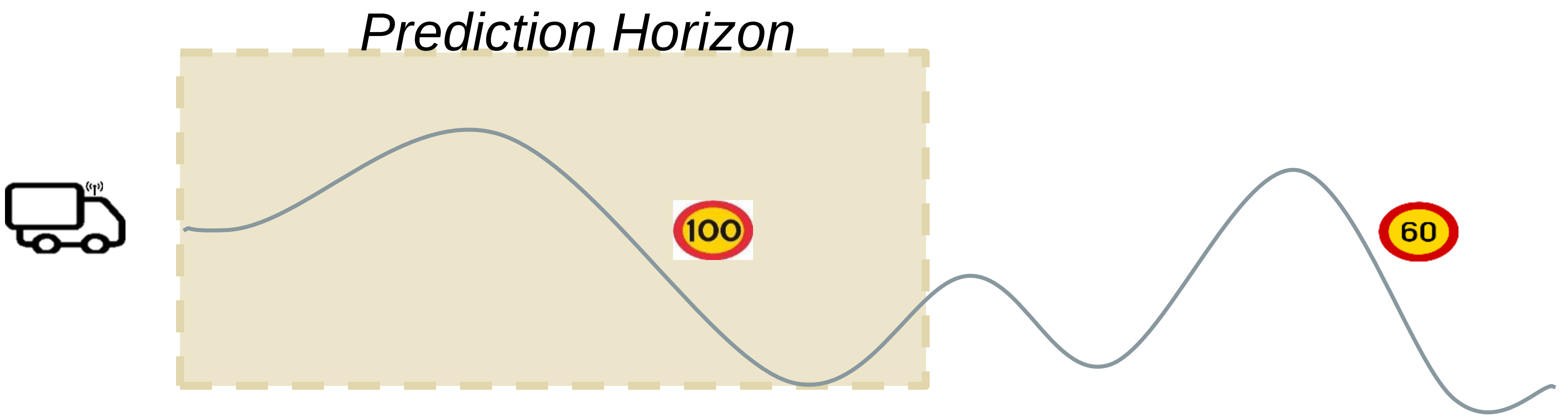
Predictive energy management for heavy duty vehicles,

Olof Lindgärde, AB Volvo

Predictive Energy Management for Heavy Duty Vehicles

Olof Lindgärde

Presenting the idea



Task: Minimize fuel consumption

Constraints: Speed within upper and lower bounds

Output: Speed, gear and eco roll (engine off)

Approach:

- Model based optimal control using prediction

Goal:

- Improve performance
- Improved variant handling and reduce calibration effort

Optimize the propulsion over a predicted horizon

$$\min_{u_c, u_d} \int_{t_0}^{t_f} J(x, u_c, u_d)dt$$

Minimize fuel (or losses)
+ penalties (e.g. using disk brake)

$$\dot{x} = f(x, u_c, u_d)$$

Prediction Models

$$x^{min} \leq x \leq x^{max}$$

State Bounds

$$u_c^{min} \leq u_c \leq u_c^{max}$$
$$u_d^{min} \leq u_d \leq u_d^{max}$$

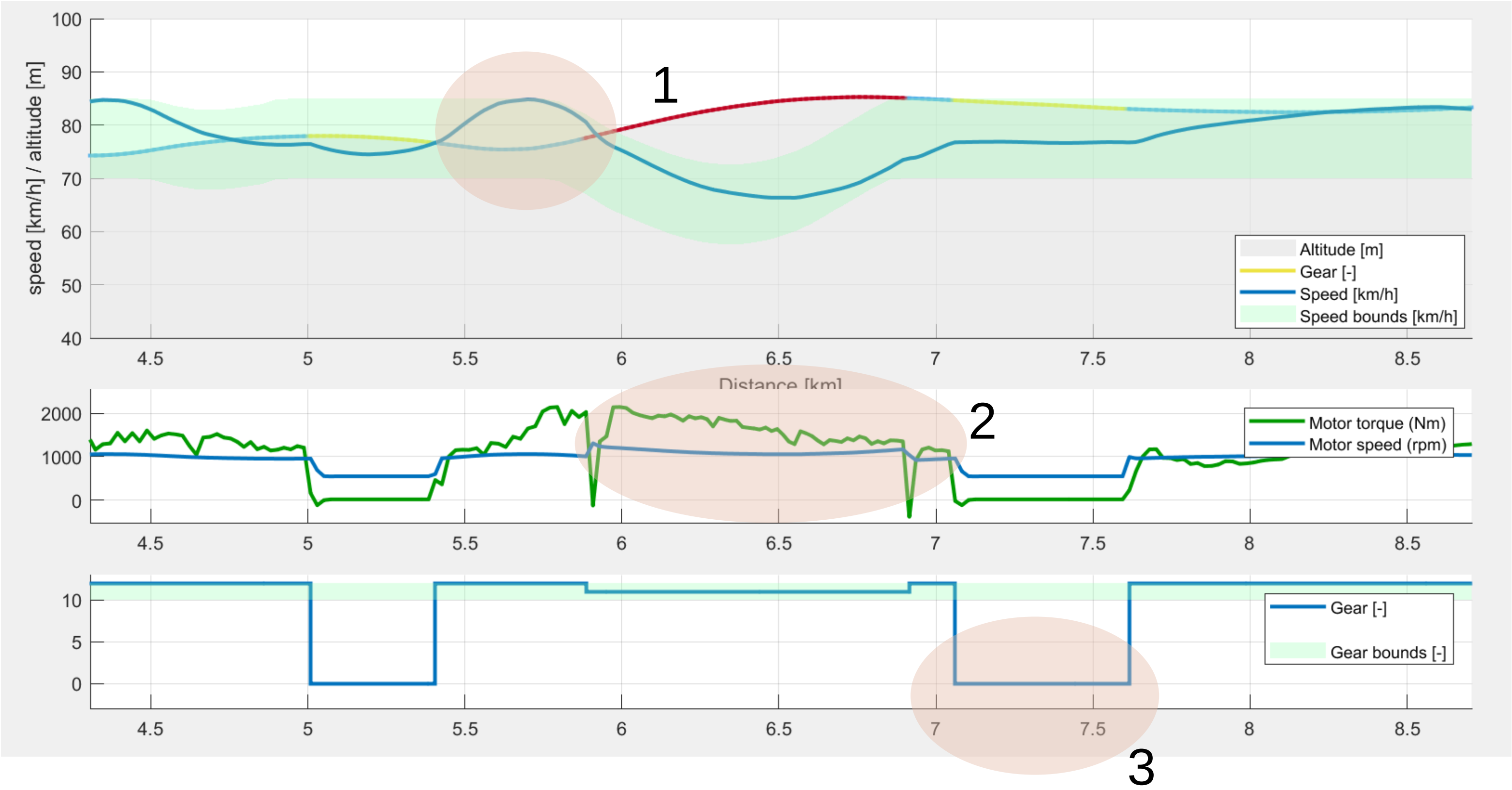
Actuator Bounds

States (vehicle kinetic energy & battery state of charge)

Continuous actuators (engine & EM torque)

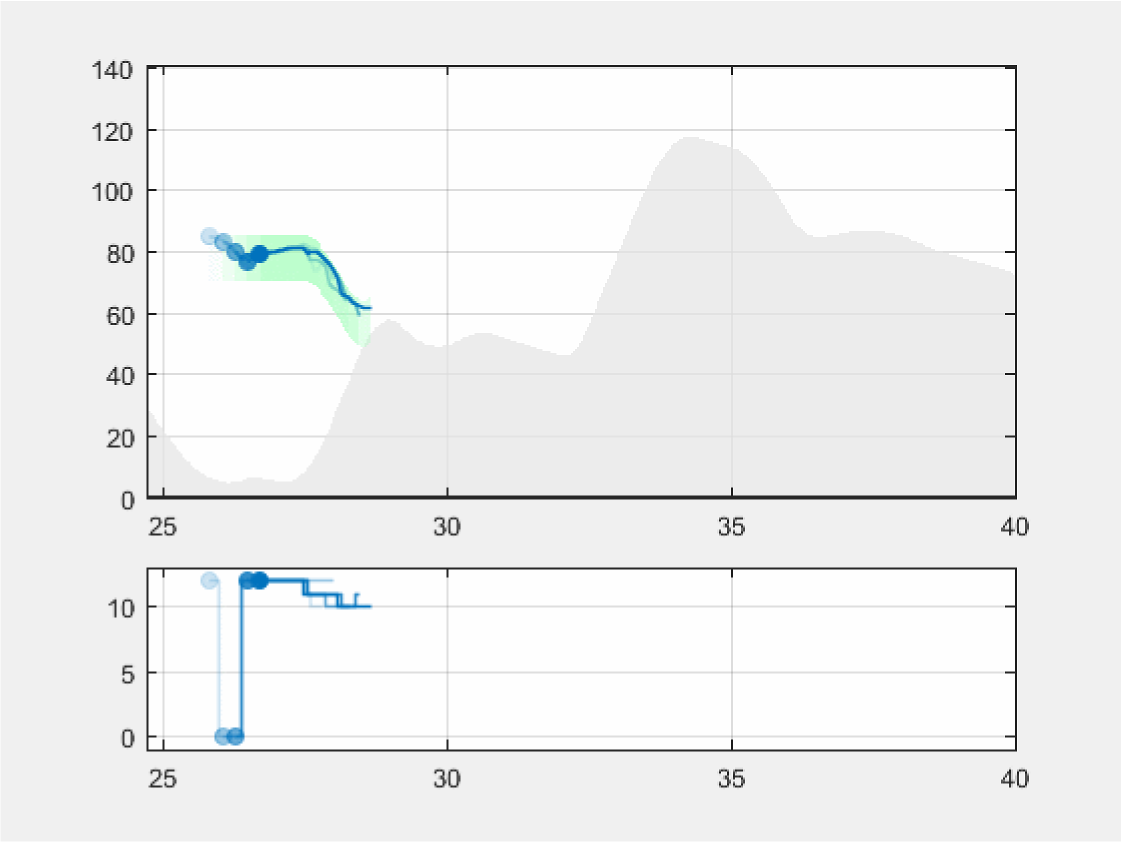
Discrete actuators (gears and clutches)

A simulation example



1. Pre-speed;
2. Gradual torque reduction on crest;
3. Eco roll.

Speed/Gear Trajectories



Way of Working

DEVELOP

SIMULATE

Software In the Loop

TEST

- Bench Test
- Road Tests

Some learnings

Strengths

- Modularity, easy to adapt to various configurations
- Reduces calibrations effort
- Adapt to requirements

Challenges and potential weaknesses

- Debugging
- Formulate correct model and cost function
- Computational effort/Memory footprint

Some Learnings:

- Mix discretes/continous: difficult
- This approach also valuable on electrified vehicles:
  - more focus on life than on energy consupmtion

Presentation:

Road surface identification and tyre-road property estimation using camera data,

Will Midgley, Loughborough University and Volvo Trucks

Road surface identification and tyre-road property estimation using camera data

Mohammad Otoofi, Will Midgley & Laura Justham – Loughborough University

Leo Laine, Leon Henderson – Volvo Trucks

Loughborough University

Loughborough University

- 5th in the UK for Mechanical Engineering (Guardian)
- Top 100 in the world for Mechanical, Aeronautical and Manufacturing Engineering
- Awarded 7 Queen's Anniversary Prizes for higher and further education
- Largest engineering activity in the UK
- 93% of research outputs "internationally excellent" or "world-leading" (REF2021)
- WhatUni Top University for Facilities 2020
- QS Rankings 5*+ university

The Project

Motivation

- Friction coefficient is important for:
  - Active safety systems (ASS)
    - Emergency collision avoidance (ECA)
    - Anti-lock braking system (ABS)
    - ...
  - Advanced driver-assistance systems (ADAS)
  - Autonomous navigation systems

- Current methods:
  - Effect-based methods
    - Estimating dynamic parameter response of the vehicle
  - Cause-based methods
    - Identifying the factors affecting friction, e.g. surface type

- What if we can use computer vision?

Previous experimental investigations using thermal imaging [1]

[1] Jonsson, Patrik, Johan Casselgren, and Benny Thörnberg. "Road surface status classification using spectral analysis of NIR camera images." IEEE Sensors Journal 15, no. 3 (2014): 1641-1656.

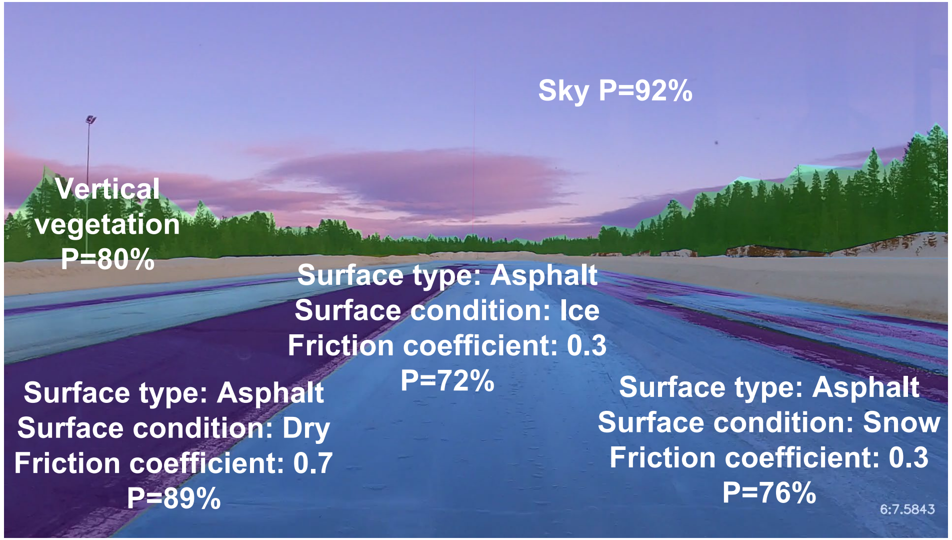
Our Approach

- Use machine learning and computer vision:
  - Determine the properties ahead in a similar way to a human driver

This breaks down into two tasks:

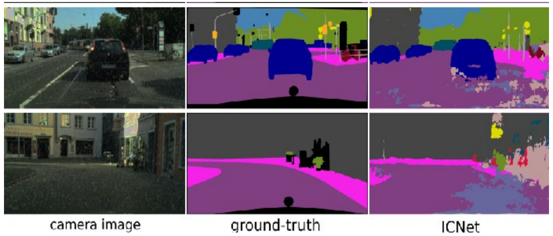
1. Surface detection/categorisation
2. Friction coefficient estimation

1. Surface detection/Categorisation:
   - *Semantic segmentation*: pixel-by-pixel classification of image into surface types and surface condition
2. Friction
   - Detected regions are fed to a second function to provide an estimate of friction coefficient

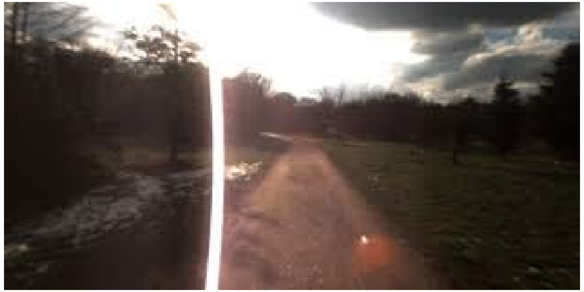


Challenges

- Producing a scalable solution:
  - Performing in real-time
  - Using a *monocular* dashcam
- Ambiguous situations
  - Inherent noise in environment
    - Sun glare
    - Shadows
    - Poor visibility
    - Fog
    - Rain
    - Snow
  - **Solution**: *multiple hypotheses*



Previous work on semantic segmentation [1]



Example of difficult operating conditions [2]

[1] Pfeuffer, Andreas, and Klaus Dietmayer. "Robust Semantic Segmentation in Adverse Weather Conditions by means of Fast Video-Sequence Segmentation." In 2020 IEEE 23rd International Conference on Intelligent Transportation Systems (ITSC), pp. 1-6. IEEE, 2020.
[2] Valada, Abhinav, Johan Vertens, Ankit Dhall, and Wolfram Burgard. "Adapnet: Adaptive semantic segmentation in adverse environmental conditions." In 2017 IEEE International Conference on Robotics and Automation (ICRA), pp. 4644-4651. IEEE, 2017.

Challenges II

- Lack of data
  - No visual data for friction estimation
  - Desired categories cannot be found in any dataset
  - Rural environment
  - **Solution**: Vehicle testing with Volvo Trucks on a range of surfaces

Dataset	Real	Location Accuracy	Diversity	Annotation			
				3D	2D	Video	Lane
CamVid	✓	-	day time	no	pixel: 701	✓	2D / 2 classes
Kitti	✓	cm	day time	80k 3D box	box: 15k pixel: 400	-	no
Cityscapes	✓	-	day time 50 cities	no	pixel: 25k	-	no
Toronto	✓	cm	Toronto	focus on buildings and roads exact numbers are not available[1]			
Mapillary	✓	meter	various weather day & night 6 continents	no	pixel: 25k	-	2D / 2 classes
BDD100K	✓	meter	various weather day 4 regions in US	no	box: 100k pixel: 10k	-	2D / 2 classes
SYNTHIA	-	-	various weather	box	pixel:213k	✓	no
P.F.B.	-	-	various weather	box	pixel:250k	✓	no
ApolloScape	✓	cm	various weather day time 4 regions in China	3D semantic point 70K 3D fitted cars	pixel: 140k	✓	3D / 2D Video 27 classes

[1] database is not open to public yet.

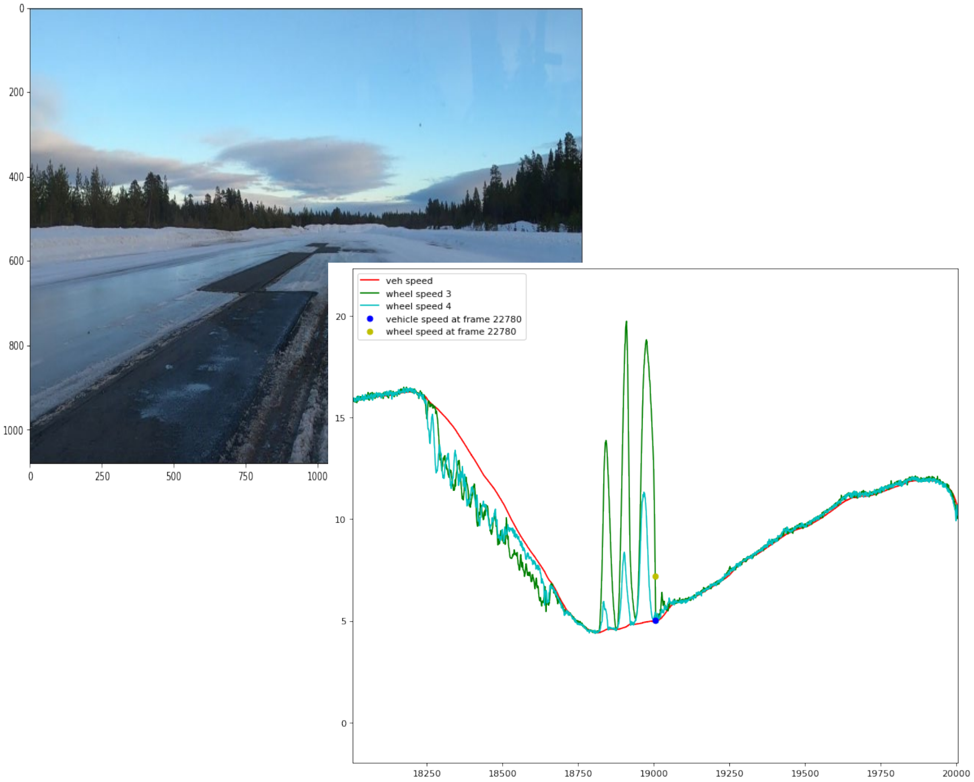
Summary of available data sources [1]

[1] Huang, Xinyu, Xinjing Cheng, Qichuan Geng, Binbin Cao, Dingfu Zhou, Peng Wang, Yuanqing Lin, and Ruigang Yang. "The apolloscape dataset for autonomous driving." In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops, pp. 954-960. 2018.

