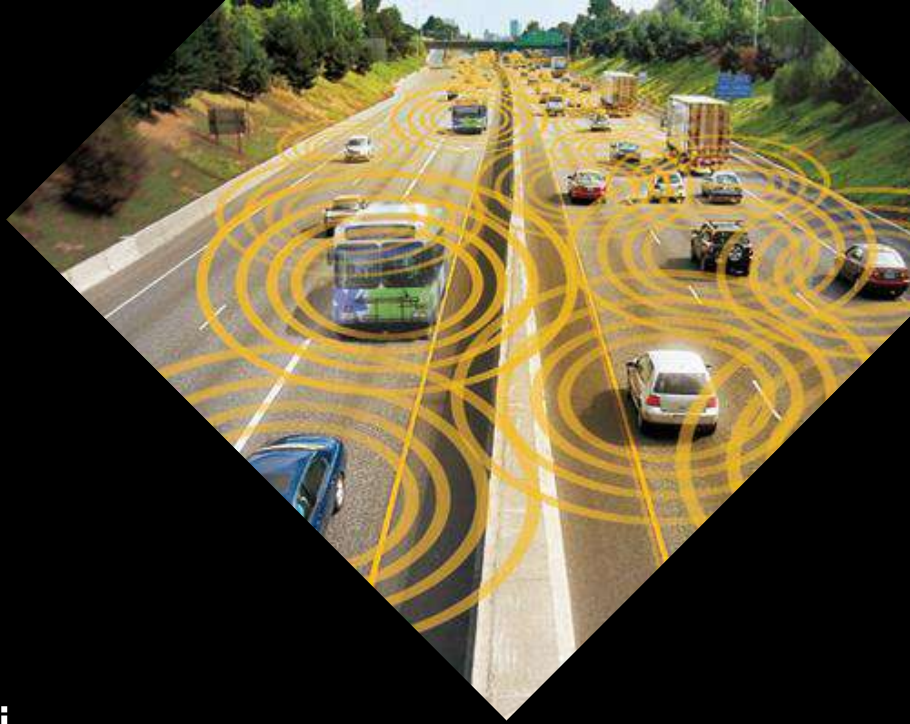

Center for
Automotive Research
and Sustainable Mobility
Cars@PoliTO
05/02/2020 – h 14.30
POLITECNICO DI TORINO
Capetti room – DENERG
Seminar
"Research activities @ CARS"
SAVE THE DATE
Speakers: CARS PhDs &
Researchers & fellows
POLITECNICO
DI TORINO
«The objective of the CARS Center is to
build an environment in which
multidisciplinary research and training
activities can be fostered to speed up
innovation and technology transfer»



Torino, 5/02/2020 – h 14.30
POLITECNICO DI TORINO
Capetti room – DENERG 1st Floor

Agenda

- 14.30 Introduction Prof. Belingardi
- 14.55 Pills Marchisio
- 15.00-16.15 Anselma, Cantoro, Dimauro, Feraco
- 16.15-16.30 Coffee break
- 16.30-17.45 Maino, Malinverno, Mangano, Miretti, Rosano
- 17.45 Pills: Fedorov, Hegde, Khan, Luciani,
  Falai, Musa, Spano, Fiumarella

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Smart Li-Ion Cells

CARS@POLITO

Center for Automotive Research and Sustainable mobility

Andrea Marchisio

Prof.ssa Silvia Bodoardo

February 05, 2020 –PhD Presentation

PhD in Chemical Engineering

Outline – smart Li-Ion cells

- Introdution - Li-Ion cells requirements for the EV market
- Current state of battery monitoring systems and issues
- Current issues and improvements
- Sensors integration concept
- Our work – early results
- Conclusions

Introdution - Li-Ion cells requirements for the EV market

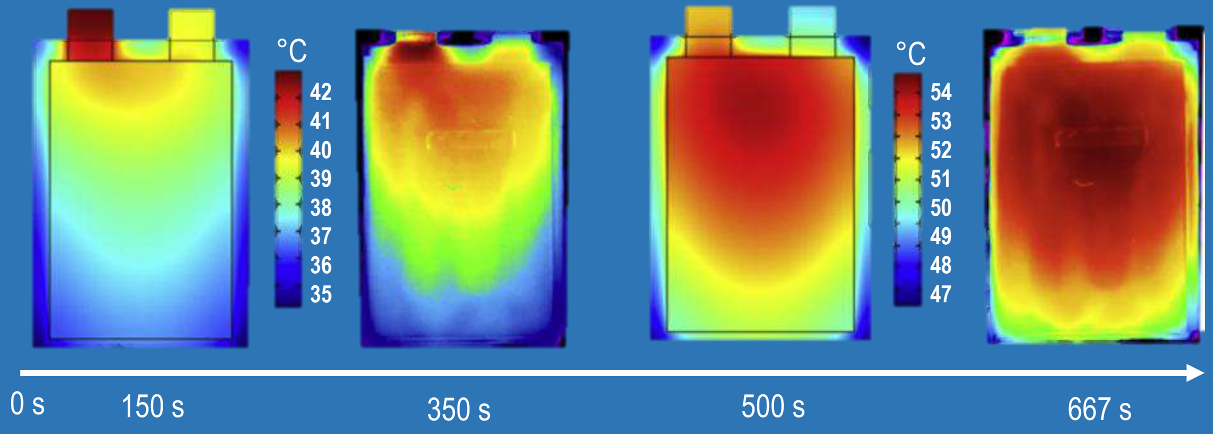
EV (Electric Vehicles) diffusion is growing faster nowadays. The market requires long range, safe and fast-rechargeable EV

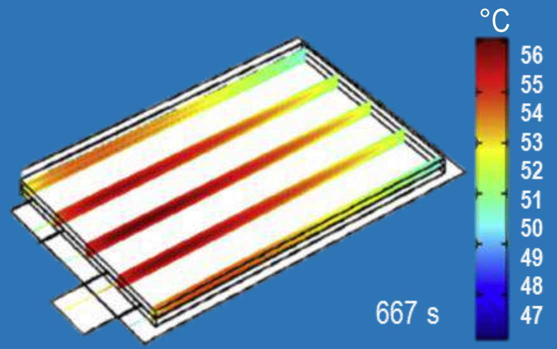
Li-Ion technology is the basis for EV power source actually:

- High energy density
- Low self-discharge rate
- Low maintenance

The market claims for long range EV with fast recharging times → Fast charging (high currents and voltages)

Li-Ion batteries are sensitive to fast charging and high voltage operations. Pushing the charging limits, overcharging or an internal defect causing a short circuit can result in a thermal runaway causing a fire in the worst case.





Current issues and improvements

Actually

The **BMS** (Battery Management System) takes care of 'optimal' control of the battery and mitigation of the dangers by detecting and limiting:

- Voltage
- power (e.g. power fade)
- capacity (e.g. capacity fade)
- temperature

BUT

- Degradation of LIBs is extremely complex - many underlying degradation processes are not included in current BMS
- Sensors are only external to the cell
- Limit the use of the available battery capacity to approx. 80%.

→

Improvements

Developing sensors that work **INSIDE** the cell fully **INTEGRATING** whitin the **BMS** unit

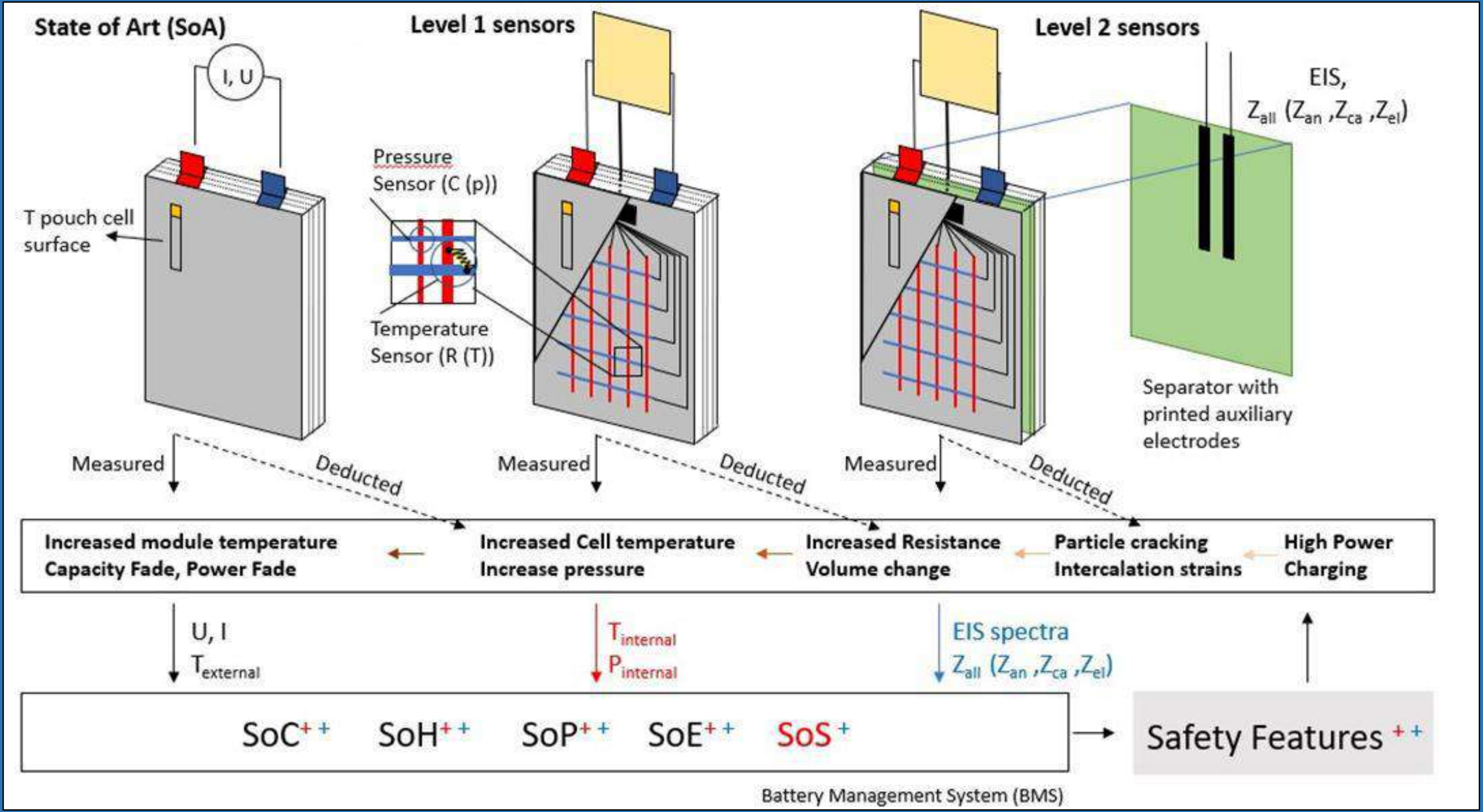
Advantages

- Real time detection
- Behaviour of cell single components
- Accurate (in space and time) parameters recognition

Through monitoring

- Temperature
- Active materials strain
- Cell internal pressure
- Electrolyte composition (composition dependendent parametrs)

Sensors integration concept



Our work – early results

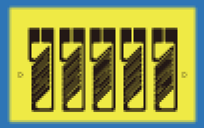
Our work is focused on the development of electric and optical sensors

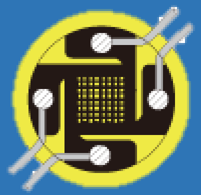
Optical sensors

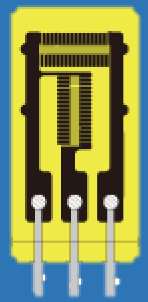
- FBG (Fiber Bragg Gratings) for temperature and strain
- Nanoplasmonics for electrolyte composition

Electric sensors (printable)

- Strain gauges with high gauge factor
- Micro-thermocouples and thermoresistors
- Printed counter-electrodes for EIS







Actually we are focused to evaluate the feasibility to print strain-gauges and therm-oresistors directly on the commercial pouch-cells separator (Celgard) using:

- LIS (Laser Induced Graphene)
- Inkjet printing
- Screen printing
- Shadow masking and PVD
- Hot-embossing transfer

Conclusions

- We obtained well conductive tracks commercial Celgard 2500 using Hot-Embossing transfer of thin graphene layers

- Parallely we are trying to optimize printing parameters to develop an inkjet printing method for PEDOT:PSS

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February 05, 2020 –PhD Presentation

Optimal Design of Electrified and Automated Vehicles

PhD Student :
Pier Giuseppe Anselma

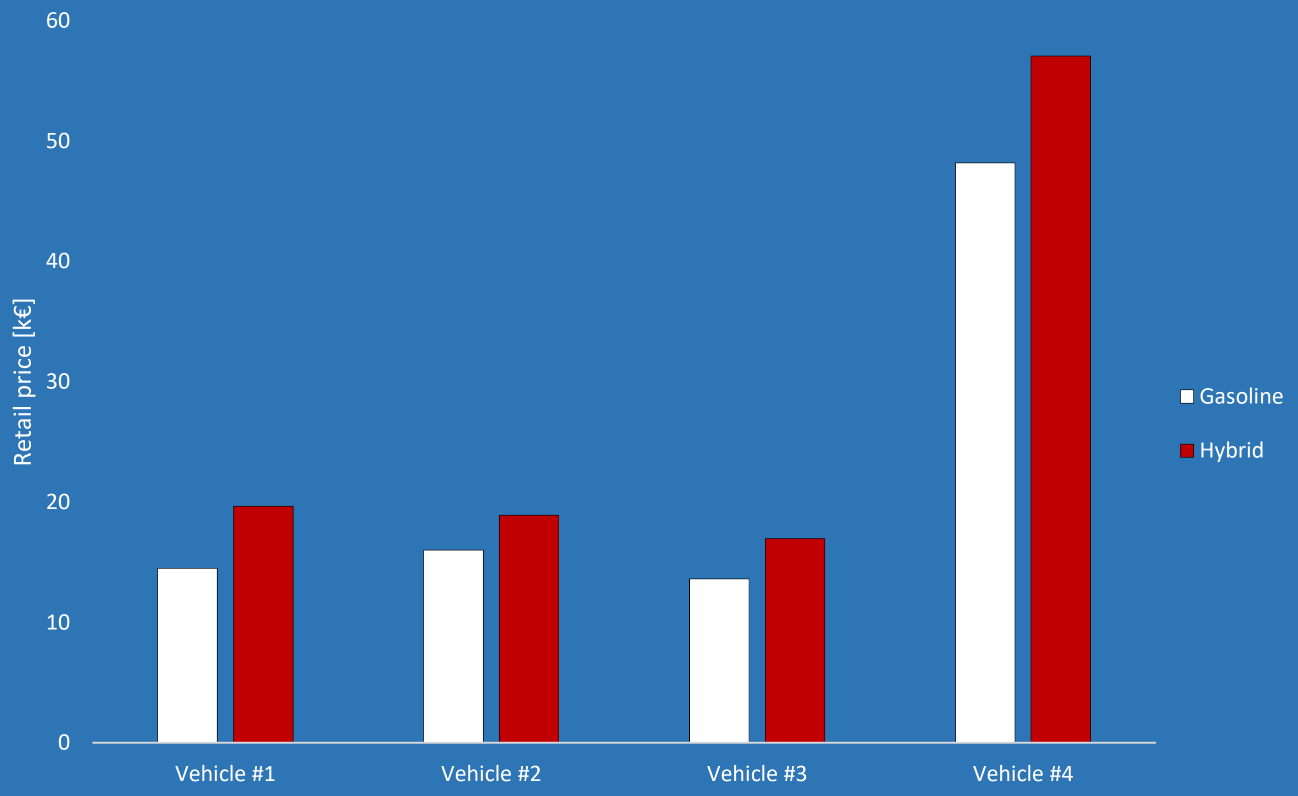
Supervisor :
Prof. Giovanni Belingardi

PhD Program : Mechanical Engineering (XXXIII cycle)

Outline

- Introduction
- Enhanced tools for designing HEVs
- High voltage battery lifetime prediction in electrified vehicles
- Sizing of powertrains for automated electrified vehicles
- Conclusions

Introduction: HEVs are getting popular…but not affordable

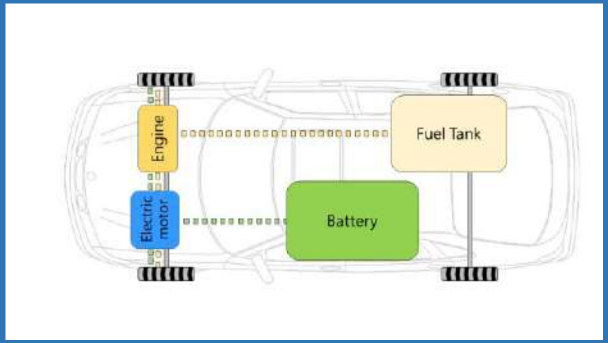


Introduction: Improving the appeal of HEVs

Designers' side :

1. Tools to face a complex **design environment**

2. Lower the cost of **high-voltage battery** and electrical components



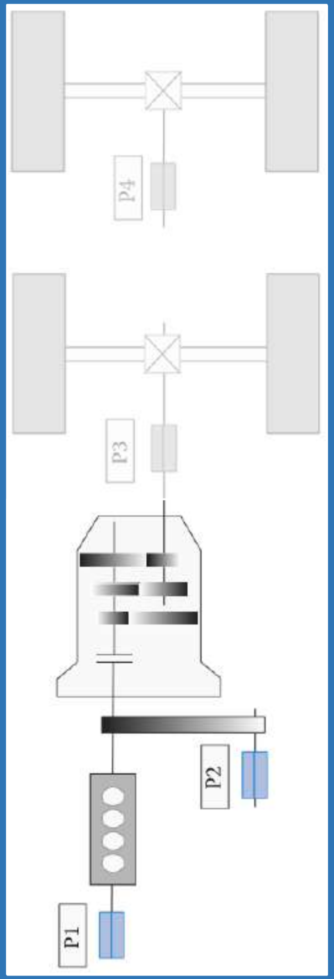
Customers' side :

3. Development of **innovative driving features** (e.g. enhanced automated driving), to be possibly assessed at early vehicle development phases

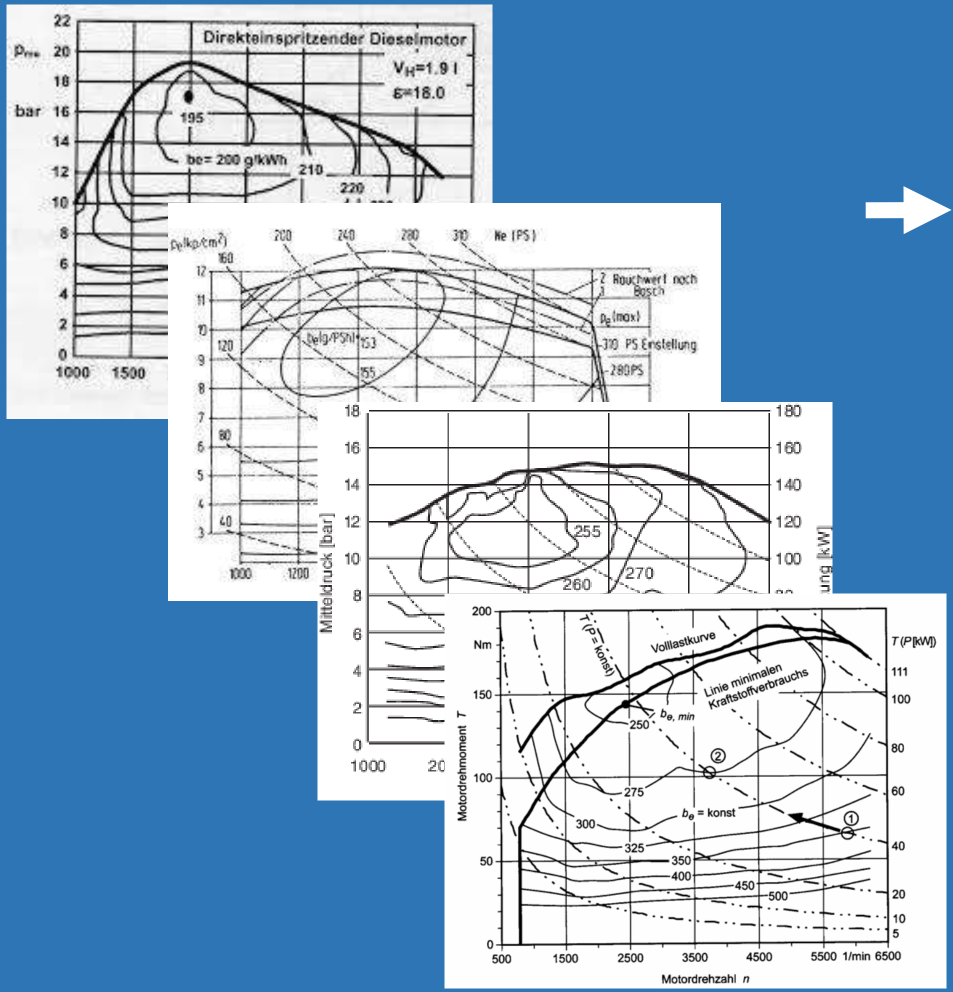
1. Enhanced tools for designing HEVs

Enhanced tools to design HEVs : design workflow

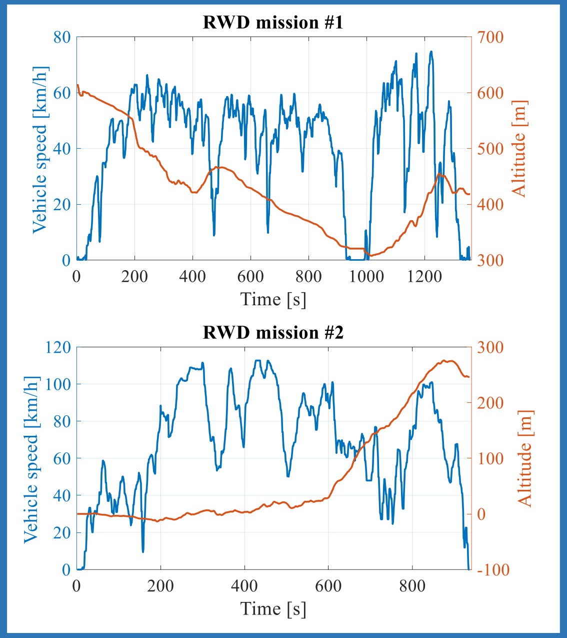
Architecture case selection



Component Selection



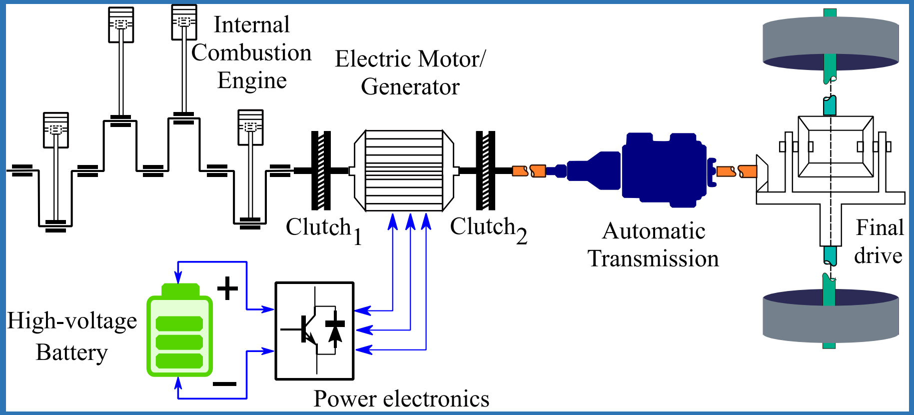
Analysis



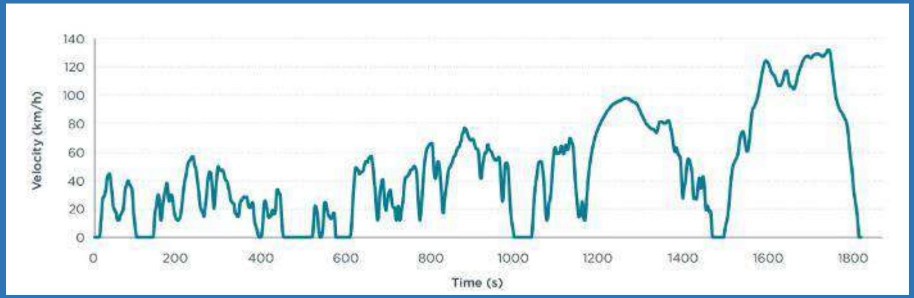
Fuel economy potential :
assessment by means of an
off-line optimal control strategy

Source : Anselma, P.G. and Belingardi, G., "Next Generation HEV Powertrain Design Tools: Roadmap and Challenges," SAE Technical Paper 2019-01-2602, 2019.

Enhanced tools to design HEVs : hybrid powertrain control



Hybrid powertrain architecture



Vehicle speed

Control actions:

1. **Gear number** to engage?
2. **ICE** on/off?
3. **Torque split** between ICE and EM?

Battery **charge-sustaining** operation

Enhanced tools to design HEVs : accelerating off-line control

Dynamic programming (DP) :

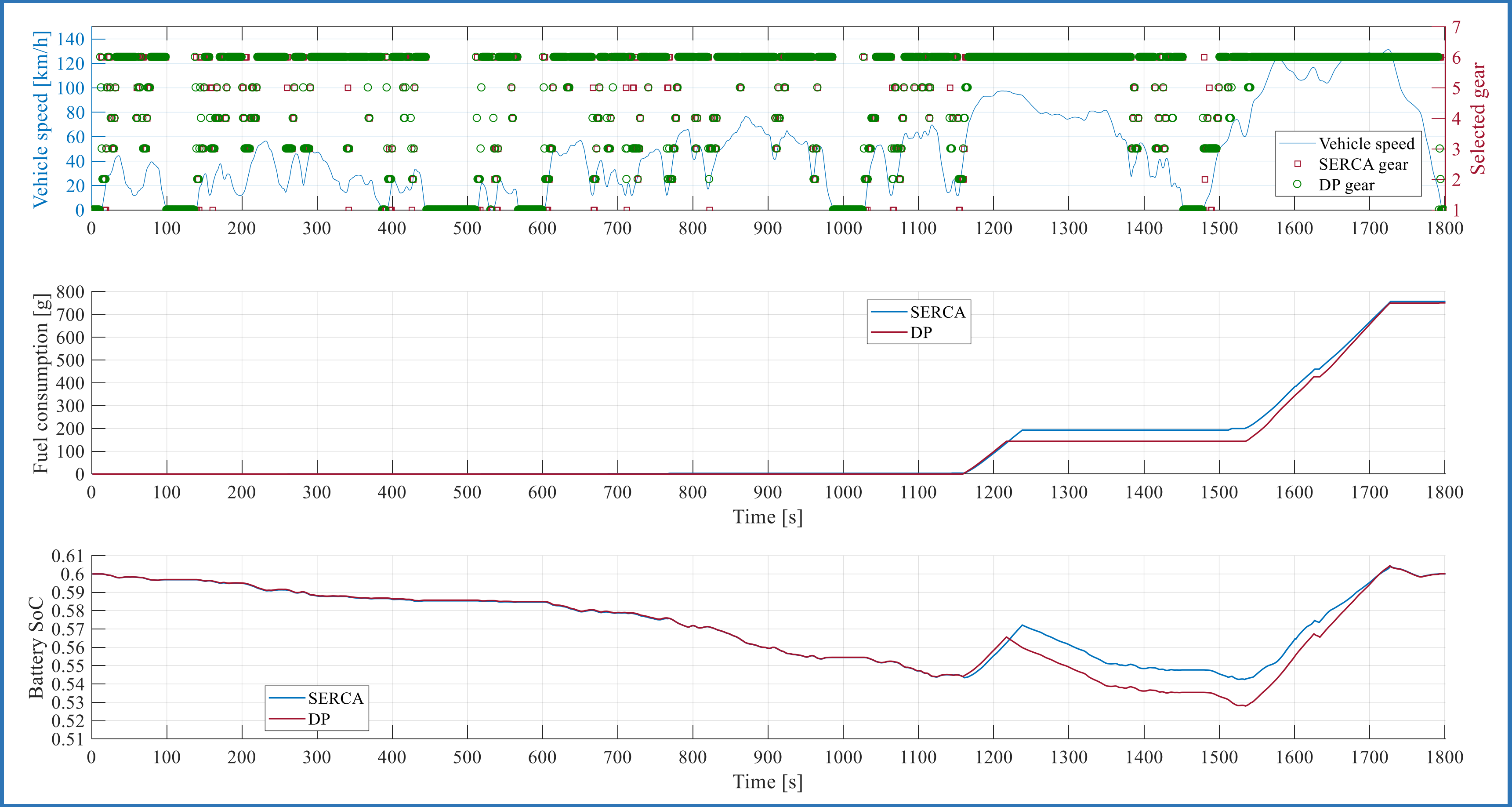
- Can achieve a global optimal solution

- Computationally expensive
- Curse of dimensionality

Slope-weighted Energy-based Rapid Control Analysis (SERCA) :

- Can produce **near-optimal results**, comparable with the ones from DP;
- Remarkable **reduction** of **computational cost:**
  - Avoid the usage of state variables;
  - Limit the size of variables stored in memory;
  - Energy-based objective achievement of charge sustained operation.

Enhanced tools to design HEVs : accelerating off-line control



	Fuel consum-ption [g]	Computa-tional time [minutes]
DP	724.2	70.53
SERCA	728.4 (+0.58 %)	0.018 (-99.97 %)

Enhanced tools to design HEVs : references

Development of SERCA approach for different HEV powertrain architectures:

1. **Power-split**: P. G. Anselma, Y. Huo, J. Roeleveld, G. Belingardi and A. Emadi, "Slope-Weighted Energy-Based Rapid Control Analysis for Hybrid Electric Vehicles," in *IEEE Transactions on Vehicular Technology*, vol. 68, no. 5, pp. 4458-4466, May 2019.
2. **Multimode power-split**: G. Buccoliero, P. G. Anselma, S. A. Bonab, G. Belingardi and A. Emadi, "A New Energy Management Strategy for Multimode Power-Split Hybrid Electric Vehicles," in *IEEE Transactions on Vehicular Technology*, vol. 69, no. 1, pp. 172-181, Jan. 2020.
3. **Parallel and series-parallel**: P.G. Anselma, G. Belingardi, "Accelerated Assessment of optimal Fuel Economy Benchmarks for Developing the next Generation HEVs ", *20th FKFS Stuttgart International Sympoium*, Stuttgart, Germany, March 2020.

Implementation of SERCA approach in HEV design methodologies:

4. Anselma, P., Biswas, A., Bruck, L., Amirfarhangi Bonab, S. et al., "Accelerated sizing of a power split electrified powertrain," *SAE Technical Paper 2020-01-0843*, 2020.

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2. High voltage battery lifetime prediction in electrified vehicles

High voltage battery lifetime prediction in electrified vehicles

<u>Downsized battery pack</u> (1.2÷1.6 kWh)

- Weight reduction;
- Cost reduction;
- Reduction of CO_2 emitted in manufacturing;

- Operation at higher c-rate → risk of derating effects and accelerated aging.

VS

<u>Oversized battery pack</u> (1.8÷5 kWh)

- Operation at lower c-rate → ease of management and reduced aging;

- Weight increase;
- Cost increase;
- Increase of CO_2 emitted in manufacturing.