Current Progress

Results from Winter Testing

- Data gathering for friction coefficient estimation
- Measuring friction ground truth using GPS, vehicle data, and dashcam
- Building our own dataset for friction estimation

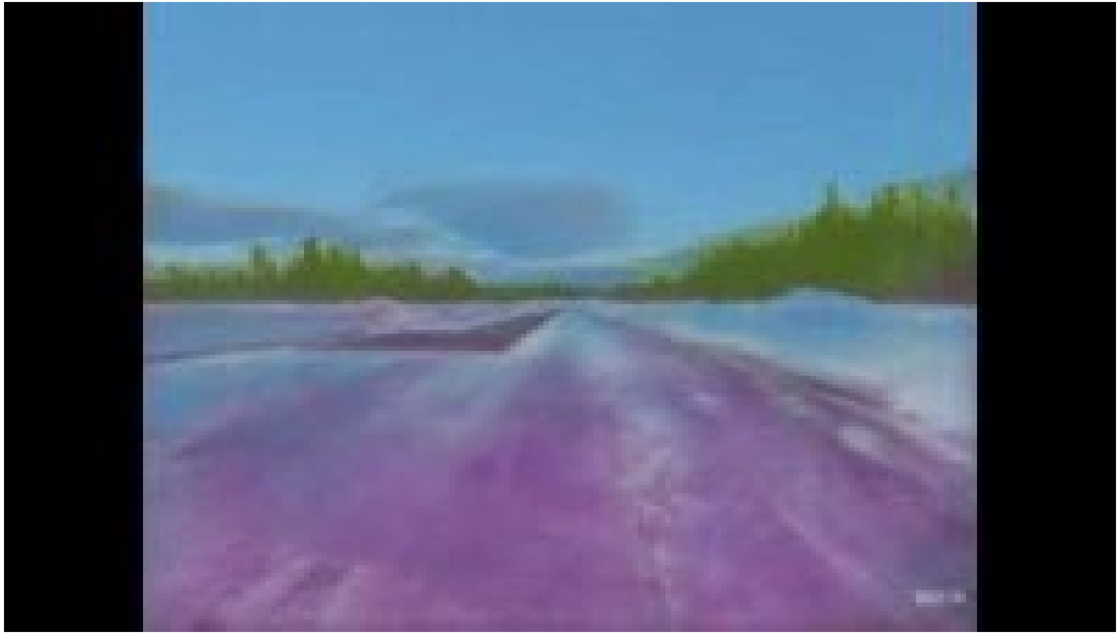


Semantic Segmentation

- INPLACE-ABN trained on Mapillary dataset [Meta AI]
- Doesn't cover all the categories we are interested in
- Generates point estimate not probabilistic outputs
- No friction estimate

Semantic Segmentation

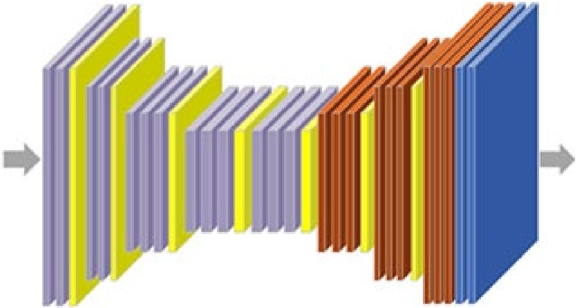
- UNet architecture
- Trained on Mapillary dataset [by Mohammad]

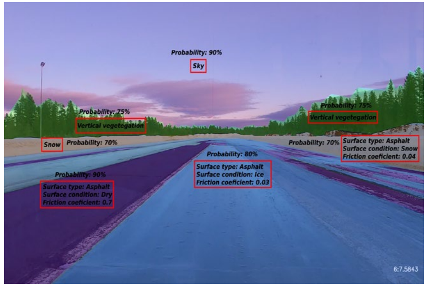


Solution Architecture

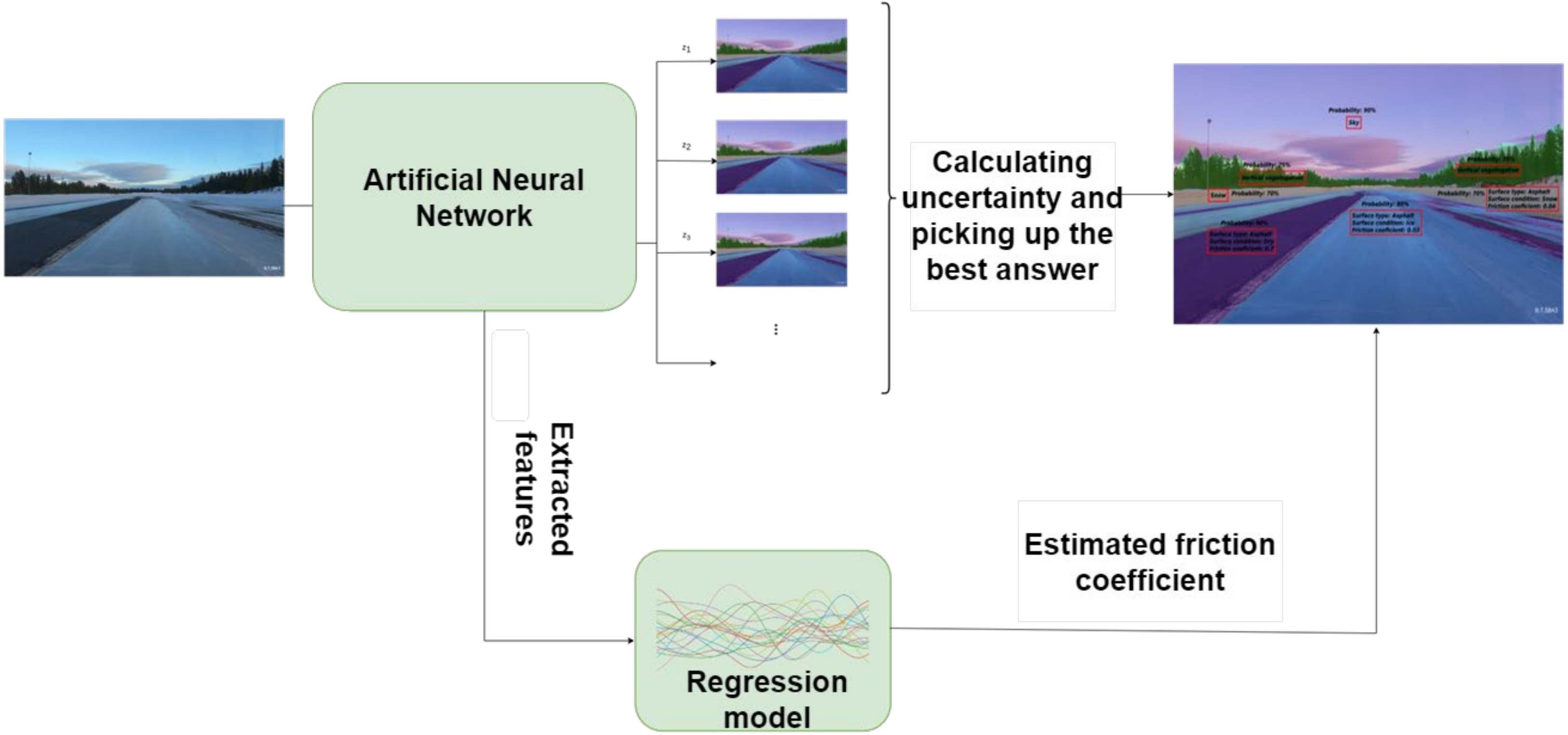
Proposed Solution:

- Detecting surface characteristics
  - Semantic segmentation
  - Probabilistic method
- Estimate friction coefficient
  - Regression
- Synthetic data
  - Generating samples for the desired categories
- Winter testing 2022
  - Gathered more samples for friction estimation





Method – System Overview



Questions?

Presentation:

***Vehicle as a sensor*,**

Bas Oremus, Scania

BAS OREMUS

VEHICLE AS A SENSOR

SCANIA

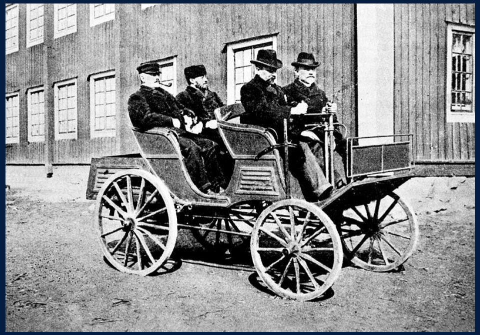
BAS OREMUS

STARTED AT SCANIA 2003

- TEST ENGINEER VEHICLE DYNAMICS
- SW DEVELOPER WITHIN DRIVER SUPPORT
- MANAGER CONNECTED PLATFORM
- MANAGER ONLINE LOCATION INTELLIGENCE
- RESEARCH ENGINEER AUTONOMOUS SYSTEMS

SCANIA

THE TRUCK, AN ISOLATED SYSTEM <2011



1897

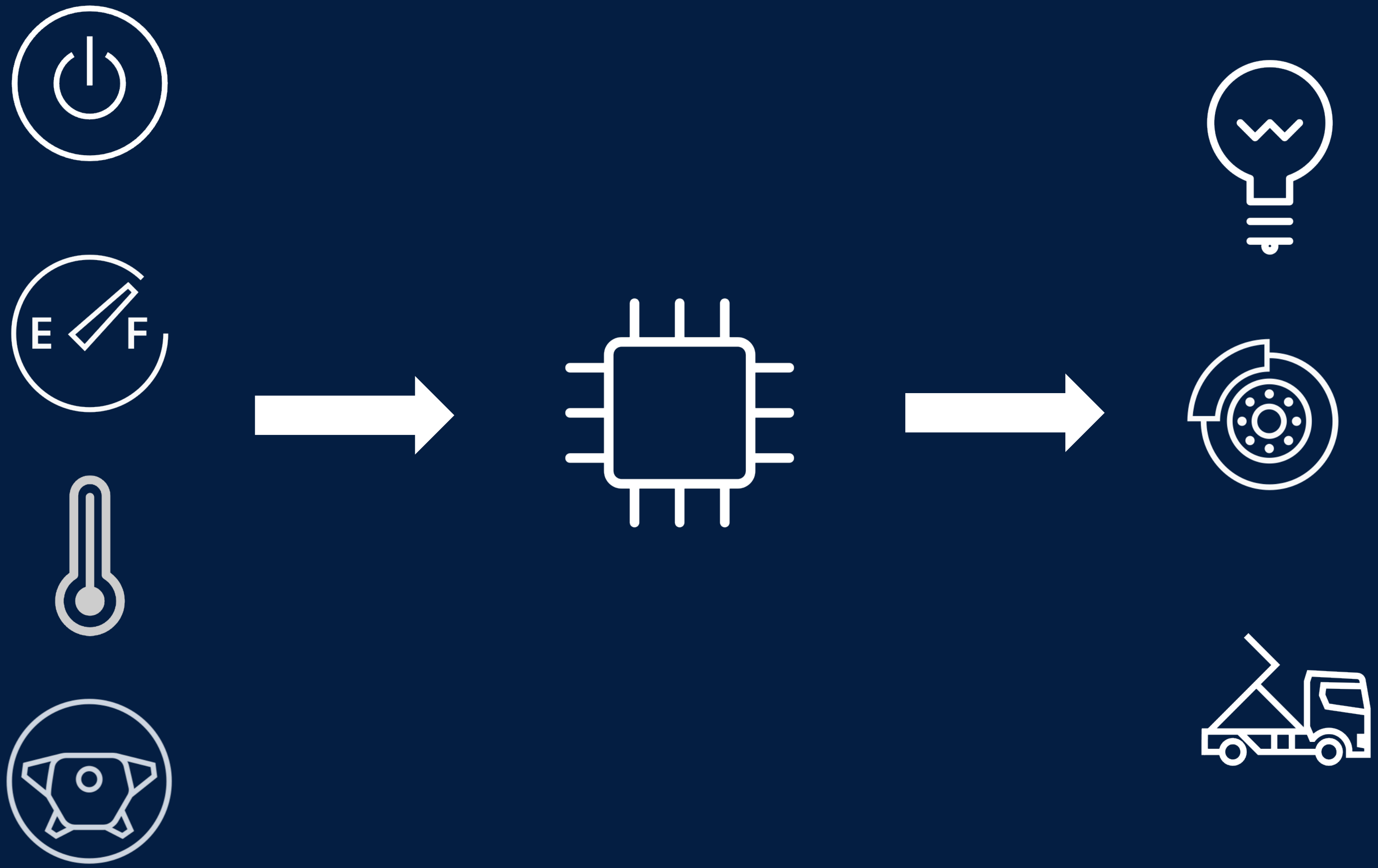
1923

0-series
1970

4-series
1995

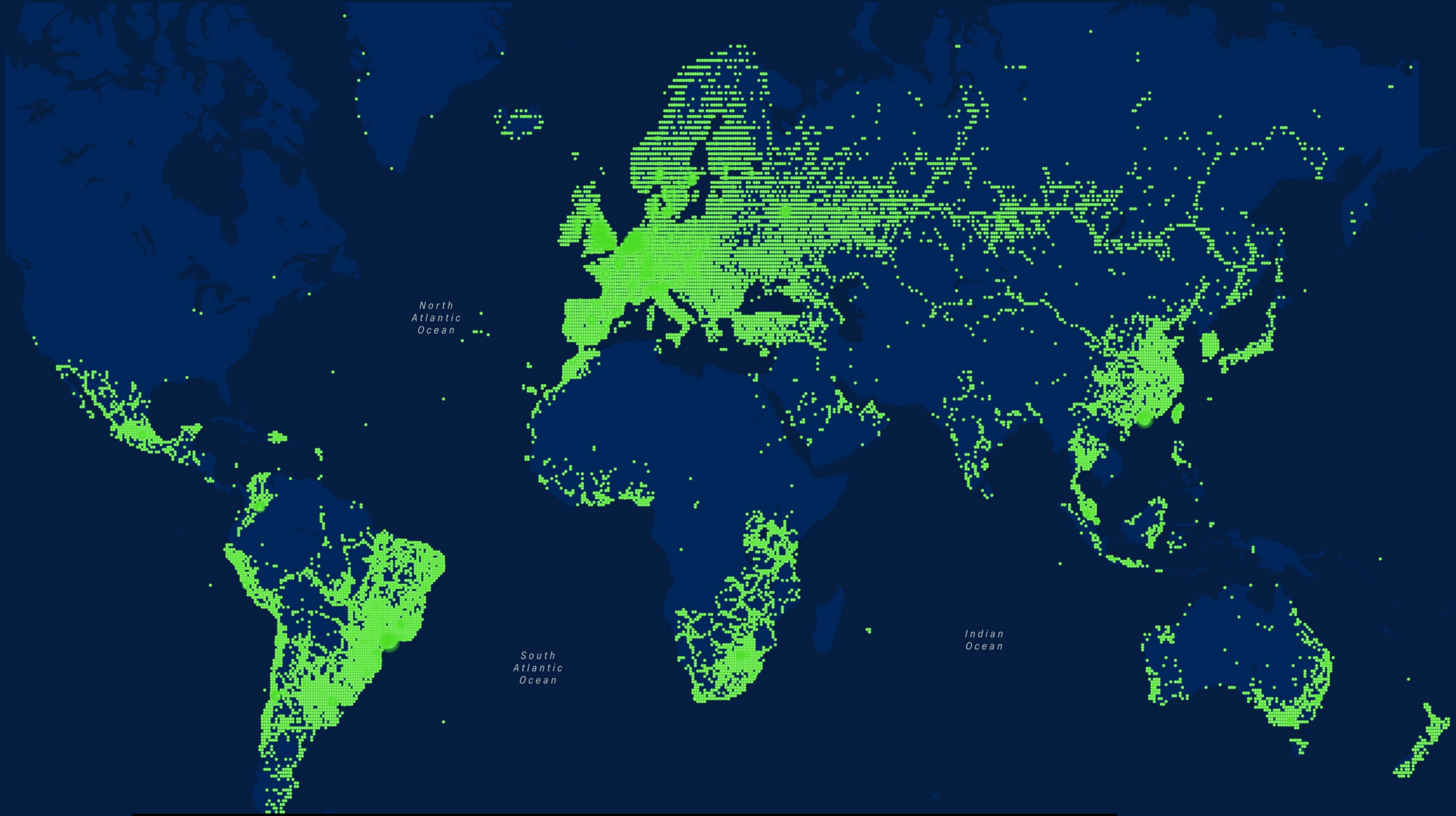
PGRS-series
2004

A FUNCTION



IN 2011 WE STANDARDISED CONNECTIVITY

550.000+ CONNECTED VEHICLES

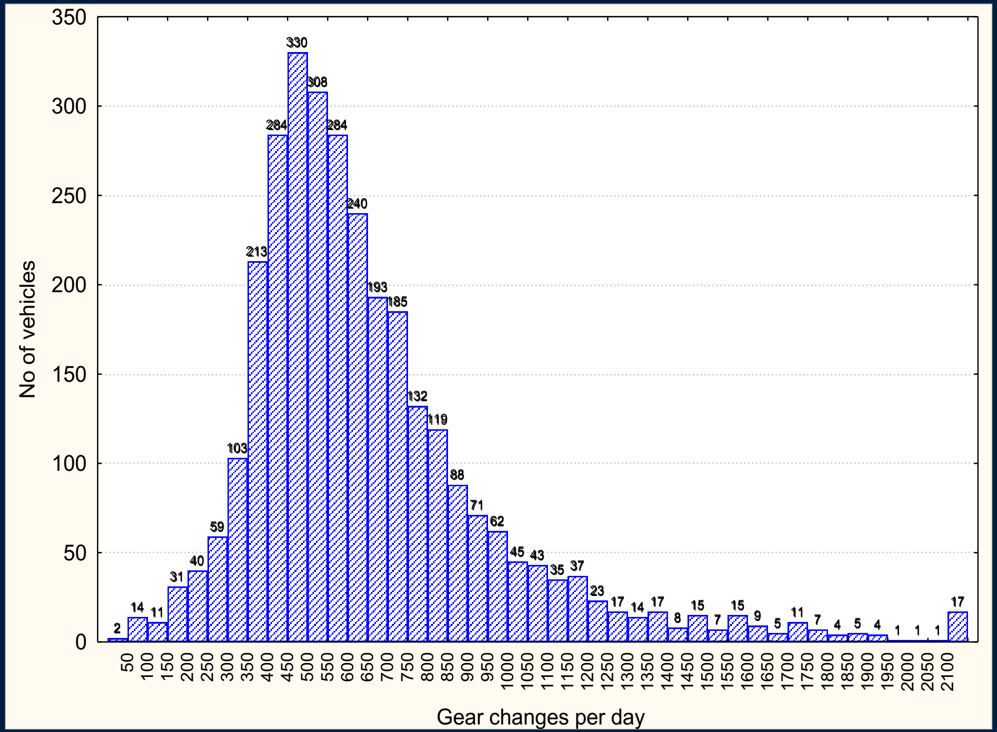


CONNECTED FUNCTION

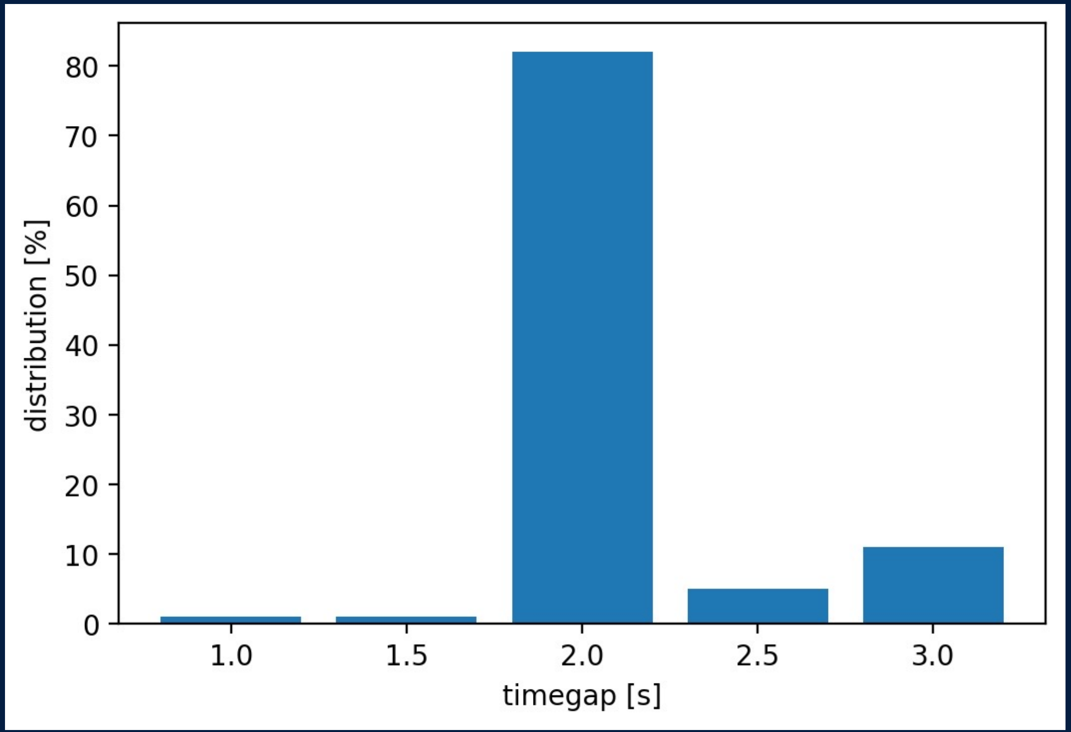
- Daily contact with factory
- Data collection
  - Digital twin
  - Vehicle is sensor for itself
- Data analytics

DATA DRIVEN PRODUCT DEVELOPMENT

Dimension the hardware:
Automatic clutch

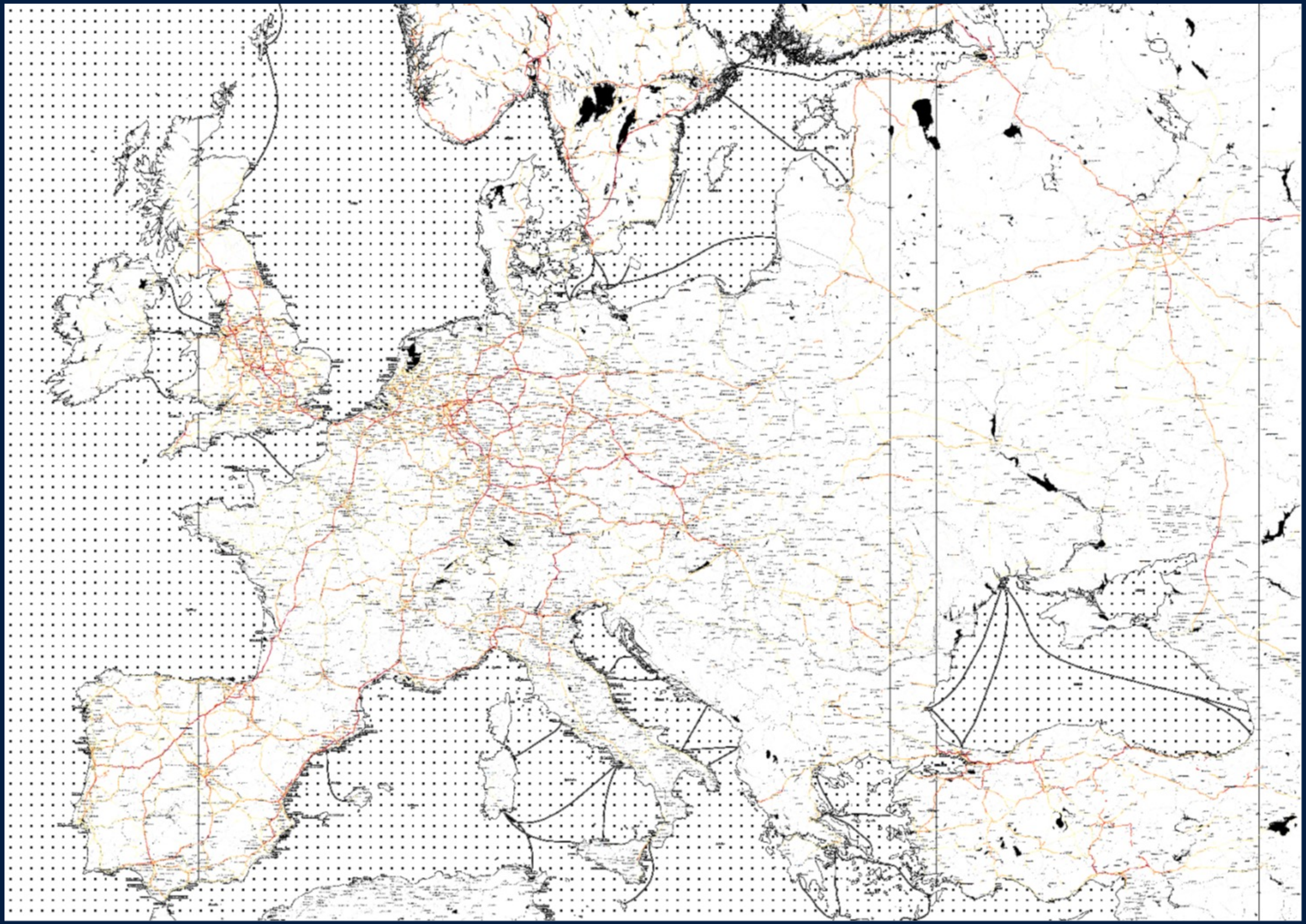


Decide a parameter setting:
Timegap for adaptive cruise control



Most people use default (2) or higher, let’s make it longer

CONNECTIVITY ENABLES GEOSPATIAL ANALYTICS



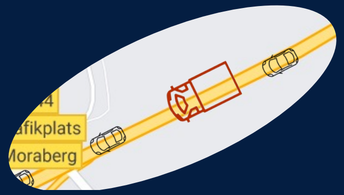
Fuel Consumption on Motorway

MACHINE LEARNING

DRIVER IS RESPONSIBLE

- Functions to assist the driver
- Compromise between safety and drivability

AUTOMATED VEHICLES & CONNECTIVITY



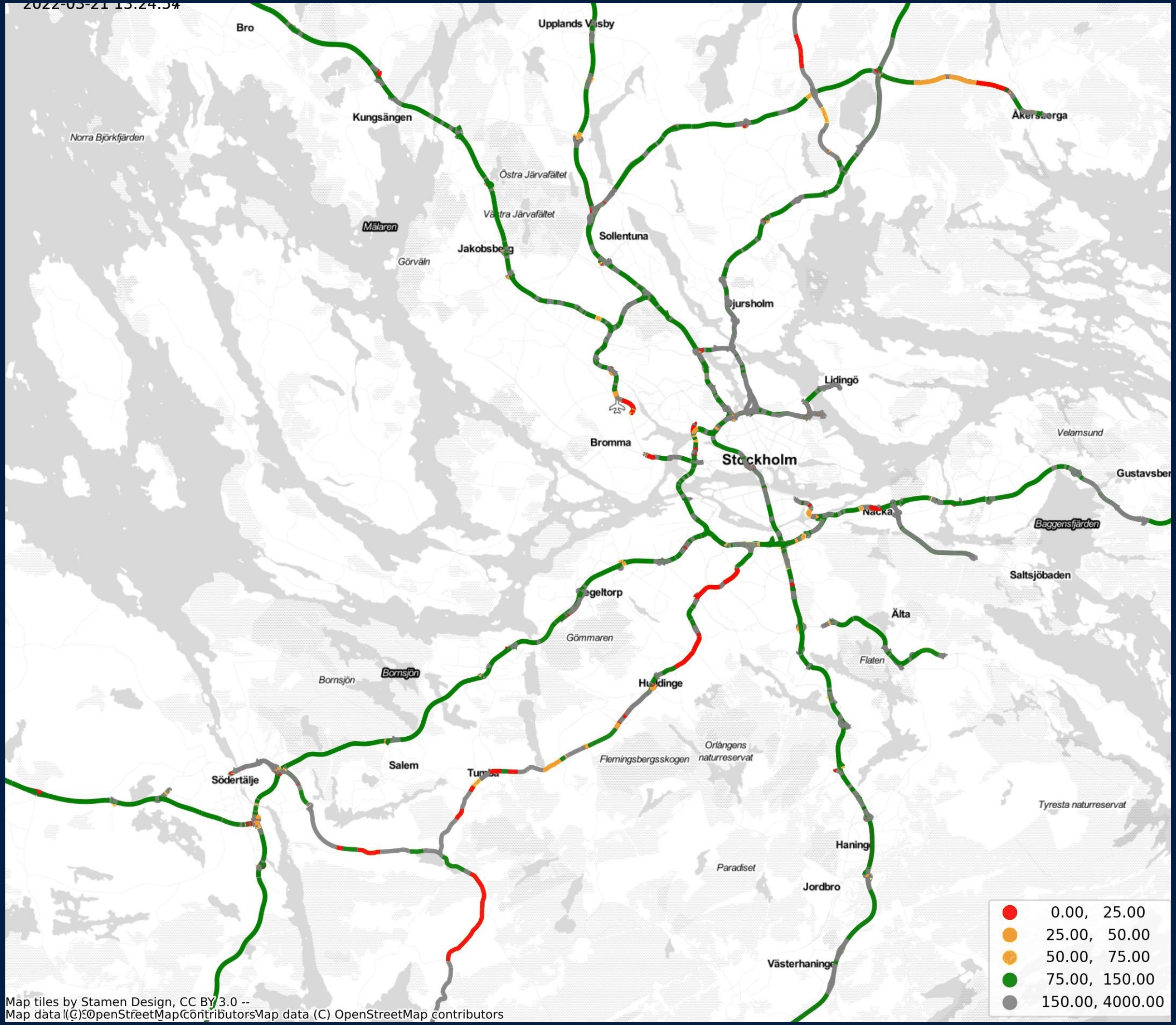
Range with vehicle sensors (also the case for manual driver)

CONNECTED AWARENESS BEYOND SENSOR RANGE

Manual vehicles can *benefit from* being connected to and cooperating within the transport system while automated/autonomous will be *dependent* on it to operate efficiently.

VEHICLES DETECT ROAD STATUS

- Scania connected fleet
  - Relative to legal speed
- Yes it is like google maps
  - New to OEM
  - Access to more vehicle sensors



VEHICLES -> SENSORS FUNCTIONS -> SERVICES

- Dependency
  - On external data
  - On connectivity
- Evolve over time
  - Information sharing
  - Correct map data

QUESTIONS ?

bas.oremus@scania.com

Presentation:

Path following and lateral stability of automated vehicles,

Wenliang Zhang, KTH

Active safety of autonomous electric vehicles

Wenliang Zhang
Ph.D. Candidate
KTH Vehicle Dynamics

May 18, 2022

Outline

Introduction

Road safety

- Traffic accidents $\rightarrow \approx 1.3$ million deaths every year [1]
- Road accident injuries $\rightarrow \approx 3\%$ of most countries' GDP
- Vehicle occupant deaths $\downarrow$ 14% in 2018 (vs. 2010) [2]
  - Safer roads
  - Passive safety devices, e.g., airbags and seat belts
  - Active safety systems, e.g., electronic stability control (ESC) [3]

Introduction

Electronic stabilty control

- A closed-loop system to improve vehicle handling and braking response
- Helps prevents the vehicle from over- or under-steering

Figure 1: Car in an obstacle-avoidance manoeuvre [4].

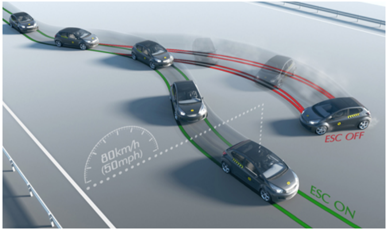


Figure 2: ESC in an obstacle-avoidance manoeuvre [5].

Introduction

Over-actuation

- Production vehicles with more motion actuators
  - BYD Han: one electric motor (EM) on each axle [6]
  - Polestar 1: one ICE in the front axle + two EMs in the rear [7]
  - Tesla Model S Plaid and Audi e-tron S: one EM in the front axle + two EMs in the rear [8, 9]

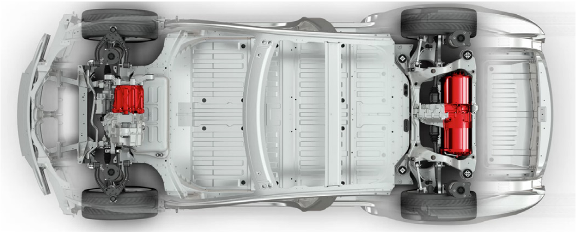


Figure 3: Tesla Model S Plaid [8].

- Over-actuated vehicle platforms
  - Zoox: individual traction + all wheel steering + active suspension [10]
  - KTH RCV: individual steering + camber + drive [11]

Research topic

KTH Research Concept Vehicle (RCV)

- Individual steering + drive + camber

Figure 4: KTH Research Concept Vehicle (RCV) [11].

Benefits of over-actuated electric vehicles

- Improved vehicle dynamics control
- Fast and accurate motor torque generation

Means of over-actuation studied

- Active front steering (AFS)
- Torque vectoring (TV)
- Active camber (AC)
- Integrated control

Research questions

Path following and yaw stability control strategies using over-actuation

- How can **path following** and **yaw stability** performance be improved in critical conditions?
- How would different means of **over-actuation** influence path following and yaw stability performance?

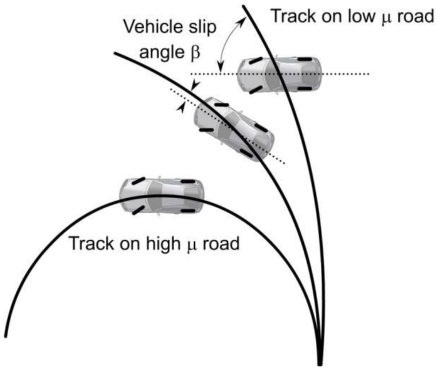


Figure 5: Path following and yaw stability control [12]

Vehicle modelling

- Double-track dynamic vehicle model
- Seven degrees of freedom

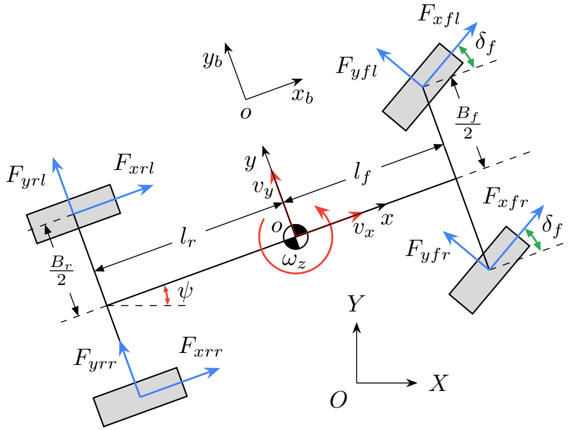


Figure 6: Double-track dynamic vehicle model.

Tyre modelling

Dugoff tyre model

- Combined slip conditions
- Uniform vertical load distribution

Camber effect modelling

$$F_{y\gamma i} = C_{\gamma i}\gamma_i \quad (1a)$$

$$C_{\gamma i} = \begin{cases} C_{\gamma 0i} + C_{\gamma \alpha i}\left|\alpha_i\right|, & \text{if } \left|\alpha_i\right| < \alpha_{lim} \\ C_{\gamma fi}, & \text{if } \left|\alpha_i\right| \geq \alpha_{lim} \end{cases} \quad (1b)$$

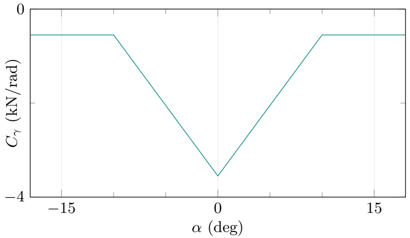


Figure 7: Tyre camber stiffness variation with respect to slip angle.

Tyre modelling

Camber effect modelling – Lateral tyre forces and camber gains

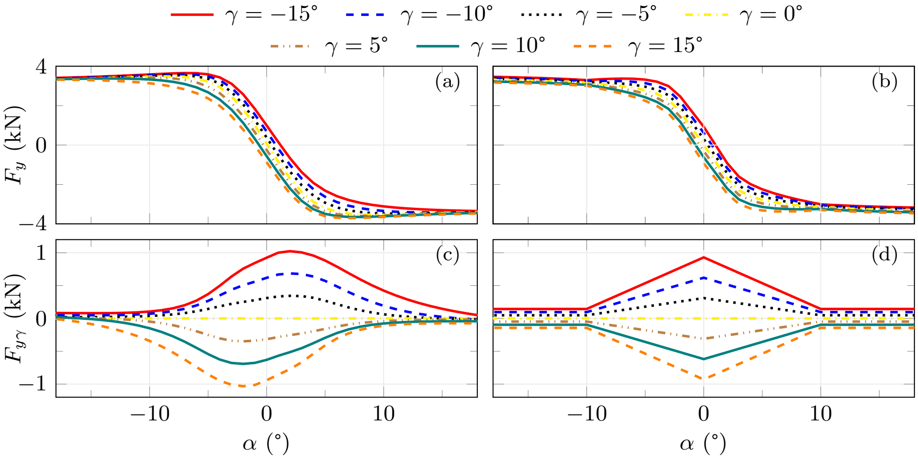


Figure 8: The Magic Formula [13] [(a) and (c)] and the Dugoff model with camber effect [(b) and (d)].