High voltage battery lifetime prediction in electrified vehicles

Downsized battery pack (1.2÷1.6 kWh)

- Weight reduction
- Cost reduction
- Reduction of CO2 emitted in manufacturing

- Operation at higher c-rate ➔ risk of derating effects and accelerated aging

Research challenges :

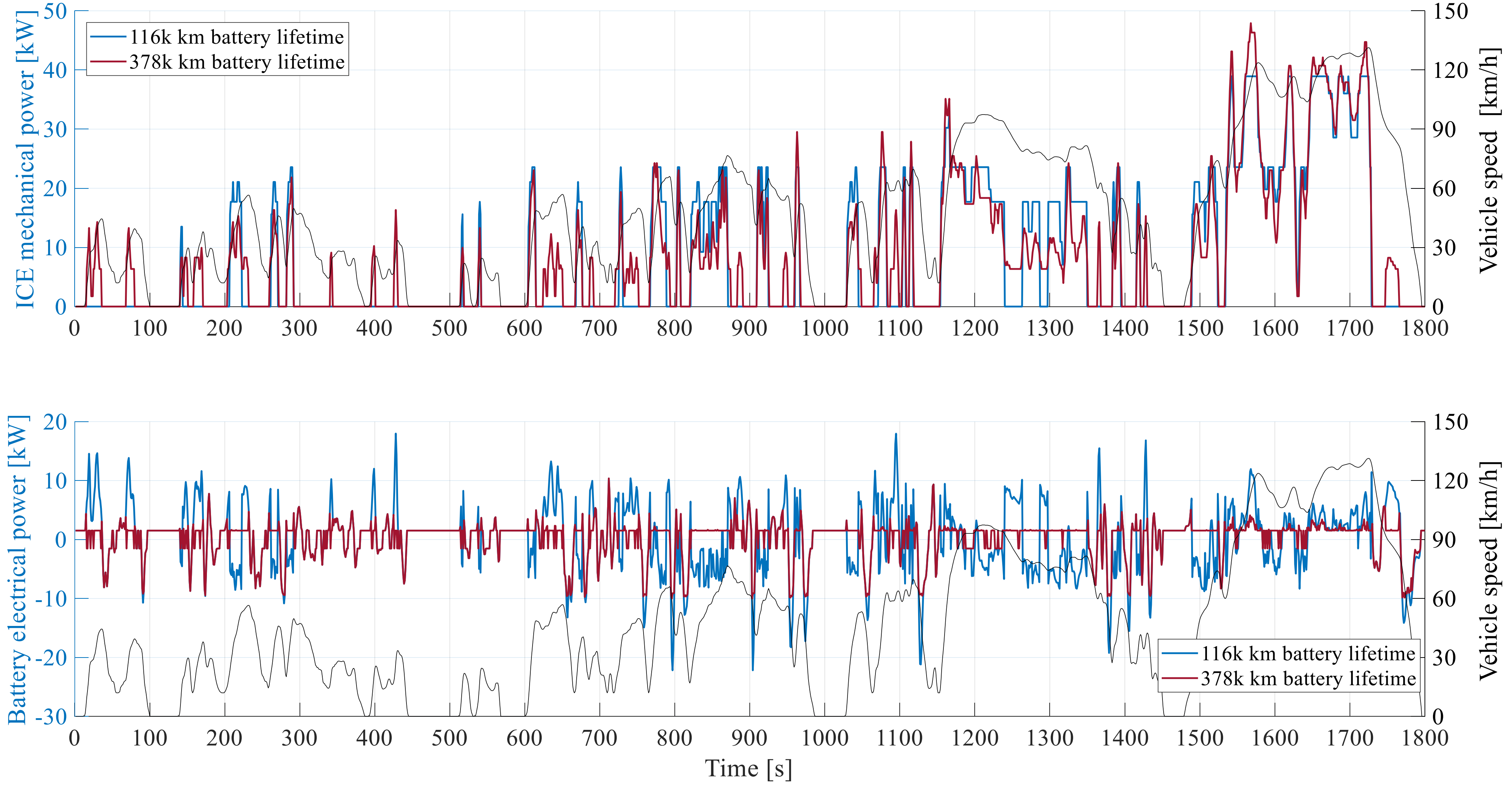
- Embedding **prediction of battery lifetime** in HEV powertrain **design** tools
- Development of **dedicated on-board** HEV **control systems** and strategies

Implementation of a **multi-objective DP** formulation (fuel economy and battery state-of-health)

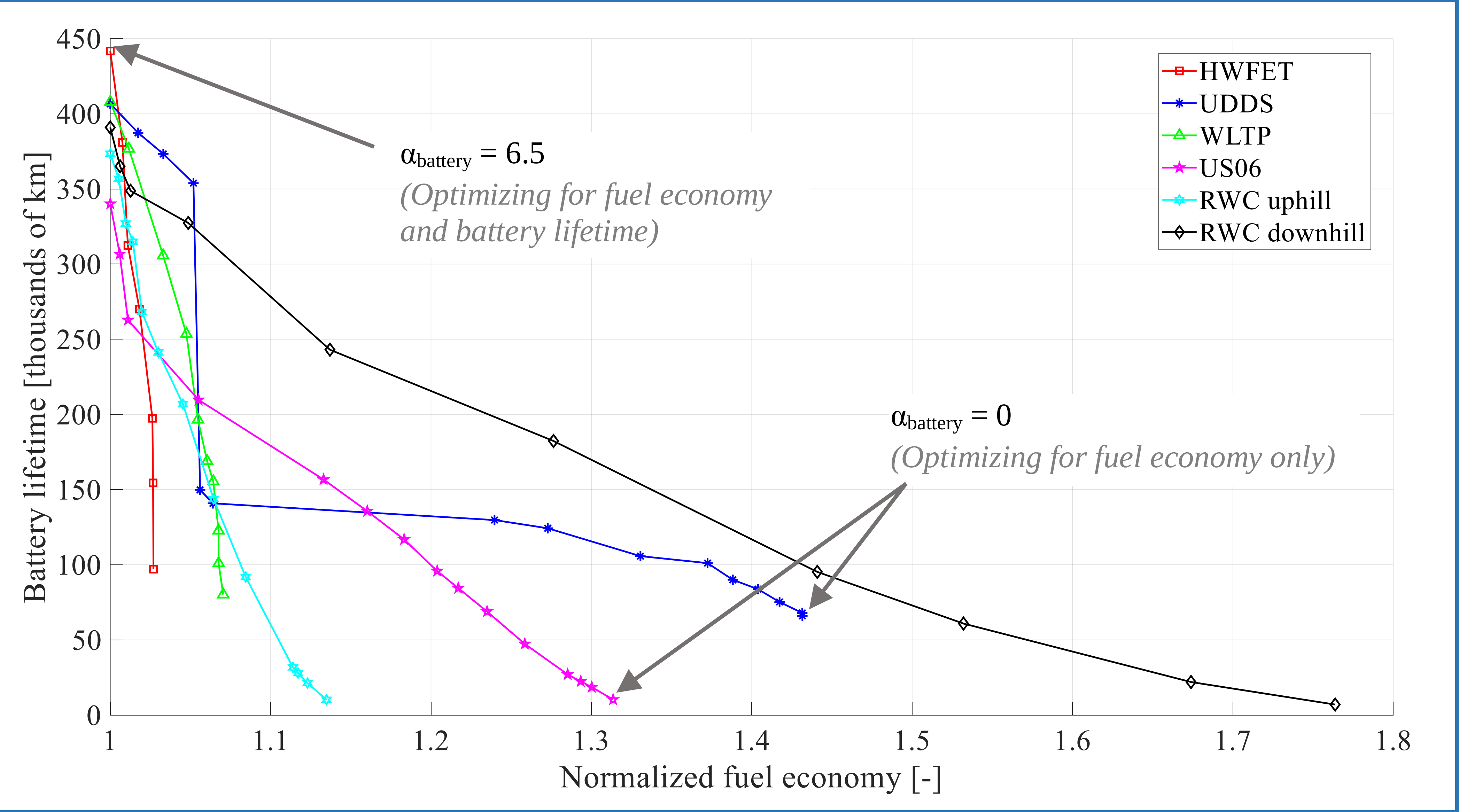
$$L(t) = \dot{m}_{fuel} \cdot \$_{fuel} + \alpha_{batt} \cdot \$_{batt} \cdot S\dot{o}H$$

Throughput-based battery capacity fade model

High voltage battery lifetime prediction in electrified vehicles



High voltage battery lifetime prediction in electrified vehicles



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3. Sizing of powertrains for automated electrified vehicles

Sizing of powertrains for automated electrified vehicles

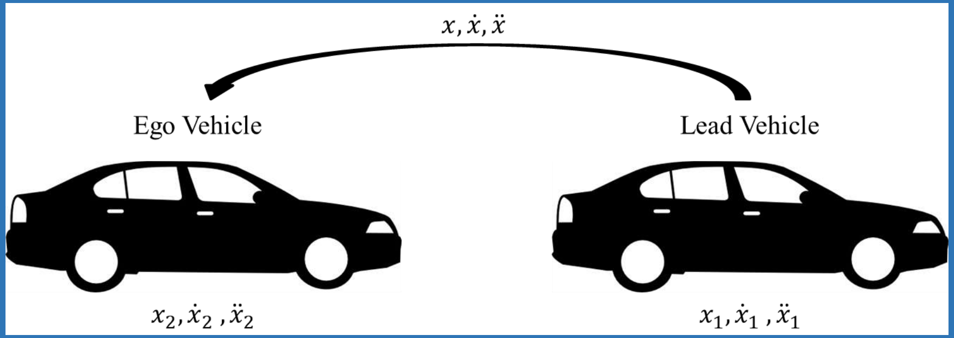
1. Current advances in connected and automated mobility claim to change driving scenarios worldwide.
2. The impact of automated mobility on the design of vehicle powertrains still need exhaustive assessment.

↓

- Vehicle-to-vehicle (V2V) driving scenario with off-line optimal driving management of Ego vehicle.
- Battery electric vehicle (BEV) powertrain.

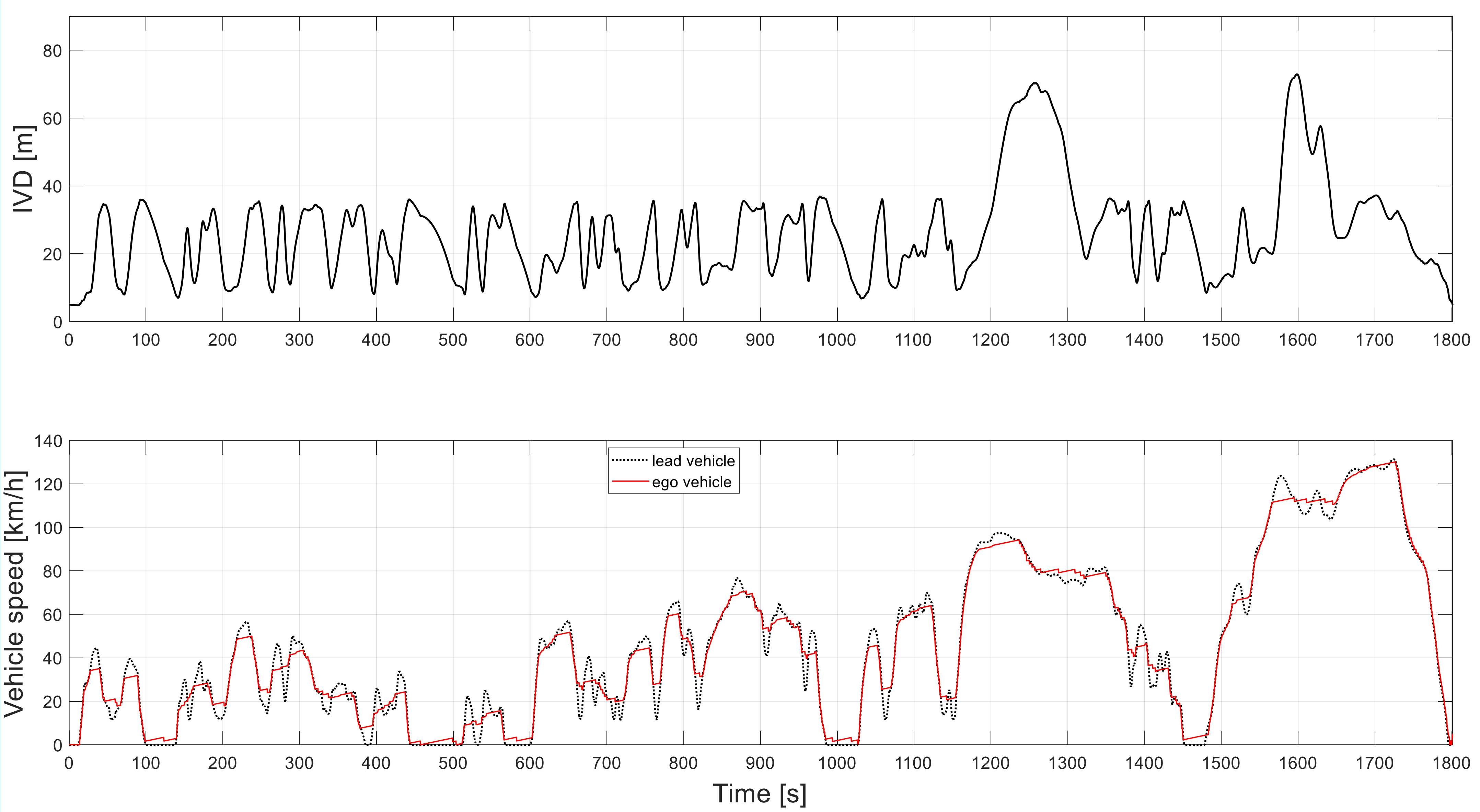
Sizing of powertrains for automated electrified vehicles

- Vehicle-to-vehicle (V2V) driving scenario with off-line optimal driving management of Ego vehicle.
- DP formulation for V2V driving:
  - Multi-objective cost function (energy saving, comfort);
  - Inter-vehicular distance as constraint;
  - Control action = ego vehicle acceleration.

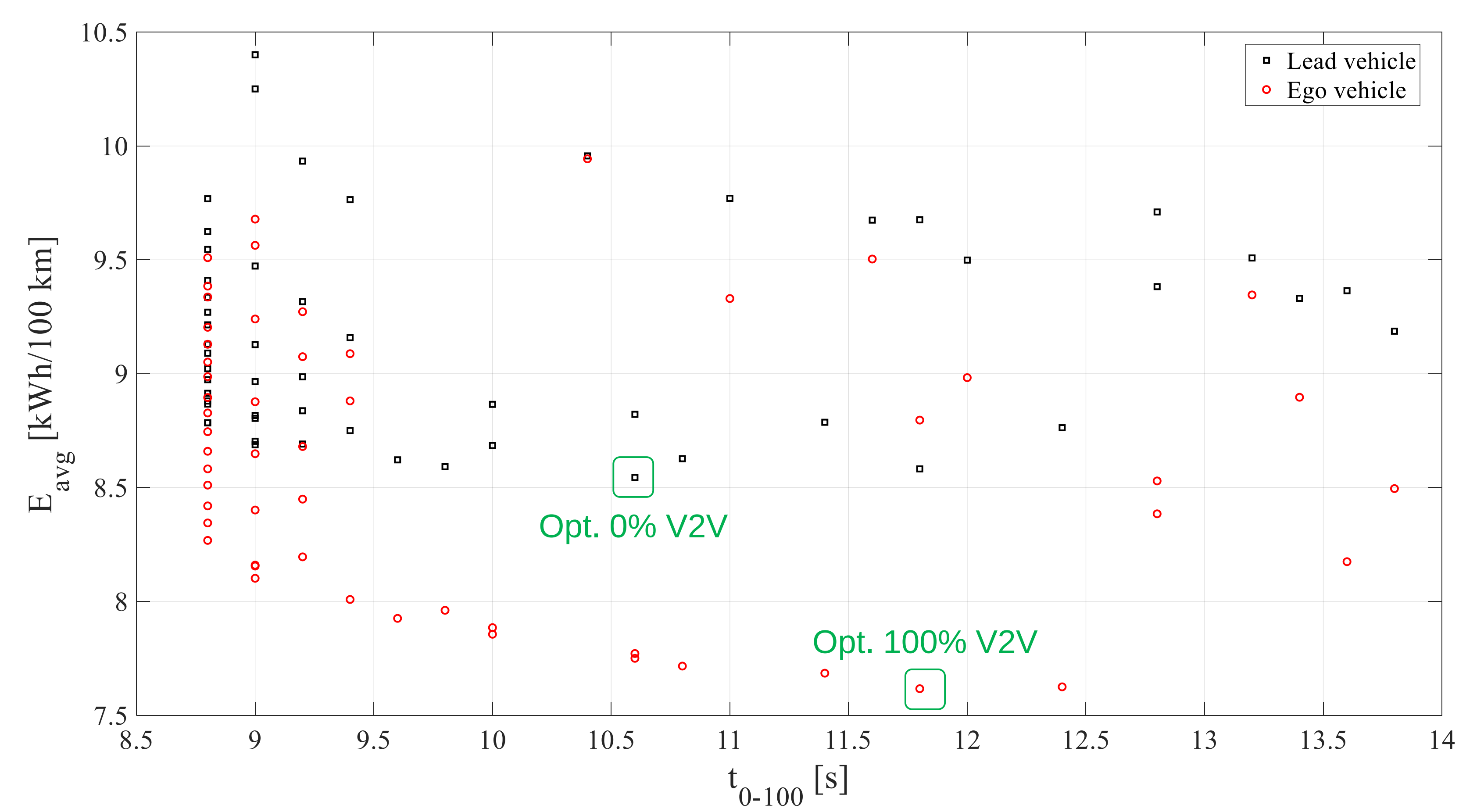


$$J_{DP} = \int_{t_0}^{t_{end}} [e_{batt}(\dot{x}_2, \ddot{x}_2, t) + \alpha_{jerk}]\, dt \qquad U = \{\ddot{x}_2\} \qquad X = \begin{Bmatrix} IVD \\ \dot{x}_2 \end{Bmatrix}$$

Sizing of powertrains for automated electrified vehicles



Sizing of powertrains for automated electrified vehicles



$\%_{V2V}$	Ran-king	EM size [kW]	Direct drive ratio (τ)	$E_{avg_{mix}}$ [kWh/ 100 km]
0 %	# 1	80	6.5	10.61
	# 2	80	5.5	11.82
	# 3	80	7.5	9.80
100 %	# 1	80	5.5	7.62
	# 2	90	4.5	7.63
	# 3	100	4.5	7.69

Source : Anselma, P.G. and Belingardi, G., "Enhancing Energy Saving Opportunities through Rightsizing of a Battery Electric Vehicle Powertrain for Optimal Cooperative Driving", *SAE International Journal of Connected and Automated Vehicles*, In press, 2020.

Sizing of powertrains for automated electrified vehicles

Future work:

- Extension to **different** types of electrified **powertrain** (e.g. parallel HEV, power-split HEV)
- More **detailed** and **multidisciplinary modeling** approaches:
  - V2V **wireless communication**
  - **Changes** in **aerodynamic drag** depending on the IVD
- Development and implementation of **real-time optimal control** approaches for V2V driving

Conclusions

- A **technique** under development has been presented to **rapidly predict** the optimal **fuel economy** benchmarks for **HEV** powertrains.
- A numerical tool has been developed to **estimate** the high voltage **battery lifetime** in electrified vehicles.
- An optimal **design** approach has been implemented for **electrified powertrains** of **automated** road vehicles in **cooperative driving** mode.

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February 5, 2020 – Research work progress

Riccardo Cantoro

Riccardo Cantoro

- Ph.D. in Control and Computer Engineering at Politecnico di Torino
  - 29th cycle: 2014-2017
- I'm currently working in the CAD and Reliability group as a Researcher (RTD/A)
- I'm an Assistant Professor for the courses of Computer Architectures, Operating Systems, and Testing and Reliability @PoliTo
- I also teach Signal Processing (exercises) and Computer Security (lectures) @SUISS (UniTo)
- I'm actively researching on the field of testing of microprocessor-based systems
- I'm involved in research collaborations with other universities and companies (e.g., STMicroelectronics, Infineon, Magneti Marelli).

Outline

- Introduction
- Research activities

Autonomous driving – a safe(ty) affair

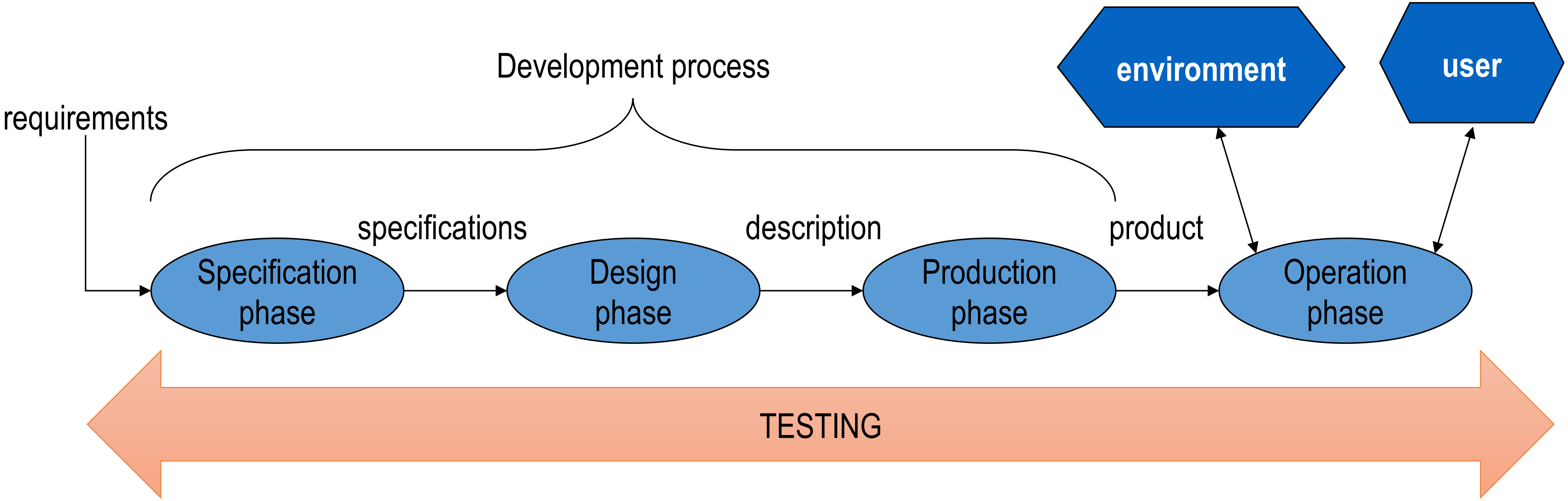
Level 3: Drivers are still necessary in level 3 cars, but are able to completely shift "safety-critical functions" to the vehicle, under certain traffic or environmental conditions …

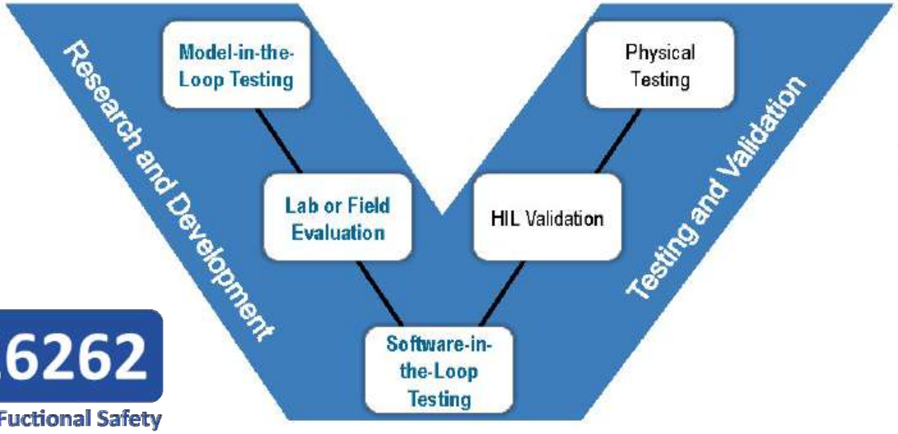
Level 4: This is what is meant by "fully autonomous." Level 4 vehicles are "designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip." …

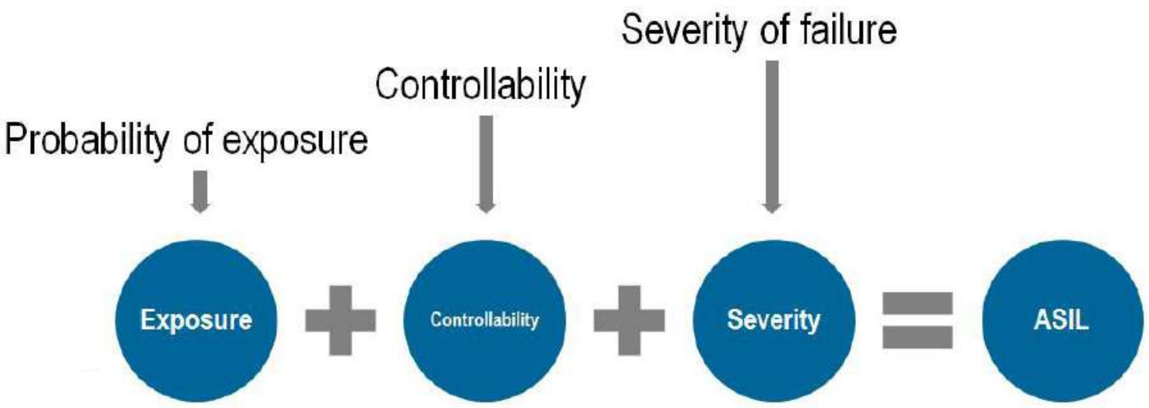
Level 5: This refers to a fully-autonomous system that expects the vehicle's performance to equal that of a human driver, in every driving scenario—including extreme environments like dirt roads that are unlikely to be navigated by driverless vehicles in the near future.

Source: techrepublic.com

Product Life-cycle and Functional Safety







ISO 26262

Road Vehicles - Fuctional Safety

Functional test of SoCs

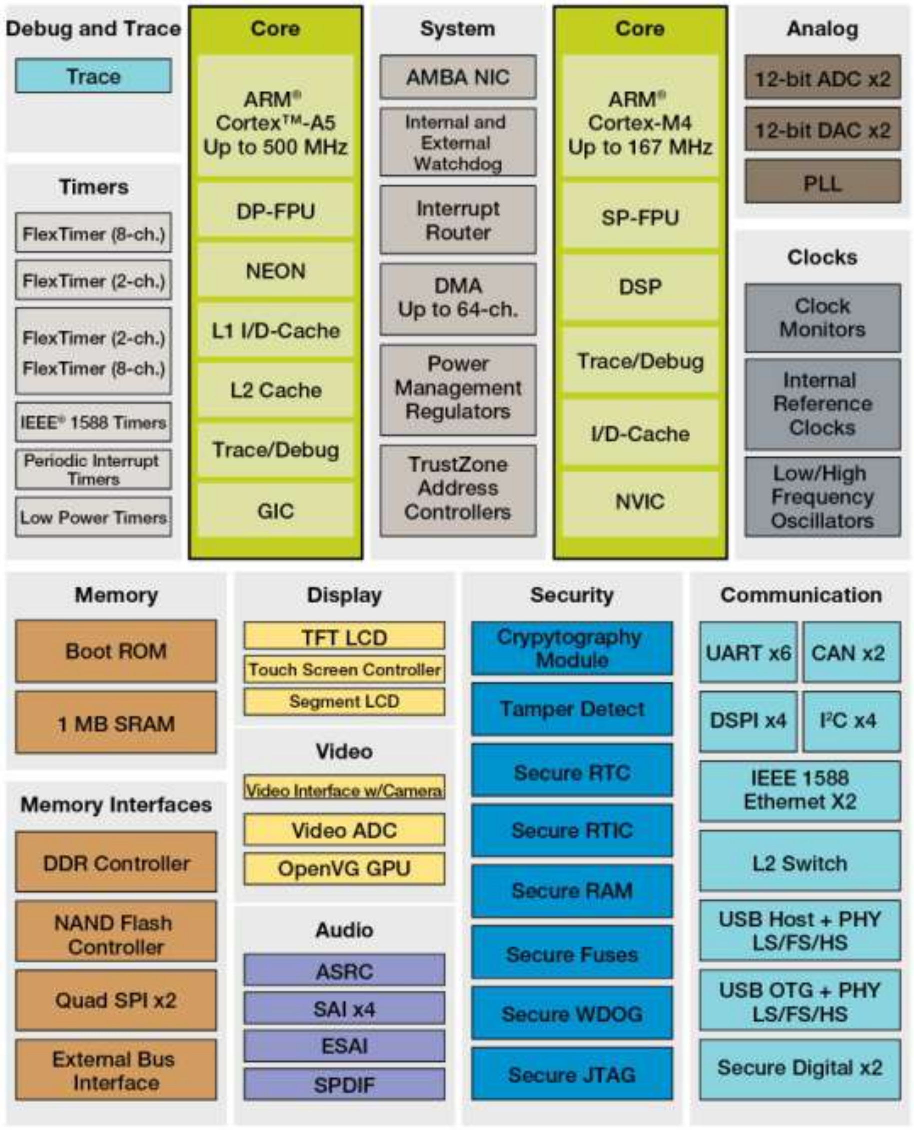
Increasingly important for manufacturing and in-field test (to increase defect coverage and to match requirements of safety-critical applications)

Targeting processors, peripherals, memories

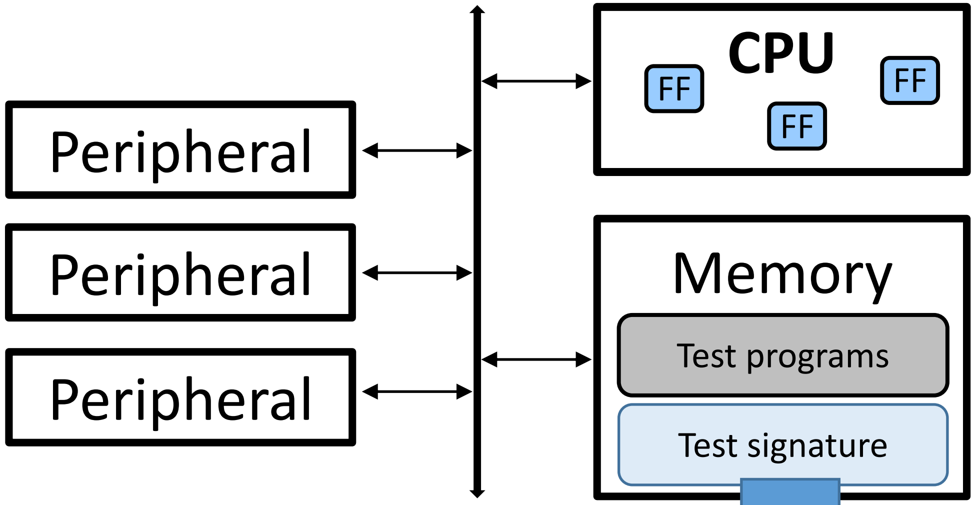
Special focus on SoCs and GPGPUs

Techniques for

- manual or automated generation of test programs for specific cores
- test program optimization (e.g., compaction)



Software-Based Self-Test




```
...
lbzu r24, 0x0(r2)
lbz r25, 0x4(r2)
lhzu r28, 0x8(r2)
lha r29, 0xc(r2)
xor r30, r24, r29
rlwinm r30,r30,5,0,25
xor r30, r30, r28
rlwinm r30,r30,5,0,31
stwu 29, 0x10(r2)
stw 30, 0x14(r2)
...
```

Compared against an expected value

Triggers an alerting system and puts the car in a safe state

Research activities

- In-field functional test of CAN Bus Controllers
- Using memory encryption as Safety Mechanism
- Automotive eFLASH memories production testing

Work in progress

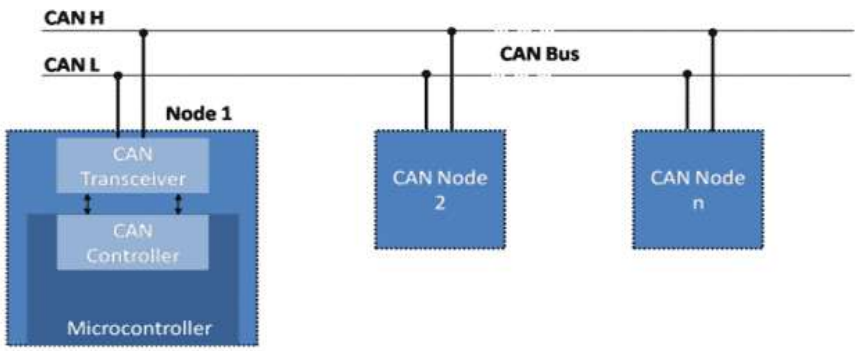
- Automotive SoCs performance modeling during production
- Path delay functional testing

In-field functional test of CAN Bus Controllers

In an integrated circuit, while performing its tasks during its operative lifetime, physical defects can arise due to aging

Defects in a CAN controller may degrade or completely compromise the CAN bus communication

In-field testing is required to detect those defects that can manifest causing errors that could possibly be harmful.

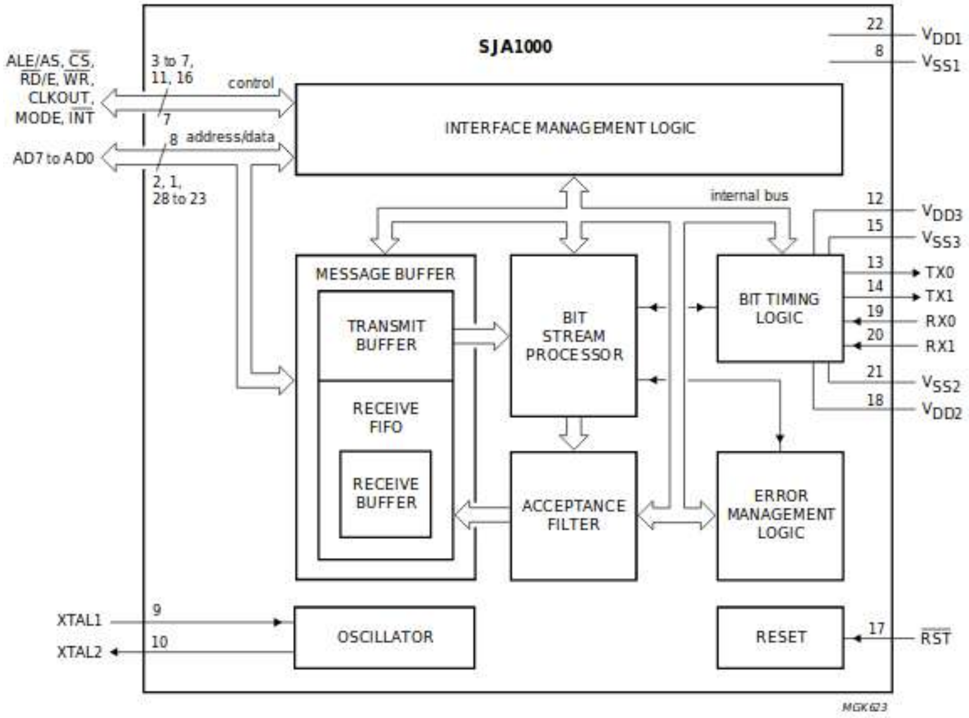


Goals of this work

To develop a test strategy for the CAN controller based on software test programs, which are embedded in the devices attached to the CAN bus

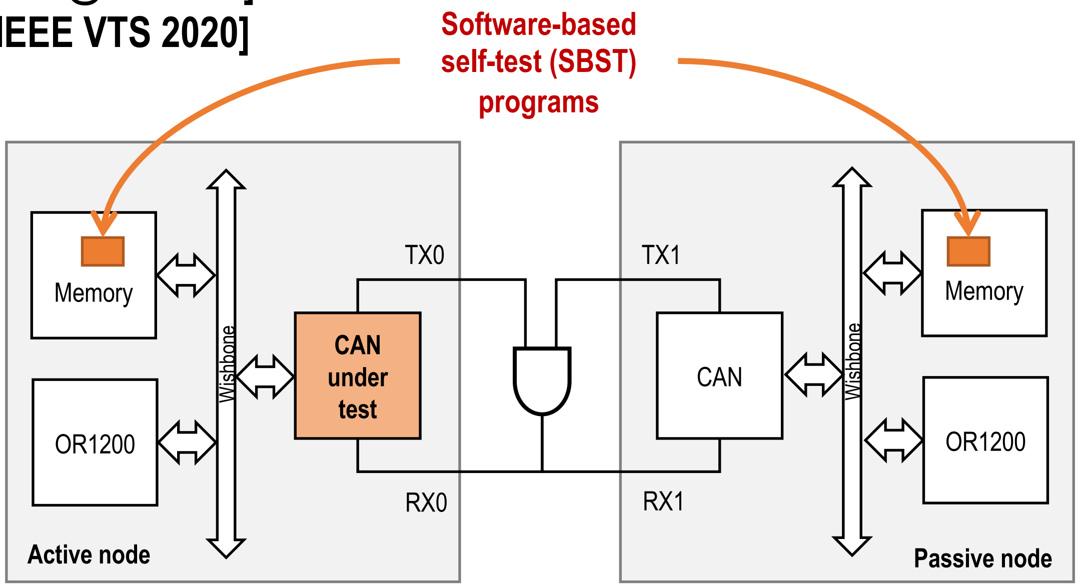
To evaluate the self-test capability offered by the CAN controller

To identify functionally untestable faults.



In-field functional test of CAN Bus Controllers

[ART@ITC 2019]
[IEEE VTS 2020]



We developed test programs covering all the functionalities of the CAN Controller, when the system is connected to the CAN Bus

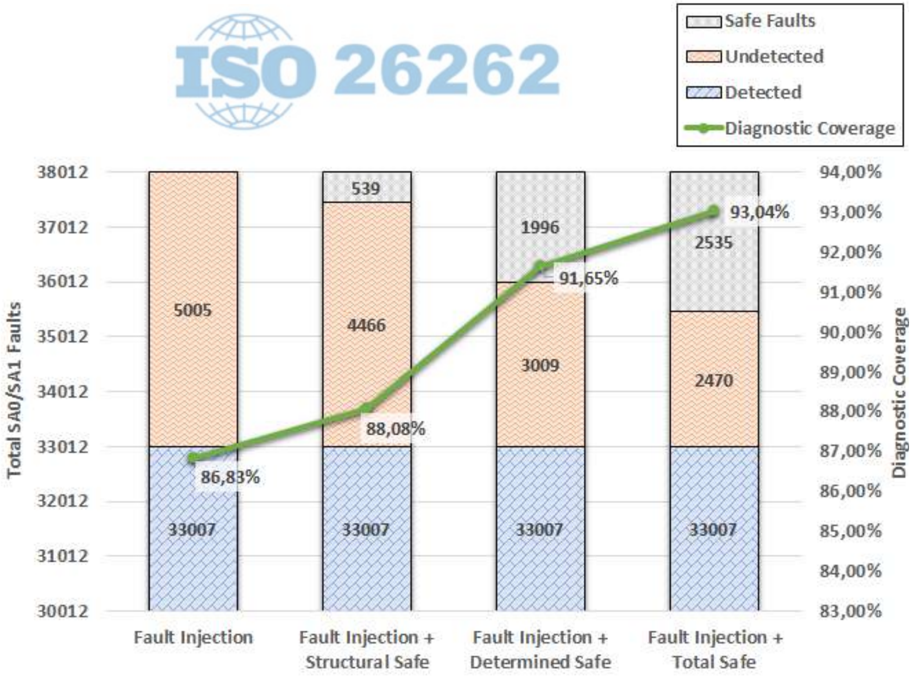
Test programs are composed by sequences of configuration operations and messages exchanged by active and passive nodes

Self-test mode configuration is used as much as possible to minimize the activity on the bus.