Vehicle plant modelling

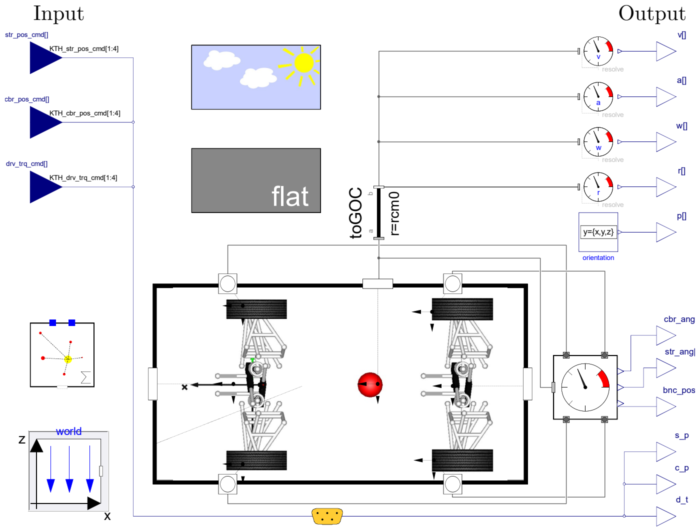


Figure 9: Dymola vehicle plant model.

Controller formulation

Formulation considerations

- Concurrent path following and yaw stability control
- Explicit constraints on sideslip angle and yaw rate
- Transient limits on reference yaw rate

$$\omega_{zmax} = \frac{\mu g}{v_x} - \dot{\beta} \quad (2a)$$

$$\omega_{zmin} = -\frac{\mu g}{v_x} - \dot{\beta} \quad (2b)$$

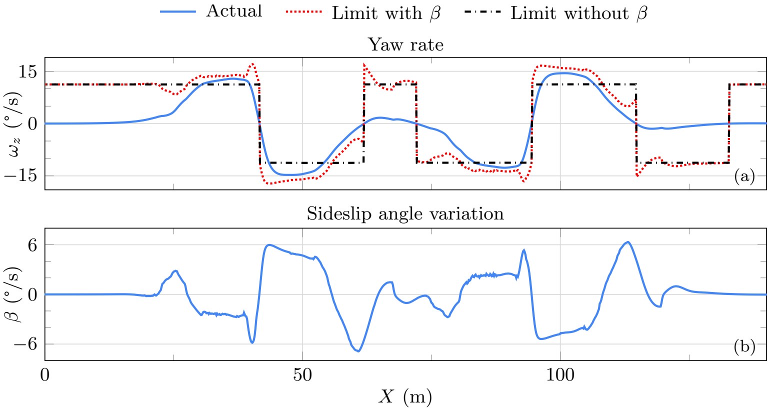


Figure 10: Reference yaw rate limits.

Controller formulation

Model predictive control

$$\min_{\boldsymbol{x}_p,\boldsymbol{u}_p,\Delta\boldsymbol{u}_p,\boldsymbol{s}} \underbrace{\sum_{i=0}^{N_p-1} \left\| y_{k+i|k} - y_{k+i|k}^{ref} \right\|_{Q_y}^2}_{\text{tracking error}} + \underbrace{\sum_{i=0}^{N_p-1} \left\| u_{k+i|k} \right\|_{R_u}^2}_{\text{control action}} + \underbrace{\sum_{i=0}^{N_p-1} \left\| \Delta u_{k+i|k} \right\|_{R_{du}}^2}_{\text{change of control action}}$$

$$+ \underbrace{\left\| y_{k+N_p|k} - y_{k+N_p|k} \right\|_{Q_{yf}}^2}_{\substack{\text{terminal cost of}\\ \text{tracking error}}} + \underbrace{\sum_{i=0}^{N_p-1} \left\| s_{k+i|k} \right\|_{Q_s}^2}_{\text{slack term}} + \underbrace{\left\| s_{k+N_p|k} \right\|_{Q_{sf}}^2}_{\substack{\text{terminal cost of}\\ \text{slack variable}}} \tag{3a}$$

s. t.

$$x_{k+i+1|k} = f(x_{k+i|k}, u_{k+i|k}) \tag{3b}$$

$$y_{k+i|k} = h(x_{k+i|k}),\ i \in \{0, 1, \cdots, N_p\} \tag{3c}$$

$$\Delta u_{k+i|k} = \begin{cases} u_{k+i|k} - u_{k+i-1|k}, & \text{if } i \geq 1 \\ u_{k|k} - u_{k-1|k-1}, & \text{if } i = 0 \end{cases} \tag{3d}$$

$$u_{min} \leq u_{k+i|k} \leq u_{max} \quad \Delta u_{min} \leq \Delta u_{k+i|k} \leq \Delta u_{max} \tag{3e}$$

$$\mathcal{H}_p(x_{k+i|k}, u_{k+i|k}, s_{k+i|k}) \leq 0 \tag{3f}$$

$$s_{k+i|k} \geq 0 \tag{3g}$$

Results and discussion

Why concurrent path following and yaw stability control?

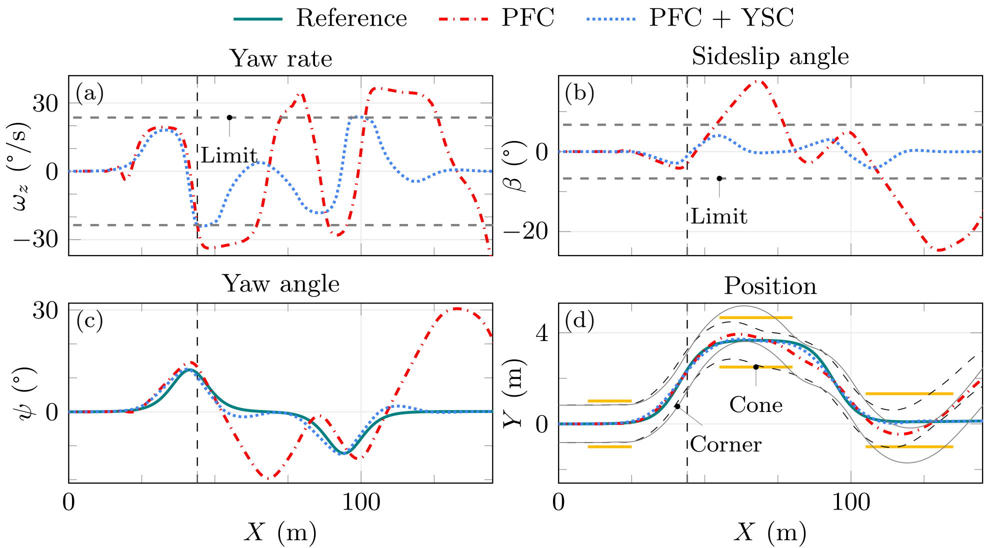


Figure 11: Tracking performance with and without yaw stability control ($\mu = 0.6$, $v_{xref} = 76$ km/h).

Results and discussion

Torque vectoring

- Aim
  - Evaluate the effects of **torque vectoring** and **controller structure** on control performance[1]
- Comparison items

One-level controllers		Two-level controllers	
OLTV	OLEA	TLOA	TLRA
Torque vectoring	Equal allocation	Optimisation-based	Rule-based

[1]Wenliang Zhang, Zhenpo Wang, Lars Drugge and Mikael Nybacka. Evaluating model predictive path following and yaw stability controllers for over-actuated autonomous electric vehicles, IEEE Transactions on Vehicular Technology, vol. 69, no. 11, 2020.

Results and discussion

Torque vectoring

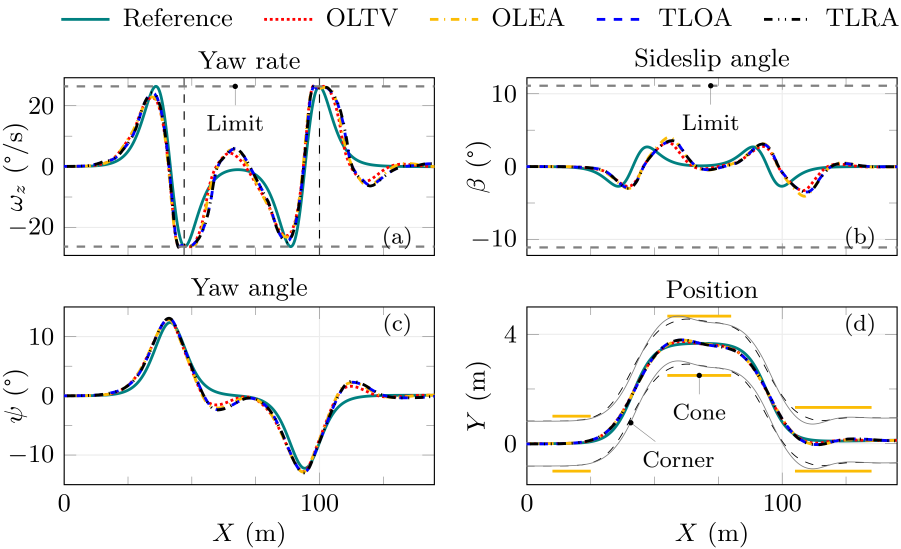


Figure 12: Tracking performance of the four controllers ($\mu = 1$, $v_{xref} = 85$ km/h).

Results and discussion

Torque vectoring

Table 1: Tracking accuracy of the four controllers ($\mu = 1$).

Ref. velocity (km/h)	Controller	ω_z (°/s)	Y (m)
		e_{rms}	e_{rms}
85	OLTV	4.1	0.08
	OLEA	4.6	0.10
	TLOA	4.4	0.10
	TLRA	4.6	0.10
86	OLTV	4.3	0.08
	OLEA	4.8	0.10
91	OLTV	5.2	0.11

[a] The colour red indicates the highest value, whilst the colour blue indicates the lowest.

Results and discussion

Active camber

- Aim
  - Evaluate the effects of **active camber** and **camber rate** on control performance[2]
- Comparison items
  - No camber control
  - Camber controllers with various camber rates

[2]Wenliang Zhang, Lars Drugge, Mikael Nybacka and Zhenpo Wang. Active camber for enhancing path following and yaw stability of over-actuated autonomous electric vehicles, Vehicle System Dynamics, vol. 59, no. 5, 2020.

Results and discussion

Active camber

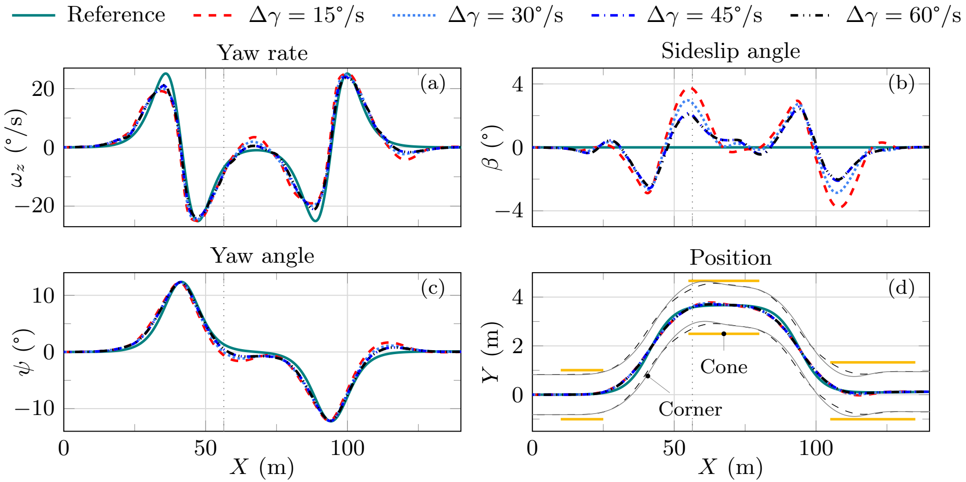


Figure 13: Tracking performance of the camber controllers ($\mu = 0.6$, $v_{xref} = 81$ km/h).

Results and discussion

Active camber

Table 2: Tracking accuracy with ($\Delta\gamma = 15 - 60^{\circ}/\text{s}$) and without ($-$) camber control ($\mu = 1$).

Ref. velocity $(\mathrm{km/h})$	Camber rate $(^{\circ}/\text{s})$	ω_z $(^{\circ}/\text{s})$	Y (m)
		e_{rms}	e_{rms}
84	–	3.64	0.09
91	15	3.47	0.11
99	30	3.68	0.13
	45	3.03	0.12
	60	2.95	0.12

[a] The colour red indicates the highest value, whilst the colour blue indicates the lowest.

Results and discussion

Integrated control

- Aim
  - Evaluate the effects of **over-actuation configurations** on control performance[3]
- Comparison items

Controller	Configuration
S	Active front steering (AFS)
ST	AFS + torque vectoring (TV)
SC	AFS + active camber (AC)
STC	AFS + TV + AC

[3] Wenliang Zhang, Lars Drugge, Mikael Nybacka, Jenny Jerrelind and Zhenpo Wang. Integrated control of motion actuators for enhancing path following and yaw stability of autonomous electric vehicles, Submitted for publication, 2022.

Results and discussion

Integrated control

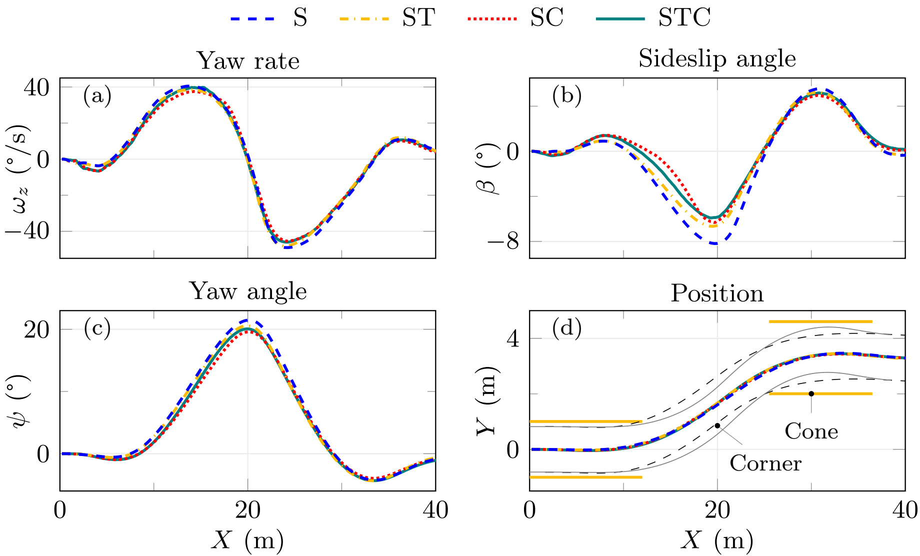


Figure 14: Tracking performance of the four over-actuation configurations ($v_{x0} = 76$ km/h).

Results and discussion

Integrated control

Table 3: Tracking accuracy of the four over-actuation configurations.

Initial velocity (km/h)	Controller	β (°) e_{rms}	ψ (°) e_{rms}
73	S	0.6	0.9
	ST	0.5	0.8
	SC	0.3	0.6
	STC	0.2	0.5
76	ST	0.6	0.9
	SC	0.4	0.6
	STC	0.2	0.6
79	STC	0.5	0.8

[a] The colour red indicates the highest value, whilst the colour blue indicates the lowest.

Results and discussion

Integrated control

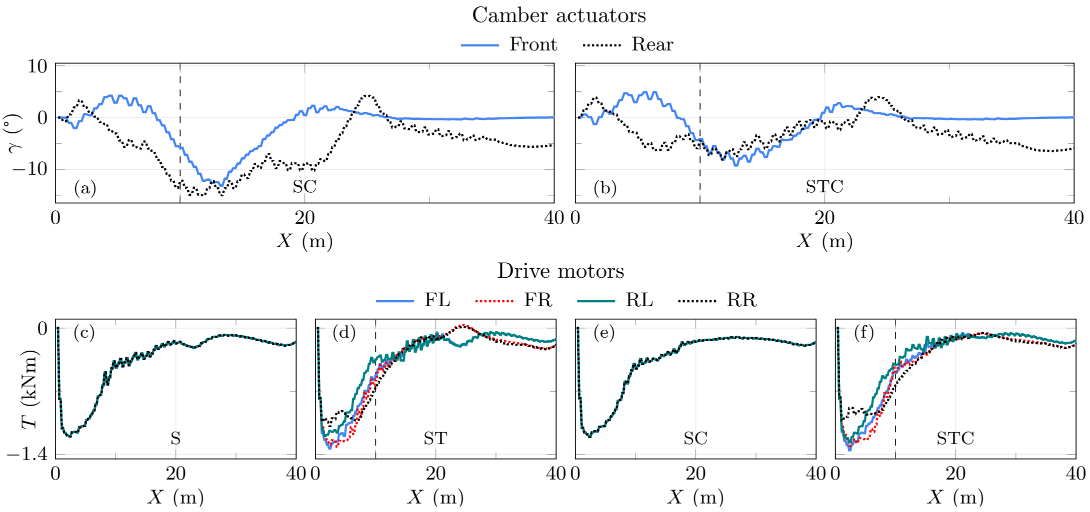


Figure 15: Control actions of the four over-actuation configurations ($v_{x0} = 76$ km/h).

Conclusions

Torque vectoring[4]

- Improved passing velocity + tracking accuracy
- One-level controller structure:
  - Torque vectoring → highest passing velocity
- Two-level structure:

Optimisation-based	Rule-based
+	Same passing velocity
+	Comparable tracking accuracy
More degrees of freedom in design and tuning	-

[4] Wenliang Zhang, Zhenpo Wang, Lars Drugge and Mikael Nybacka. Evaluating model predictive path following and yaw stability controllers for over-actuated autonomous electric vehicles, IEEE Transactions on Vehicular Technology, vol. 69, no. 11, 2020.

Conclusions

Active camber[5]

- Improved path following + yaw stability + passing velocity
- Desired camber rate at different friction levels

High and medium	Low
Wide effective camber region	Narrow effective camber region
$\Delta\gamma = 45\,^{\circ}/\mathrm{s}$	$\Delta\gamma = 30\,^{\circ}/\mathrm{s}$

- Required peak power and consumed energy

	Camber actuators	Wheel motors
Required peak power	$\downarrow\downarrow\downarrow$	$\uparrow\uparrow\uparrow$
Consumed energy	$\downarrow\downarrow\downarrow$	$\uparrow\uparrow\uparrow$

[5] Wenliang Zhang, Lars Drugge, Mikael Nybacka and Zhenpo Wang. Active camber for enhancing path following and yaw stability of over-actuated autonomous electric vehicles, Vehicle System Dynamics, vol. 59, no. 5, 2020.

Conclusions

Integrated control[6]

- AFS + TV + AC outperformed the other configurations
  - Increased **passing velocity**
  - Decreased peak values and tracking errors for **sideslip angle**
  - Enlarged **safety distance** in the most critical location
  - Improved response to reference **trajectory variations**
- AFS + AC outperformed AFS + TV
  - More effective **tyre utilisation** of active camber over torque vectoring
- AFS and AFS + TV
  - Not robust to reference **trajectory variations**

[6] Wenliang Zhang, Lars Drugge, Mikael Nybacka, Jenny Jerrelind and Zhenpo Wang. Integrated control of motion actuators for enhancing path following and yaw stability of autonomous electric vehicles, Submitted for publication, 2022.

Papers

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- Wenliang Zhang, Zhenpo Wang, Lars Drugge and Mikael Nybacka. Evaluating model predictive path following and yaw stability controllers for over-actuated autonomous electric vehicles, IEEE Transactions on Vehicular Technology, vol. 69, no. 11, 2020.
- Wenliang Zhang, Lars Drugge, Mikael Nybacka and Zhenpo Wang. Active camber for enhancing path following and yaw stability of over-actuated autonomous electric vehicles, Vehicle System Dynamics, vol. 59, no. 5, 2020.
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[13] H. Pacejka, *Tire and Vehicle Dynamics*, 3rd ed. Oxford, UK: Elsevier, 2012.

Presentation:

Towards automating High Capacity Transport vehicles,

Abhijeet Behera, VTI and LIU

Foto Geran De Klerk, Unsplash

TOWARDS AUTOMATING HIGH-CAPACITY TRANSPORT VEHICLES

Abhijeet Behera

Supervisors: Sogol Kharrazi (VTI), Erik Frisk (LiU)

18 May 2022

About me

1st year Institute PhD Student at VTI and LiU

- HCT vehicles

Past experience

- M.Sc in Automotive Technology (Vehicle Dynamics and Control), TU Eindhoven, The Netherlands
- B.Tech in Mechanical Engineering, NIT Rourkela, India

Objectives (1)

Automated Vehicles

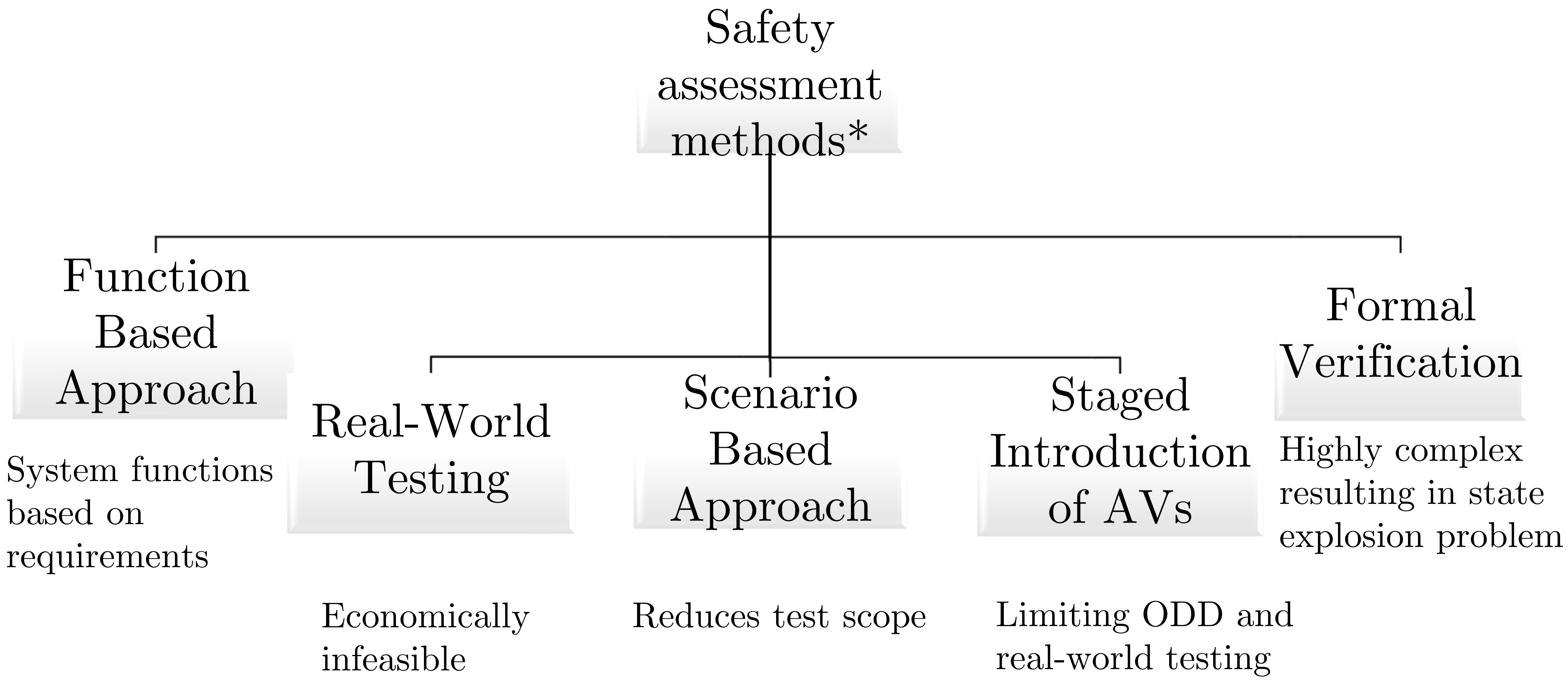
- Motion Planning
- Control Systems
- Software and Hardware Architecture
- etc.

Adouble combination

Safety of vehicles must be thoroughly tested before introducing to the market !

Primary objective: Safety assessment of automated vehicles (HCT Vehicles)

Objectives (2)



LINKÖPING UNIVERSITY

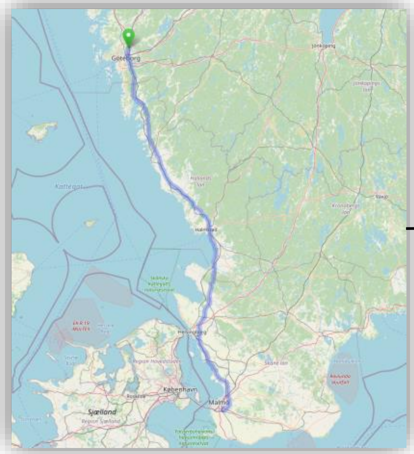
*S. Riedmaier, T. Ponn, D. Ludwig, B. Schick and F. Diermeyer, "Survey on Scenario-Based Safety Assessment of Automated Vehicles," in *IEEE Access*, vol. 8, pp. 87456-87477, 2020, doi: 10.1109/ACCESS.2020.2993730.

vti

Taxonomy of followed approach

- **Source**: Naturalistic Driving Data (NDD)
- **Scenario Extraction**: Extraction of Scenarios (Lane Change, Roundabout, Intersection, Long corner)
- **Scenario Generation**: Generation of Synthetic Scenarios (Stochastic variation)
- **Scenario Selection**: Selection of Concrete Critical Scenarios
- **Scenario Execution**: Physical Tests, Driving Simulator, XiL (X= Hardware, Software)

NDD: Scenario Extraction

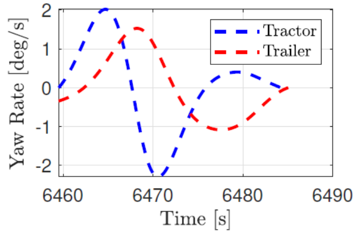


ND data

- Gothenburg-Malmo (Adouble)
- Trips ≈ 12
- Positions, translational and angular velocities, and corresponding accelerations

Data processing

Lane change: Based on yaw rate

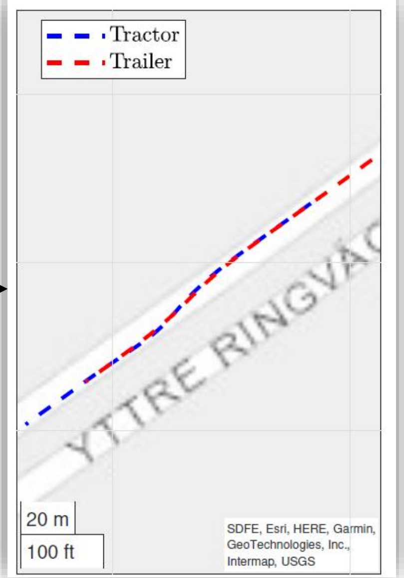


Roundabout: Using open street maps

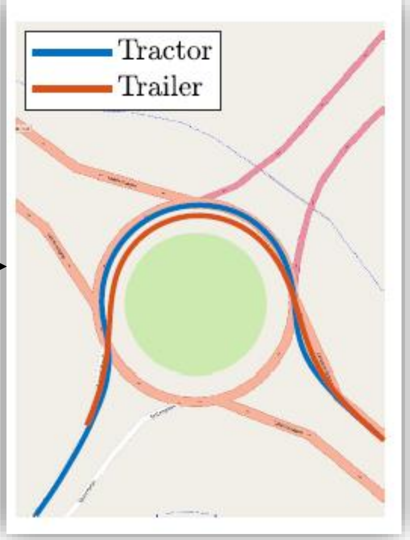
- Fixed in real world
- Crop the rounbabouts in OSM
- Segregate data when truck enters the cropped area

Detection Algorithms

Lane change



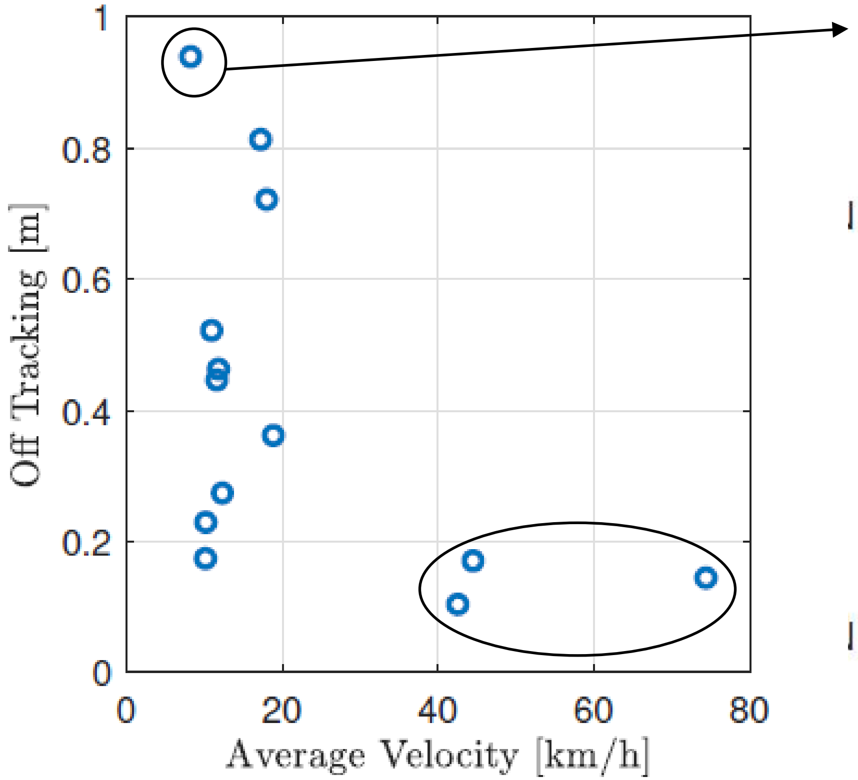
Roundabout

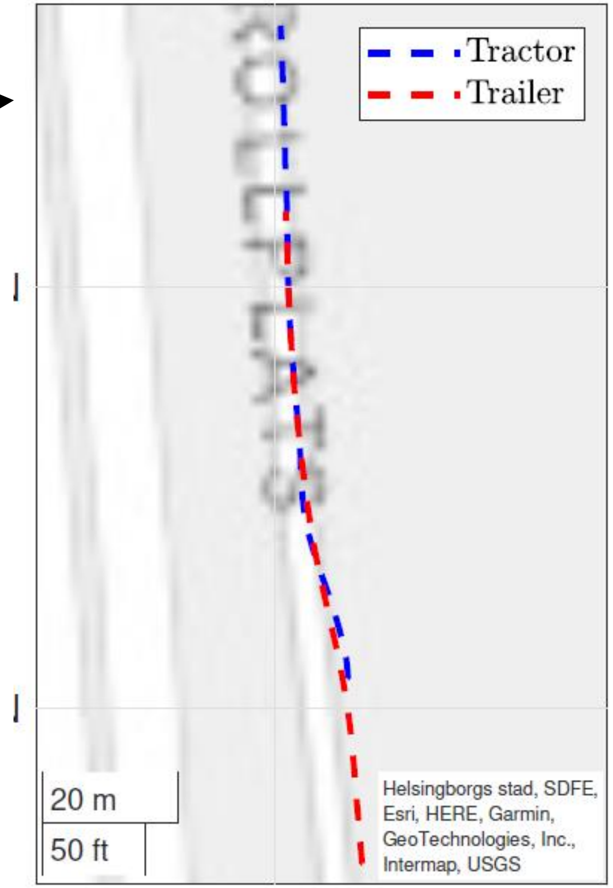


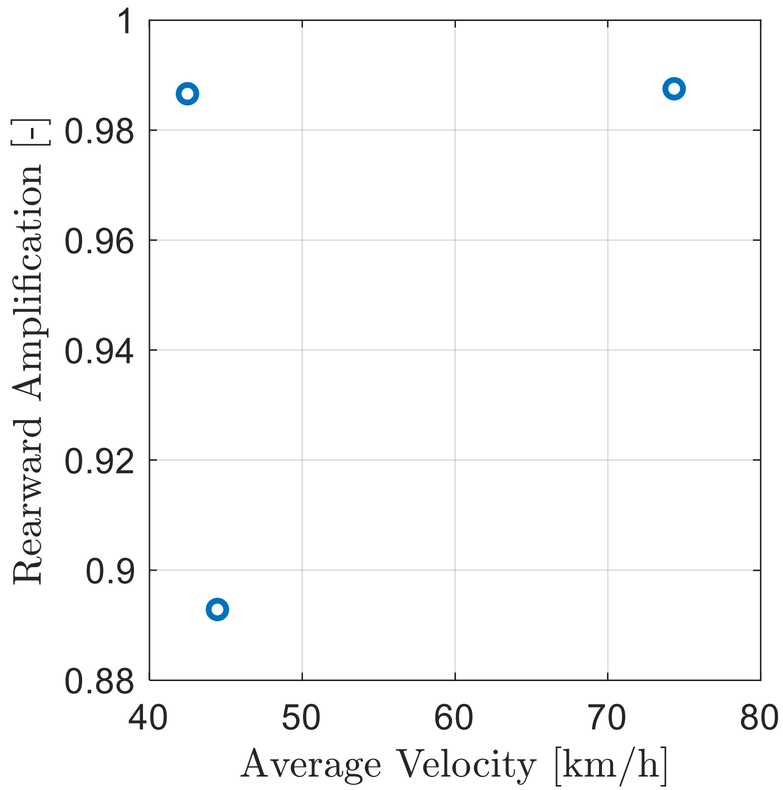
LINKÖPING UNIVERSITY

vti

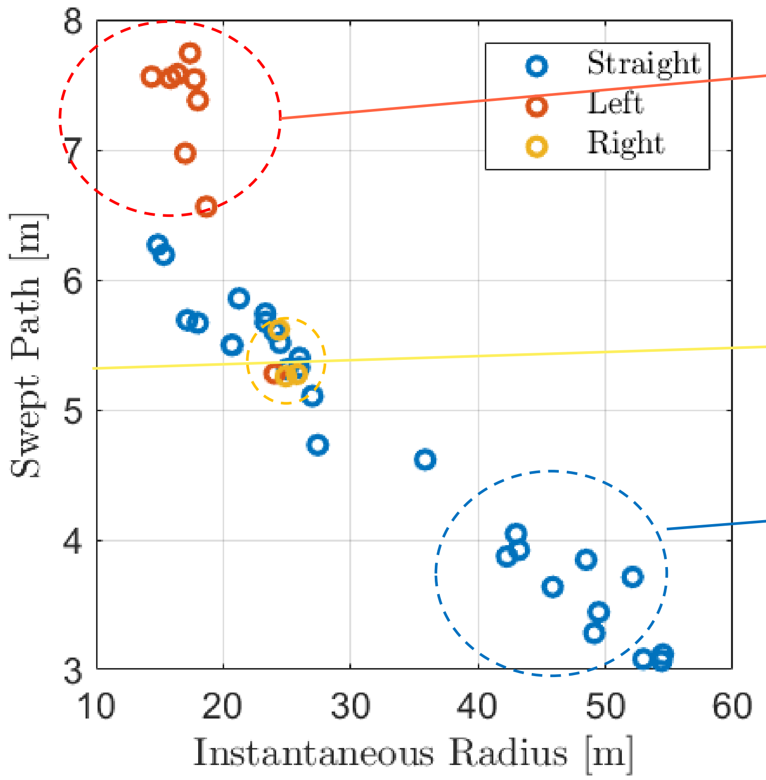
Lane change analysis

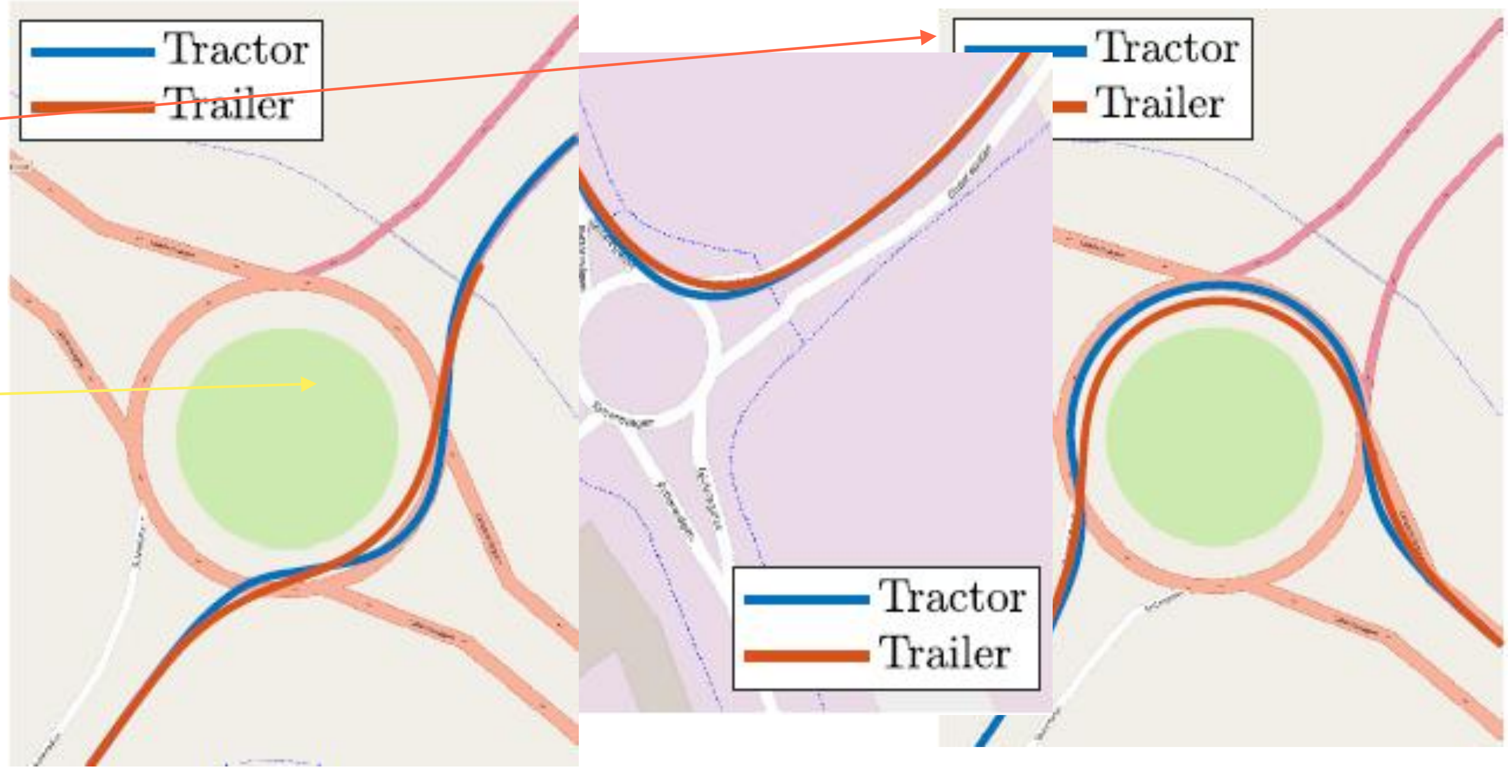






Roundabout analysis





Conclusions (Until now)

- Trucks are driving safe (in Roundabouts and Lane changes)
- Critical scenarios (Merging !)