[IEEE ETS 2020]

We developed a systematic approach to identify faults that do not disrupt safety-critical functionalities and consequently can be considered Safe

The Diagnostic Coverage is improved by screening out the faults classified as safe.

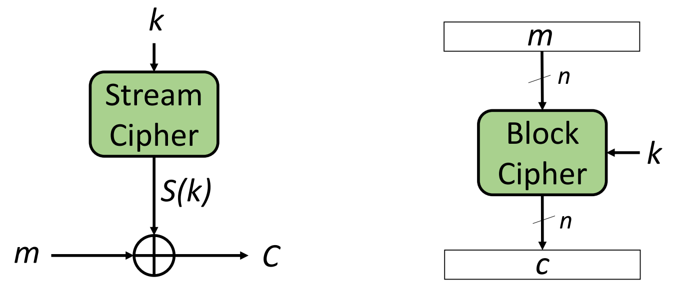


Using memory encryption as Safety Mechanism

In safety-critical systems, the application code and data are generally stored into Non-Volatile Memories (NVMs) that are prone to faults (e.g., due to radiation effects).

Error detection/correction mechanisms (e.g., ECC) are implemented to avoid Silent Data Corruption (SDC).

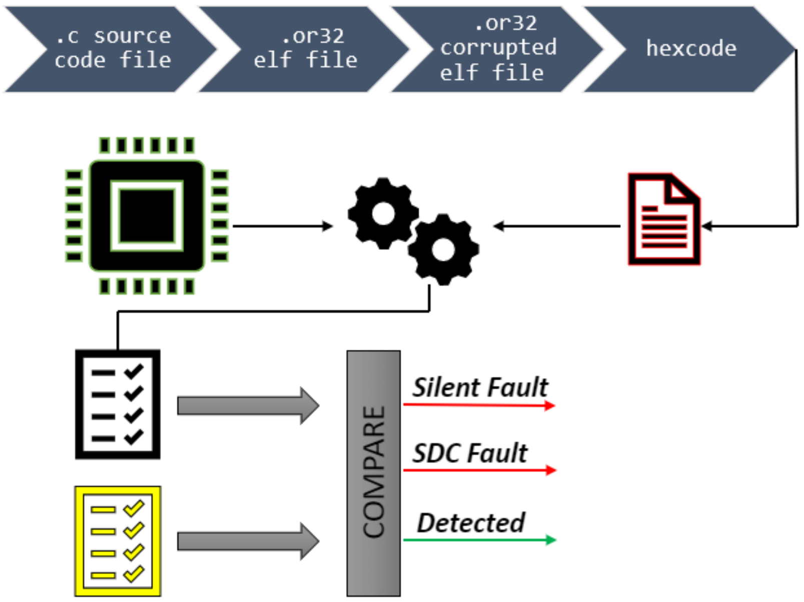
Memory encryption is also implemented to prevent malicious access to the code and data.



Goals of this work

To classify the effects of possible faults affecting the code/data memory, with and without encryption.

To compare existing detection/correction mechanism against a solution based on encryption.



LIRMM

Using memory encryption as Safety Mechanism

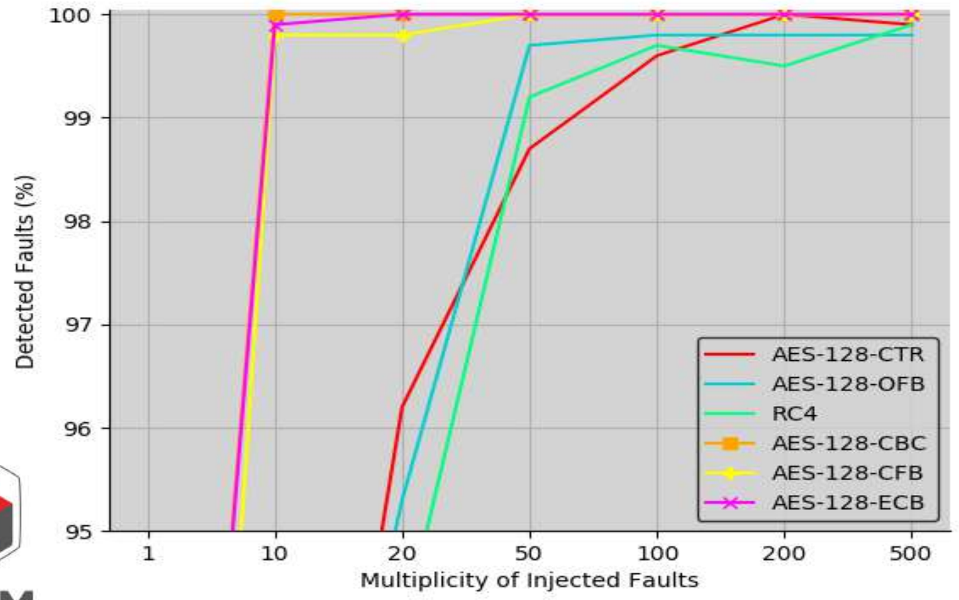
[IEEE LATS 2020]

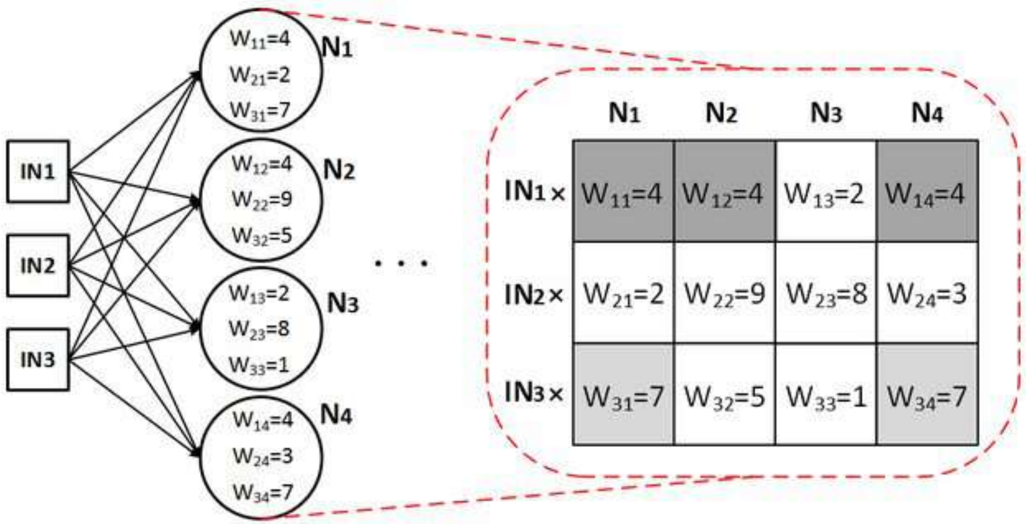
We evaluated the effect on a fault affecting the Code Memory

A single corruption of a memory bit is amplified as the effect of the decryption, causing a deviation in the control flow.

Programs	NO ENC	*Stream Ciphers* CTR	*Stream Ciphers* OFB	*Stream Ciphers* RC4	*Block Ciphers* CBC	*Block Ciphers* ECB	*Block Ciphers* CFB
Matrix Multiplication	20.2%	22%	22.2%	21.8%	90 %	89.9%	84.1%
Bubble Sort	35.1%	34.6%	34.4%	34.2%	85.1%	85 %	81.5%
Dijkstra	34 %	33%	35%	35,5%	93.5%	93.5%	89.5%
Average	**29.8%**	**29.9%**	**30.5%**	**30.5%**	**89.5%**	**89.5%**	**85.0%**

Encryption Methods





Work in progress

We are evaluating the corruptions inn the Data Memory

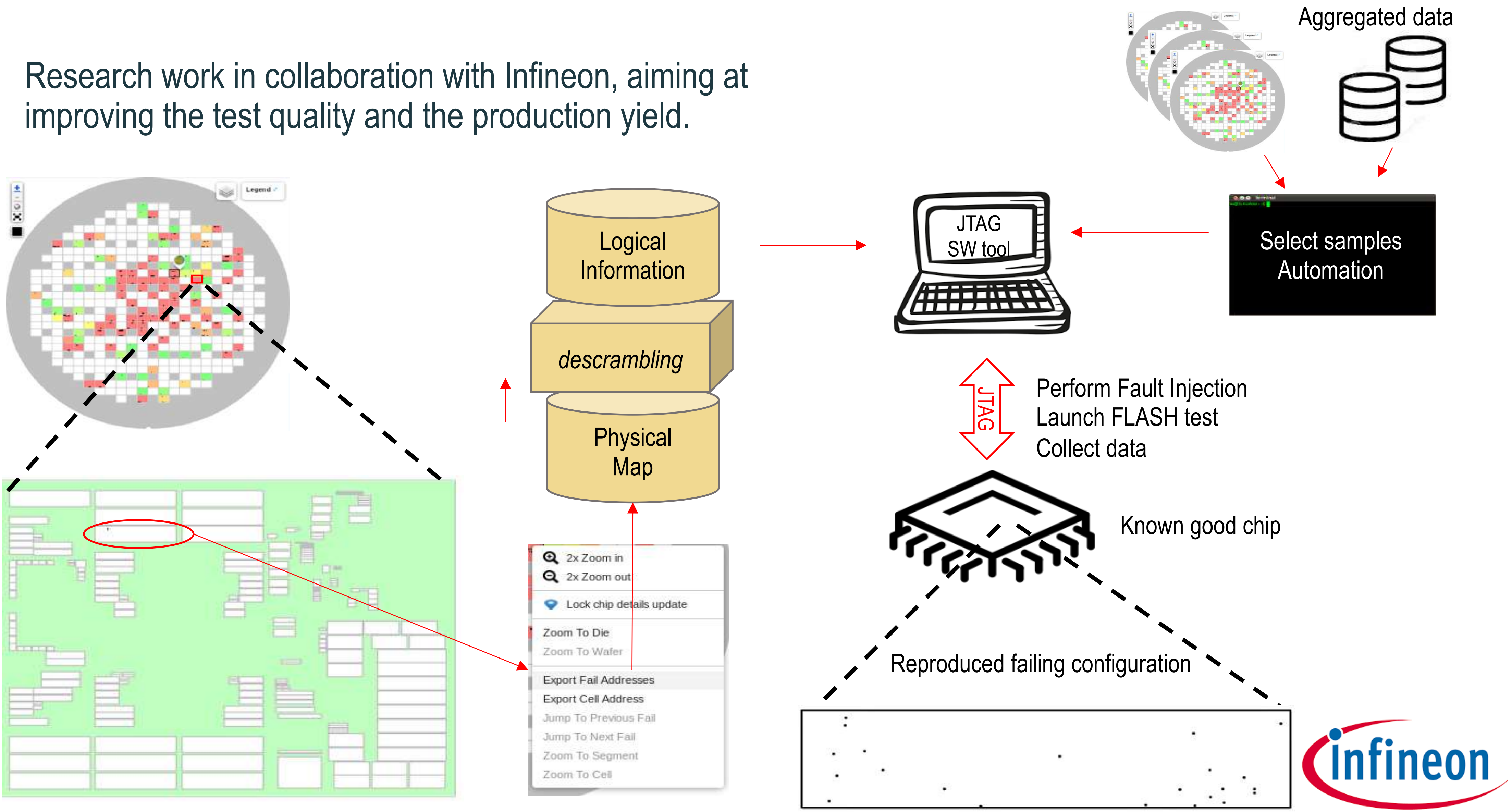
Results are strongly affected by the application

In the case of Neural Networks, the decryption of a corrupted bit affects multiple bits in the weight matrix, resulting in an incorrect classification.

LIRMM

Automotive eFLASH memories production testing

Research work in collaboration with Infineon, aiming at improving the test quality and the production yield.



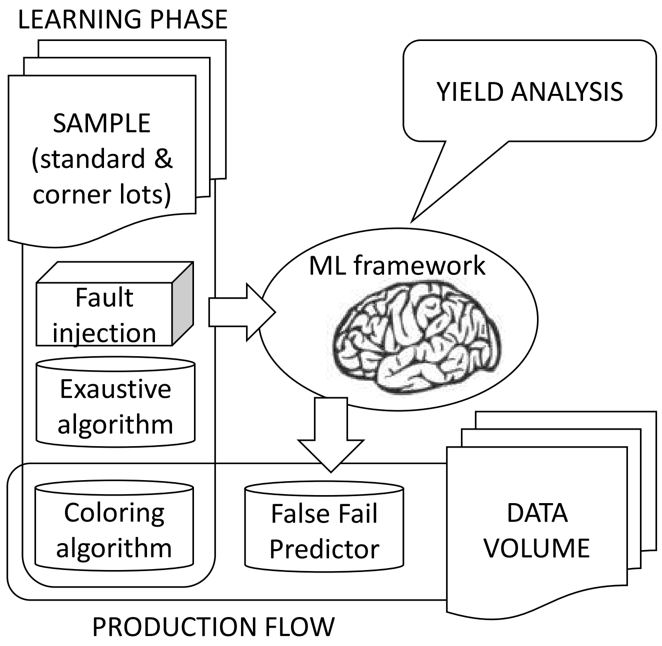
Automotive eFLASH memories production testing

[IEEE ETS 2019]

We developed an optimal algorithm for the allocation of the redundant resources in presence of failing bits in the Flash memory

The improved algorithm is installed on-board besides the existing (sub-optimal and faster) algorithm and activated when needed

The decision is taken by a classifier installed on-board, which takes as input aggregated features (running a so-called coloring algorithm)



Work in progress

We are working on efficient pattern recognition algorithms to be installed on-board to support the redundancy algorithm

We are developing lossy and lossless bitmapping algorithms aimed at statistically producing a complete taxonomy of failing behaviors.

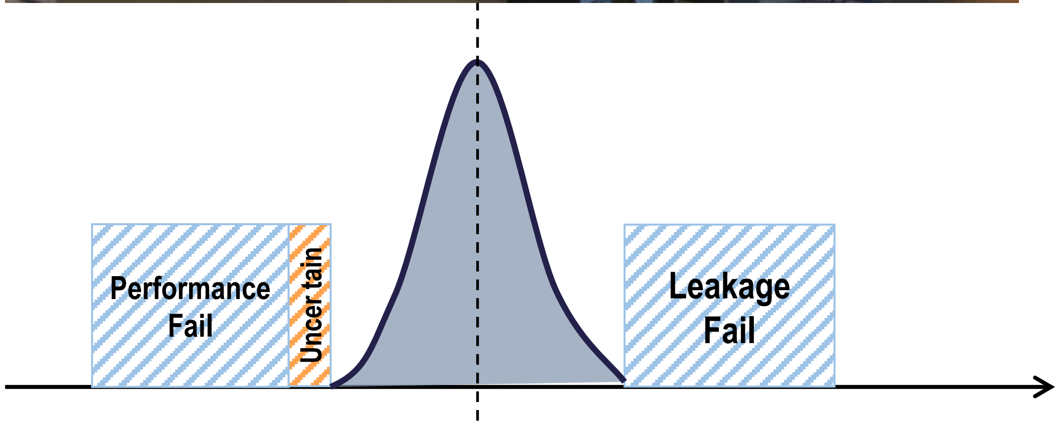
Automotive SoCs performance modeling during production

Performance of a device is the **highest frequency** where the device can run any legal application under any legal operating condition (voltage and temperature)

Goals of this work

- Find parameters
  - that can be measured accurately on tester
  - that correlate well with performance
- Find reference devices
  - label them using functional tests on customer boards
- Find the correct correlation
  - use Machine Learning for classification
  - derive guard bands using statistical methods

Work in progress



infineon

Path delay functional testing

The application of delay fault models requires much more computational effort with respect to simpler and more widespread fault models

Aging effects are involved in the selection on critical paths in the circuit

Commercial tools able to evaluate a test program against path delay faults are missing.

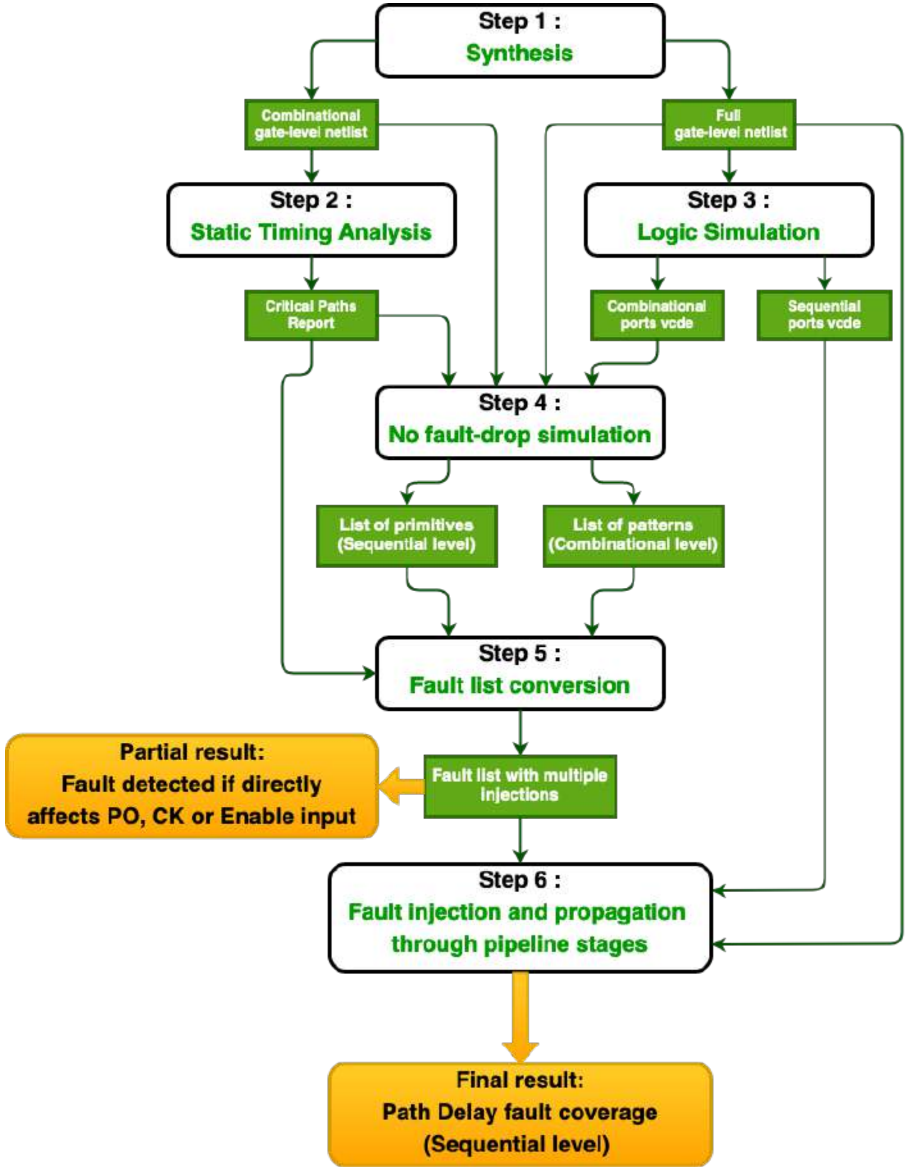
Goals of this work

To develop an efficient path delay fault simulator

To evaluate, using the path delay fault model, test programs while varying aging parameters

To devise manual and automatic approaches for the generation of test programs specifically targeting such a fault model.

Work in progress



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February 05, 2020 – PhD Presentation

An integrated multi-modelling and experimental approach to NVH performance

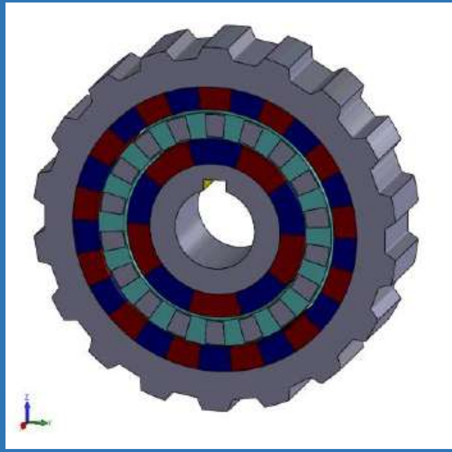
PhD Student:
Luca Dimauro

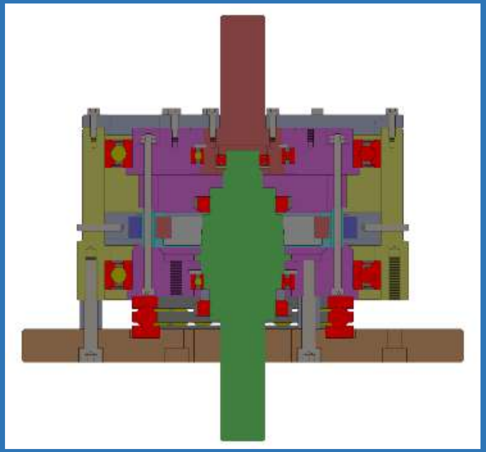
Supervisors:
Prof. Elvio Bonisoli, DIMEAS
Prof. Mauro Velardocchia, DIMEAS
Prof. Federico Millo, DENERG

PhD Program: Mechanicl Engineering

Main research activities

- Vehicle NVH performance
  - Development of a Dual Clutches Transmission model
  - Parametric uncertainty effects on linear dynamics of vibrational systems
- Development of an integrated tool for magneto-mechanical simulation to get a parametric functional model of magnetic gear
  - Design of a test bench for powertrain application with the adoption of magnetic gear to validate possible innovative solutions





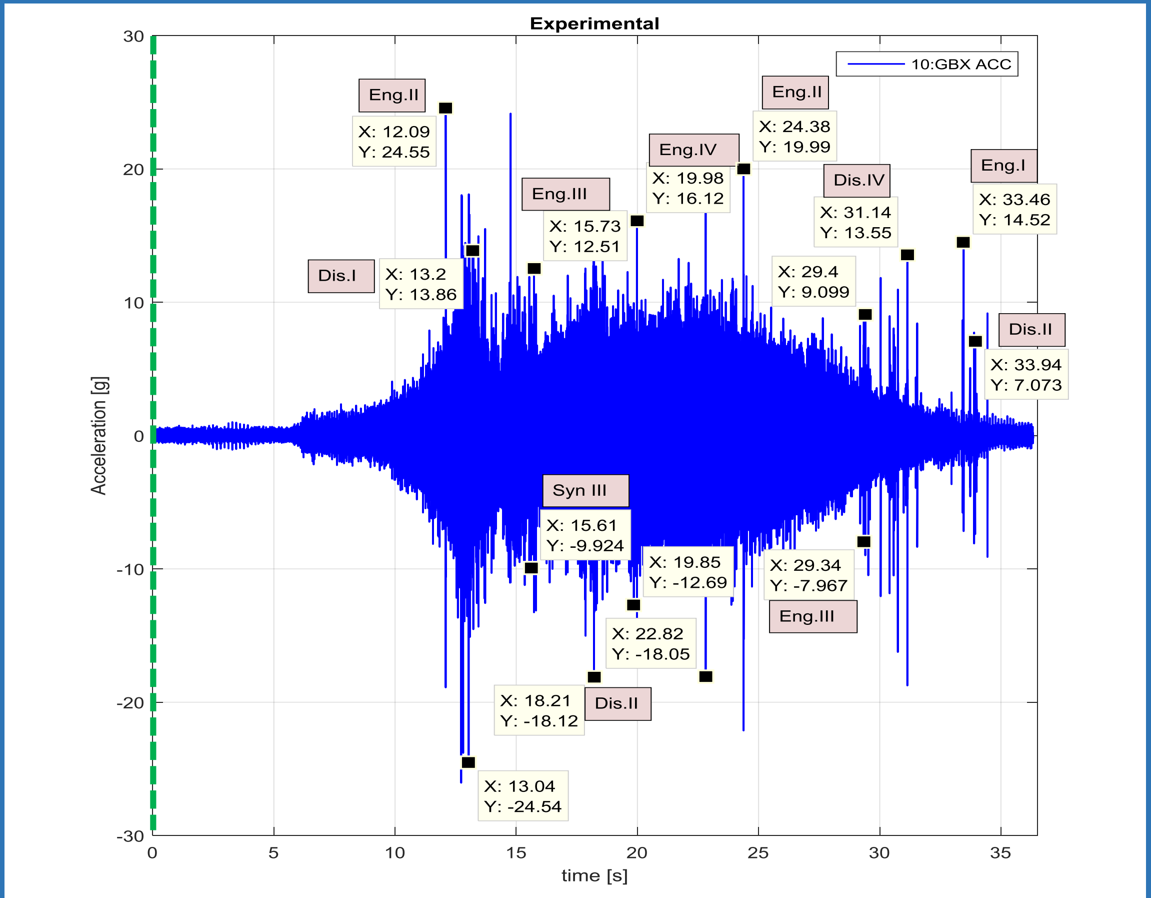
NVH issues in transmission

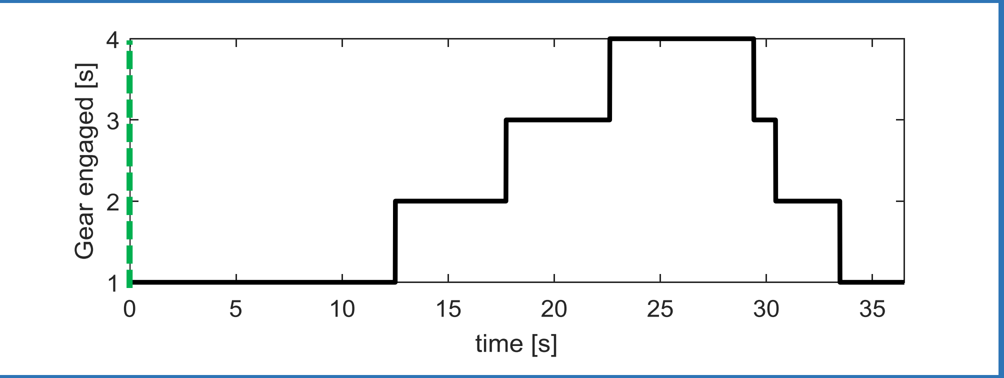
Type	Reason
Shudder	Torsional oscillations during clutch engagement process influenced by frictional characteristics. The frequency range is 5÷20 Hz.
Whine	It is an acustic issue due to transmission error and to variation of gears meshing stiffness. The frequency range is 2÷15 kHz.
Clunk	Metallic noise under tip-in/out condition due to impacts in gears teeth when engine torque is suddenly applied. Broad band frequency range.
Rattle	Torsional vibrations due to the backlashes between unloaded gear pairs. Gear rattle intensity is directly related to engine angular acceleration.
Gear-shift	It is due to axial and rotational impacts between teeth flanks of different synchronizer elements during gear engagement.

Aim:
methodology for the objective evaluation of gear-shift induced vibration in a Dual Clutch Transmission (DCT)

How:
using simulations of transmission dynamics with computation of gearbox housing acceleration

Gearshift events producing acceleration peaks





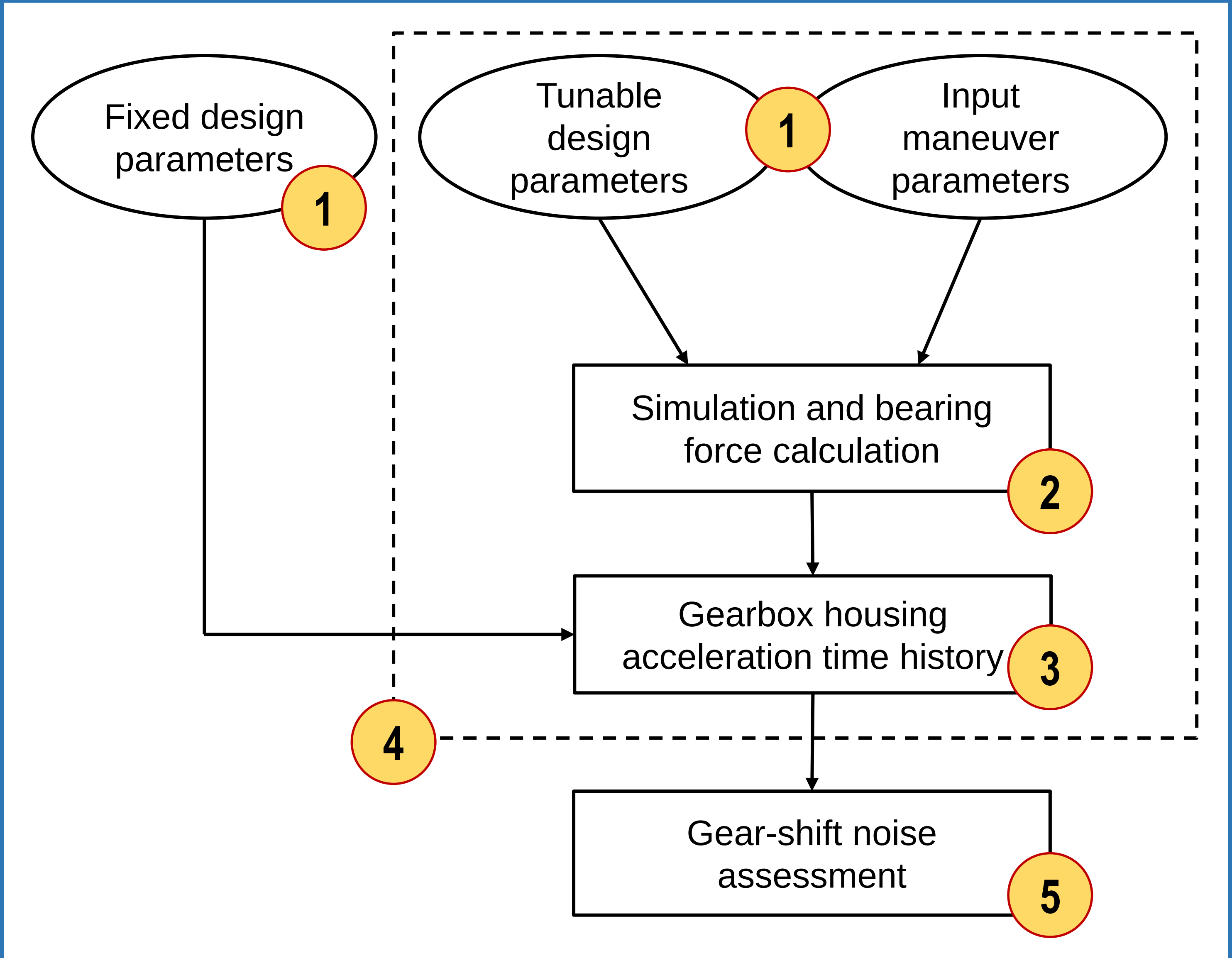
Higher acceleration peaks due to:

- Gear engagement
- Gear disengagement

Others acceleration peaks due to:

- Oncoming clutch start of engagement during cross-shift
- Outgoing clutch end of engagement during cross-shift
- Zero-crossing of torque on an active (engaged) transmission path (kiss/touch point).

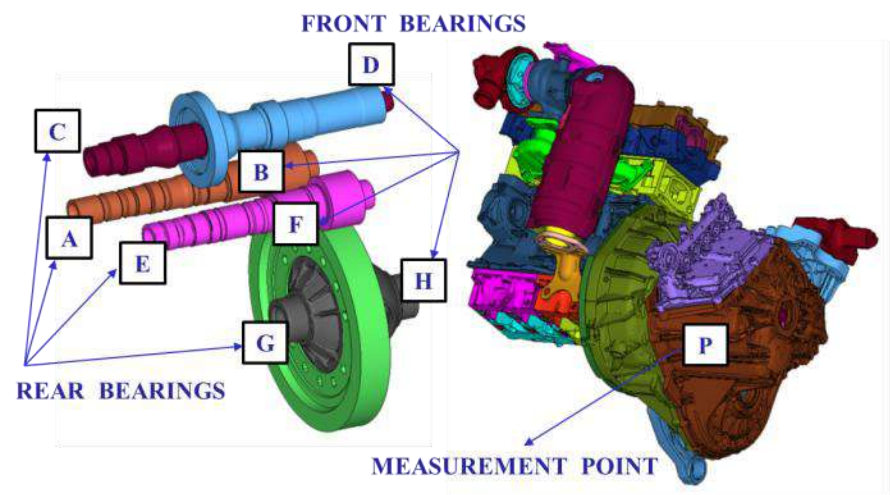
Methodology for NVH assessment



Steps for NVH assessment :

1. Define the transmission design parameters and the maneuver to be tested
2. Simulation AMESim: evaluate whole transmission inner dynamics and bearing forces
3. Calculate the gearbox housing acceleration time history
4. Repeat steps 1, 2 and 3 for different values of the design parameters
5. Perform comparative gear-shift noise assessment using indices based on gearbox acceleration

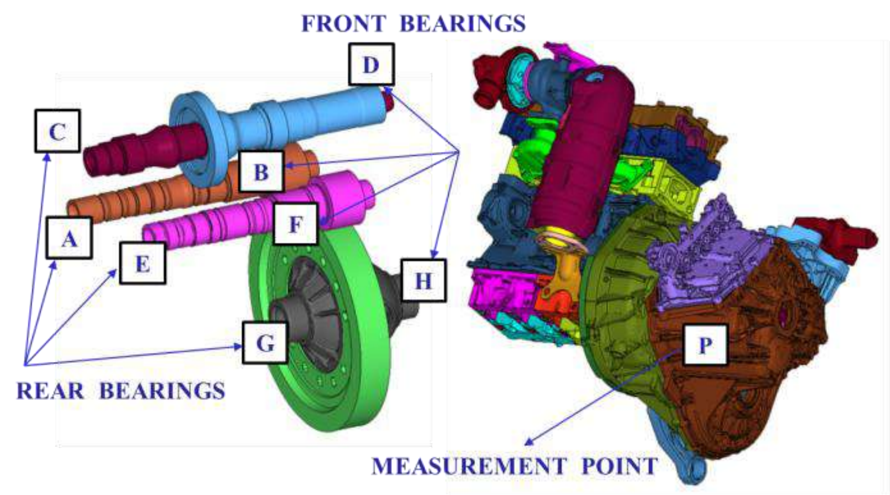
Gearbox housing acceleration computation

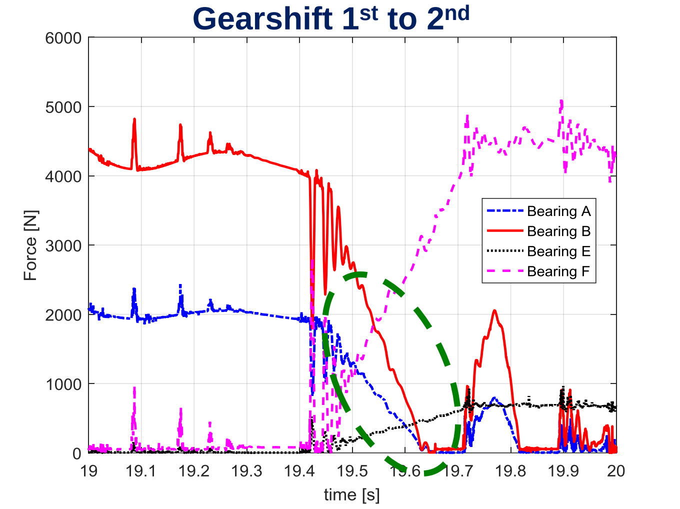


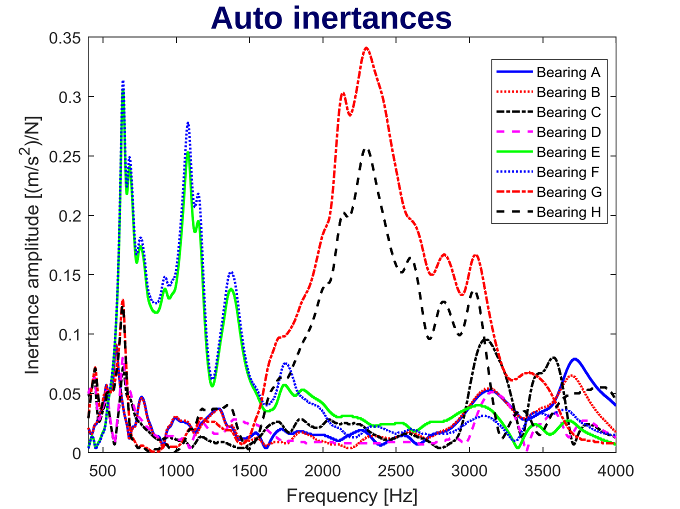
Assumptions:

- Gearbox is considered a MDOFs linear system, with free-free boundary conditions, to reproduce engine mounts
- The source of gearbox housing vibration is transmission inner dynamics. The inner dynamics of the transmission is not influenced by the gearbox housing vibration. (one-way coupling)
- Gearbox acceleration (point P) computed using a post-processing tool from the bearing forces

Gearbox housing acceleration computation







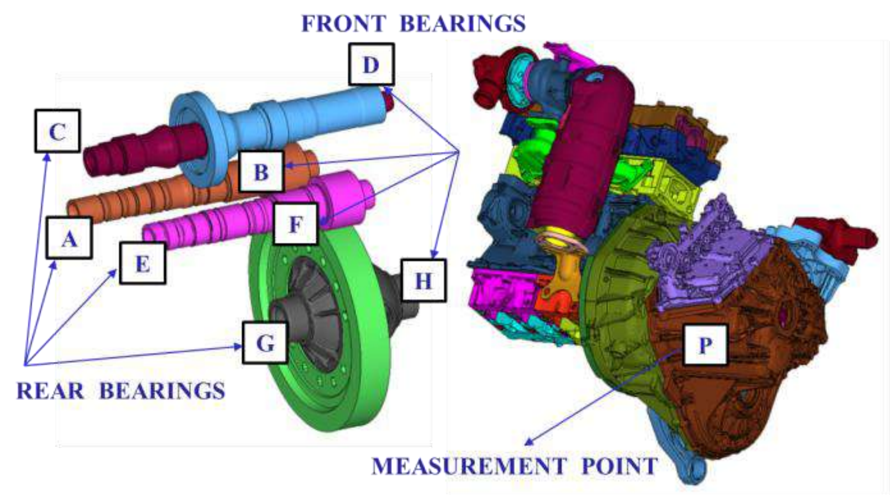
Procedure:

- Export inertance FRF from FEA model data
- Perform the IFFT of the inertance FRF, i.e., get the impulse acceleration response of the system
- Perform time-domain convolution between the excitation and the impulse acceleration response
- Repeat the previous 2 steps for each inertance FRF between the single component of force (X,Y,Z) applied in all bearings (A - H) and the single component of acceleration (P)

$$\ddot{h}(t) = IFFT\left(H_{j,k}(\omega)\right) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} H_{j,k}(\omega)\, e^{i\omega t} d\omega$$

$$a(t) = \ddot{h}(t)\cdot F(t) = \int_{0}^{+\infty} \ddot{h}(\tau)\cdot F(t-\tau)\, d\tau$$

Gearbox housing acceleration computation



$$\begin{Bmatrix} a_X \\ a_Y \\ a_Z \end{Bmatrix} = \begin{bmatrix} a_X/F_{X_A} & \cdots & a_X/F_{X_H} & a_X/F_{Y_A} & \cdots & a_X/F_{Y_H} & a_X/F_{Z_A} & \cdots & a_X/F_{Z_H} \\ a_Y/F_{X_A} & \cdots & a_Y/F_{X_H} & a_Y/F_{Y_A} & \cdots & a_Y/F_{Y_H} & a_Y/F_{Z_A} & \cdots & a_Y/F_{Z_H} \\ a_Z/F_{X_A} & \cdots & a_Z/F_{X_H} & a_Z/F_{Y_A} & \cdots & a_Z/F_{Y_H} & a_Z/F_{Z_A} & \cdots & a_Z/F_{Z_H} \end{bmatrix} \begin{Bmatrix} F_{X_A} \\ \vdots \\ F_{X_H} \\ F_{Y_A} \\ \vdots \\ F_{Y_H} \\ F_{Z_A} \\ \vdots \\ F_{Z_H} \end{Bmatrix}$$

Procedure:

- Export inertance FRF from FEA model data
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$$a(t) = \ddot{h}(t)\cdot F(t) = \int_{0}^{+\infty} \ddot{h}(\tau)\cdot F(t-\tau)\, d\tau$$

Superposition principle:

- Linear dynamic response of gearbox housing
- Total response is the sum of each bearing force contribution

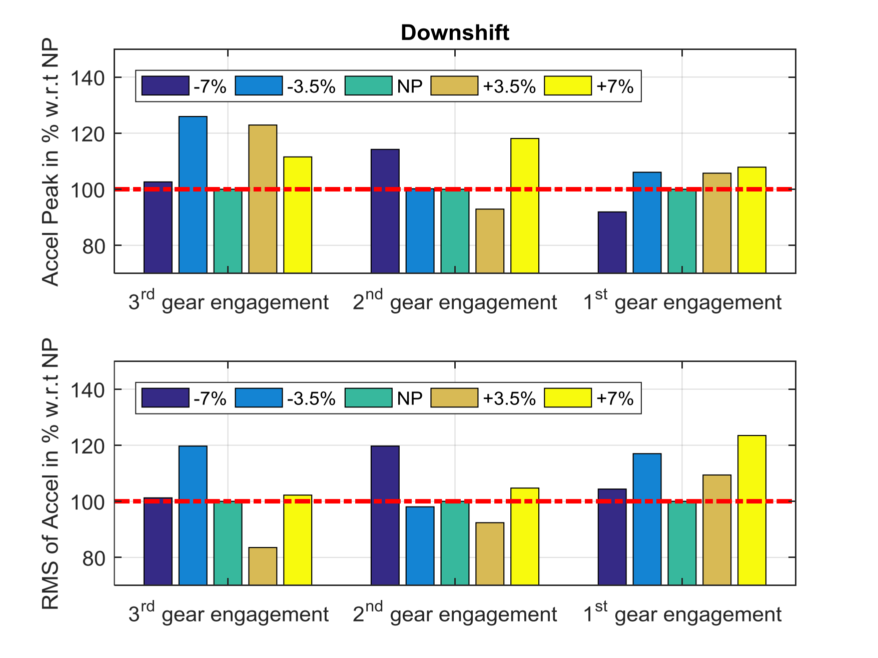
Results and future development

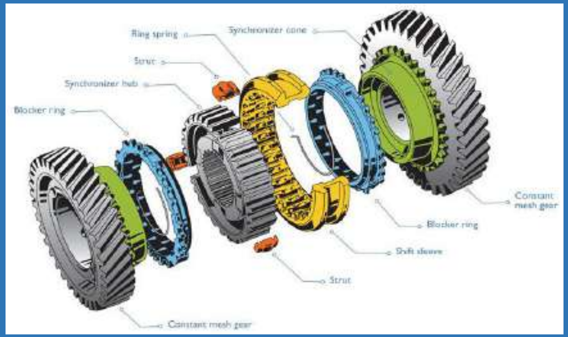
Case study (idle gear weight modifications):

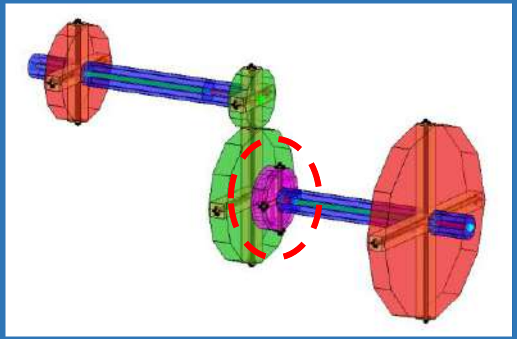
- Two different indices are used to assess clunk severity: peak to peak amplitude and RMS of the gearbox housing acceleration

- Improvements for 1st to 2nd gearshift, that is the most critical, with an increase of inertia of 3.5% for the 2nd idle gear

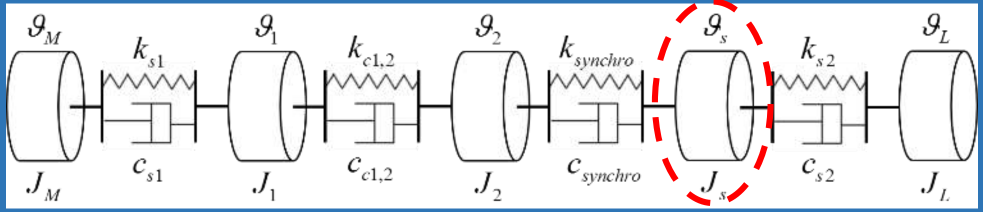
2nd idle gear

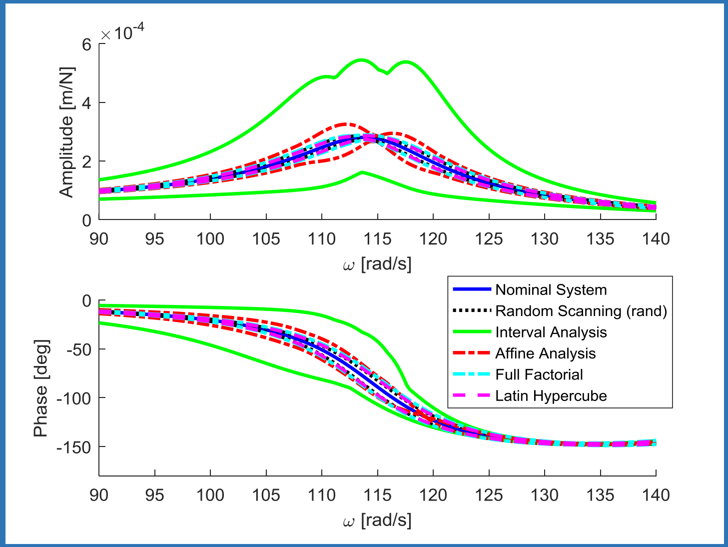






5 DoFs Transmission Linear Model

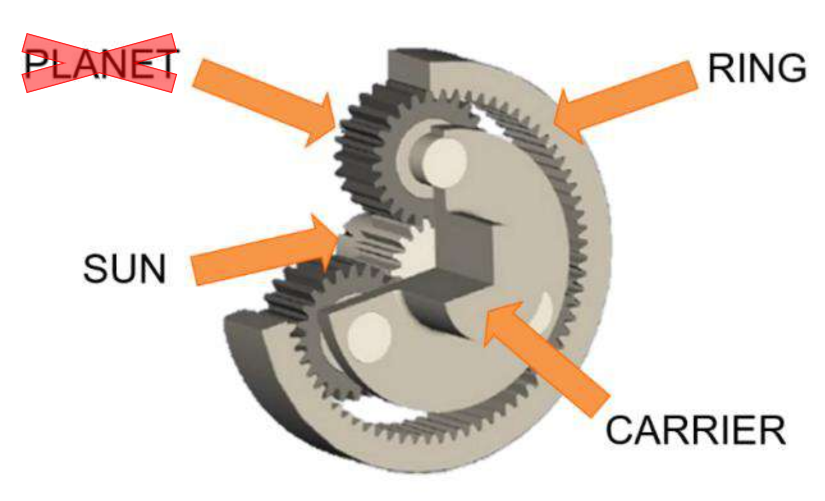


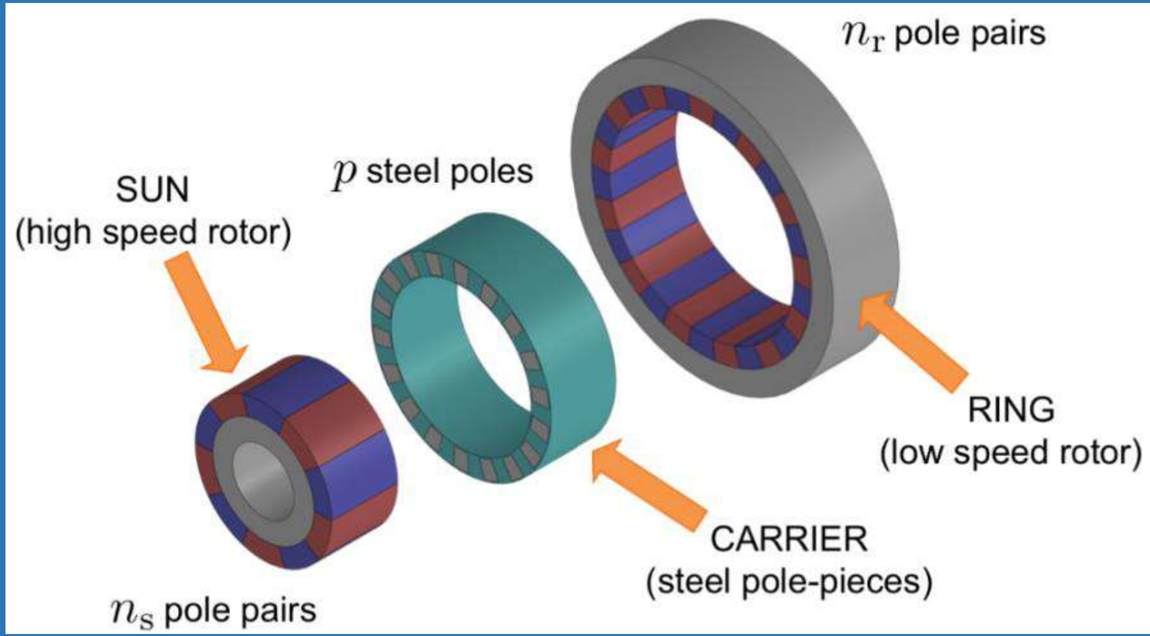


- Study of the effects of uncertain parameters on the dynamic response of a mechanical system using deterministic and stochastic approaches

- Apply uncertainty dynamics concept on the design of a control strategy for the synchronisation phase

Magnetic gear





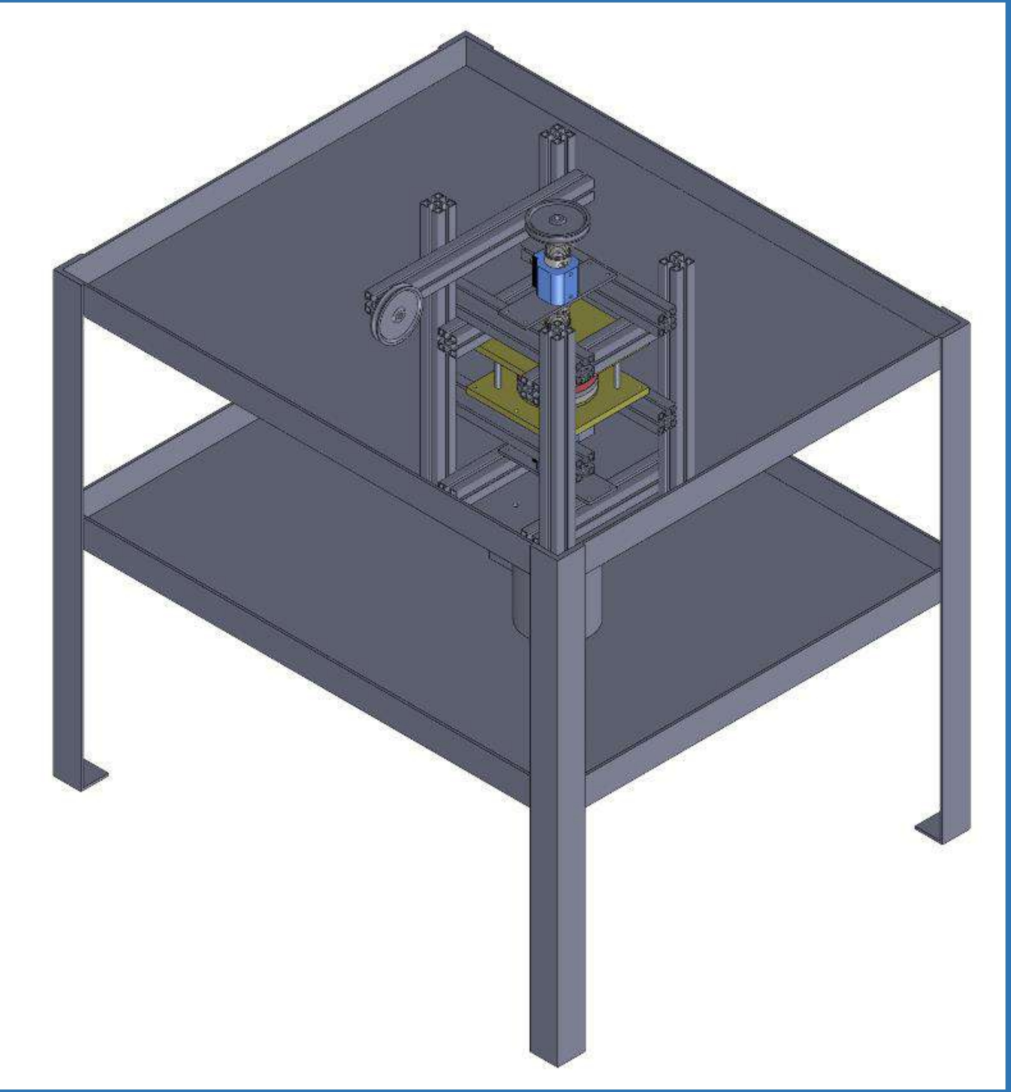
A magnetic gear is the magnetic version of a traditional mechanical planetary gear but with several advantages such as:

- Wear limited to bearings (no surface contact)
- Low maintenance necessities (no lubrication)
- Self overload protection

What's been done:

- Development of an integrated tool for magneto-mechanical simulations using FEMM
- Development of an optimisation process to get a functional parametric model of magnetic gear
- Study of possible applications of magnetic gear in automotive field (PSD for hybrid vehicles)

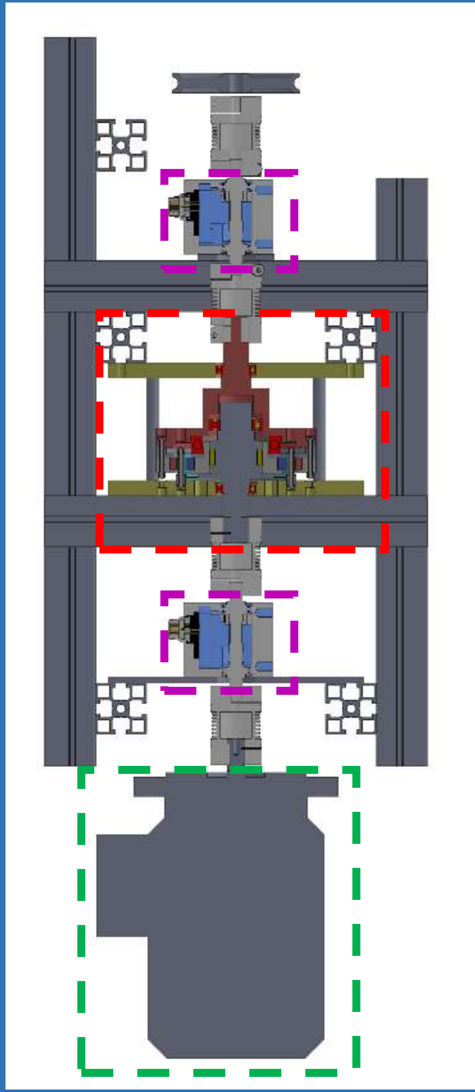
Test Bench for powertrain application



The dimensions of magnetic gear are scaled w.r.t. the optimized one to create a first prototype to test

Aims:

- To transfer torque from an input shaft (sun) to the optput shaft connected to carrier/ring
- To measure the efficiency of the device using 2 torque sensors
- To test the device in 3 different conditions:
  - stationary
  - transition
  - self-overload protection

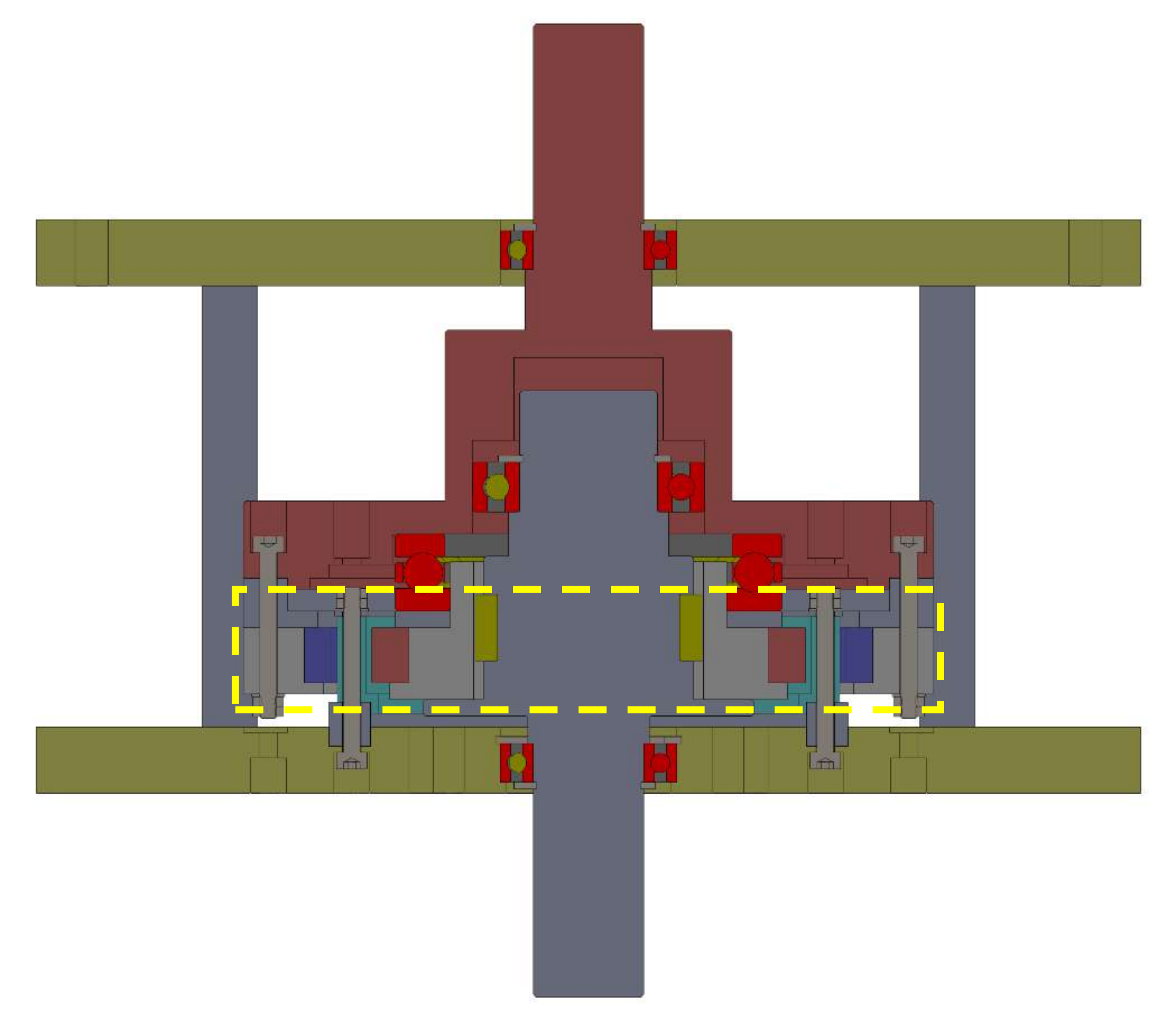


Electric motor

Torque sensors / encoders

Magnetic gear prototype

First model



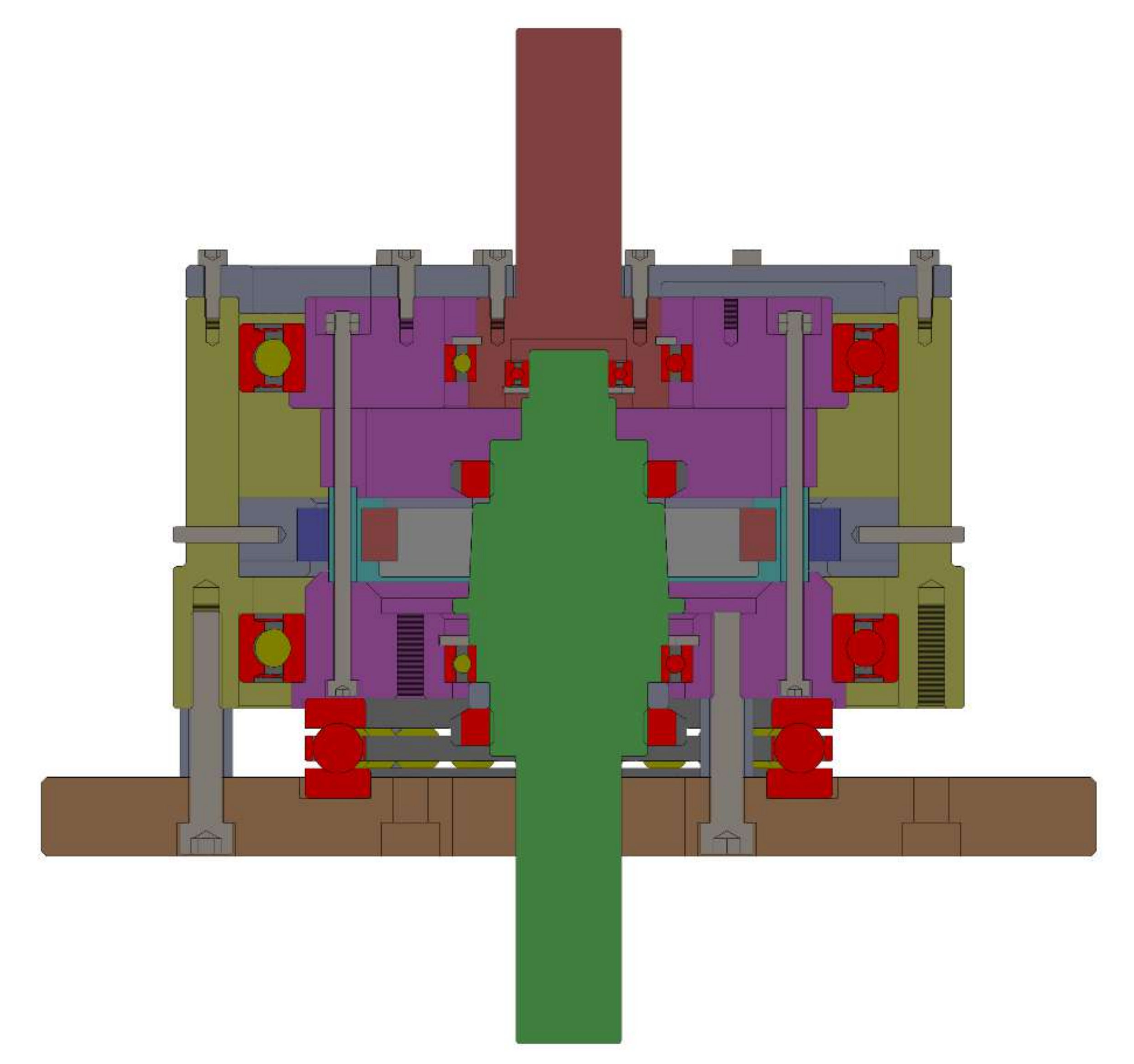
Advantages:

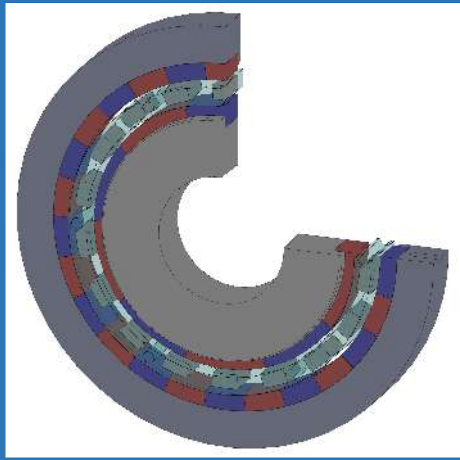
- The number of components is small
- The system weight is limited

Drawbacks:

- Difficult to assembly
- It is possible to change the configuration, but in a very invasive way
- The concentricity of magnetic gear rotors is very difficult to be replicated in case of disassembly

Second model





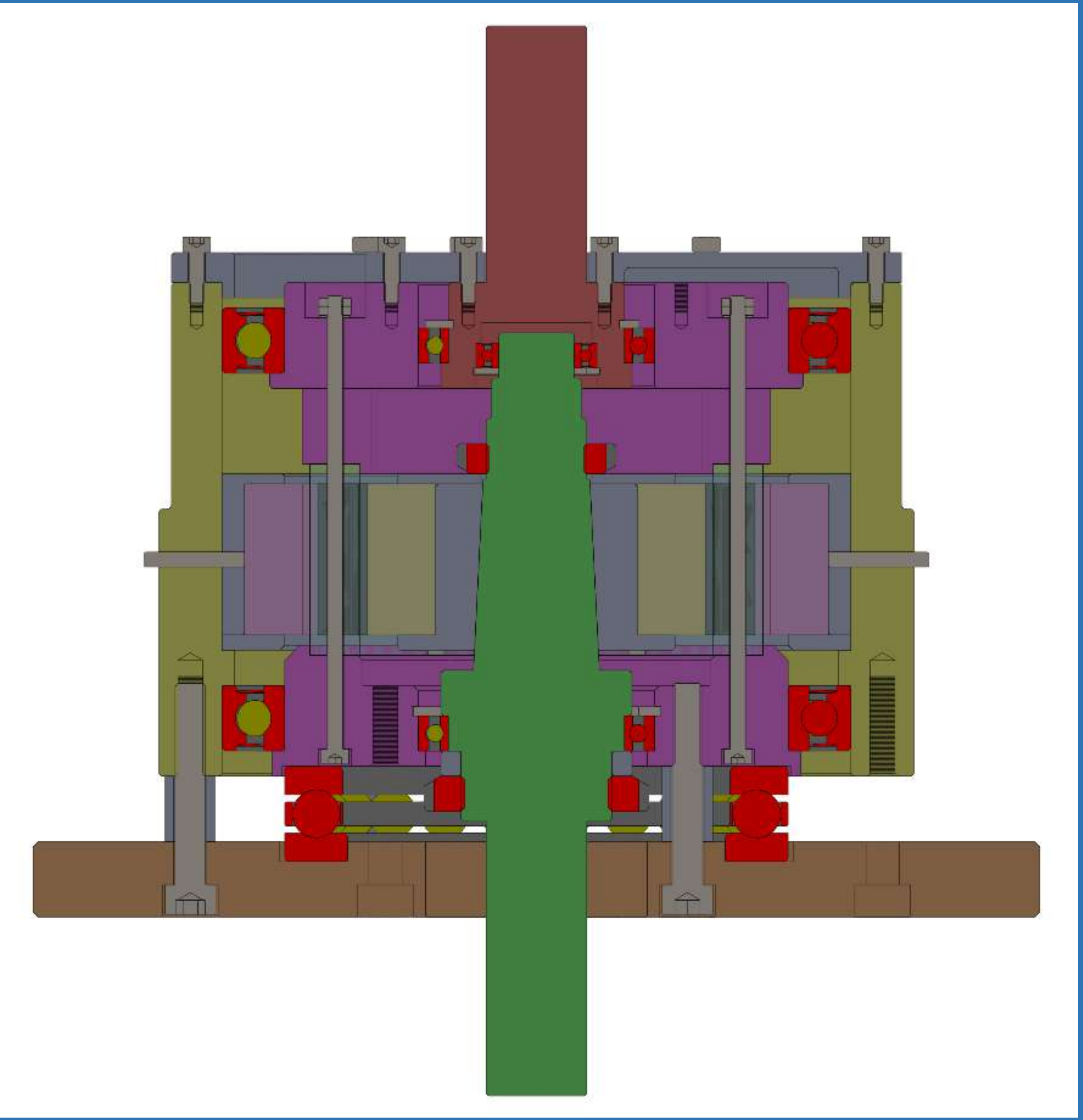
Advantages:

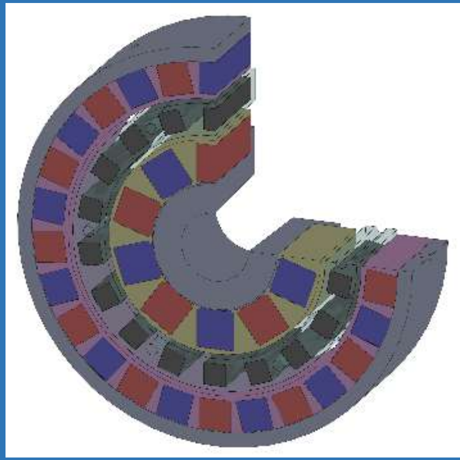
- The device is independent from the test bench
- Change of configuration is very easy, switching only some screws

Drawbacks:

- 6 bearings instead of 4 (more dissipations)
- Expensive rare-earth customised permanent magnets (angular sectors and segmentation) and iron poles
- Expensive adoption of titanium components (paramagnetic and non-conductive material)

Third model





Advantages:

- The device is independent from the test bench
- Change of configuration is very easy, switching some screws
- Low cost solution with commercial rare-earth permanent magnets and commercial ferrite poles
- Possible adoption of plastic material for magnetic gear and external components to realise with 3D printing

Drawbacks:

- Larger air-gaps between rotors
- Smaller torque density w.r.t previous solutions

Publications

International Journal Papers

- Cirimele V., **Dimauro L.**, Repetto M., Bonisoli E., “Multi-objective Optimization of a Magnetic Gear for Powertrain Applications”, International Journal of Applied Electromagnetics and Mechanics”, Vol. 60, Issue S1, 2019, pp. S25-S34
- Filippini M., Alotto P., Cirimele V., Repetto M., Ragusa C., **Dimauro L.**, Bonisoli E., “Magnetic loss analysis in coaxial magnetic gears”, Electronics, Vol. 8, Issue 11, 2019, paper n° 1320

Book Chapters

- Bonisoli E., Lisitano D., **Dimauro L.**, Peroni L., “A proposal of dynamic behaviour design based on mode shape tracing: numerical application to a motorbike frame”, Dynamic Substructures, Vol. 4,Proceedings of the 37th IMAC.
- Bonisoli E., Casazza M., Lisitano D., **Dimauro L.**, “Parametric experimental modal analysis of a modern violin based on a Guarneri del Gesù model”, Rotating Machinery, Vibro-Acoustics & Laser Vibrometry, Vol. 7, Proceedings of the 36th IMAC

International Conference Papers

- Galvagno E., **Dimauro L.**, Mari G., Velardocchia M. et al., " Dual Clutch Transmission vibrations during gear shift: a simulation based approach for clunking noise assessment ", SAE Technical Paper, 2019-01-1553, 2019
- Bonisoli E., Lisitano D., **Dimauro L.**, “Experimental and numerical mode shape tracing from components to whole motorbike chassis”, International Conference on Noise and Vibration Engineering, ISMA, 2018, Leuven, Belgium, September 17-19 , pp. 1-8.