Next Steps?

Source	Naturalistic Driving Data (NDD)
Scenario Extraction	Scenarios from NDD (Lane Change, Roundabout, Intersection, Long corner)
Scenario Generation	Generation of Synthetic Scenarios (Stochastic variation)
Scenario Selection	Selection of Critical Scenarios
Scenario Execution	Physical Tests, Driving Simulator, XiL (X= Hardware, Software)

THANK YOU

QUESTIONS ?

Presentation:

Vehicle Engineering Master programme,

Mikael Nybacka, KTH

KTH ROYAL INSTITUTE
OF TECHNOLOGY

Master program in Vehicle Engineering

Program director:

Mikael Nybacka, KTH Vehicle Engineering and Solid Mechanics

Master program in *Vehicle Engineering*

ROYAL INSTITUTE OF TECHNOLOGY

Program responsible:

Mikael Nybacka, KTH Vehicle Engineering and Solid Mechanics

Road vehicle

Rail vehicle

Vehicle engineering

- some quick facts

Two-year programme (120 ECTS credits) given in English

Two tracks, road and rail vehicles

600-700 applicants and 300 1st hand applicants over the last 5 years

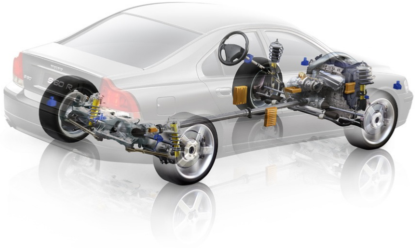
Admitted 53 students 2021 (14% acceptance rate)

Around 1/3 Swedish and 2/3 international students

Specific entry requirements

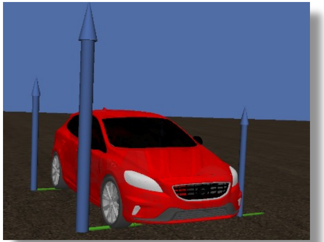
- A bachelor's degree, or equivalent, corresponding to 180 ECTS credits, with courses in
  - **Mathematics and programming:** must include
    - > *(i) differential and integral calculus in several variables,*
    - > *(ii) linear algebra,*
    - > *(iii) numerical analysis),*
    - > *(iv) ordinary and partial differential equations and integral transforms,*
    - > *(v) basic control theory,*
    - > *(vi) mathematical statistics and*
    - > *(vii) basics of programming in a higher programming language*
    - > *equivalent to at least 25 ECTS credits in total.*
  - **Applied mechanics:** must include
    - > *(i) rigid body mechanics,*
    - > *(ii) solid mechanics,*
    - > *(iii) fluid mechanics and*
    - > *(iv) thermodynamics,*
    - > *equivalent to at least 20 ECTS credits in total.*

Learning goals



Students will learn about:

- future *demands* and *challenges*,
- vehicles *components* and *functions*,
- vehicles *dynamic properties* and *interaction with its environment*,
- *active vehicle systems* for safety, monitoring and comfort,
- vehicles *role in the transport system and in society*.



Program structure

Industry and research projects

From HT2022

Common

- Vehicle System Technology
- Vehicle Dynamics Project Course Part I
- Theory and Methodology of Science with Applications

Road / Rail Vehicles

Road Vehicles

- Vehicle Components
- Road Vehicle Dynamics
- ~~Internal Combustion Engines I~~
- Hybrid Vehicle Drives

Rail Vehicles

- Rail Vehicle Technology
- Rail Vehicle Dynamics
- Electric Traction
- Railway Signalling System

Conditional compulsory

- Choose courses from a specified course list relating to *Vehicle design*, *Functional design*, *Structural design*, Control design, *Transport systems* and *Vehicle engineering*.

Lightweight Structures and FEM
Experimental Structure Dynamics
Structural Optimisation and Sandwich Design
Vehicle Acoustics and Vibration
Flow Acoustics
Vehicle Aerodynamics
Comp. Vehicle Aerodynamics
Mechatronics basic course
Robust mechatronics
Dynamics and Motion Control
Control Theory and Practice, Adv.
Applied Vehicle Dynamics Control
Model Predictive Control
Urban modelling and decision
Traffic Engineering Management
Transport Data Collection and Analysis
Traffic Simulation Modelling and Application
Vehicle Dynamics Project course (Part 2)
Engineering acoustics
Fluid mechanics, basic course
Fluid mechanics for engineers
Fluid Mechanics
Sustainable vehicle design
Electric power systems
Electrical machines and drives
Power electronics
Electric traction
…

Additional courses will be added

Mandatory courses (52-55.5 credits)

At least 75 credits

Elective

- Courses of your own choice, approximately 15 credits

Master thesis

- Thesis work (30 credits) in a vehicle engineering field of your interest.
- The thesis work is commonly performed in industry.

Mandatory courses

ROAD

1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4
	EJ2410 Hybrid vehicle drives 7.5 hp			AK2030 Theory & science 4.5 hp	SA2002 Sustainable dev. & research methods 3.0 hp	SD221X Master thesis 30 hp	
SD2221 Vehicle system technology 8 hp	SD2222 Vehicle components 8 hp	SD2225 Road vehicle dynamics 11 hp		SD2229 Vehicle dynamic project Part I 7.5 hp			

RAIL

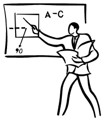
1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4
AK2030 Theory & science 4.5 hp				AH2029 Railway signalling systems 7.5 hp	SA2002 Sustainable dev. & research methods 3.0 hp	SD221X Master thesis 30 hp	
SD2221 Vehicle system technology 8 hp	SD2307 Rail vehicle technology 7.5 hp	SD2313 Rail vehicle dynamics 8 hp	EJ2400 Electric traction 6 hp	SD2229 Vehicle dynamic project Part I 7.5 hp			

- mandatory
- mandatory, but can be read during 1st or 2nd year
- mandatory, can be read in any study period

Vehicle Engineering Lab

- Teknikringen 8

Our common laboratory:

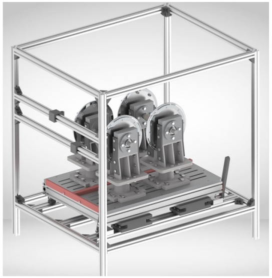



– Teaching
– Experiments
– Computer exerc.
– Own studies


Experiment vehicles, equipment and test tracks

Volvo S90 D5 AWD Geartronic

Renault Twizy



Roller rig

Arlanda test track

RCV

Research
Concept Vehicles

RCV-E

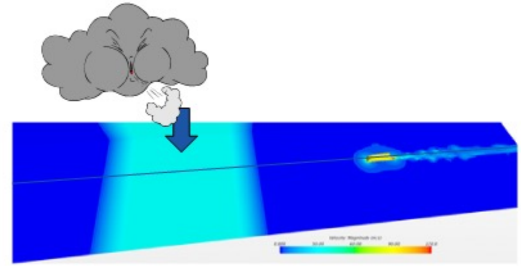
Driving simulator

Lunda flygfält

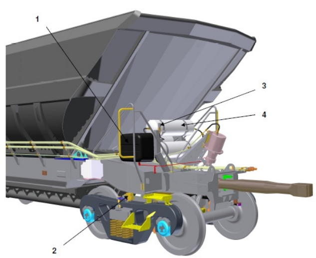
MSC thesis examples

Advertise Thesis proposals in October
For double degree in March

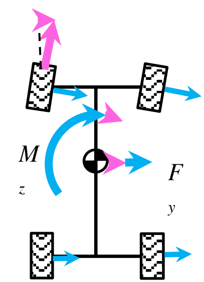
Develop new body tilting for Regina 250



Side wind sensitivity of vehicles



Simulation model of a iron ore carridge



Energy efficient propulsion whith in-wheel motors

Vehicle Engineering

- Fordonsteknik

Mikael Nybacka
Programme responsible

mnybacka@kth.se

Research groups ***Rail vehicles***, ***Vehicle dynamics***, ***Aero dynamics*** and ***Conceptual vehicle design***
At the division of Vehicle Engineering and Solid Mechanics

Teknikringen 8

www.kth.se/en/studies/master/vehicleengineering

Presentation:

Mobility Engineering Master programme,

Giulio Bianchi Piccinini, Chalmers

CHALMERS

Mobility engineering, MSc (MPMOB)

Giulio Bianchi Piccinini,

Associate professor & Director of master’s programme,

Department of Mechanics and Maritime sciences (M2)

MPMOB: programme in a nutshell

CHALMERS

Broad knowledge on mobility

- Mechatronics for mobility
- Propulsion for mobility
- Connected fleets and automated data collection
- System engineering

In-depth knowledge in one of these profiles

- Aerospace engineering
  - Fluids
  - Structural
  - Artificial intelligence
- Automotive engineering
  - Active and passive safety
  - Powertrain and propulsion systems
  - Vehicle engineering and aerodynamics
- Marine technology and naval architecture
  - Structures
  - Fluid
  - Systems engineering
- Railway technology
  - Railway mechanics
  - Structural deterioration
  - Asset management

MPMOB: study plan

Year 1				Year 2			
LP1	LP2	LP3	LP4	LP1	LP2	LP3	LP4
Systems and mechatronics for mobility engineering (EEN130)	Elective / Compulsory elective	Elective / Compulsory elective	Connected fleets in data-driven engineering (MMS210)	Elective / Compulsory elective	Elective / Compulsory elective	Master thesis	
Introduction to propulsion and energy systems for transport (MMS195)	Elective / Compulsory elective	Elective / Compulsory elective	Elective / Compulsory elective	Elective / Compulsory elective	Elective / Compulsory elective		

- Compulsory courses for 52.5 ECTS
- Compulsory elective courses for 37.5 ECTS (to be chosen among 32 different courses)
- Elective courses for 30 ECTS (to be chosen from 12 different Master programmes)

MPMOB: project work

- Project in aerospace (Aerospace engineering)
- Automotive engineering project (Automotive engineering)
- Marine design project (Marine technology)
- Project in railway technology (Railway technology)
- Chalmers formula students (Automotive engineering)

MPMOB: industrial connections

- Abetong
- Autoliv
- Alstom
- Consulting companies (Alten, Altran, ÅFRY, Atkins)
- China Euro Vehicle Technology (CEVT)
- GKN Aerospace
- Green Cargo
- Heart Aerospace
- Lucchini
- SAAB
- SSPA
- Stena Line
- SJ
- SweMaint
- Trafikverket
- Volvo Group
- Volvo Cars
- Wabtec

MPMOB: research-based education

CHALMERS

CHARMEC
Chalmers Railway Mechanics – a NUTEK/VINNOVA Competence Centre
Chalmers University of Technology

http://www.charmec.chalmers.se/

CERC
Combustion Engine Research Center

https://www.chalmers.se/en/centres/cerc/Pages/default.aspx

Swedish Electromobility Centre

https://emobilitycentre.se/

TechForH2 – Hydrogen Centre

https://www.chalmers.se/en/departments/m2/news/Pages/TechForH2---for-a-sustainable-hydrogen-economy-of-tomorrow.aspx

LIGHTHOUSE
SWEDISH MARITIME COMPETENCE CENTRE

https://lighthouse.nu/

SAFER
VEHICLE AND TRAFFIC SAFETY CENTRE AT CHALMERS

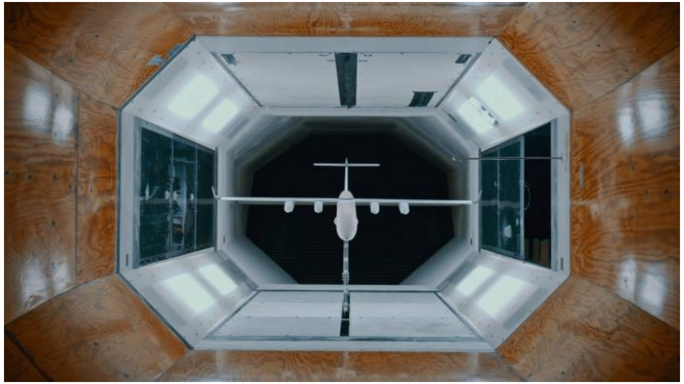
https://www.saferresearch.com/

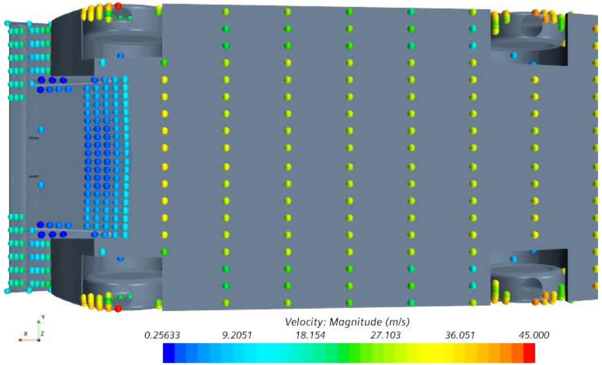
MPMOB: international opportunities

- Double degree with University of Stuttgart (automotive engineering)
- Nordic Master in Maritime engineering, within Nordic Five Tech (marine technology)
- Erasmus exhanges (https://cth.moveon4.de/publisher/1/eng#)

MPMOB: job opportunities

- Design of parts and systems (e.g., yacht designer, powertrain integration engineer)
- Simulation engineer (e.g., crash simulation engineer, vehicle dynamics CAE engineer)
- Asset management (e.g., asset management railway engineer, maintenance engineer)
- Technical sales engineer
- Project manager
- Research & development (e.g., railway technical specialist, traffic safety research specialist)
- Academia (e.g., PhD student)
- Other (e.g., offshore engineer)



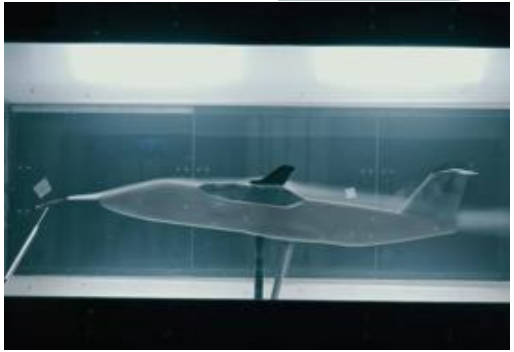


MPMOB: facilities for education

Hybrid powertrain lab

Driving simulator

Brake rig for rail



Low-speed wind tunnel

Resource for vehicle research (REVERE)

Maritime simulator

Low-pressure compressor rig

AVANCEZ

1829

CHALMERS

UNIVERSITY OF TECHNOLOGY

Poster:

A study on the energy consumption impact of environmental parameters on heavy vehicles,

Manish Raathimiddi, Chalmers and HAN

A study on the energy consumption impact of environmental parameters on heavy vehicles

Manish Varma Raathimiddi, MSc student | Division of Vehicle Engineering and Autonomous Systems (VEAS), Mechanics and Maritime Sciences

1. BACKGROUND

Analysing the various powertrain parameters that affect energy consumption is the most crucial step during drivetrain design (for example, battery weight, motor efficiencies, or engine operating point). Thereby one can predict and optimize these crucial factors.

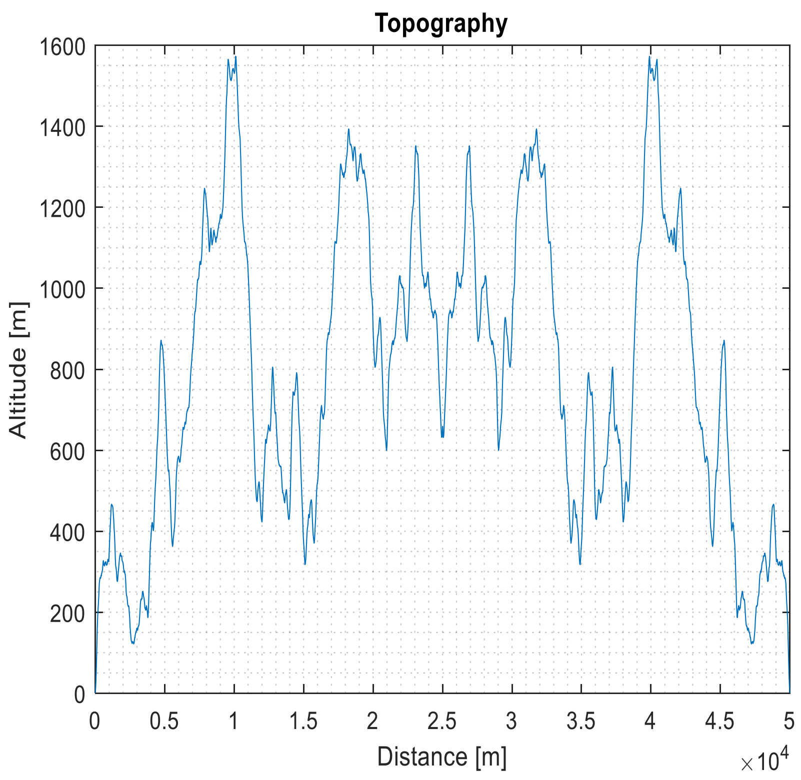
Environmental parameters	Powertrain parameters
Topography	Battery mass
Legal speed	Motor efficiencies
Curvature	Engine operating points

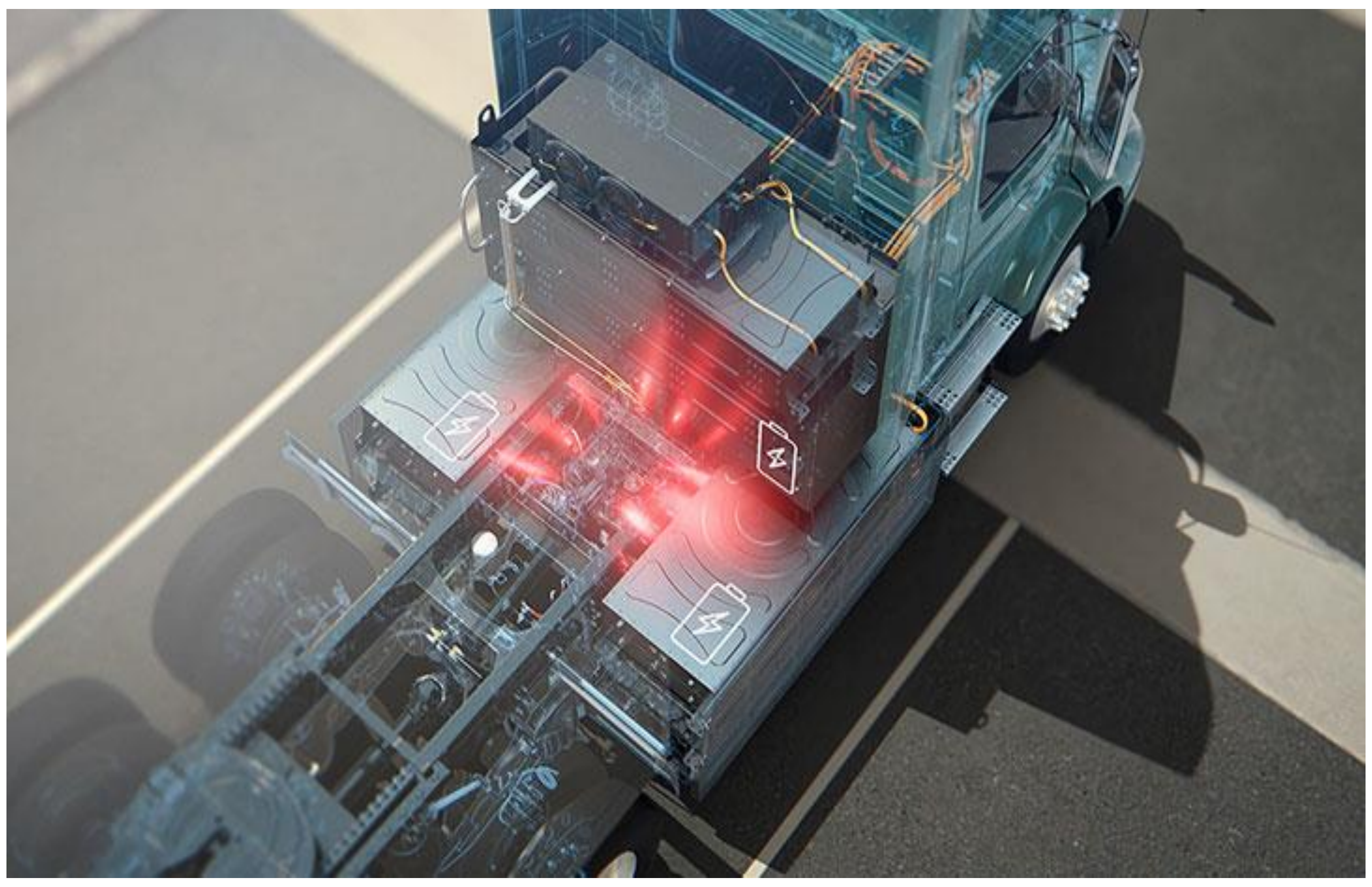
2. REASONS FOR PARAMETER SELECTION

- Heavy vehicles possess higher mass, high drag coefficient, deceleration, and accelerations. These have a significant impact on energy consumption, making it an ideal choice to evaluate topography, legal speeds, and road curvature parameters.
- Battery mass: An increase in the range can be done by adding the number of battery cells which eventually leads to an increase in weight.
- Motor efficiencies: Electric machine losses at various torque and speed working points show a significant impact on machine efficiency.
- Engine operating points: Engine efficiency fluctuates greatly depending on the route, driving style, and other factors, which causes engine operating points to deviate significantly from their optimal point.