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February 05, 2020 – PhD Presentation

PhD student
Stefano Feraco

Supervisor: prof. Nicola Amati

PhD Program in Mechanical Engineering – XXXIV Cycle

Research activities and personal background

Apr. 2017 – Dec. 2017
M.Sc. in Mechatronic Engineering
Thesis @ LIM (Mechatronics Lab)
«SOC Estimation in Lithium Batteries with Artificial Neural Networks»

Jan. 2018 – Oct. 2018
Research scholarship @ LIM (Mechatronics Lab)

Nov. 2018 – now
XXXIV Cycle PhD programme (funded by CARS)

❑ **Research fields**

2017-2019

- ***Side slip angle estimation***
- ***Longitudinal speed estimation***
- ***Road condition identification***
- ***Battery SOC and SOH estimation***

2019-now

- ***Longitudinal and lateral dynamics control***
- ***Autonomous driving***

- **Publications**

1. Bonfitto, A., Feraco, S., Tonoli, A., Amati, N., & Monti, F. (2019). "Estimation Accuracy and Computational Cost Analysis of Artificial Neural Networks for State of Charge Estimation in Lithium Batteries." *Batteries*, *5*(2), 47.
2. Bonfitto, A., Tonoli, A., Feraco, S., Zenerino, E. C., & Galluzzi, R. (2019). "Pattern recognition neural classifier for fall detection in rock climbing." *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technolog*.
3. Bonfitto, A., Feraco, S., Tonoli, A., & Amati, N. (2019). "Combined regression and classification artificial neural networks for sideslip angle estimation and road condition identification." *Vehicle System Dynamics*, 1-22.
4. Bonfitto, A., Ezemobi, E., Amati, N., Feraco, S., Tonoli, A., & Hegde, S. (2019). "State of Health Estimation of Lithium Batteries for Automotive Applications with Artificial Neural Networks." In *2019 AEIT International Conference of Electrical and Electronic Technologies for Automotive (AEIT AUTOMOTIVE)* (pp. 1-5). IEEE.
5. Bonfitto, A., Feraco S., Amati, N., Tonoli A. (2019). "Virtual Sensing in High-Performance Vehicles With Artificial Intelligence". In Proceedings of the ASME 2019 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC-CIE 2019), 21st International Conference on Advanced Vehicle Technologies (AVT).
6. Feraco, S., Bonfitto A., Amati N., Tonoli A. (2019). "Combined Lane Keeping and Longitudinal Speed Control For Autonomous Driving". In Proceedings of the ASME 2019 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC-CIE 2019), 21st International Conference on Advanced Vehicle Technologies (AVT).
7. Galluzzi, R., Feraco, S., Zenerino E. C., Tonoli A., Bonfitto A., & Hegde S. (2020), "Fatigue monitoring of climbing ropes". In Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology.

Outline

- Autonomous vehicles research background
- Obstacles position estimation for autonomous racecars with a clustering techique
- Probabilistic Road Map algorithm for optimal trajectory planning in autonomous driving

AUTONOMOUS VEHICLE RESEARCH BACKGROUND

TRAFFIC SIGNS RECOGNITION

QUEUE ASSIST

LANE KEEPING ASSIST

LANE DETECTION

TRAJECTORY PLANNING

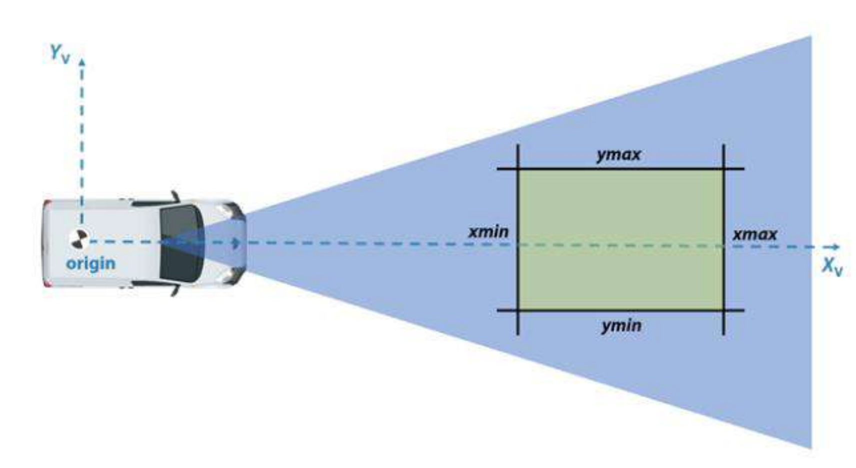
CONTROL AND SIMULATION

SENSOR FUSION

LOCALIZATION AND MAPPING

LANE DETECTION

Camera mounted on the vehicle top



Bird's eye view

Lane detection

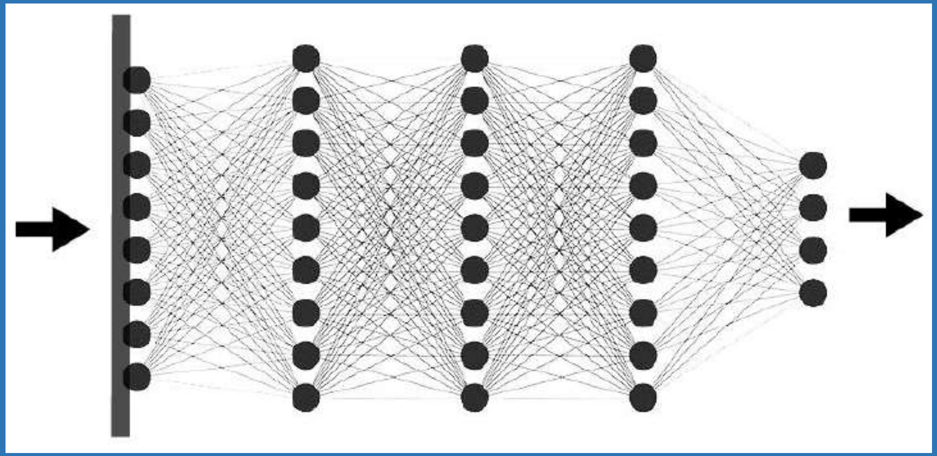
Tested on-board : Torino-Rivalta

[1] Feraco, S., Bonfitto, A., Amati, N., & Tonoli, A. Combined Lane Keeping and Longitudinal Speed Control for Autonomous Driving. In *ASME 2019 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. American Society of Mechanical Engineers Digital Collection.

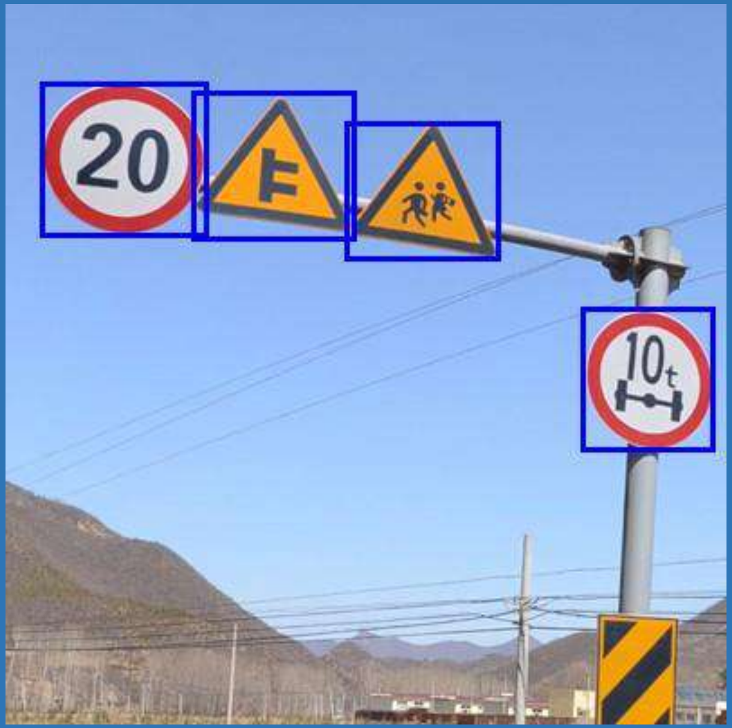
TRAFFIC SIGNS RECOGNITION

Detection

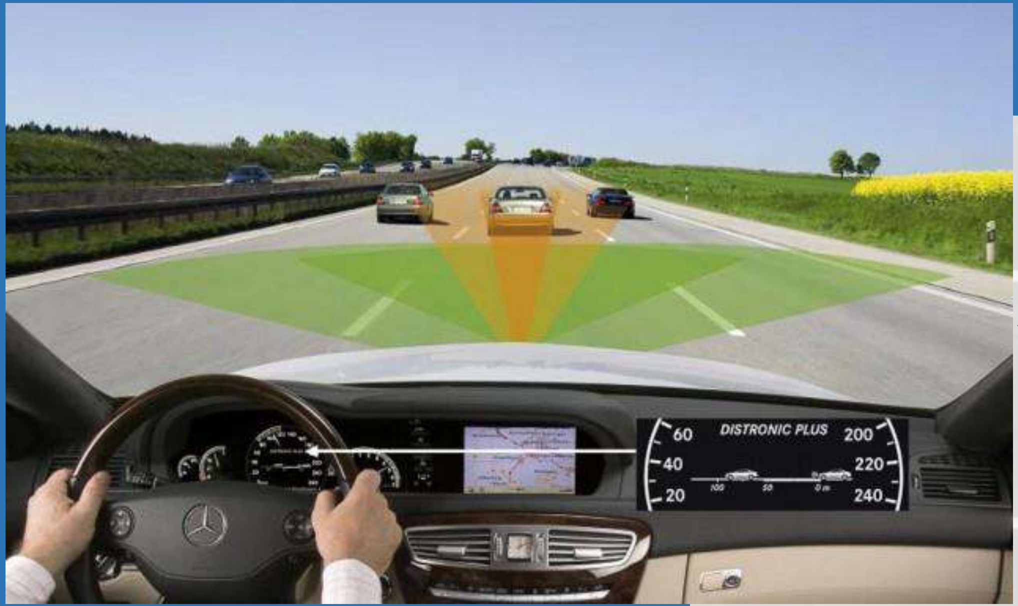
Processing (convolutional ANNs)

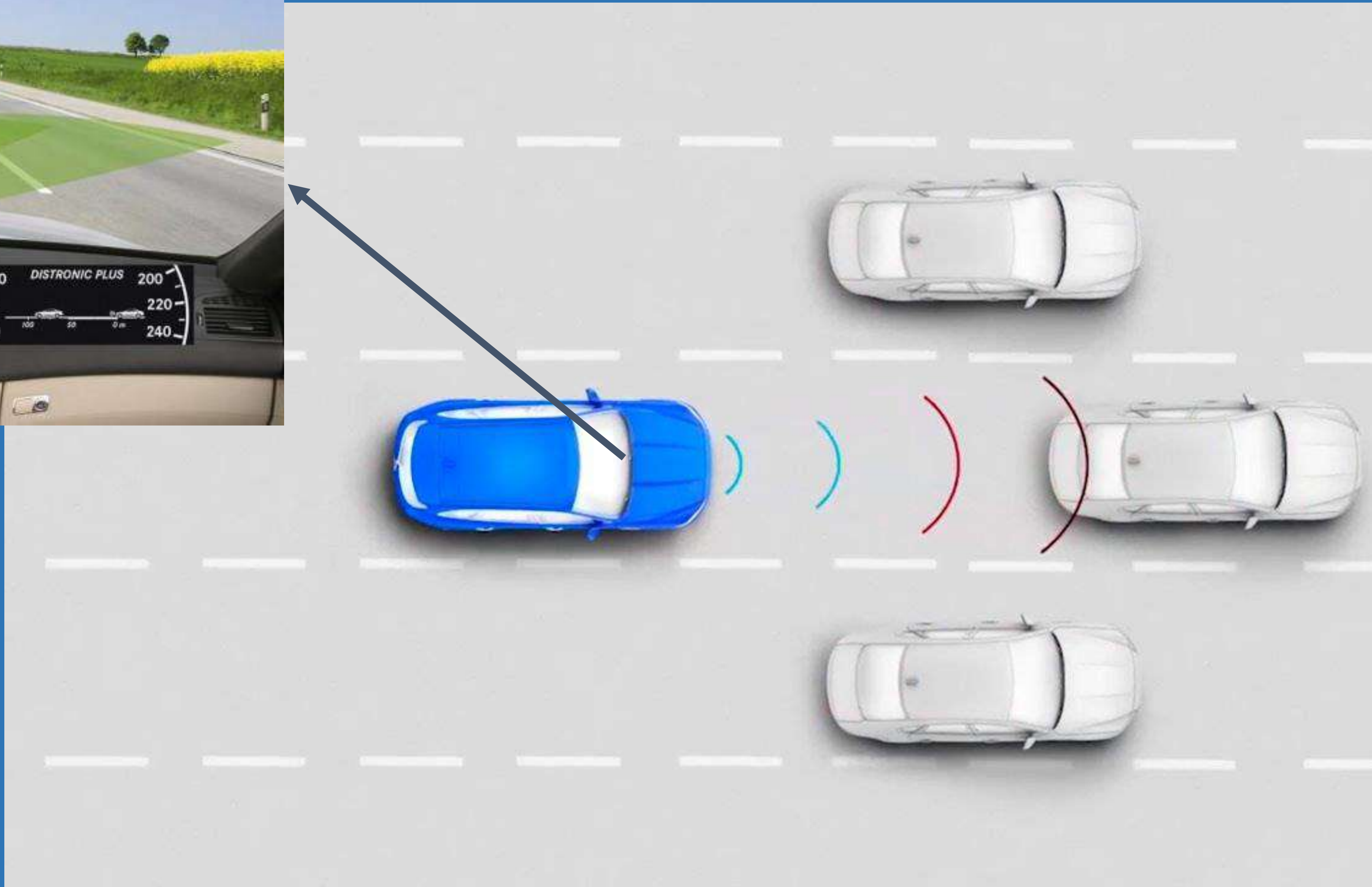


Recognition



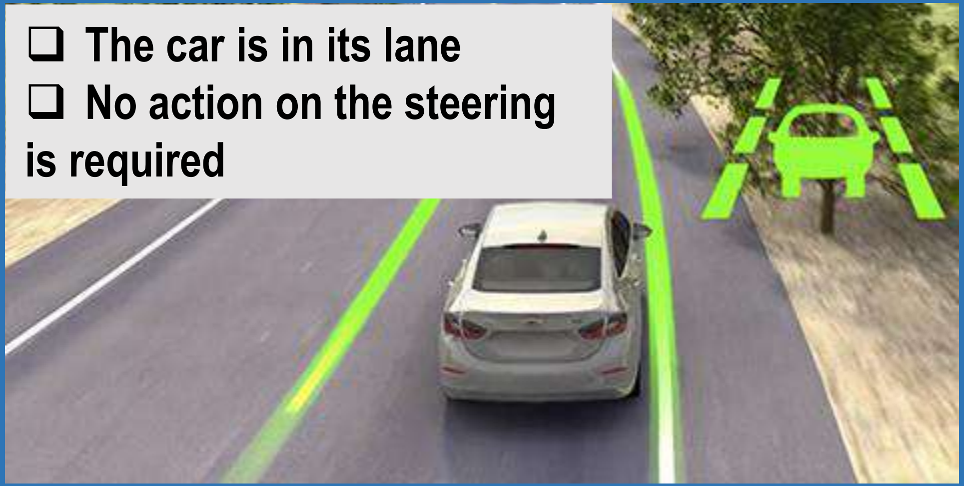
QUEUE ASSIST



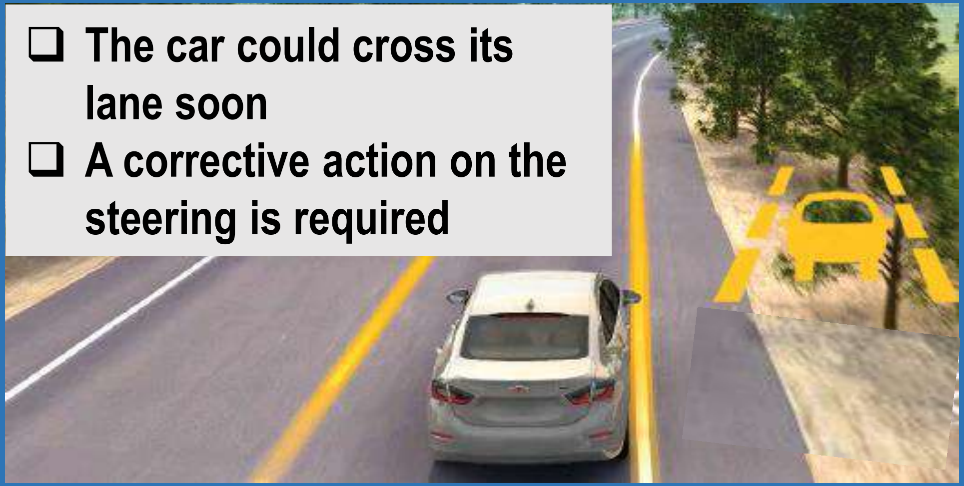


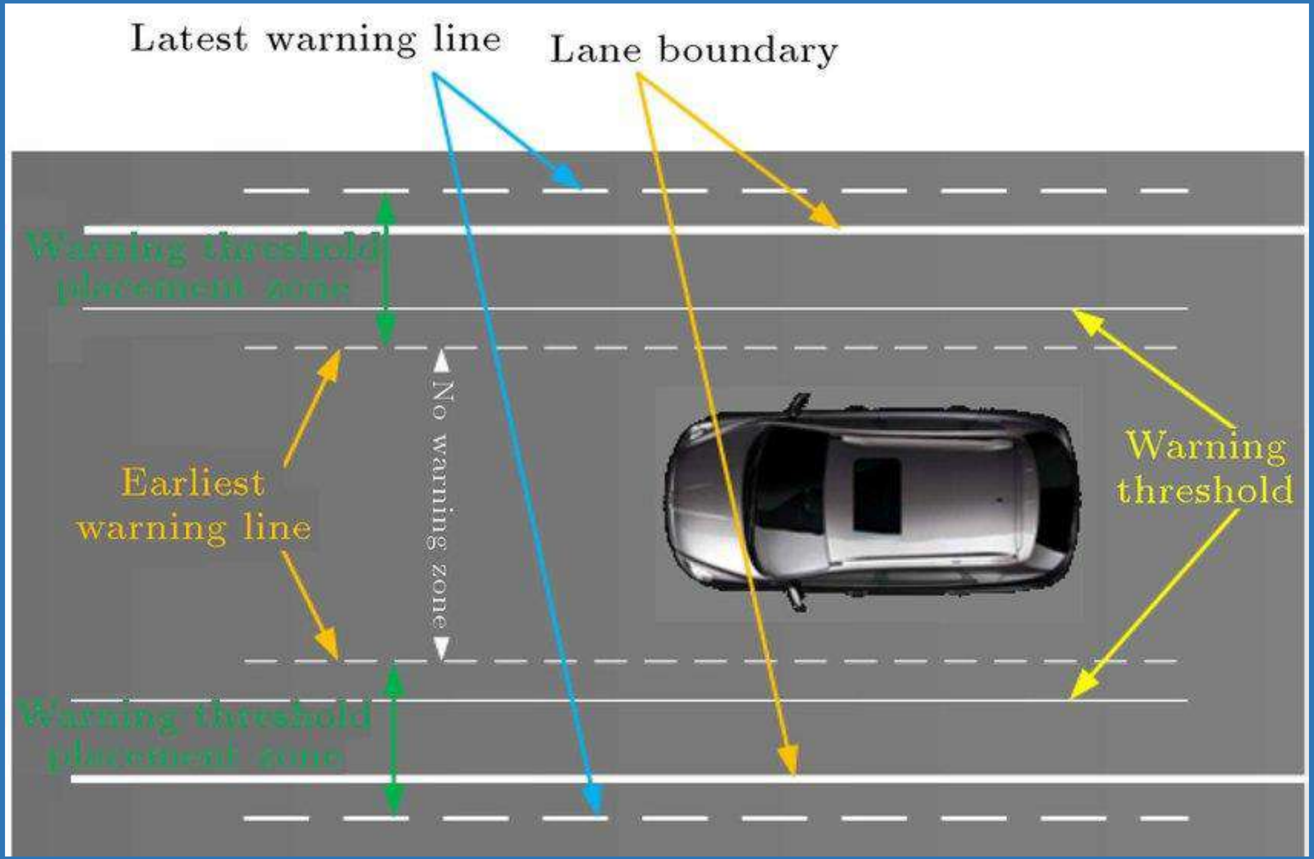
LANE KEEPING ASSIST

- ❑ The car is in its lane
- ❑ No action on the steering is required



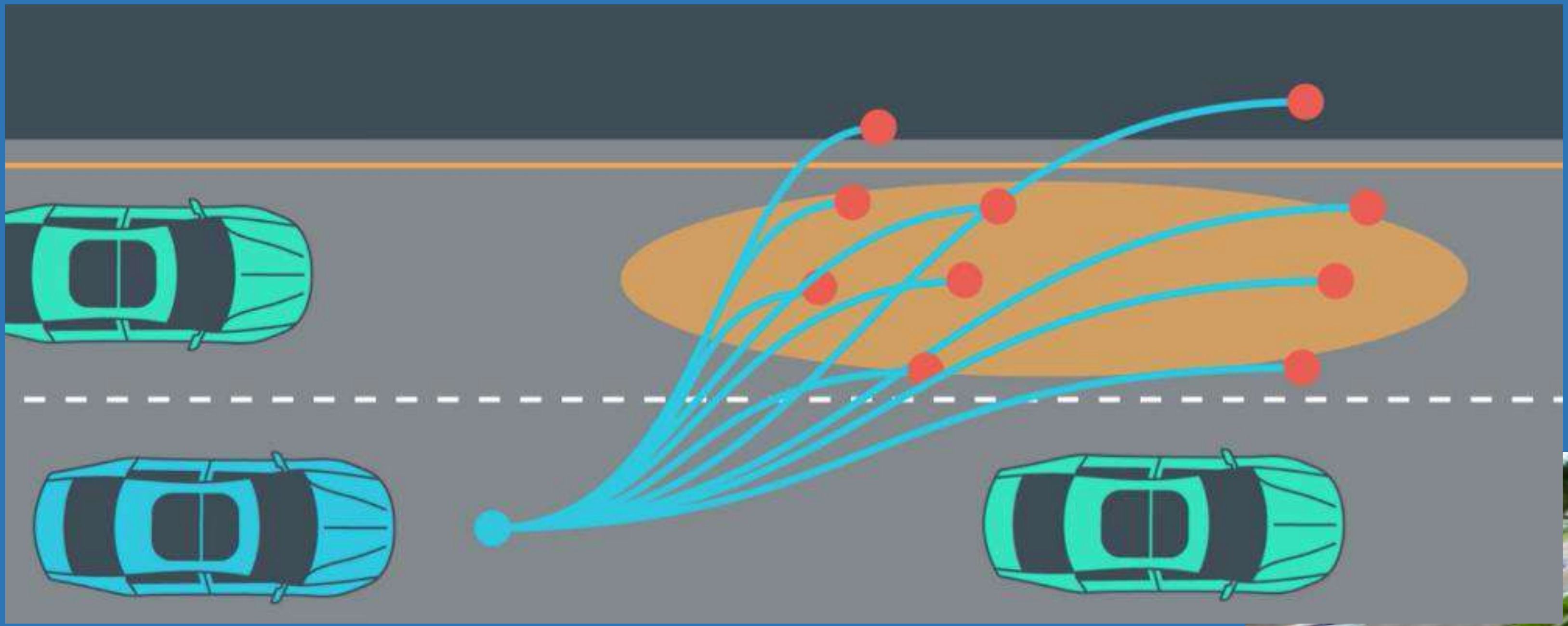
- ❑ The car could cross its lane soon
- ❑ A corrective action on the steering is required

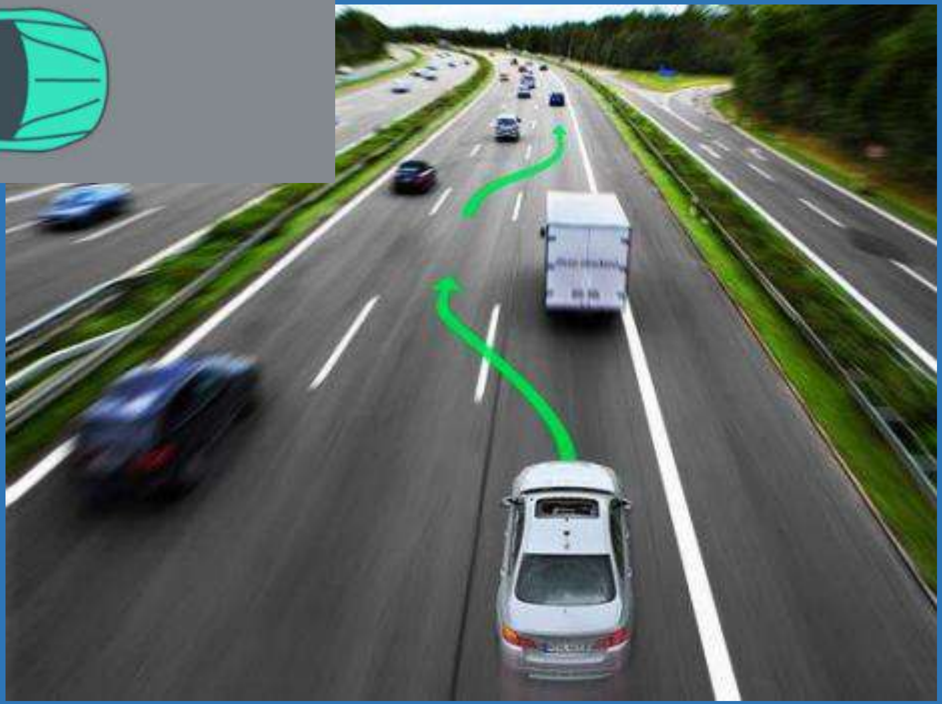




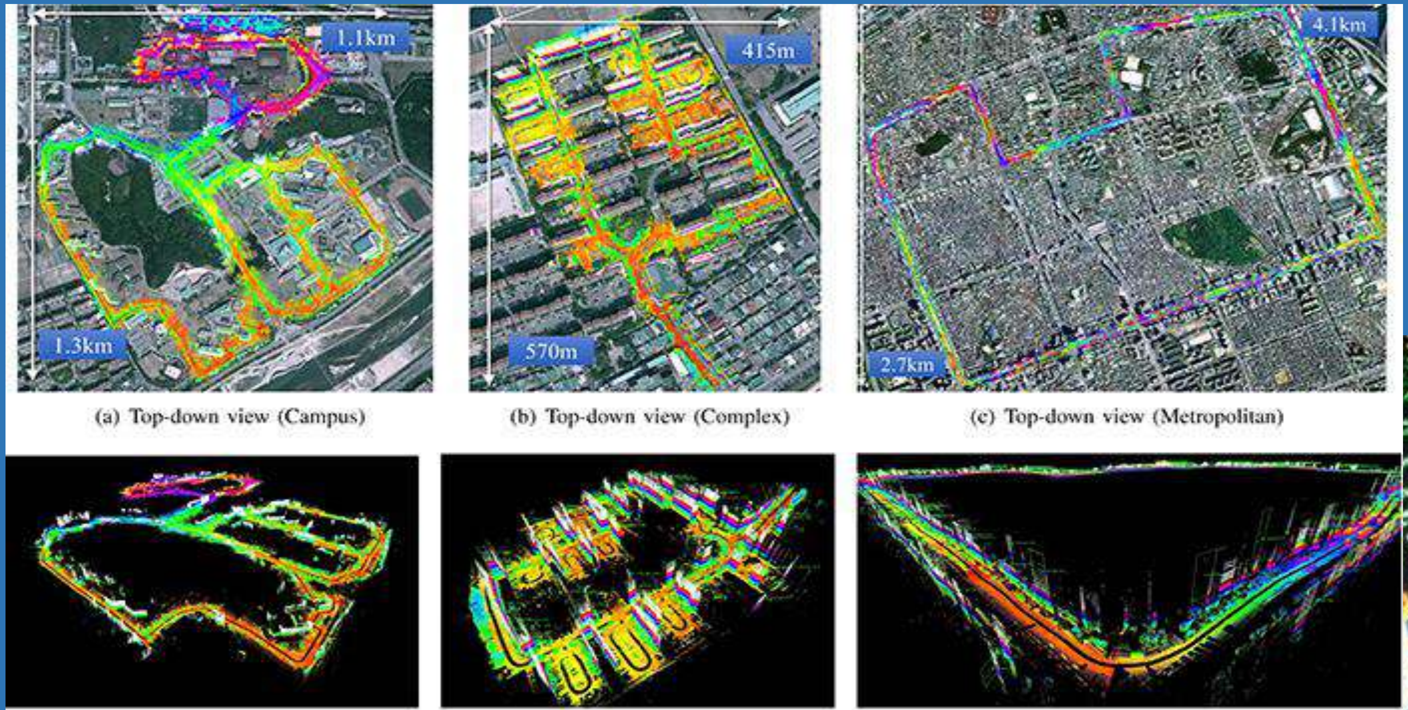
[1] Feraco, S., Bonfitto, A., Amati, N., & Tonoli, A. Combined Lane Keeping and Longitudinal Speed Control for Autonomous Driving. In *ASME 2019 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. American Society of Mechanical Engineers Digital Collection.

TRAJECTORY PLANNING

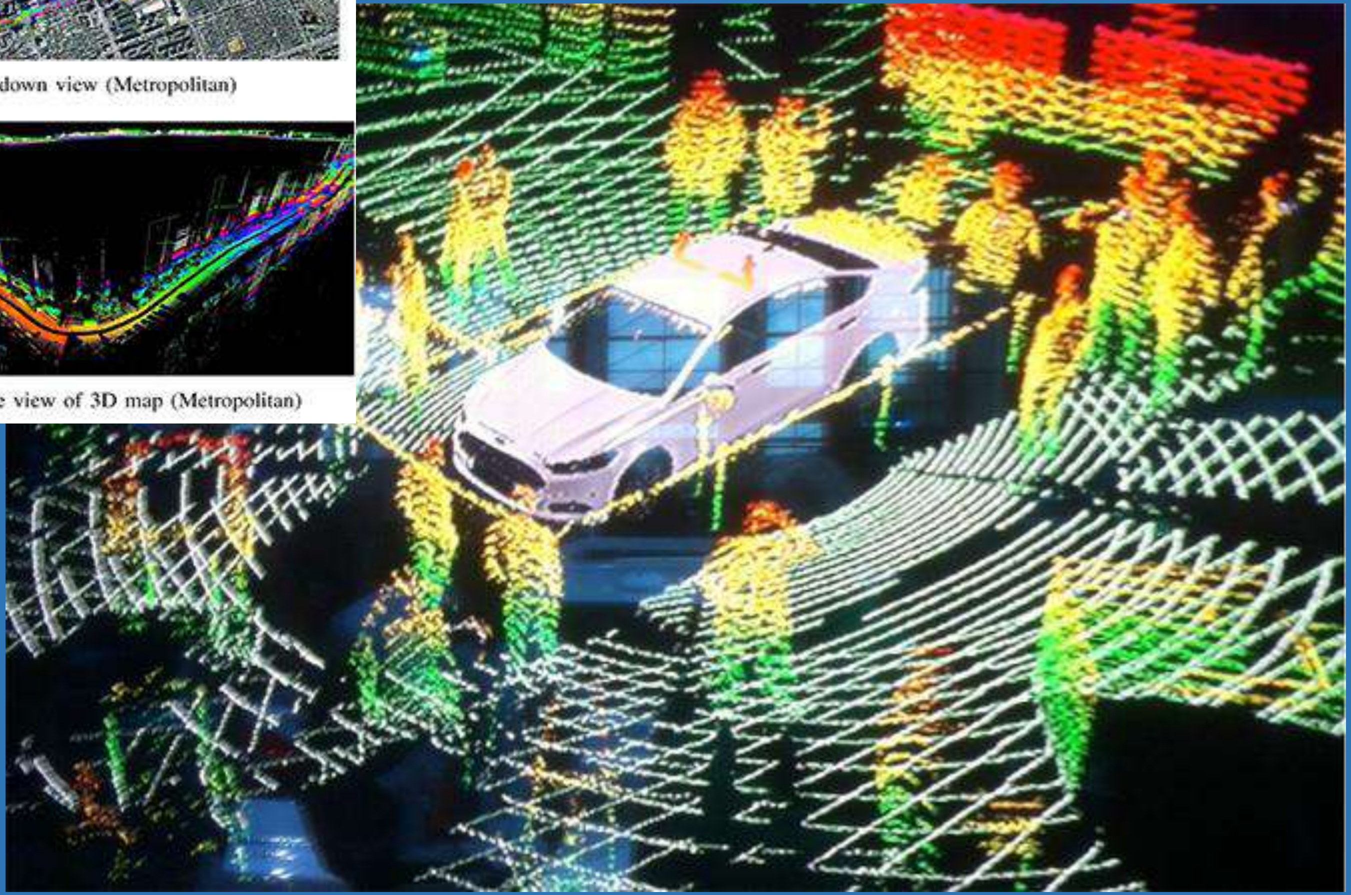




SIMULTANEOUS LOCALIZATION AND MAPPING (SLAM)

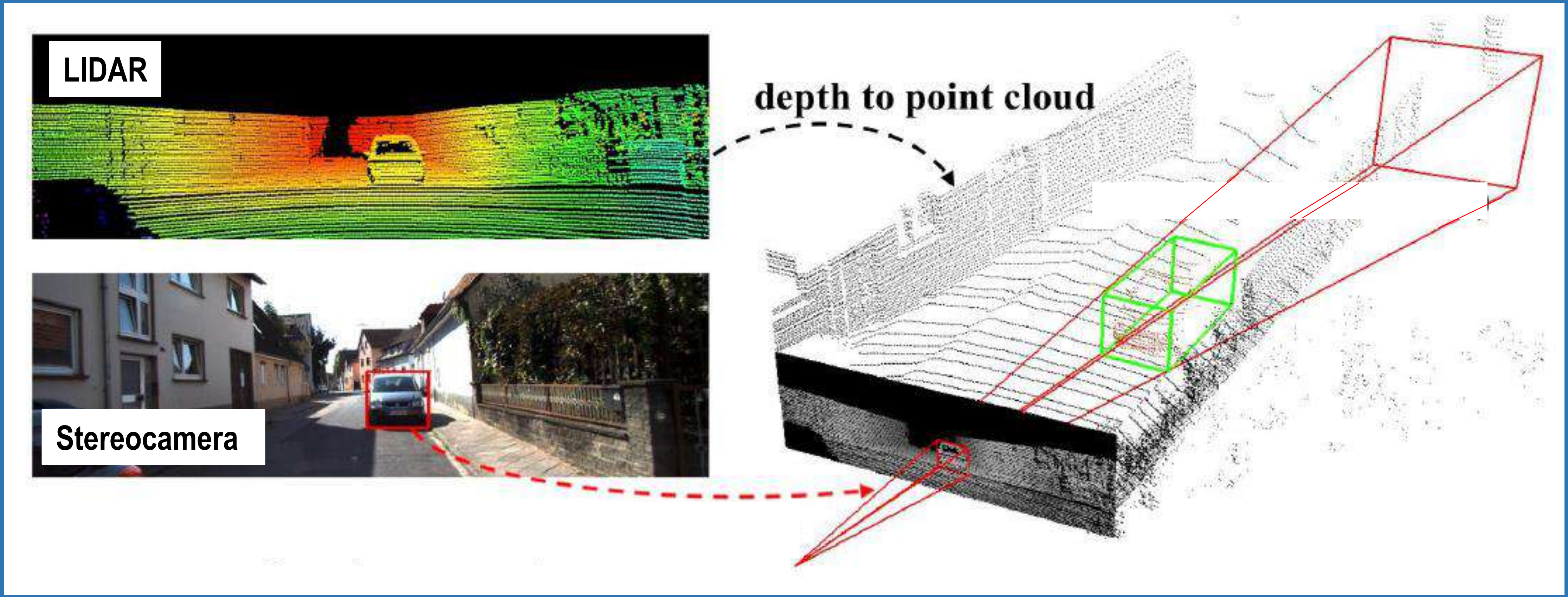


(a) Top-down view (Campus) (b) Top-down view (Complex) (c) Top-down view (Metropolitan)
(d) Perspective view of 3D map (Campus) (e) Perspective view of 3D map (Complex) (f) Perspective view of 3D map (Metropolitan)

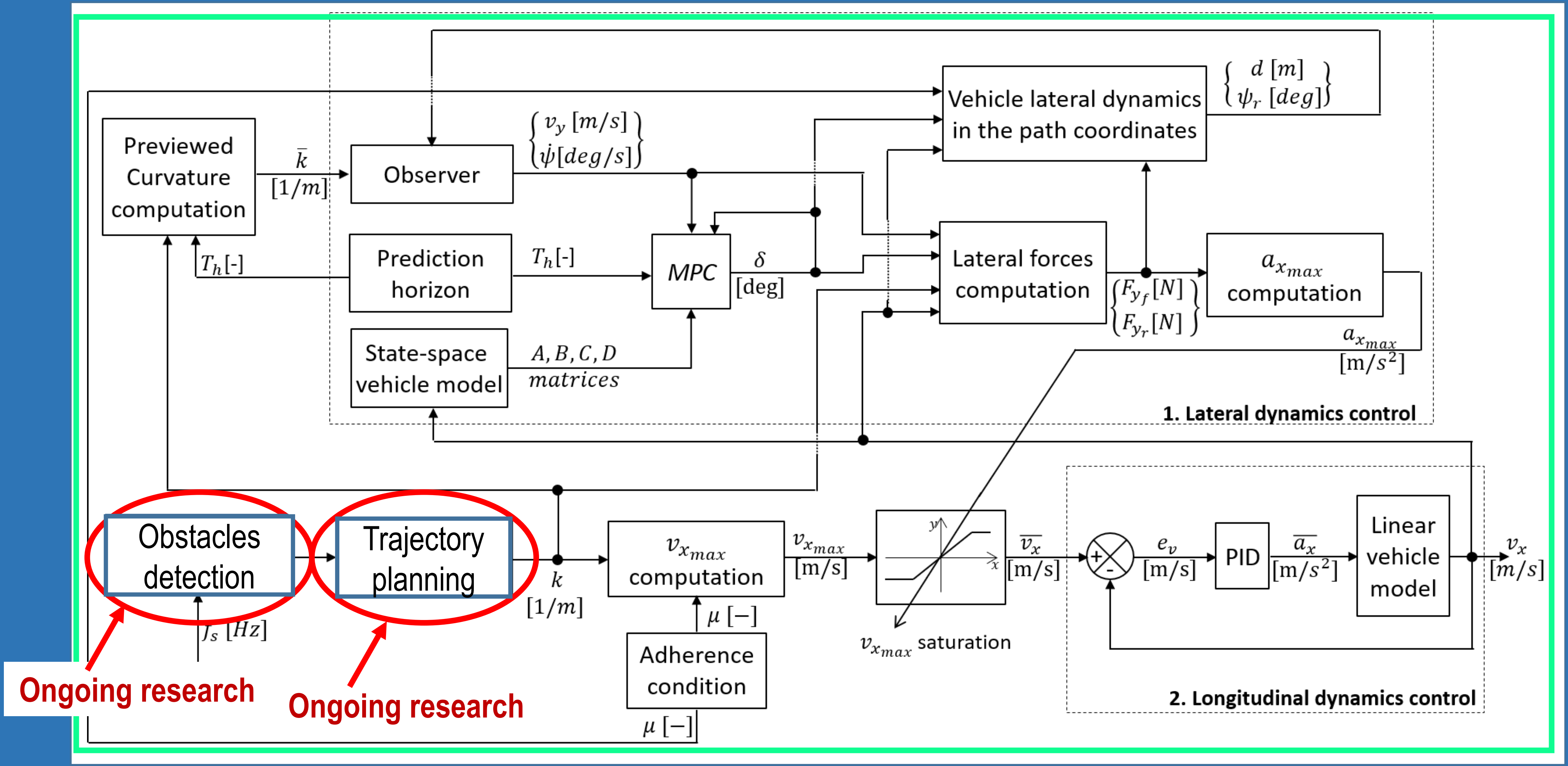


SENSOR FUSION

Fuse LIDAR and Camera data to have better point-clouds in density and accuracy



VEHICLE DYNAMICS CONTROL AND SIMULATION



[1] Feraco, S., Bonfitto, A., Amati, N., & Tonoli, A. Combined Lane Keeping and Longitudinal Speed Control for Autonomous Driving. In *ASME 2019 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. American Society of Mechanical Engineers Digital Collection.

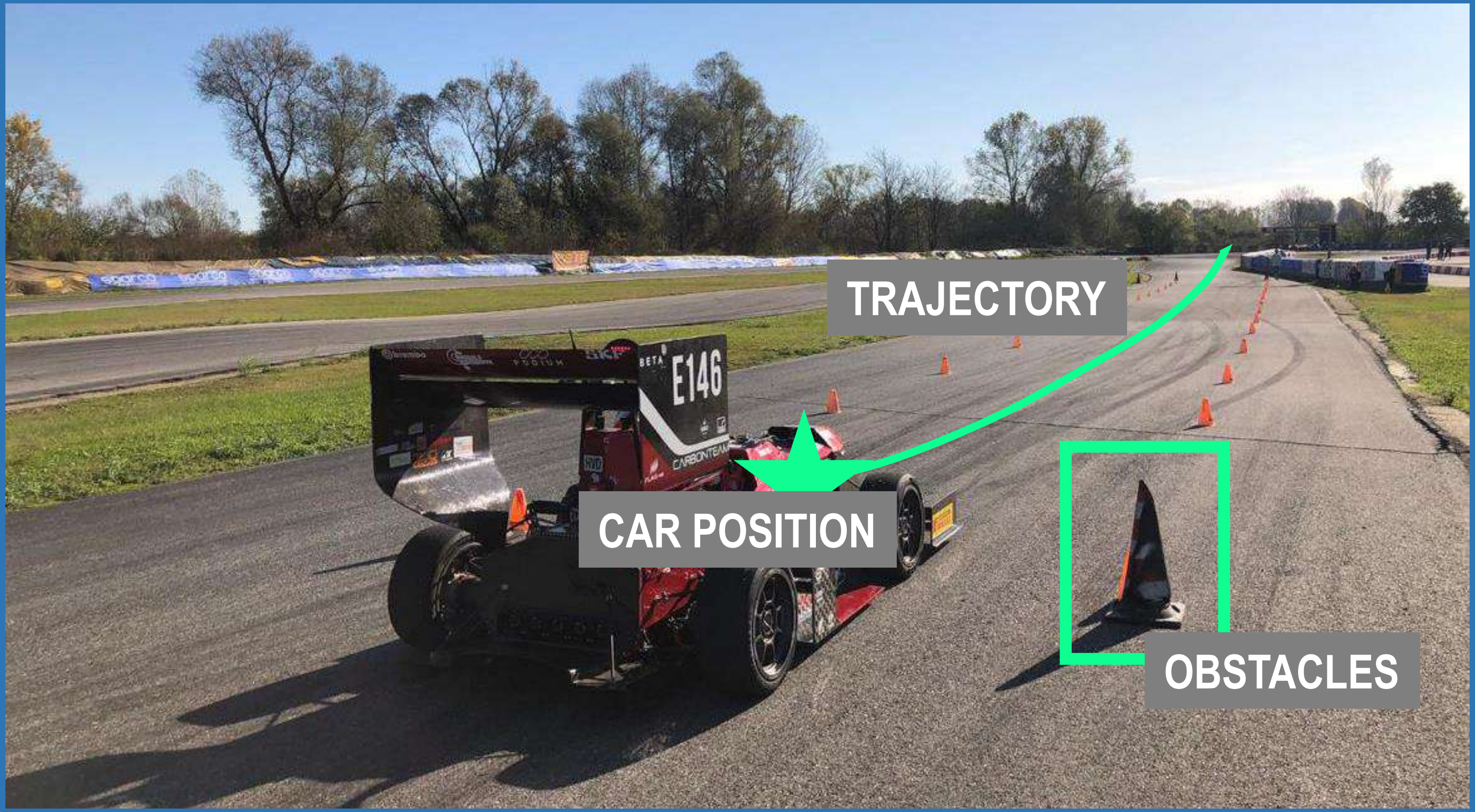
OBSTACLES POSTION ESTIMATION FOR AUTONOMOUS RACECARS WITH A COMBINED CLUSTERING TECHNIQUE

OBSTACLES POSTION ESTIMATION FOR AUTONOMOUS RACECARS WITH A COMBINED CLUSTERING TECHNIQUE

❑ TASKS

- Cones position estimation
- Car position estimation
- Trajectory planning

The test track was made with 15 orange little cones for about 75 meters and big orange cones for start and stop.



OBSTACLES POSTION ESTIMATION FOR AUTONOMOUS RACECARS WITH A COMBINED CLUSTERING TECHNIQUE

A LIDAR-based algorithm have been investigated because has a lot advantages:
a) vision-based (camera) algorithm are really object-dependent for artificial intelligence
b) stereocamera pseudo-distance estimation is useless for long distances (>5-10m)
c) LIDAR sensor can make an actual distance indirect measurement and not only an estimation = accuracy at centimeter level

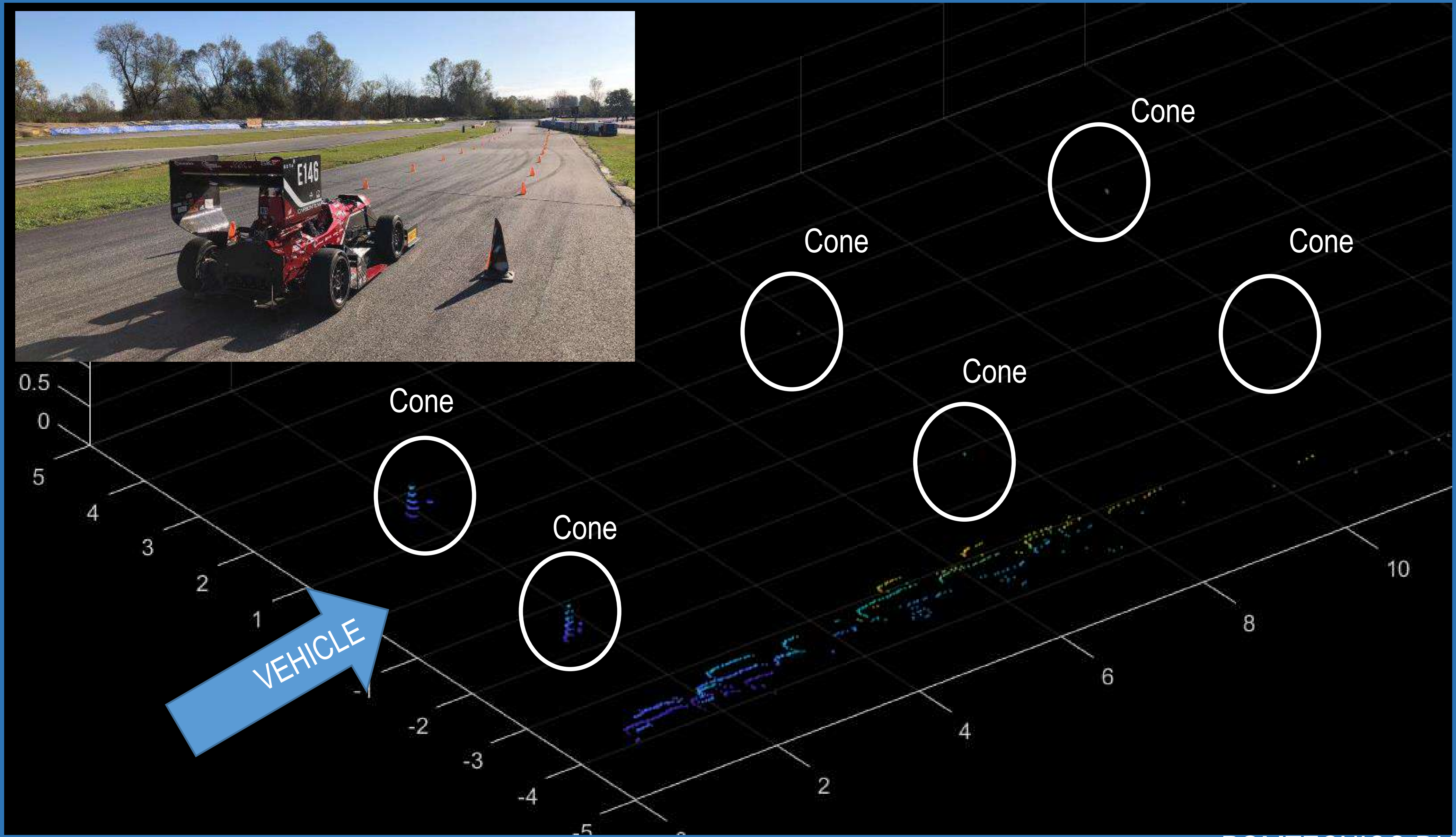
Unfortunately, LIDAR has some drawbacks:
a) generating at 10Hz point-clouds of thousands and thousands of point to manage
b) no information about the color (can retrieve some hints from th reflected light intensity parameter)
c) ground poitns have to be accurately filtered to not cut also the cones…
d) … but cutting the ground is not trivial since LIDAR has a well-known intrinsic problem of drift inaccuracy on the z-axis

Because of point 4), using thresholds on the z-axis for cutting the ground is useless and dangerous (cones gone away)

SOLUTION

SEMANTIC SEGMENTATION OF LIDAR POINT CLOUD

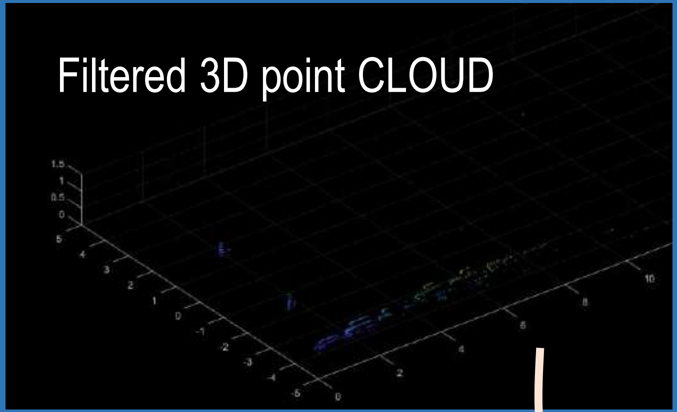
OBSTACLES POSTION ESTIMATION FOR AUTONOMOUS RACECARS WITH A COMBINED CLUSTERING TECHNIQUE



POLITECNICO DI TORINO

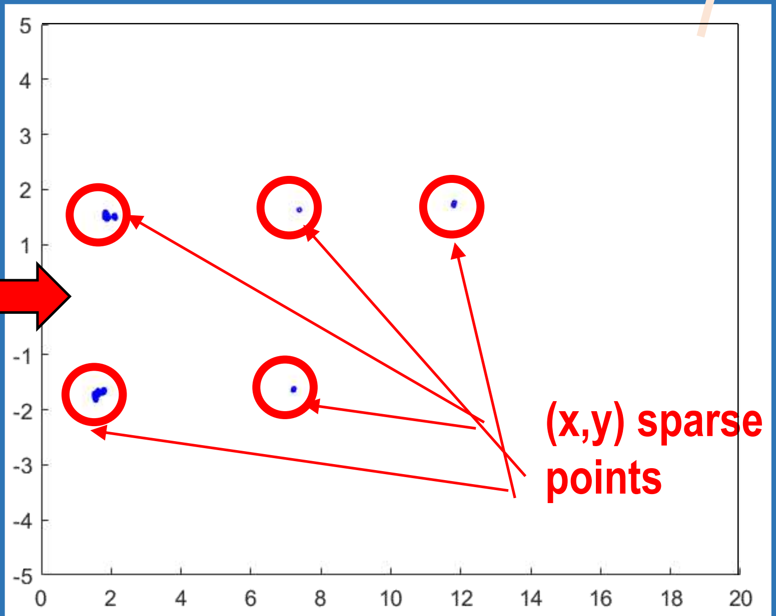
OBSTACLES POSTION ESTIMATION FOR AUTONOMOUS RACECARS WITH A COMBINED CLUSTERING TECHNIQUE

- TASK A - **Cones position estimation – Clustering**



2D REDUCTION

CAR

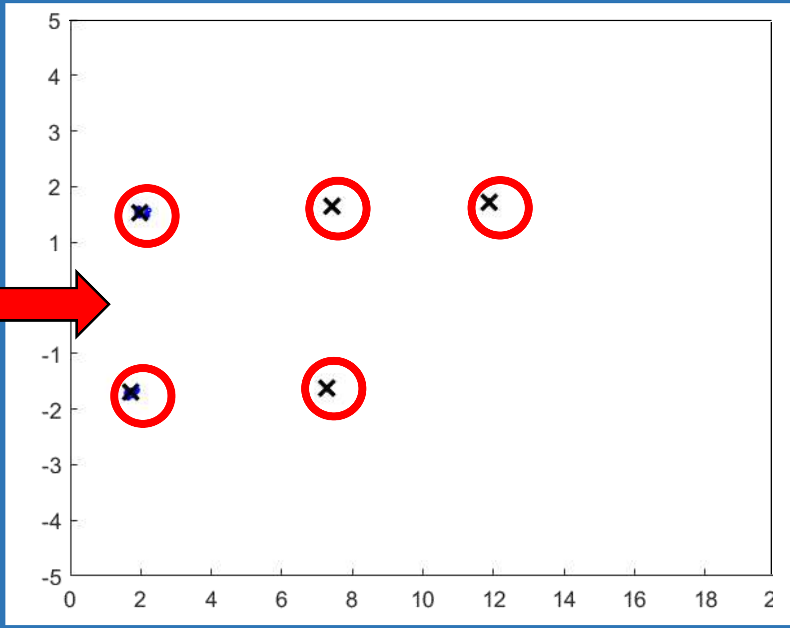


(x,y) sparse points

CLUSTERING

The black crosses are the centroids computed by the clustering process, i.e. the (x,y) position of the cones

CAR

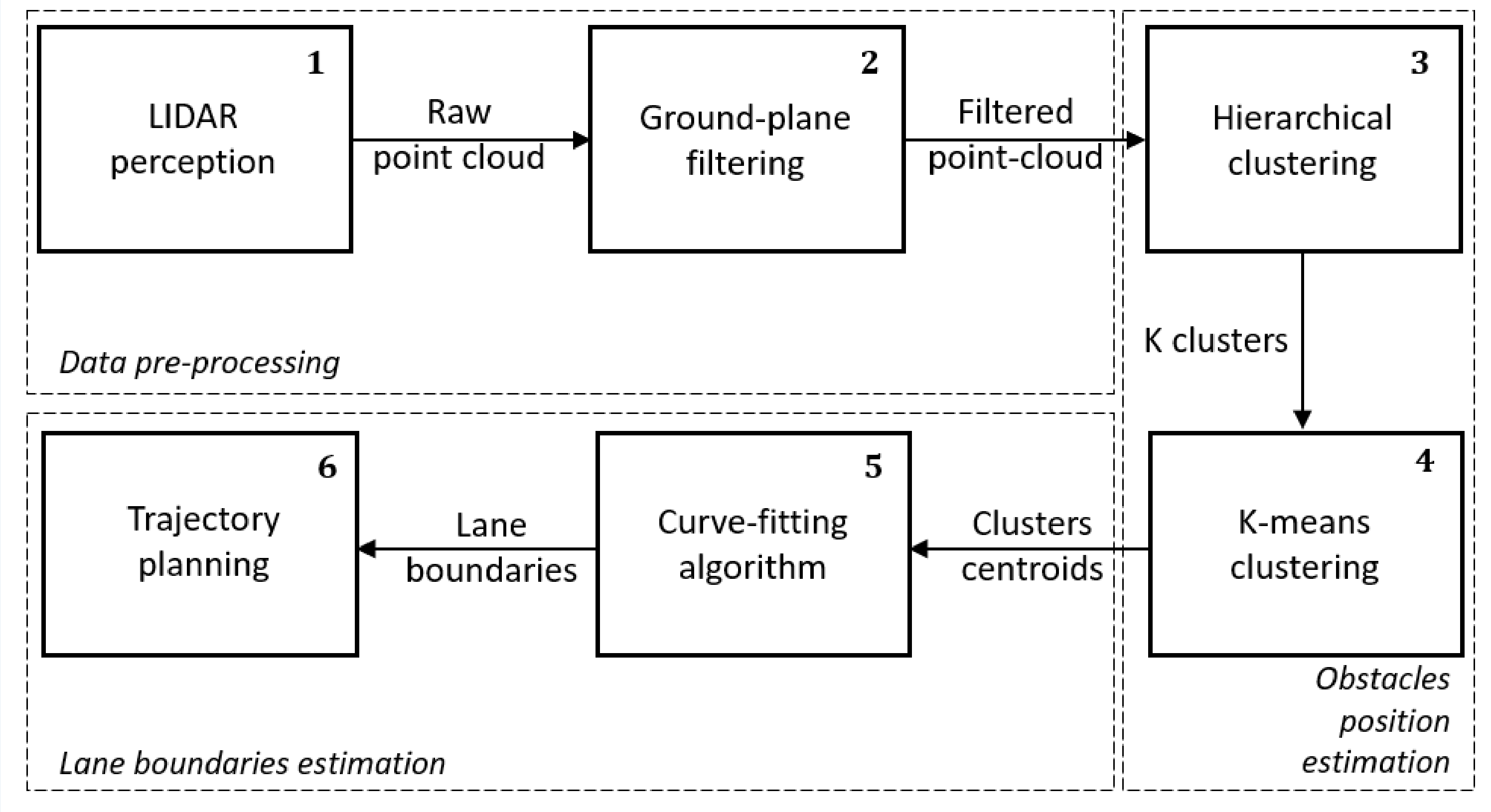


The LIDAR horizon is limited to 20 m for a better visualization

OBSTACLES POSTION ESTIMATION FOR AUTONOMOUS RACECARS WITH A COMBINED CLUSTERING TECHNIQUE

- TASK A - **Cones position estimation – Clustering**

PROBLEM: I don't know a priori how many clusters (i.e. obstacles) I have in the 2D plot.

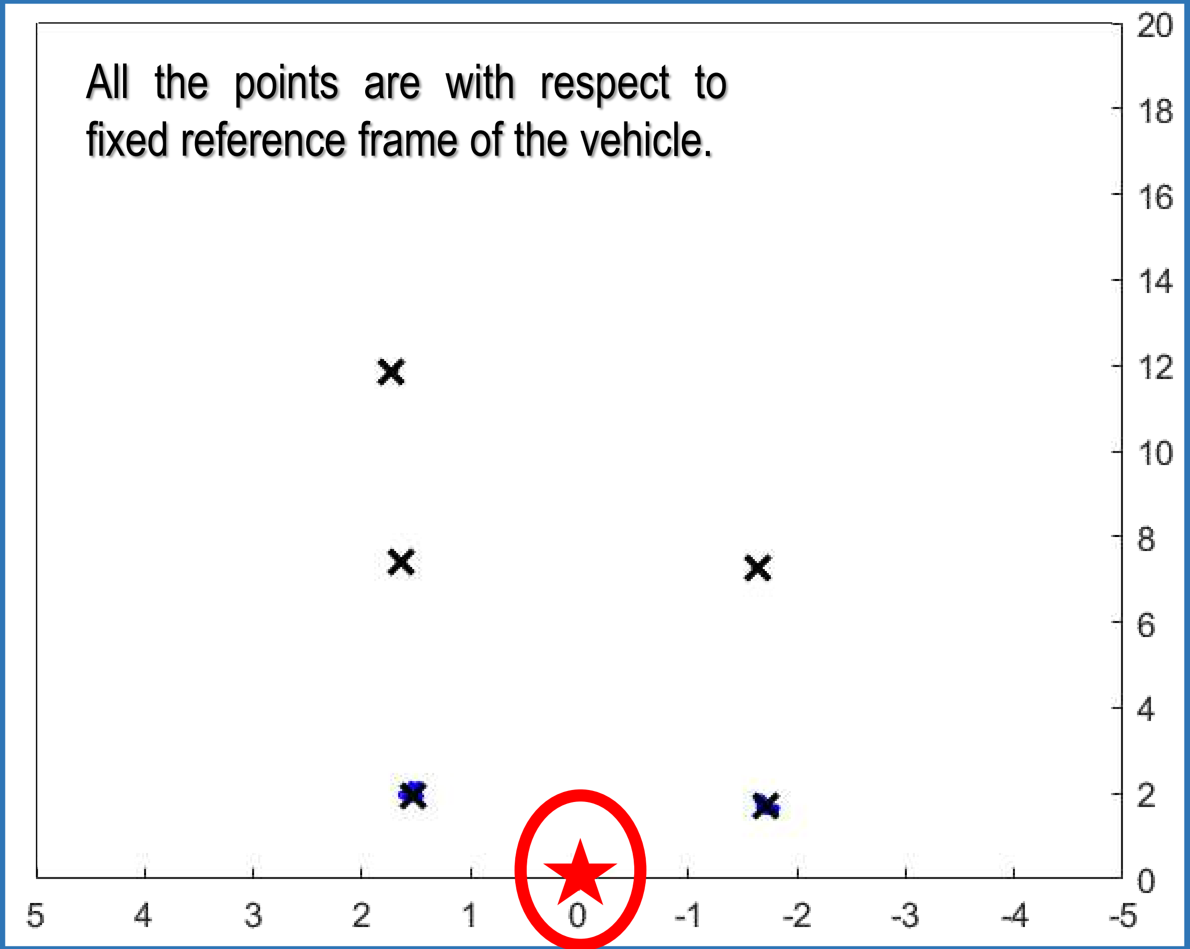


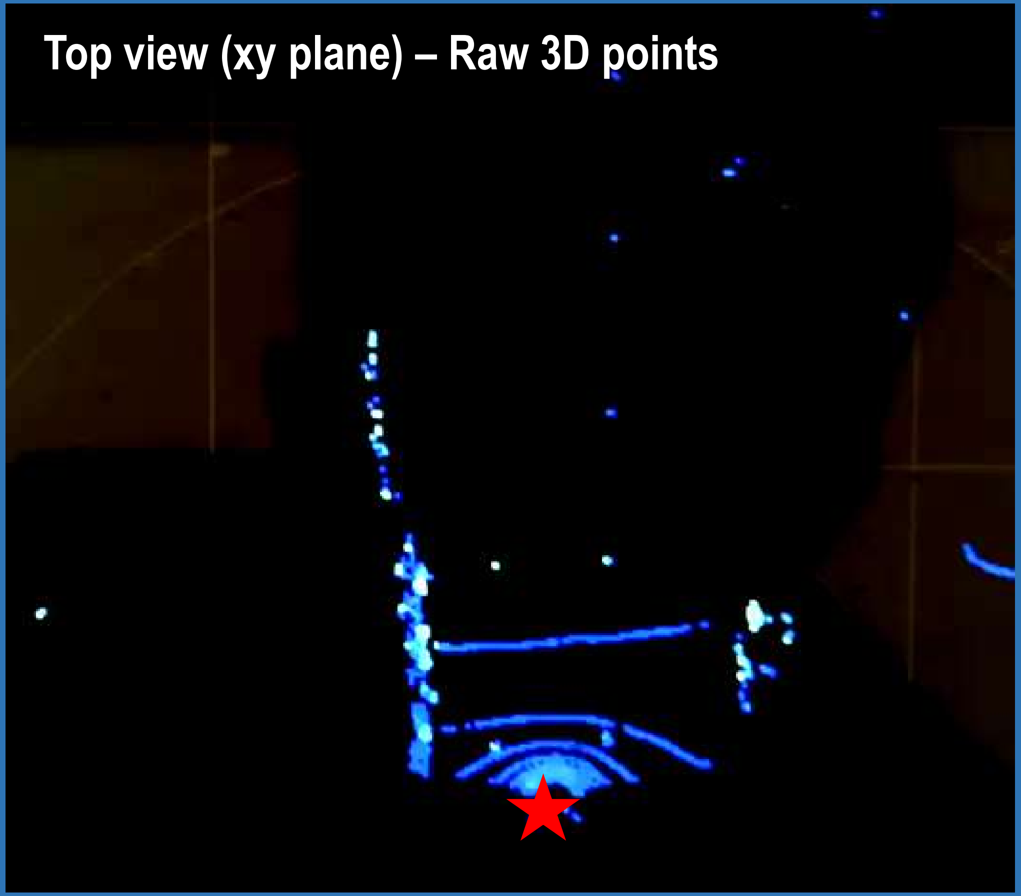
3. **<u>Hierarchical clustering</u>** can tell me how many clusters can be found in the 2D set, but not the position of their centroids.

4. Given the maximum number of clusters (k) I have to find, **k-means clustering** tells me the centroids of each cluster.

OBSTACLES POSTION ESTIMATION FOR AUTONOMOUS RACECARS WITH A COMBINED CLUSTERING TECHNIQUE

- TASK B - **Car position estimation**





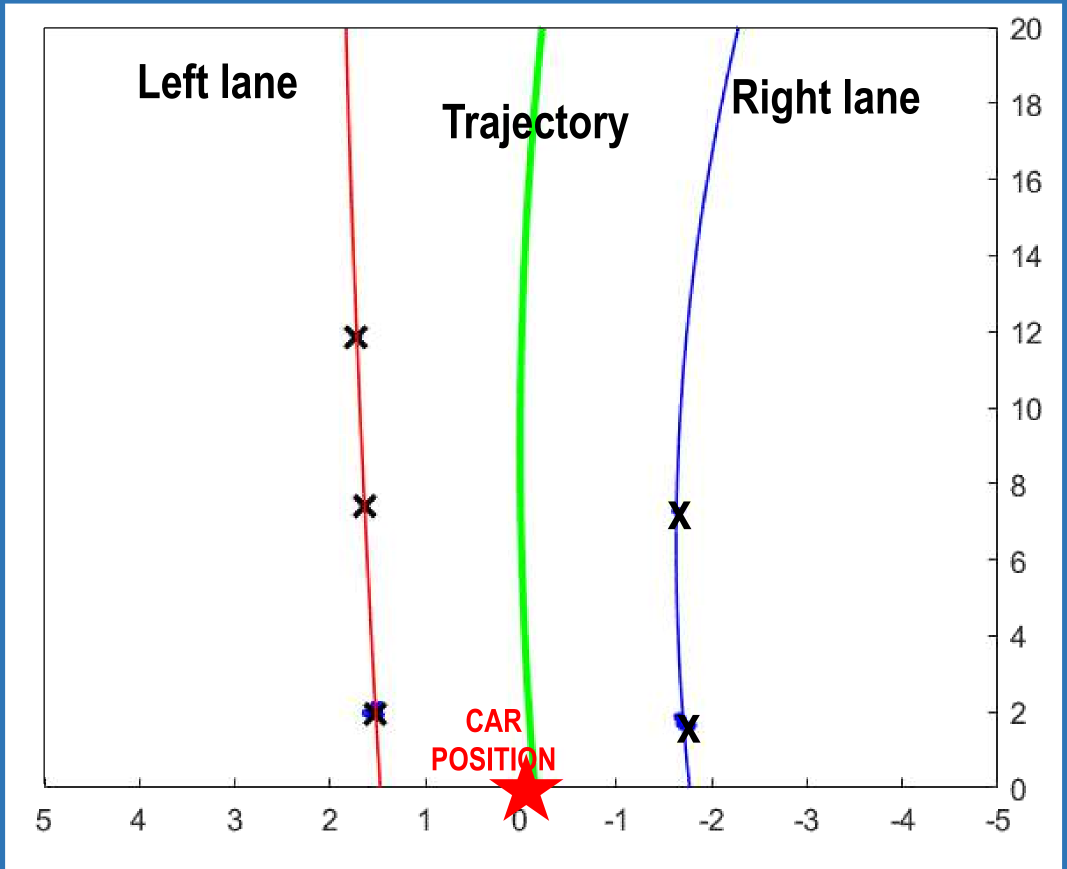
Vehicle position is always in (0,0)

OBSTACLES POSTION ESTIMATION FOR AUTONOMOUS RACECARS WITH A COMBINED CLUSTERING TECHNIQUE

- TASK C – **Trajectory planning**

Trajectory is planned at each frame as the mean parabolic line between the left and right lane boundaries.

Each parabola is computed by interpolation of left and right cones, respectively.



Tested in real-time at 10Hz with real acquisitions.