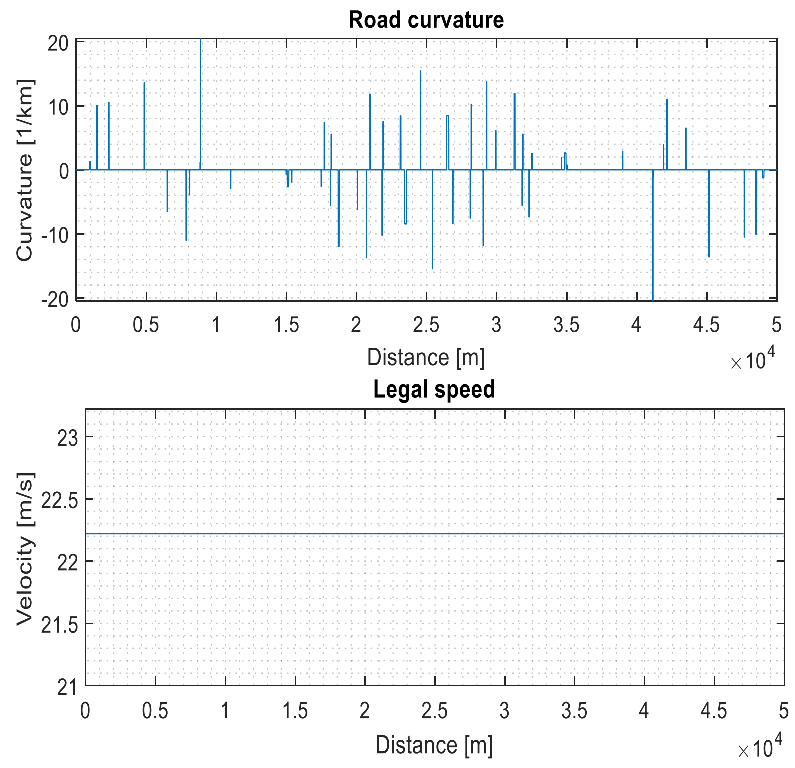
3. GENERATING ENVIRONMENTAL PARAMETERS

- **Topography**





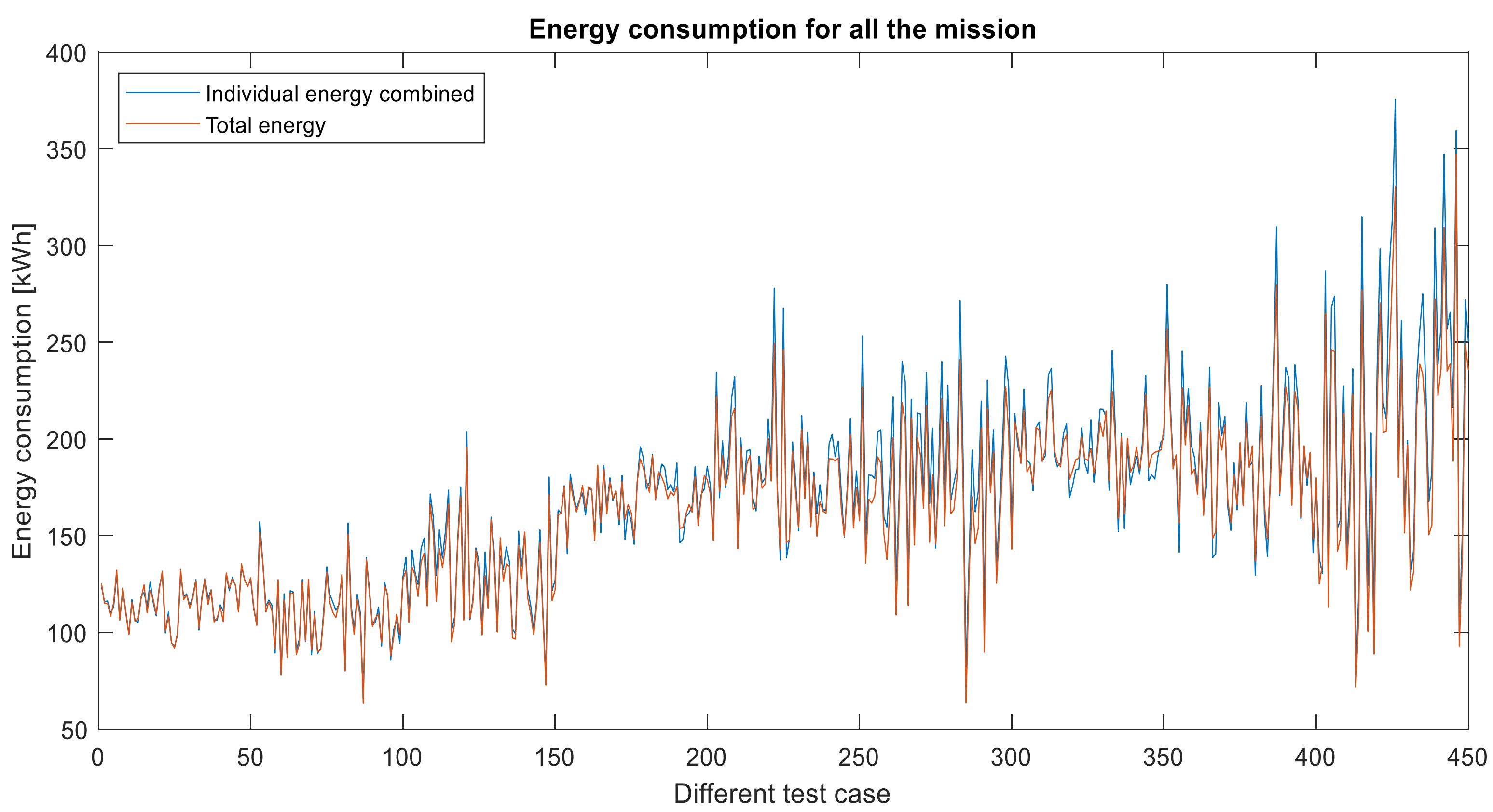
- **Curvature & legal speed**

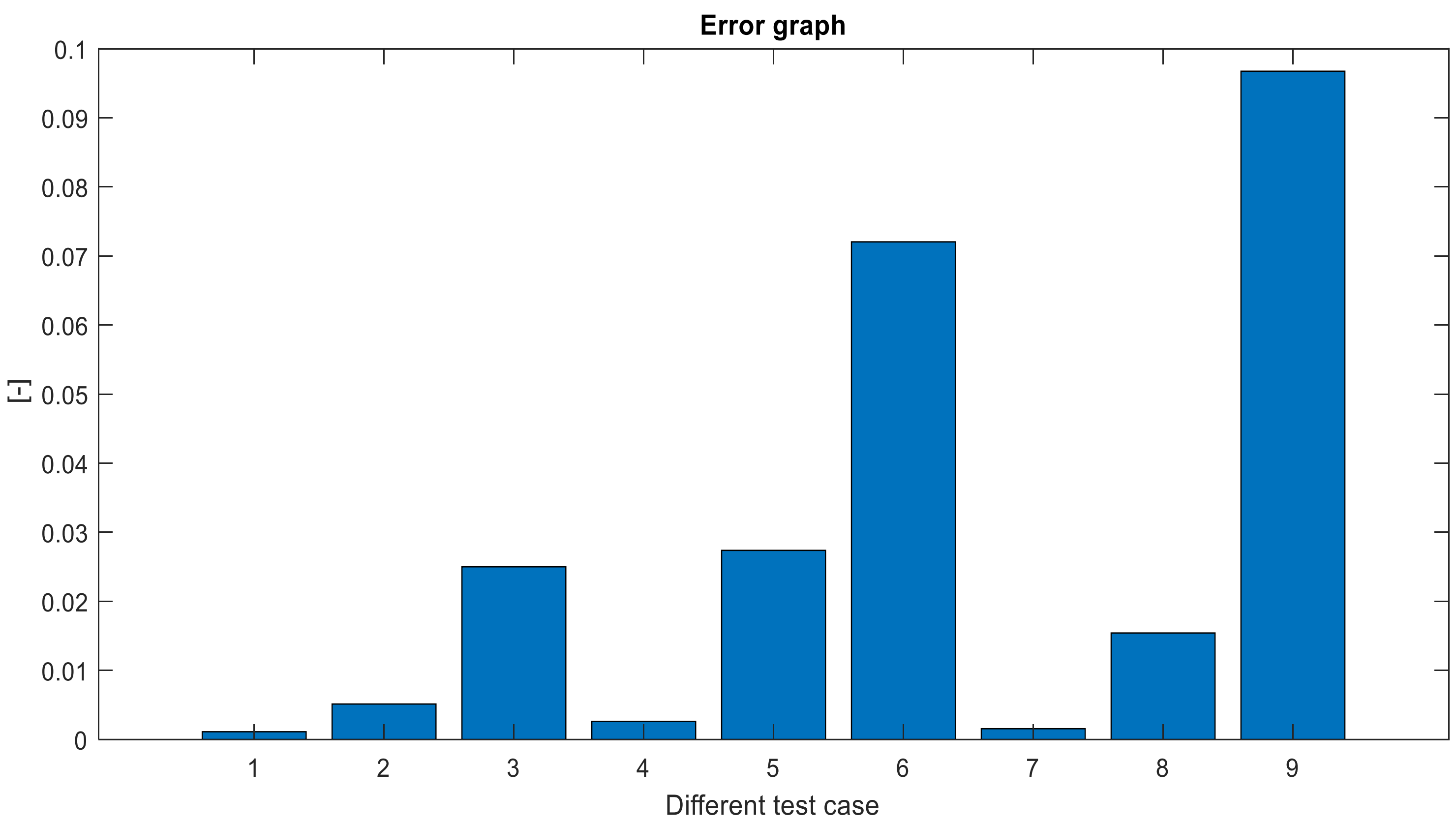


4. RESULTS

- Hill length(L_h) and variance (σ_y) are the parameters which are required for the topographical model to be parametrized. Variance shows a quadratic influence on energy use. The length of the slope has a minor influence since the driver's condition is such that the vehicle will travel at the same pace up and down the hill.
- The curviness model requires a total of 6 parameters to be parametrized. Analysis was conducted on the intensity of curves (λ_C) and log-normal mean of (shifted) radius (μ_C). The outcome is a logarithmic trend that never reaches a maximum, but the rate of energy consumption begins to level off at a certain point.
- A predicted total energy consumption (E_{tot}) was generated to evaluate how much this differs from the individual contributions of each environmental parameter (i.e., E_{topo}, E_{curv}).

$$E_{tot} = E_0 + E_{topo} + E_{curv}$$





4. CONCLUSION

- Simulation data demonstrate a developing trend of energy usage as anticipated, based on powertrain factors such as battery mass, motor efficiency, and engine operating points.
- Curvature yielded higher energy consumption compared to other parameters due to curve clustering.
- The combined energy efficiency was lower than individual energy distribution due to the predetermined threshold value for lateral acceleration provided to the driver model
- Finally, a relation has been established between external variables and drivetrain characteristics in order to determine which parameter affects energy usage.

Reference:
1. https://www.volvotrucks.us/trucks/vnr-electric/

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Poster:

Heavy duty EPS and its theoretical requirements,

Christopher Essén and David Wikman, KTH and Scania

Heavy Duty EPS and its Theoretical Requirements

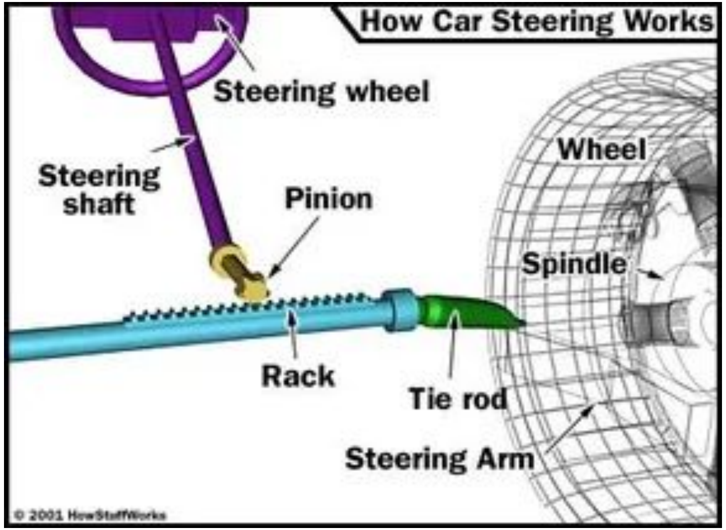
Christopher Essén and David Wikman

Supervised by Malte Rothhämel

13 maj 2022

Introduction

- Steering
- EPS
- HPS och E-HPS
- History

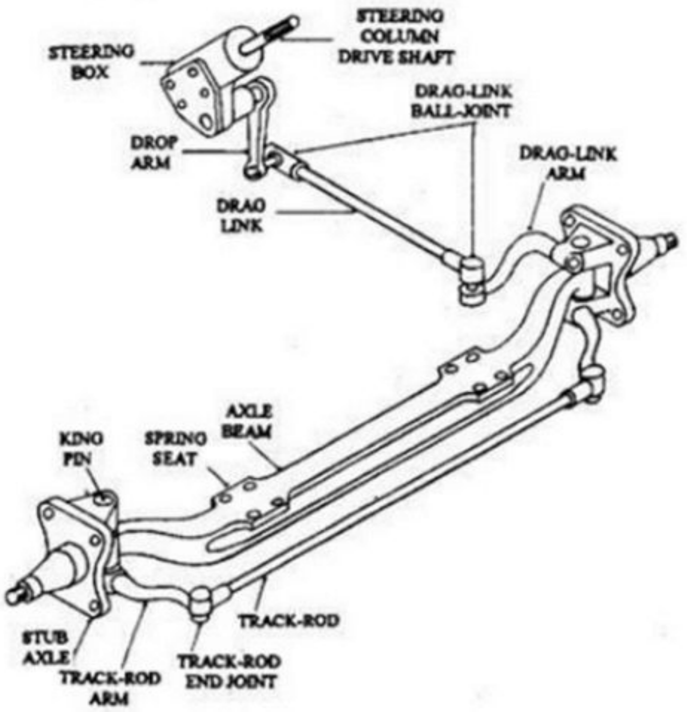


Purpose

- Starting Point
- Specification, EPS
  - Dimensions 25x25x50 cm
  - Steering velocity 600 °/s
  - Input Torque 8 Nm
  - Output Torque 8000 Nm

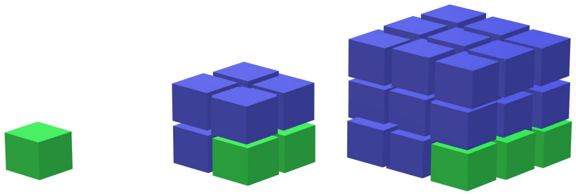
Steering Systems

- EPS and no gearbox
- Steering column mounted EPS
- Drop arm mounted w/ variants



Specifications of the electric motor

- Resistance, voltage and current, U=RI
- Volume vs surface area
- Correlation between torque and RPM



1 cm cell	
SA	6 cm^2
V	1 cm^3
SA:V	6:1

2 cm cell	
SA	24 cm^2
V	8 cm^3
SA:V	3:1

3 cm cell	
SA	54 cm^2
V	27 cm^3
SA:V	2:1

Joules Heating Law:

$$P = RI^2$$

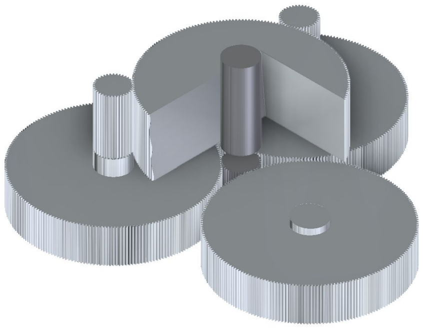
$$[P] = W = J/s = Nm/s = [\tau\omega]$$

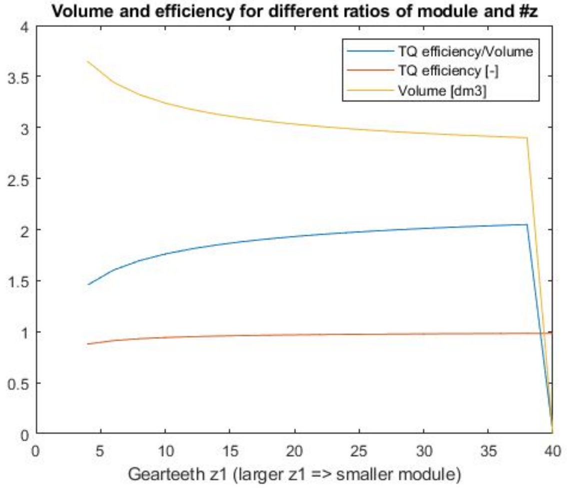
$$\tau = \eta P/\omega$$

$$\omega = \pi RPM/30 => \tau = 30P\eta/\pi RPM$$

Gearbox

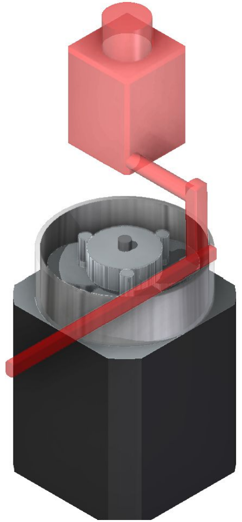
- 4-wheel planetary gearbox
- Exchange limits
- Optimization
  - Cog count vs cog size
  - Efficiency
  - Dimensioning => cog width (SS1871)

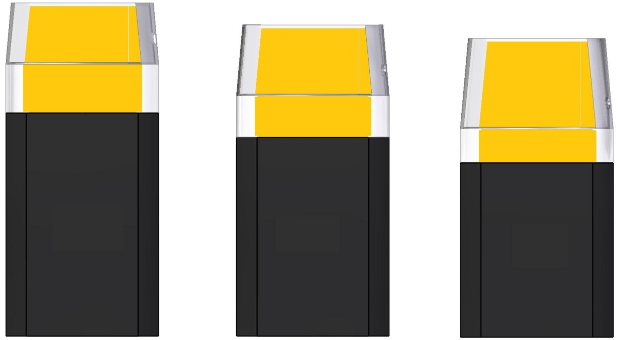




Gearbox

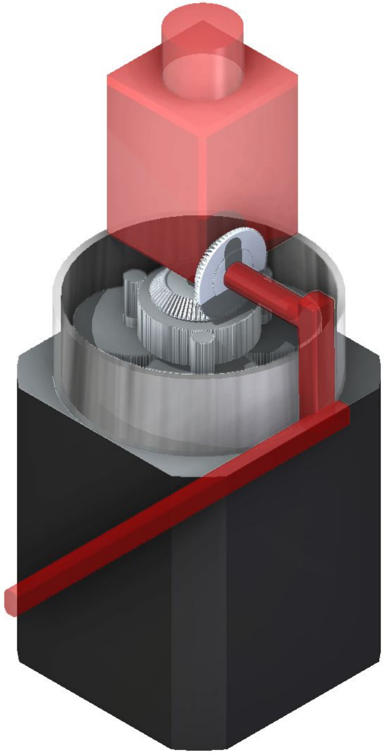
- 90° bevel final gear
- Calculated as a “virtual” spur gear
- Different ratios for different EM’s





Results

- Specification
  - 165Nm EM -> 48.4:1 gearbox
  - 8400Nm reach the front axle
  - Steering velocity 530 vs demand 600 °/s
  - Measurements: 25x25x49cm
- Future iterations
  - Unified gearbox for steering wheel and electric motor
  - Weaker electric motor, higher exchange
  - Utilize maximum torque



Discussion

- Space constraints
- Costs
- Time

Honorable Mentions:

- Malte Rothhämel
- Mats Leksell
- Study visit: Scania trucks
- Annika Stensson Trigell

Poster:

***Variable steering ratio design for steer-by-wire system*,**

Jakob Roempke and Gustav Lindahl, KTH and Volvo Cars

Design of Variable Ratio for Automotive Steer-by-wire Systems

Bachelor thesis in Fordonsteknik SA115X

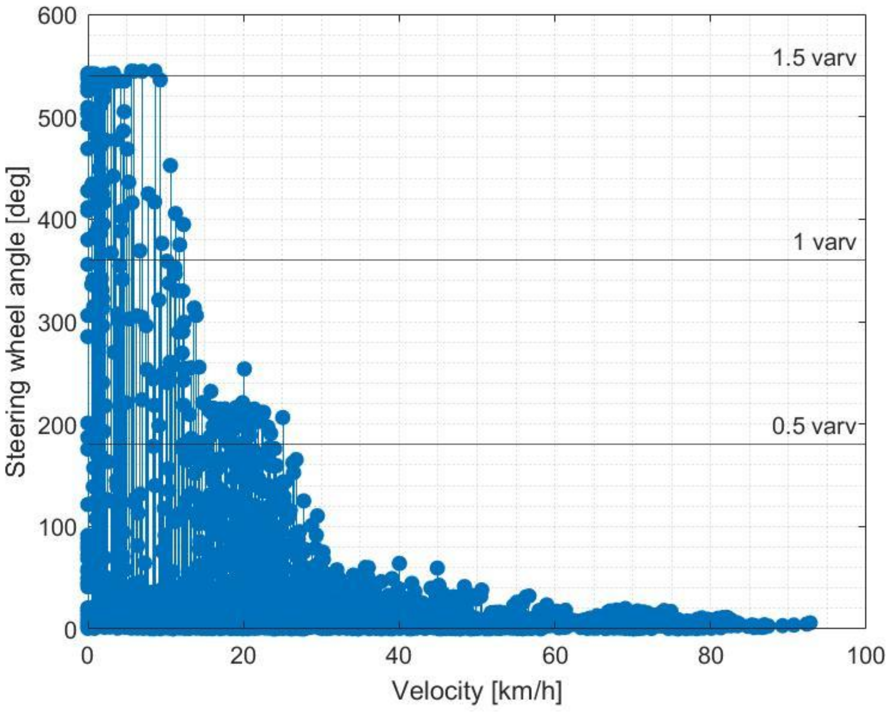
Gustav Lindahl and Jakob Roempke

Supervisor:

- Lars Drugge, KTH
- Matthijs Klomp, Volvo Cars

Results

Physical tests and comfort



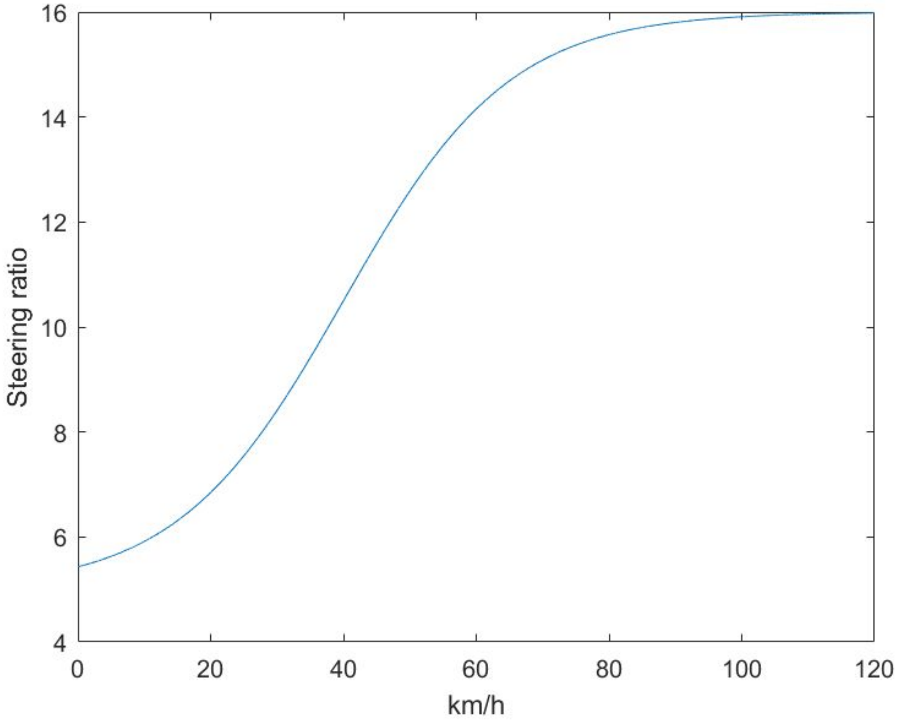
Two hands

Test person	Comfortable	Maximum
1	$-145^o \leq \theta_{sw} \leq 143^o$	$-189^o \leq \theta_{sw} \leq 170^o$
2	$-154^o \leq \theta_{sw} \leq 159^o$	$-167^o \leq \theta_{sw} \leq 178^o$
3	$-145^o \leq \theta_{sw} \leq 154^o$	$-226^o \leq \theta_{sw} \leq 231^o$
4	$-120^o \leq \theta_{sw} \leq 130^o$	$-213^o \leq \theta_{sw} \leq 180^o$
5	$-140^o \leq \theta_{sw} \leq 143^o$	$-258^o \leq \theta_{sw} \leq 248^o$
Average	$-141^o \leq \theta_{sw} \leq 146^o$	$-210^o \leq \theta_{sw} \leq 201^o$

One hand

Test person	Maximum
1	$-208^o \leq \theta_{sw} \leq 250^o$
2	$-265^o \leq \theta_{sw} \leq 187^o$
3	$-245^o \leq \theta_{sw} \leq 195^o$
4	$-266^o \leq \theta_{sw} \leq 190^o$
5	$-250^o \leq \theta_{sw} \leq 236^o$
Average	$-247^o \leq \theta_{sw} \leq 212^o$

Variabel steering ratio



Different sections

- Dependent on speed
- Low speeds - Maneuverability and stability
- Predictable in between
- High speed - Stability

Conclusions

- A variable steering ratio should in some way be dependent on the speed of the vehicle.

- The steering wheel can comfortably be rotated about ±145° and the maximum rotation possible is about ±200° with two hands on the steering wheel.

- A yoke design is possible to implement with variable steering ratio and also open up the possibility to move the interface of the gear selection and turn signals to the steering wheel.

Poster:

***Driving simulator study on Crosswind Aeroddynamics*,**

Anup Garje Mohan Kumar and Sai Kishan Sawanth, CEVT and Chalmers

DRIVING SIMULATOR STUDY ON CROSSWIND AERODYNAMICS

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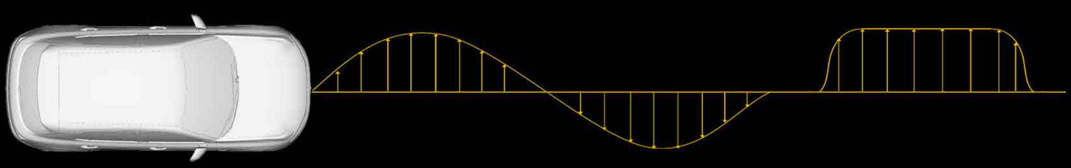
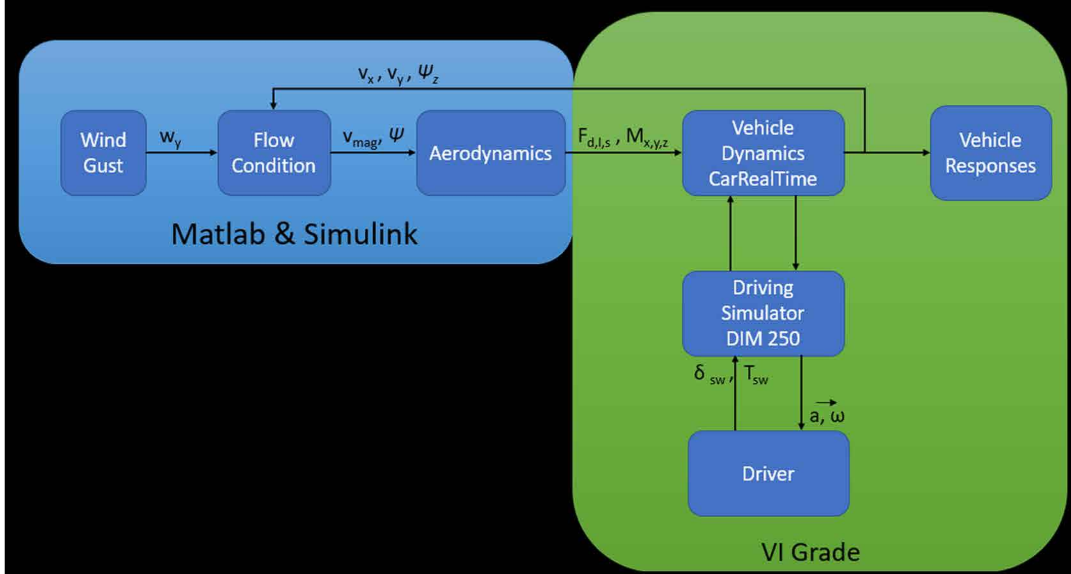
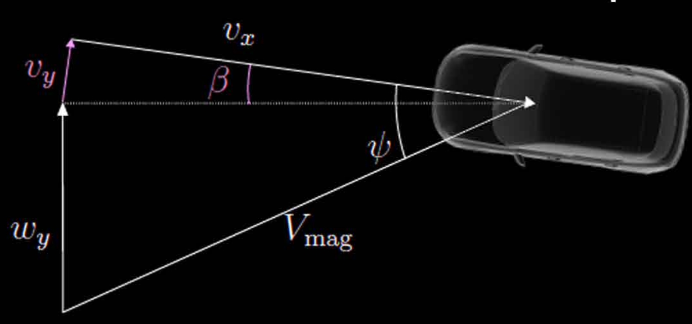
A method to study a SUV's crosswind gust sensitivity at high speed driving on a moving base driving simulator.



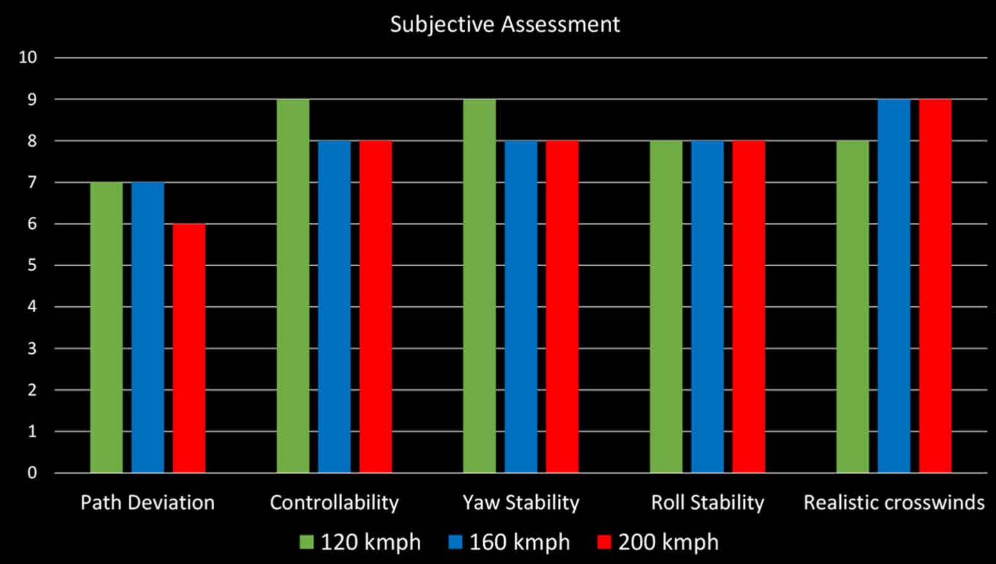
The crosswind gust are parameterised based on Hällared proving ground crosswind data.



The crosswind flow velocity and flow angle define the flow condition and are used as inputs to implement aerodynamic forces and moments on the vehicle reference point.

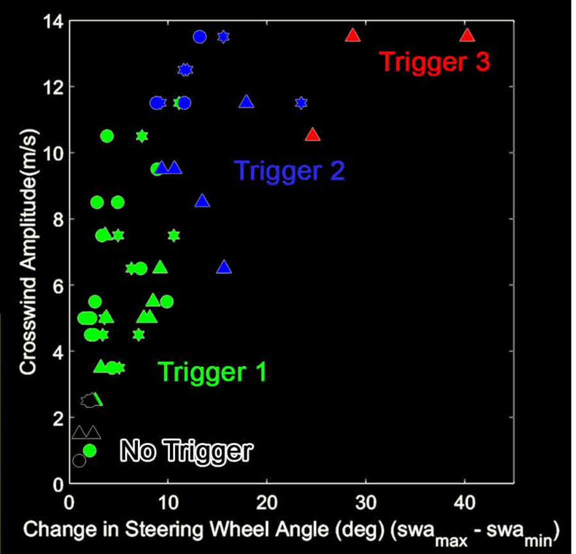


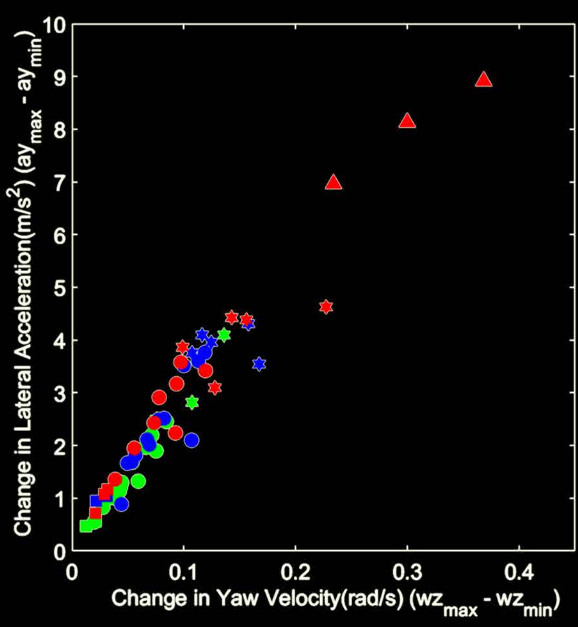
The crosswinds are implemented by using 2 way coupling method between aerodynamics and vehicle dynamics, the aerodynamic forces and moments are dictated by the flow angle and magnitude, which varies with change in wind angle and body slip.

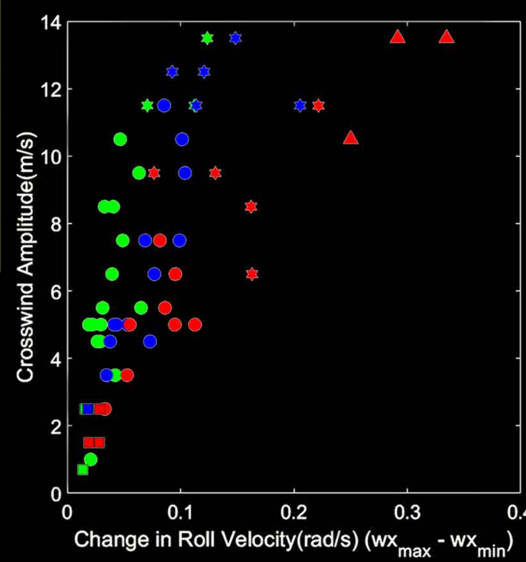


Legend	No Trigger	Trigger 1	Trigger 2	Trigger 3
120 kph	■ (green)	● (green)	★ (green)	▲ (green)
160 kph	■ (blue)	● (blue)	★ (blue)	▲ (blue)
200 kph	■ (red)	● (red)	★ (red)	▲ (red)

No Trigger - driver did not respond to the crosswind gust
Trigger 1 - felt the crosswind gust, straight line tracking with little or no effort
Trigger 2 – felt the crosswind gust, straight line tracking with some effort
Trigger 3 – felt the crosswinf gust, straight line tracking with excessive effort







The objective metrics shows the change in vehicle response at different crosswind amplitudes. The subjective assessment and subjective trigger correlates with the change in vehicle response.

The sensitivity of the vehicle to crosswind is studied by comparing the change in lateral acceleration with the change in yaw velocity of the vehicle during the crosswind gust.

A driving clinic was conducted which involved common and experienced drivers, a total of 39 drivers and each driver completed 4 driving sessions of 6 minutes each. While, no driver reported motion sickness during the driving clinic.