PROBABILISTIC ROAD MAP ALGORITHM FOR OPTIMAL TRAJECTORY PLANNING IN AUTONOMOUS DRIVING

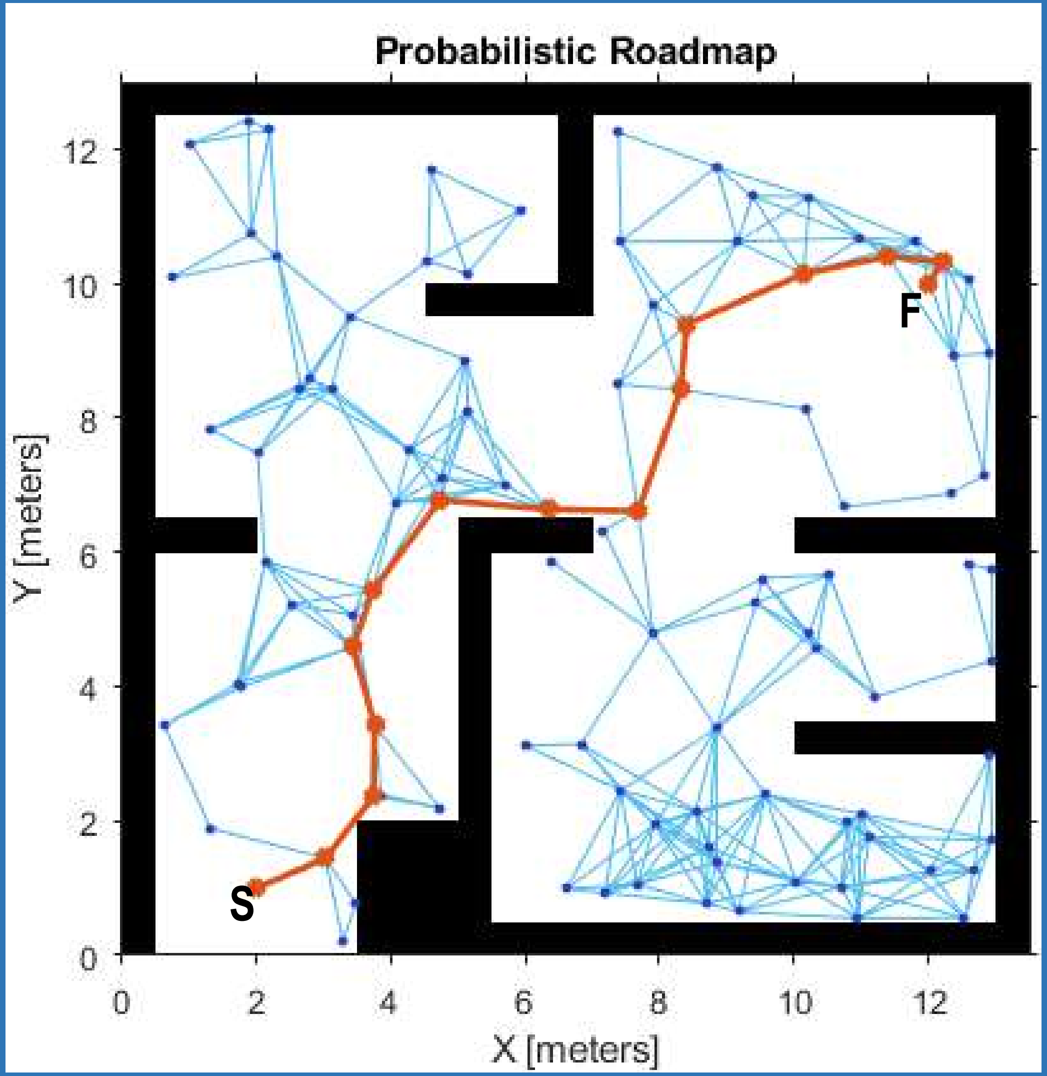
PROBABILISTIC ROAD MAP ALGORITHM
FOR OPTIMAL TRAJECTORY PLANNING IN AUTONOMOUS DRIVING

BACKGROUND

The probabilistic roadmap planner (PRM) is a robotic motion planning algorithm, which solves the problem of determining a path between a starting configuration of the vehicle and a goal configuration while avoiding collisions.

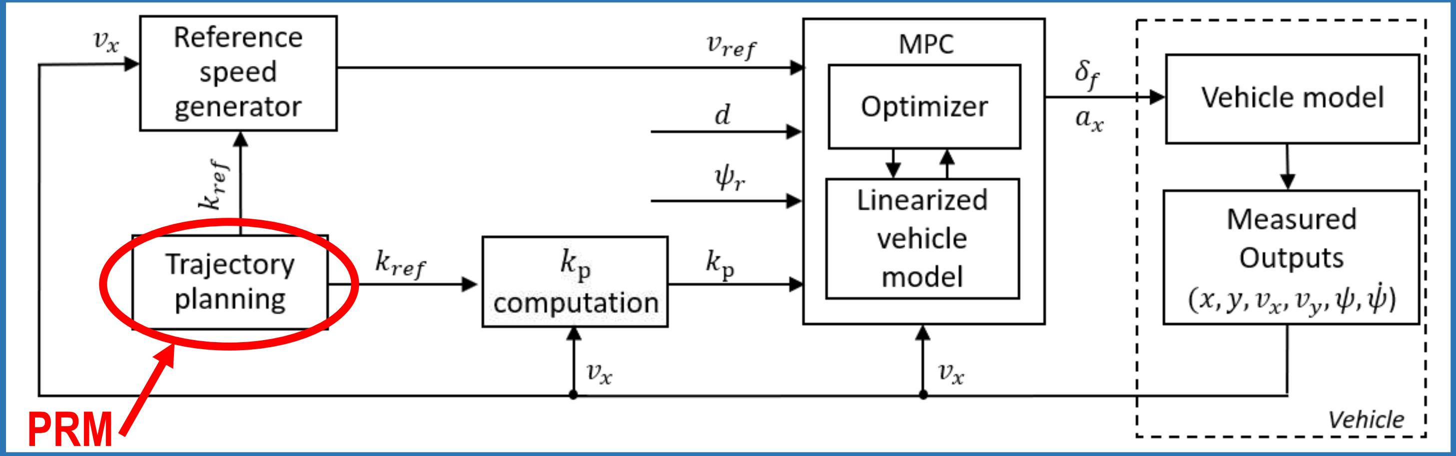
The main idea consists in taking random samples from the driving scenario, and evaluating whether they are in the region of interest. Then, use a local planner to connect these possible positions to other nearby positions of the vehicle.

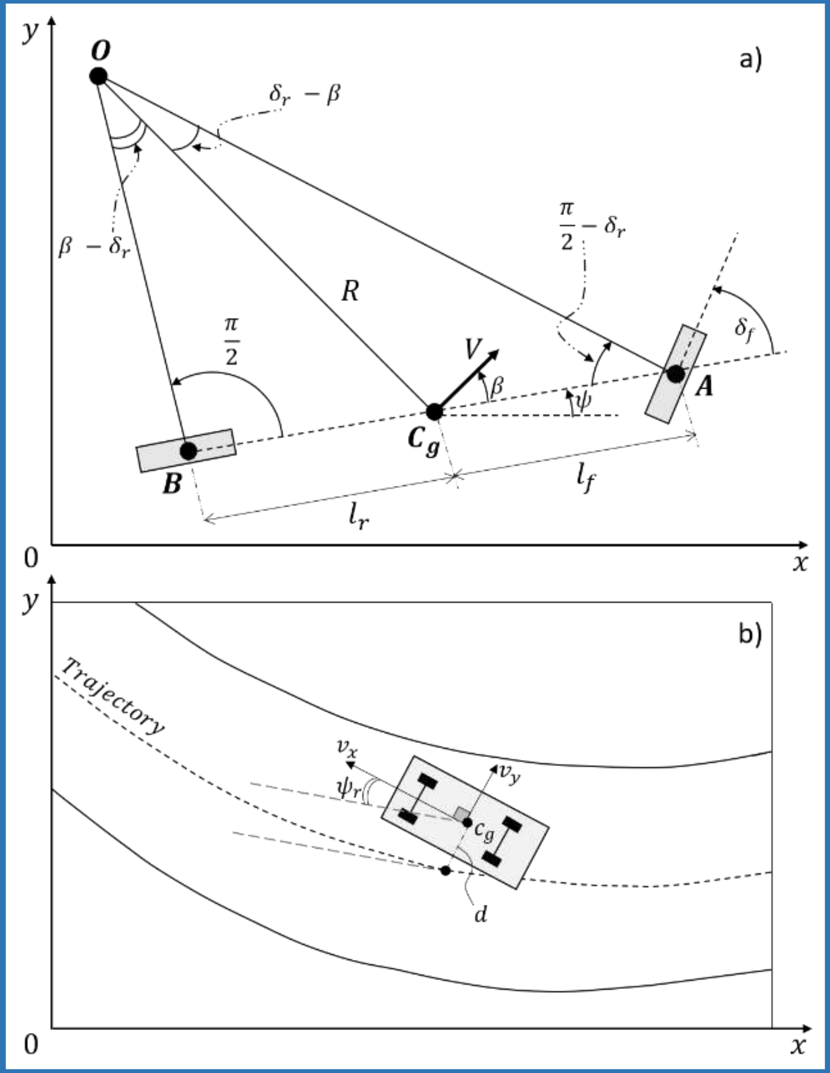
Once the starting and goal configurations are identified, a graph search algorithm (i.e. shortest path) is applied to the resulting graph to determine a trajectory between the starting and goal configurations.



PROBABILISTIC ROAD MAP ALGORITHM FOR OPTIMAL TRAJECTORY PLANNING IN AUTONOMOUS DRIVING

- A PRM-based algorithm is used for trajectory planning by the autonomous vehicle.
- The vehicle is considered as a 3-DoF bicycle linear kinematic model.
- The vehicle dynamics is controlled by a Model Predictive Control (MPC) strategy, computing the required steering angle and longitudinal acceleration to follow the trajectory [1].

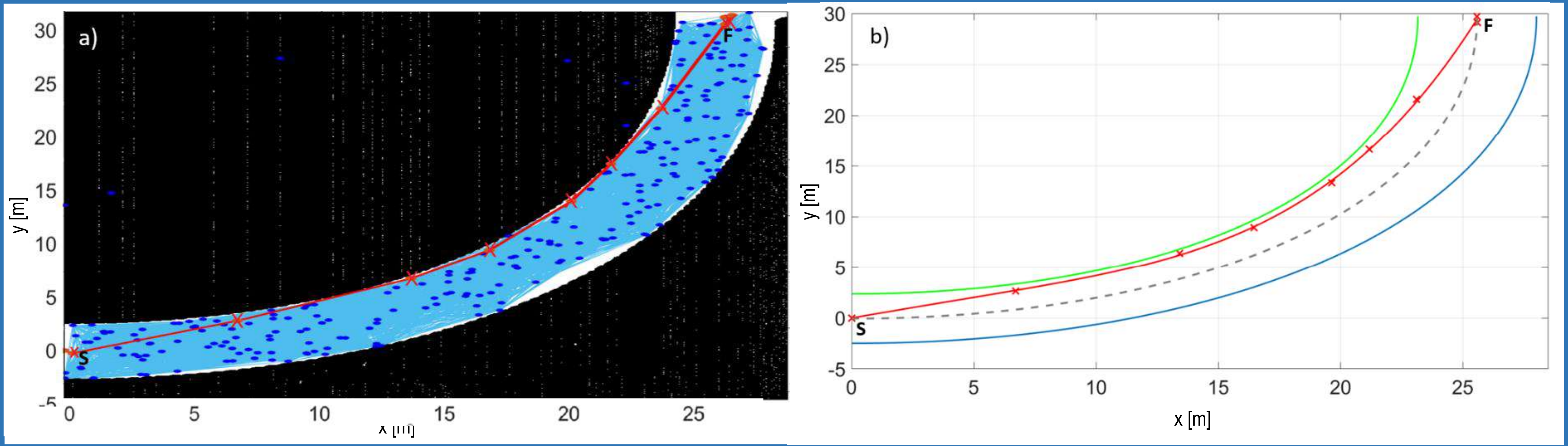




[1] Feraco, S., Bonfitto, A., Amati, N., & Tonoli, A. Combined Lane Keeping and Longitudinal Speed Control for Autonomous Driving. In *ASME 2019 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. American Society of Mechanical Engineers Digital Collection.

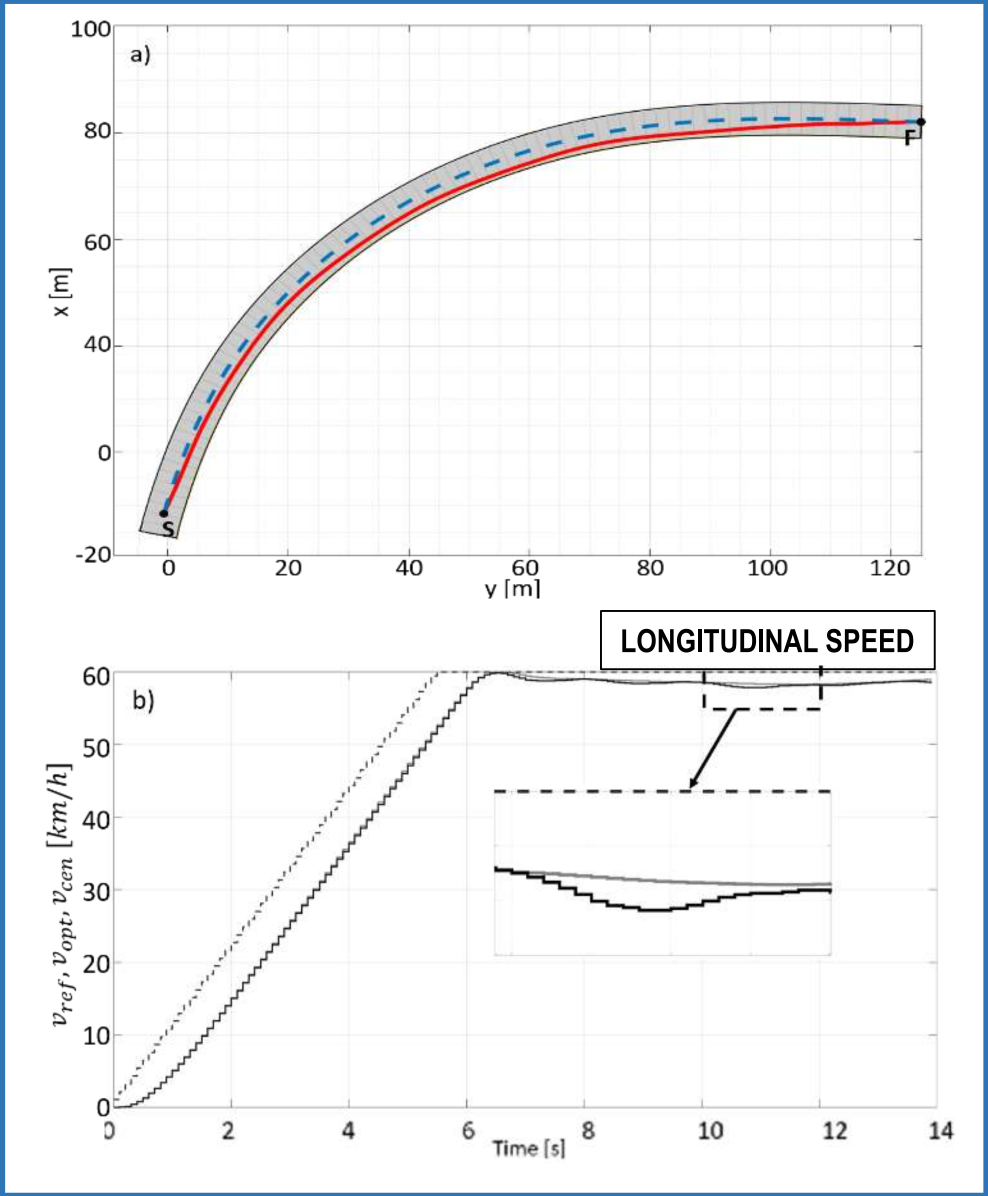
PROBABILISTIC ROAD MAP ALGORITHM
FOR OPTIMAL TRAJECTORY PLANNING IN AUTONOMOUS DRIVING

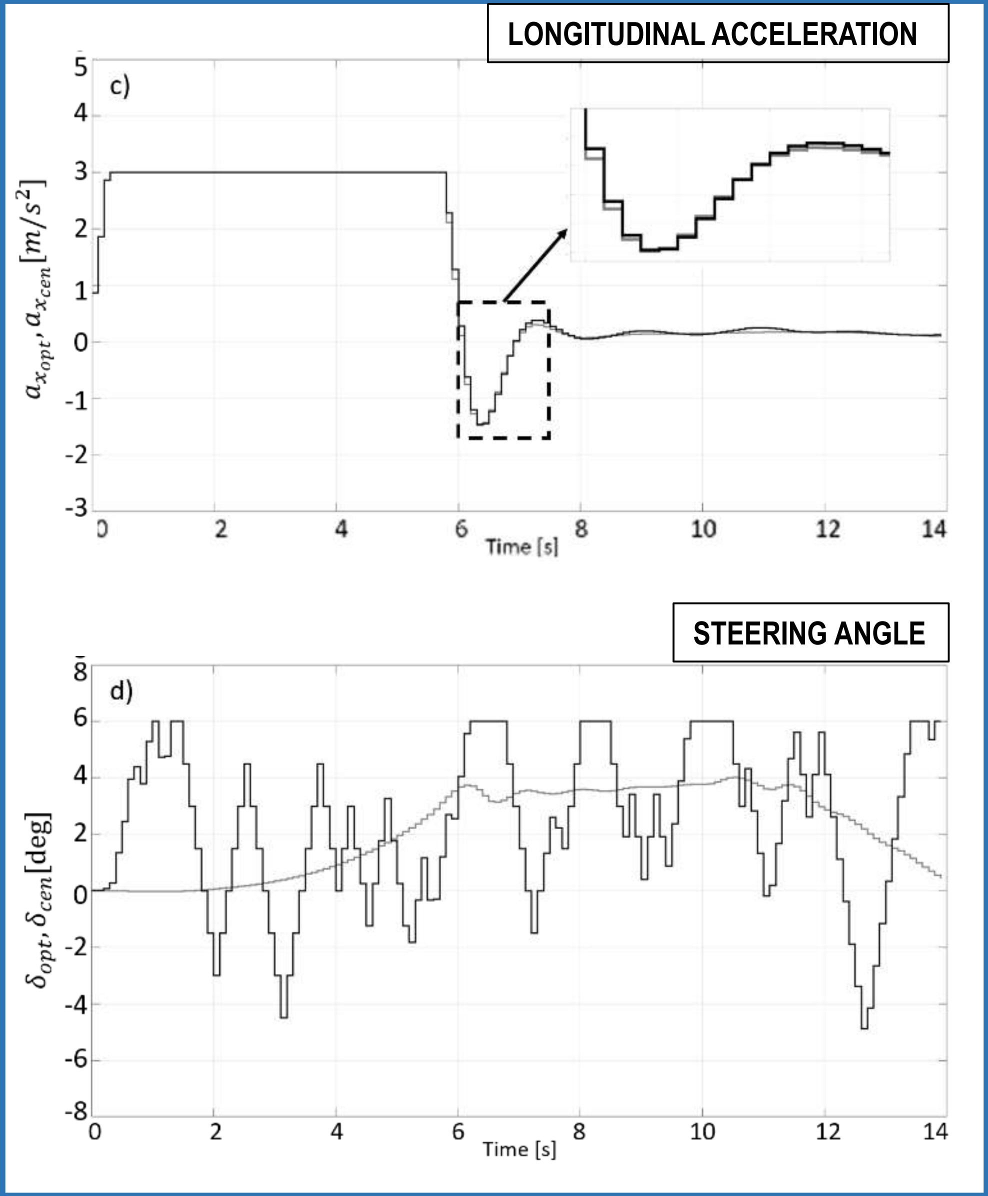
- The investigated algorithm computes the shortest path exploiting the Dijkstra's method among all the possible trajectories generated by PRM [2].
- The results are compared with respect to the case in which the reference trajectory is the central line between lane boundaries.



[2] Wang, H., Yu, Y., & Yuan, Q. (2011, July). Application of Dijkstra algorithm in robot path-planning. In *2011 second international conference on mechanic automation and control engineering* (pp. 1067-1069). IEEE.

PROBABILISTIC ROAD MAP ALGORITHM FOR OPTIMAL TRAJECTORY PLANNING IN AUTONOMOUS DRIVING

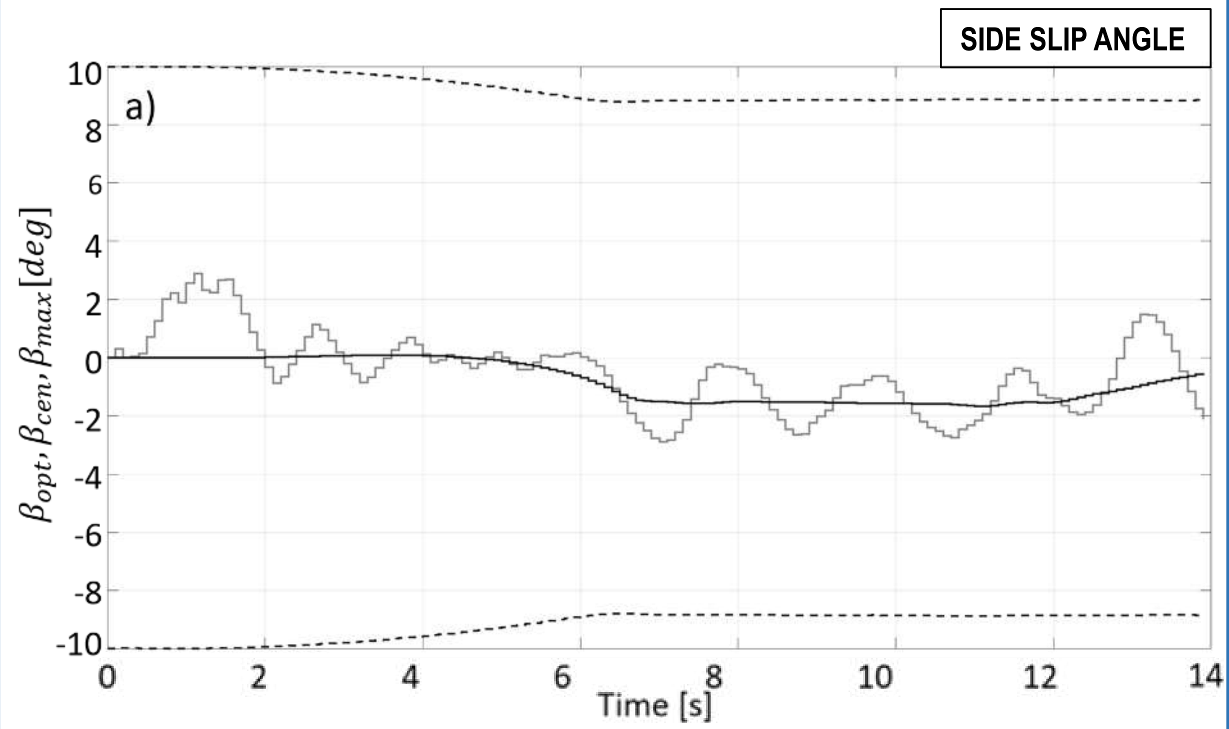


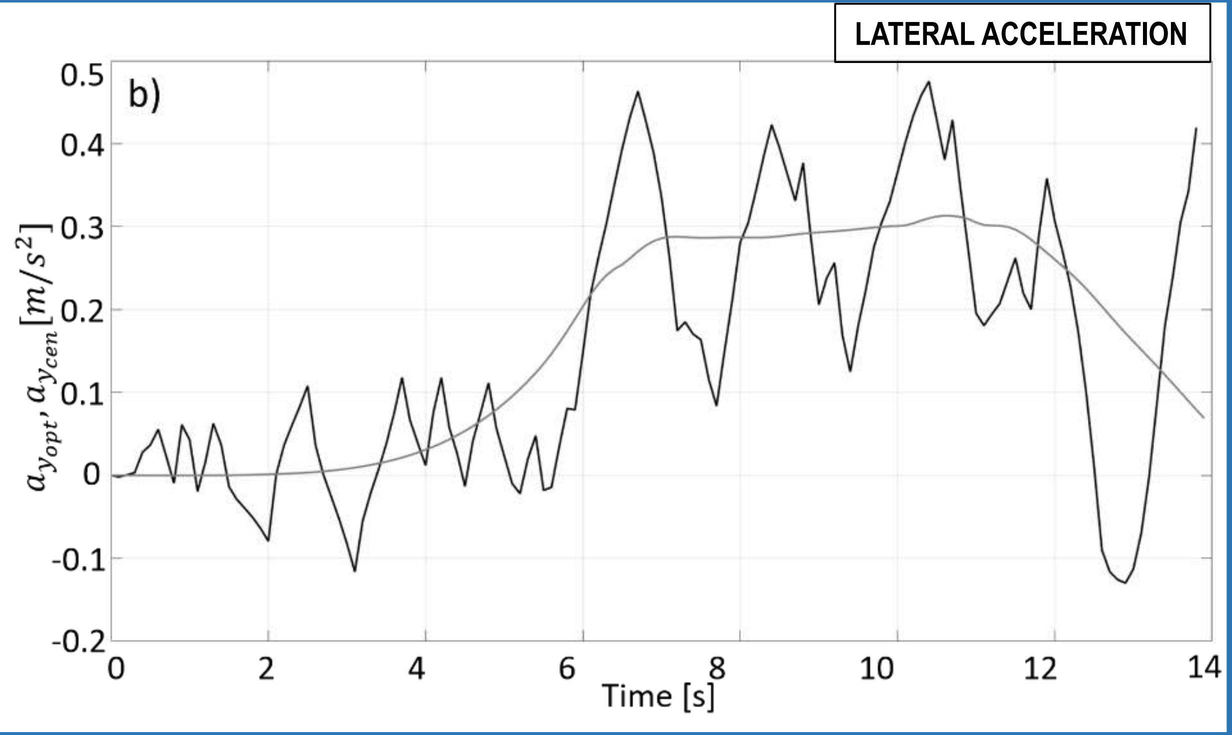


PROBABILISTIC ROAD MAP ALGORITHM
FOR OPTIMAL TRAJECTORY PLANNING IN AUTONOMOUS DRIVING

- The vehicle stability and comfort is evaluated by means of side slip angle and lateral acceleration values.
- The proposed algorithm respect the limits in terms of maximum sideslip angle (Eq. 1 [3]) and lateral acceleration [4].

$$\beta_{MAX} = 10° - 7° \cdot \frac{V^2}{(\gamma)^2} \qquad \text{(Eq. 1)}$$





[3] Kiencke, U., & Nielsen, L. "Automotive control systems: for engine, driveline, and vehicle", 2000.
[4] Xu, J., Yang, K., Shao, Y., & Lu, G. "An experimental study on lateral acceleration of cars in different environments in Sichuan", Southwest China. Discrete Dynamics in nature and Society, 2015.

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February 05, 2020 – PhD Presentation

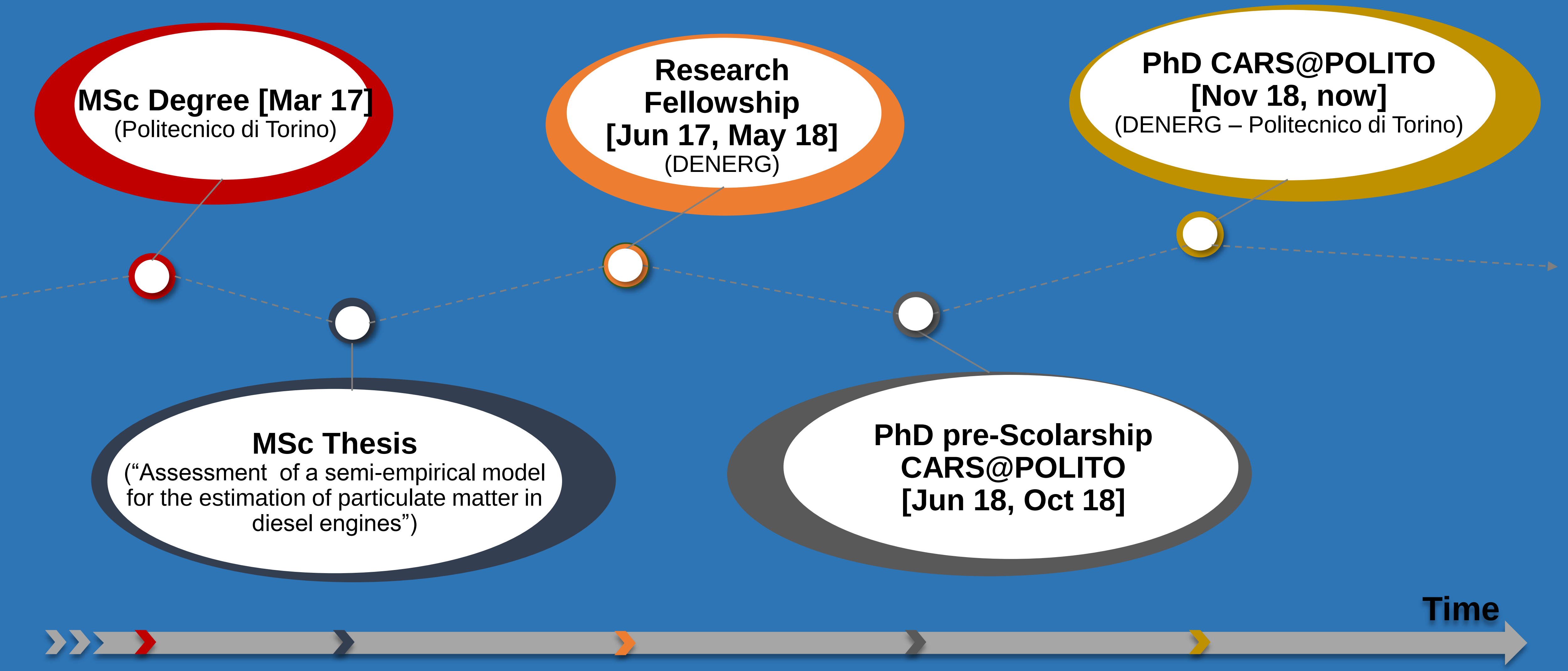
(P)HEV Optimal Design

PhD Student:
Claudio Maino

Supervisors:
Daniela Anna Misul
Ezio Spessa

PhD Program: Energetics

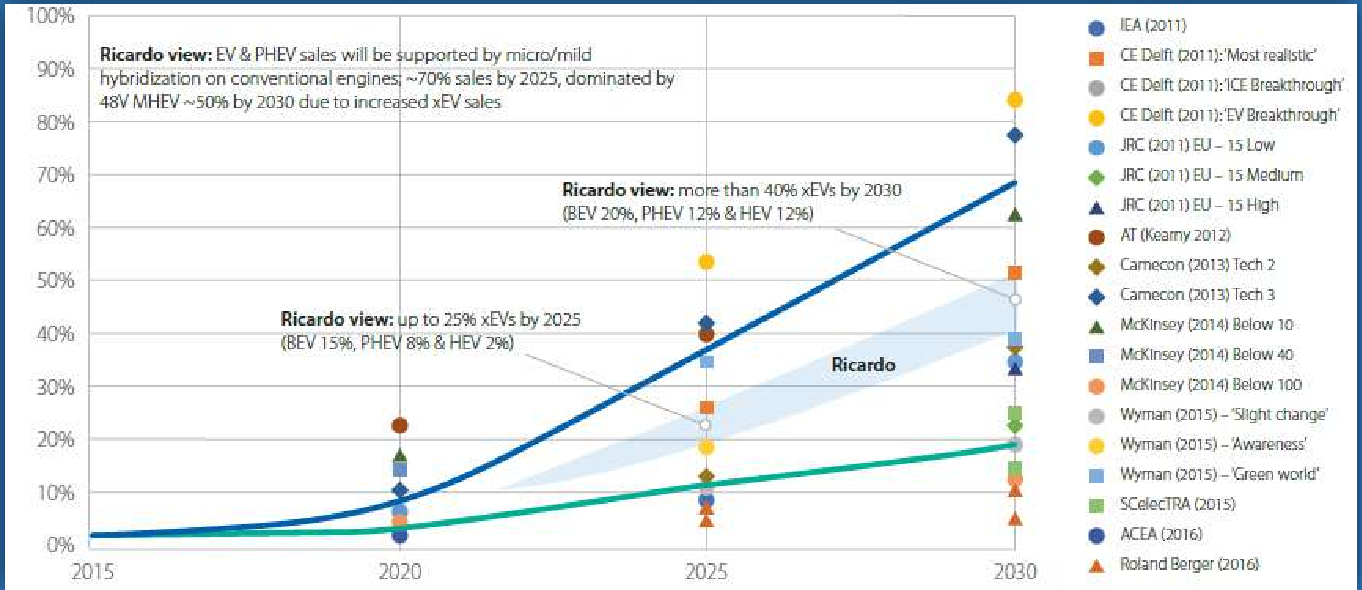
Personal Background: Claudio Maino



Motivation and Problem Overview

The increasing concern into environmental issues and the even more stringent emission regulation introduced all over the world have caused the industry to largely invest in R&D for enhanced technologies in the field of vehicles electrification. (P)HEVs retain a high potential in penetrating the market and are likely to significantly contribute to reducing the pollutant and greenhouse emissions in the near future.

European electrification forecasts xEV share <20% to >60% in 2030

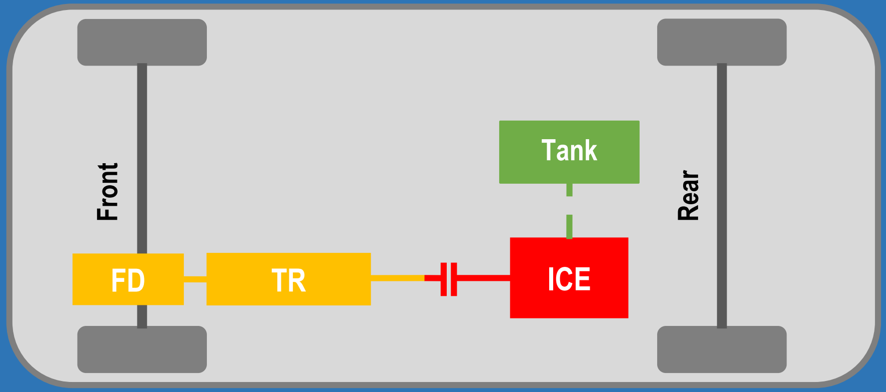


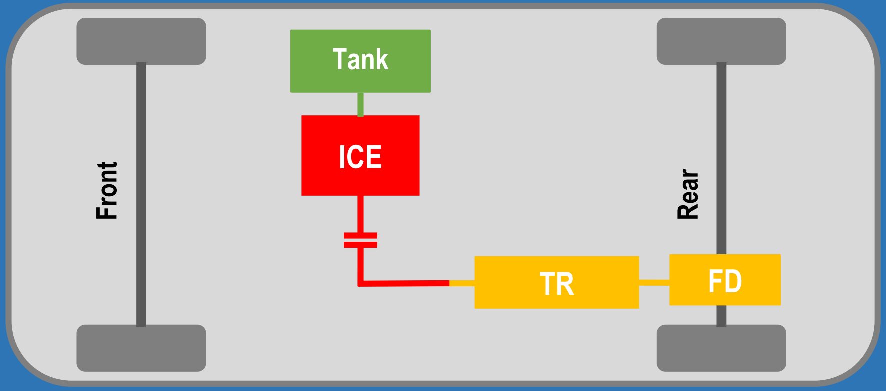
Source: ERTRAC, Ricardo Analysis

Exploiting the (P)HEV best performance for very different test cases turns to be a very hard task. Hence an optimal vehicle layout definition together with an optimal energy management during the vehicle operation are required.

The Powertrain

Conventional (cv) | Full electric (bev) | Hybrid electric ((p)hev)



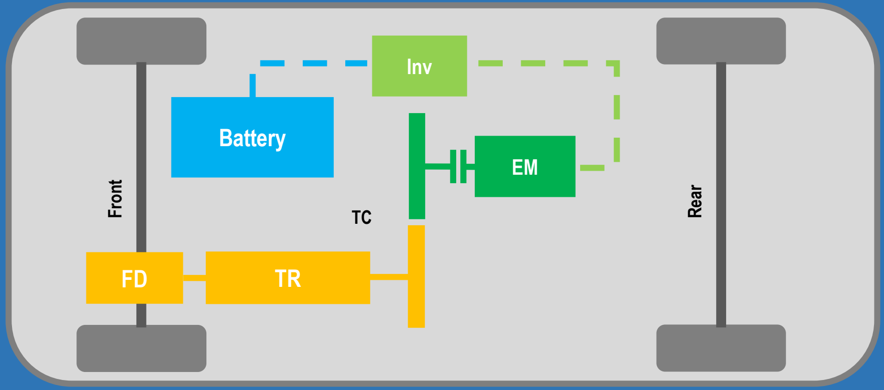


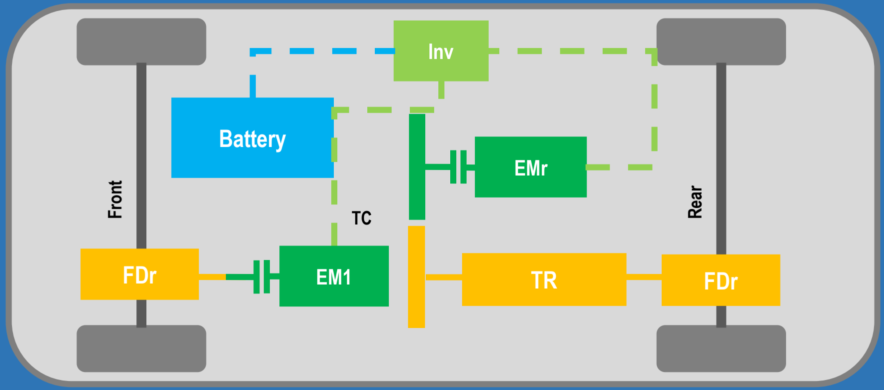
Main design requirements

- ICE (sizing, fuel, control)
- Transmission
- Final drive(s)
- Traction

The Powertrain

Conventional (cv)	*Full electric (bev)*	Hybrid electric ((p)hev)





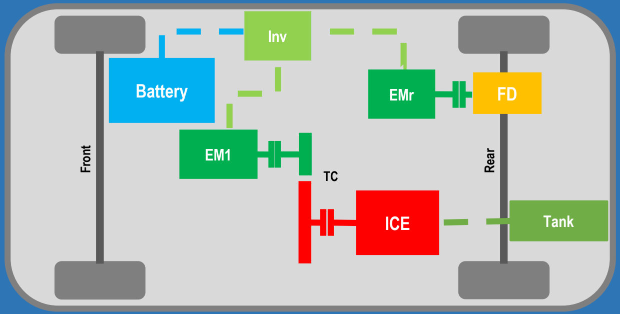
Main design requirements

- EM (number, sizing, control)
- Battery (storage capacity, type)
- Possible transmission
- Final drive(s)
- Traction

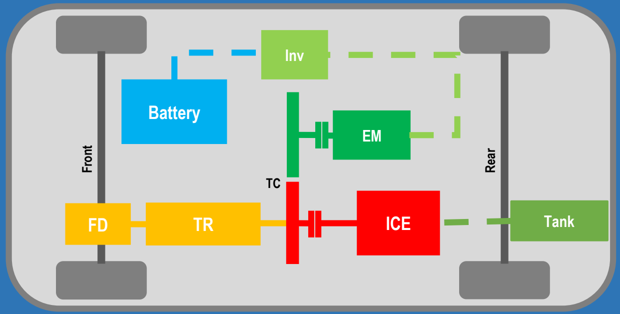
The Powertrain

Conventional (cv)	Full electric (bev)	*Hybrid electric ((p)hev)*

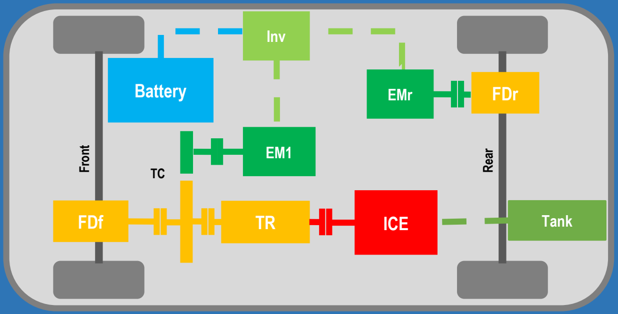
Hybrid Series Architecture



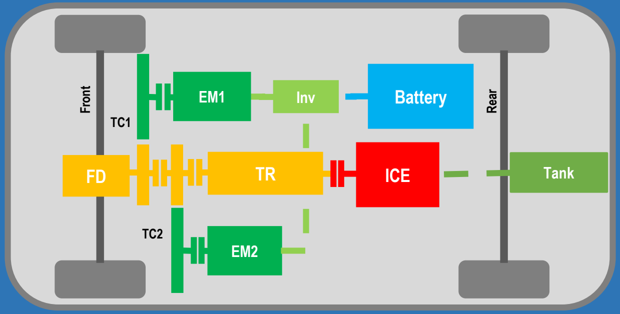
Hybrid Parallel P2 Architecture



Hybrid Parallel P3P4 Architecture



Hybrid Complex Architecture



Main design requirements

- "cv" requirements
- "bev" requirements
- Operating modes (pe, pt, ps, etc.)
- Series, Parallel, Complex, …
- Micro, Mild, Full HEV
- HEV or PHEV
- Optimization Goal

Over the Powertrain

Additional design requirements

- Vehicle type-approval tests
- Real driving mission-based learning (traffic, ZTL, etc.)
- After-Treatment System (TWC, DOC+DPF+SCR, etc.)
- Legislation limits (fuel consumption, pollutant emissions, etc.)
- Powertrain cost (Total Cost of Ownership)
- Minimum performance (user satisfaction)
- OEM constraints
- …

The Choice

What is the best solution???

Research Contribution

Target 1 (year 1)

Development of an innovative tool for performing design operations over hybrid vehicles fleets.

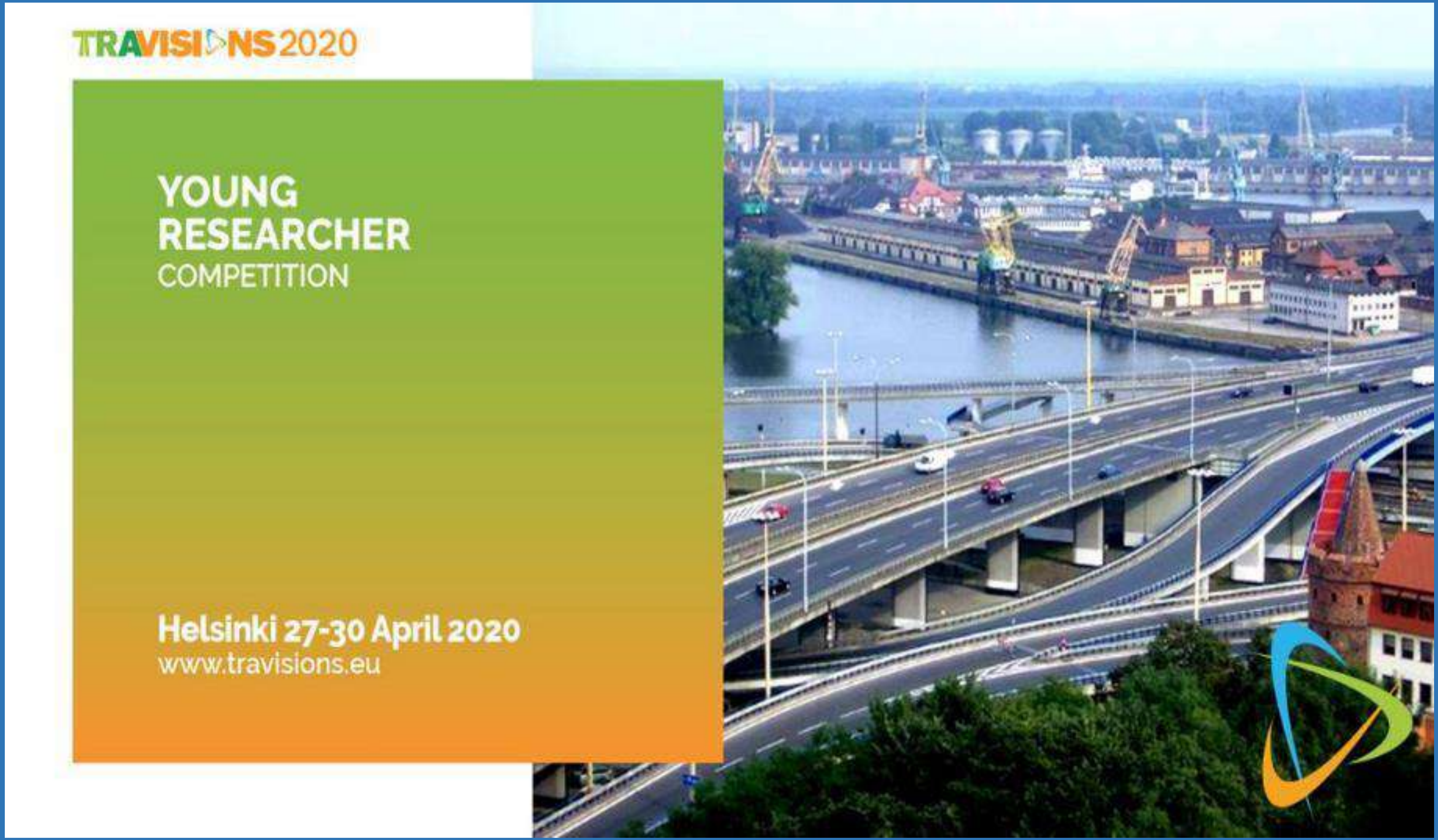
Target 2 (year 2)

Analysis and development of smart solutions for real-time hybrid powertrain control.

Target 3 (year 3)

Application to real test cases (industrial partnership).

THEO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February 5, 2020

Connected Vehicles for Autonomous Driving

PhD Student:
Marco Malinverno

XXXIII Cycle

Tutors:
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Carla Fabiana Chiasserini

Co-Tutor:
Nicola Amati

PhD Program in Electrical, Electronics and Communications Engineering

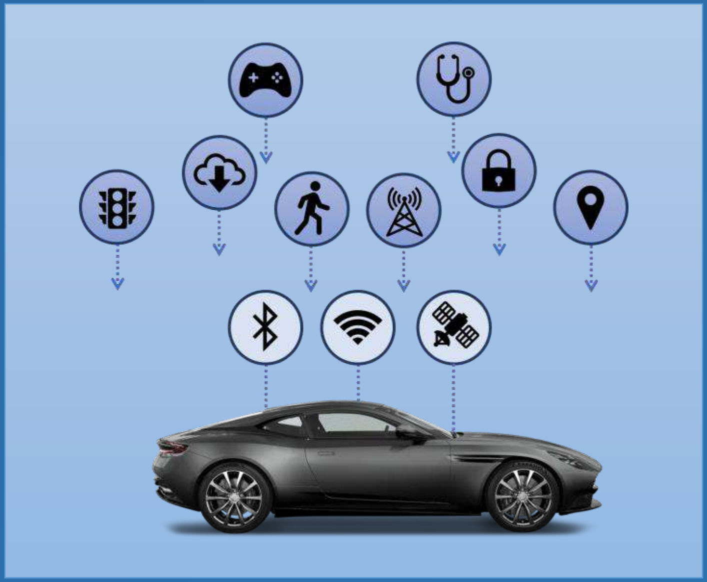
Background and Research Field

- B.Sc. in Computer Engineering (‘13) - Università degli studi di Siena
- M.Sc. in Computer and Communication Networks Engineering (‘16) - Politecnico di Torino
- Ph.D. in Electrical, Electronics and Communications Engineering (‘20) - Politecnico di Torino

- **Connected Cars technologies and vehicular applications**
- **Simulation tools and on-field implementations**

Connected Cars

Technologies, services and applications enabling the exchange of information between the vehicle and any other device (active or passive) – V2X

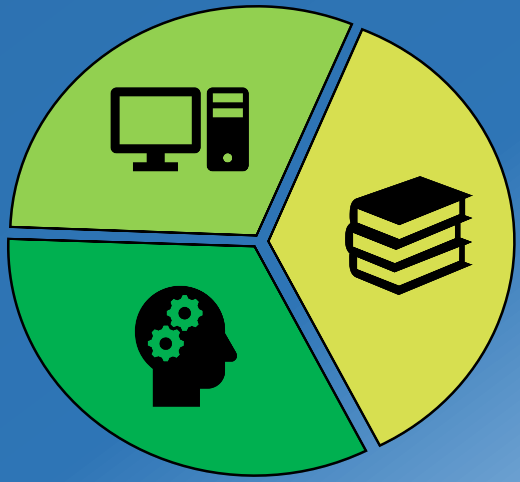


- Many applications: safety, transport efficiency, remote diagnostic…
- Many problems still to be solved: communication protocols hetereogenity, connection stability, cybersecurity, privacy, ethics…

- **Connected Cars** technologies are one of the pillar of **Autonomous Driving** paradigm

Ph.D. Objectives

- Connected cars technologies state-of-the-art assessment, referencing to scientific paper and to the main standardization bodies (IEEE, 3GPP)
- V2X software development and hardware assembling
- V2X protocols integration with ADAS (Advanced Driver Assistance System) and on-board HMI (Human-Machine Interface)



My approach

SIMULATION

- Development and testing of V2X-based applications leveraging the state-of-the-art simulation software
- Development of a simulation sandbox for V2I and V2V application testing and prototyping

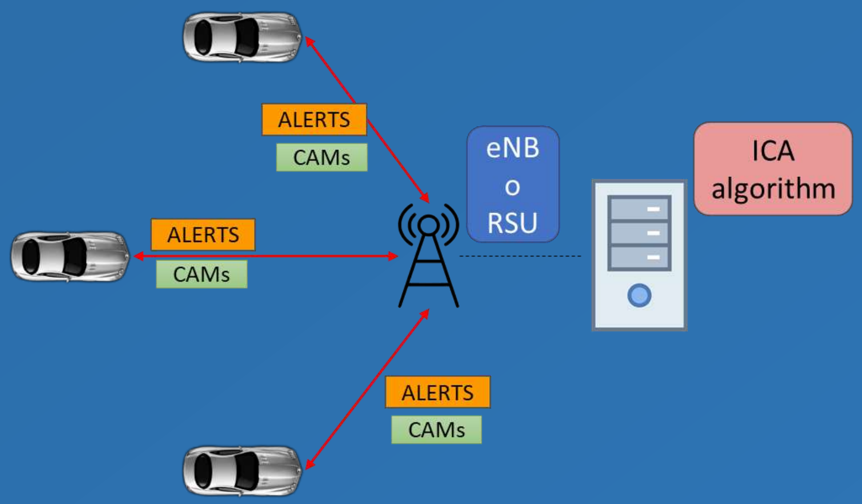
IMPLEMENTATION

- Creation of a prototype for V2X communication using off-the-shelf available devices
- Study and performance characterization of our solution
- On-field implementation

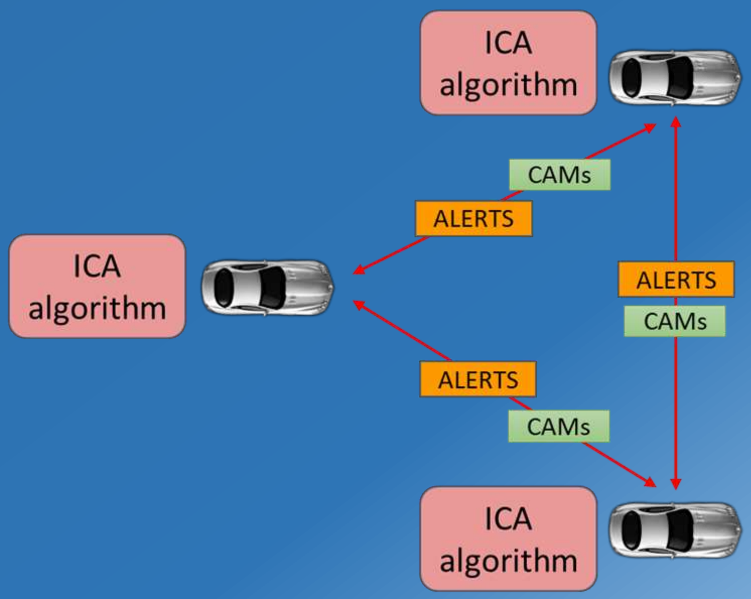
Simulation (1)

- ICA – Intersection Collision Avoidance. An application identifying possible collisions between vehicles, or between vehicles and other vulnerable users. **Entirely based on CAMs and DENMs dissemination.**

- V2I – Vehicle to Infrastructure

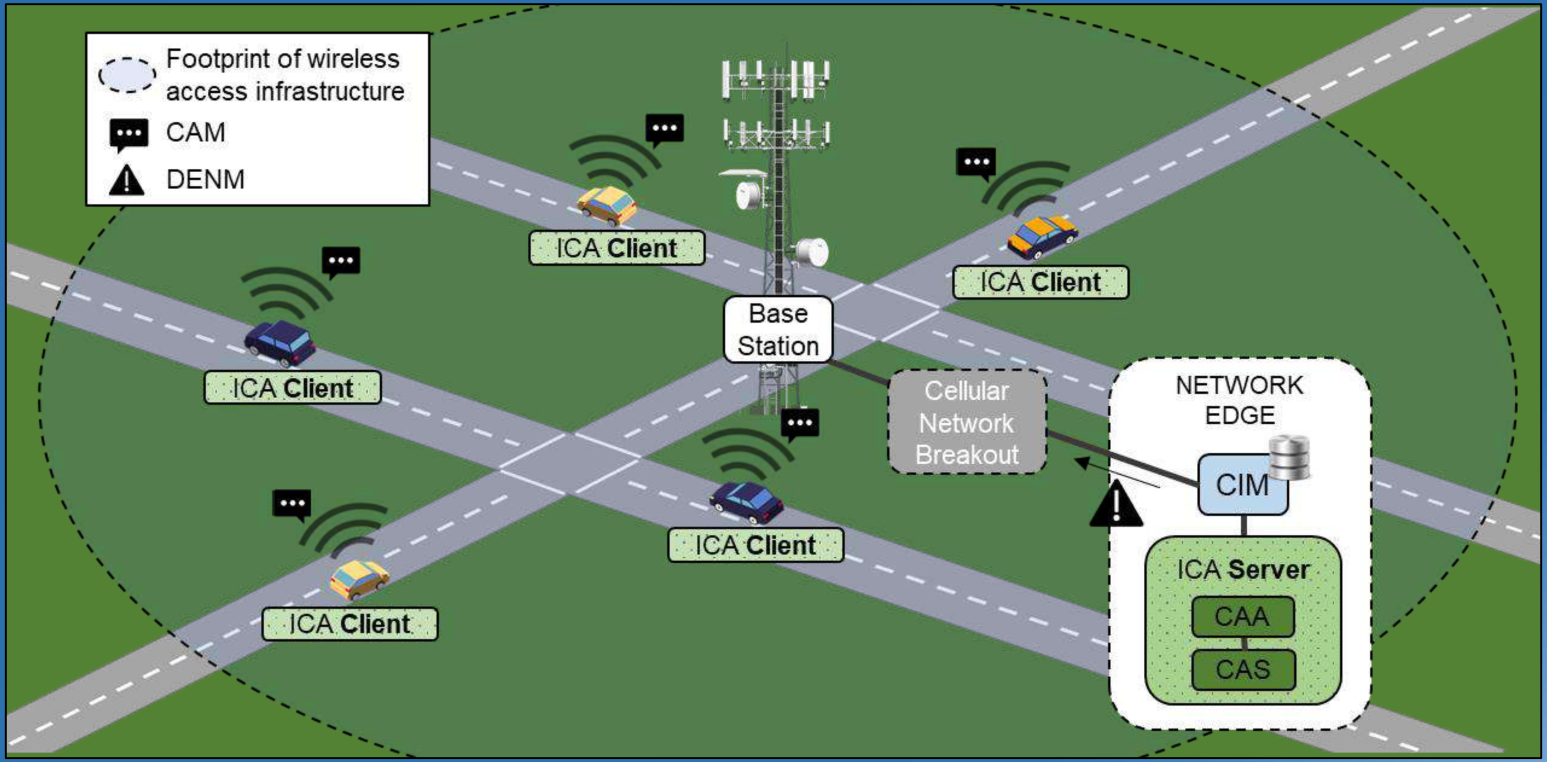


- V2V – Vehicle to Vehicle



Simulation (1)

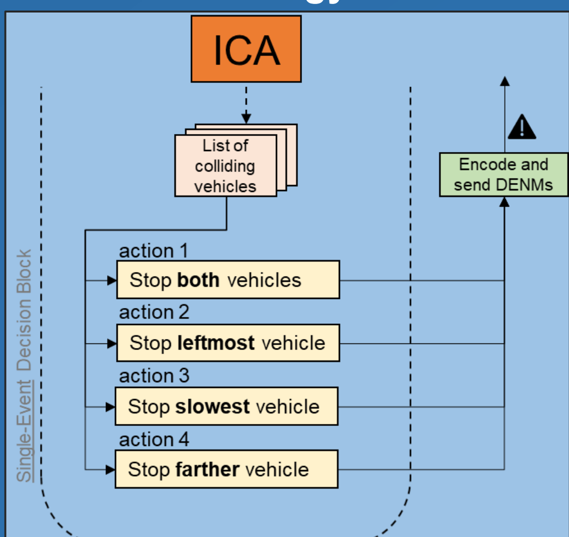
- ICA – Intersection Collision Avoidance. An application identifying possible collisions between vehicles, or between vehicles and other vulnerable users. **Entirely based on CAMs and DENMs dissemination.**



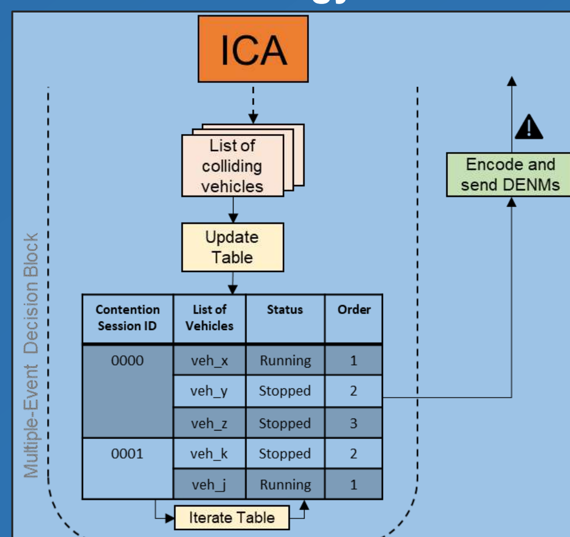
Simulation (2)

- Previous approach: determine whether a collision can be avoided or not by analysing the DENMs received at the end of the simulation
- Current approach: take actions upon reception of DENMs – development of Collision Avoidance Strategy (CAS)

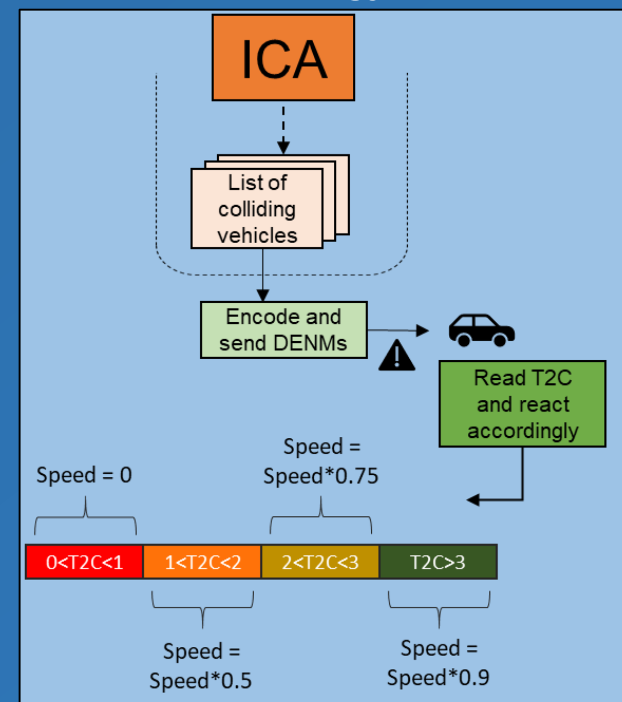
Strategy 1



Strategy 2



Strategy 3



Simulation (3)

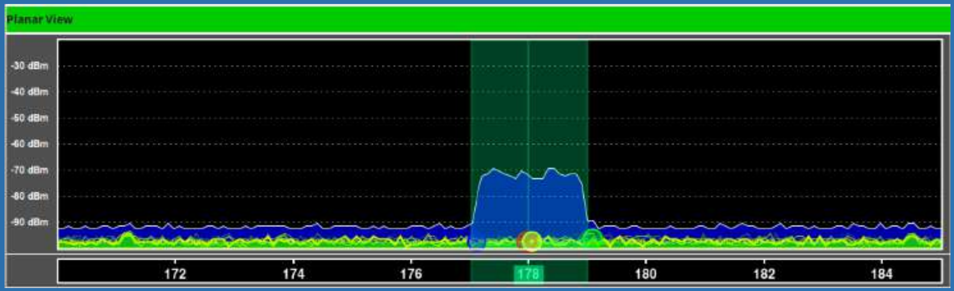
- Two simulation frameworks, to help other researchers to test and validate their vehicular applications
- ns-3 + SUMO
- Networking, mobility and CAMs + DENMs dissemination already enabled
- Users just have to insert the application's logic

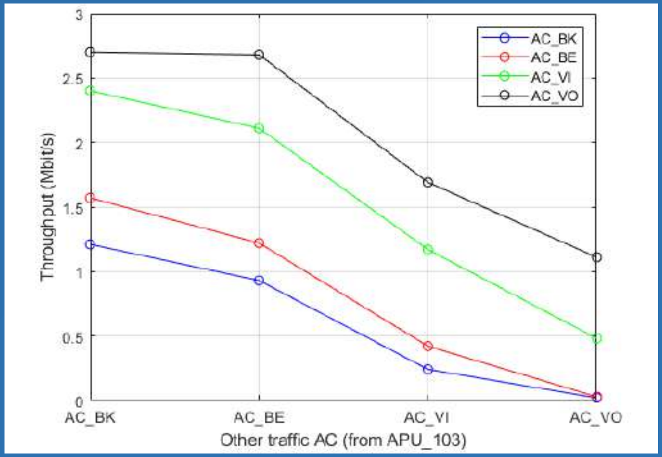
- **V2I**
  - 802.11p (RSU+OBUs)
  - LTE
- **V2V**
  - 802.11p (only OBUs)
  - C-V2X

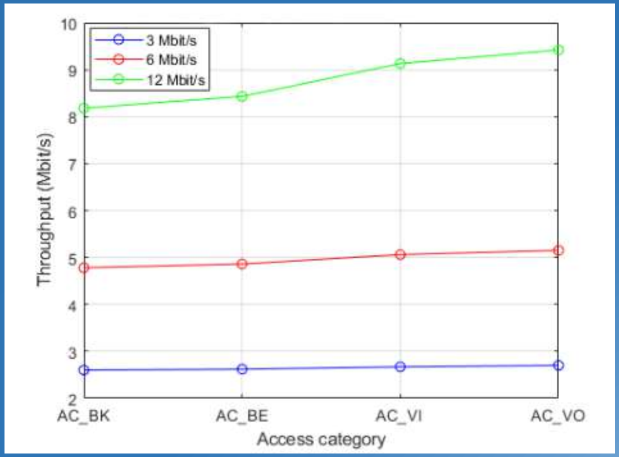
Available on GitHub

Implementation (1)

- Realization of a testbed for vehicular communication (802.11p)
  - Validation through spectrum analysis
  - Performance analysis







Implementation (2)

- Development of a **protocol** and an **application** to measure application layer latency in embedded wireless devices – LAMP + LaTe

LAMP

LAtency **M**easurement **P**rotocol

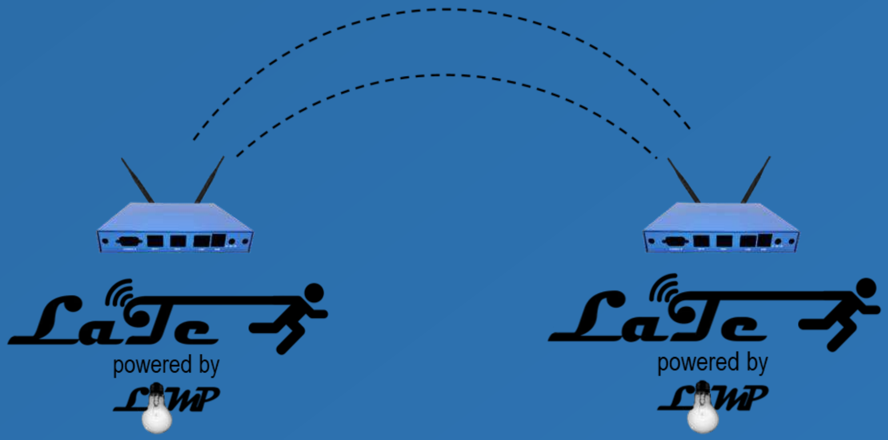
Byte	0	1	2	3	4	5	6	7
0	Reserved	Control Res. | Pkt Type	LaMP ID		Sequence Number		Payload length *or* INIT type	
8	Sec Timestamp							
16	uSec Timestamp							

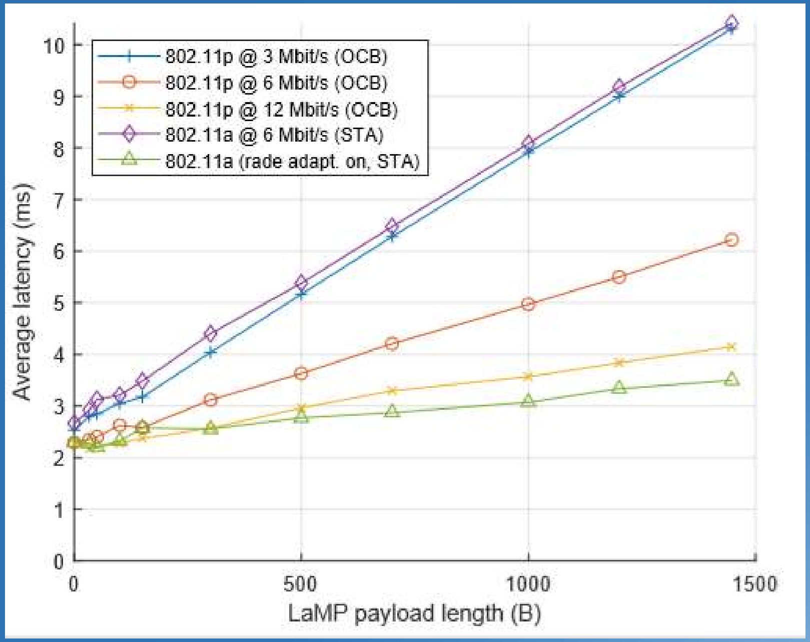
Available on GitHub

Implementation (3)

- Development of a **protocol** and an **application** to measure application layer latency in embedded wireless devices – LAMP + LaTe

Latency **Te**ster





Available on GitHub

Future Work

- Introduction of ML logics in the trajectory prediction of our Intersection Collision Avoidance service
- Development of new features for the V2I and V2V simulation frameworks, make the repository publicly available
- Collaboration with Squadra Corse for vehicle’s telemetry and box-to-driver communication
- Performance characterization of vehicular testbed under challenging conditions (mobility, urban attenuation, etc.)
- Development and testing of new applications leveraging vehicular communications

List of publications

- **Characterizing Docker Overhead in Mobile Edge Computing Scenarios**
  Avino G.; Malinverno M.; Malandrino F.; Casetti E.; Chiasserini C. F., in: ACM SIGCOMM 2017, 2017
- **From Megabits to CPU Ticks: Enriching a Demand Trace in the Age of MEC**
  Malandrino F.; Chiasserini C. F.; Avino G.; Malinverno M.; Kirkpatrick S., in: IEEE TRANSACTIONS ON BIG DATA, 2017
- **A Simulation-based Testbed for Vehicular Collision Detection**
  Avino G.; Malinverno M.; Malandrino F.; Casetti C.; Chiasserini C. F.; Nardini G.; Scarpina S., in: IEEE VNC 2017, 2017
- **Support of Safety Services through Vehicular Communications: The ICA Use Case**
  Malinverno M.; Avino G.; Casetti C.; Chiasserini C. F.; Malandrino F.; Rapelli M.; Zennaro G., in: AUTOMOTIVE 2018, 2018
- **Performance Analysis of C-V2I-based Automotive Collision Avoidance**
  Malinverno M.; Avino G.; Casetti C.; Chiasserini C. F.; Malandrino F.; Scarpina S., in: IEEE WoWMoM 2018, 2018
- **A Flexible, Protocol-agnostic Latency Measurement Platform**
  Raviglione F; Malinverno M., Casetti C., in: VTC2019-fall, 2019
- **Demo: Open source platform for IEEE 802.11p NICs evaluation**
  Raviglione F; Malinverno M., Casetti C., in: IEEE WoWMoM 2019, 2019
- **Characterization and Performance Evaluation of IEEE 802.11p NICs**
  Raviglione F.; Malinverno M.; Casetti C., in: TOP-Cars@ACM MobiHoc, 2019
- **Demo: Open source testbed for vehicular communication**
  Raviglione F; Malinverno M., Casetti C., in: ACM MobiHoc, 2019
- **Edge-based Collision Avoidance for Vehicles and Vulnerable Users**
  Malinverno M.; Avino G.; Malandrino F.; Casetti C.; Chiasserini C. F.; Scarpina S., in: IEEE VTM, 2020
- **A Framework for Enhanced Road Safety of Connected Cars at Intersections** ***(submitted)***
  Malinverno M.; Mangues J.; Chiasserini C.; Casetti C.; Requena M.; Baranda J. in: IEEE ACCESS, Special Issue 2020

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February 5, 2020

Thanks for your attention!

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Batteries Supply Chain Configurations for Electric and Hybrid Vehicles

reslog | Research Group for Engineering Systems and Logistics

Anna Corinna Cagliano
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Department of Management and Production Engineering

POLITECNICO DI TORINO

Torino (Italy)

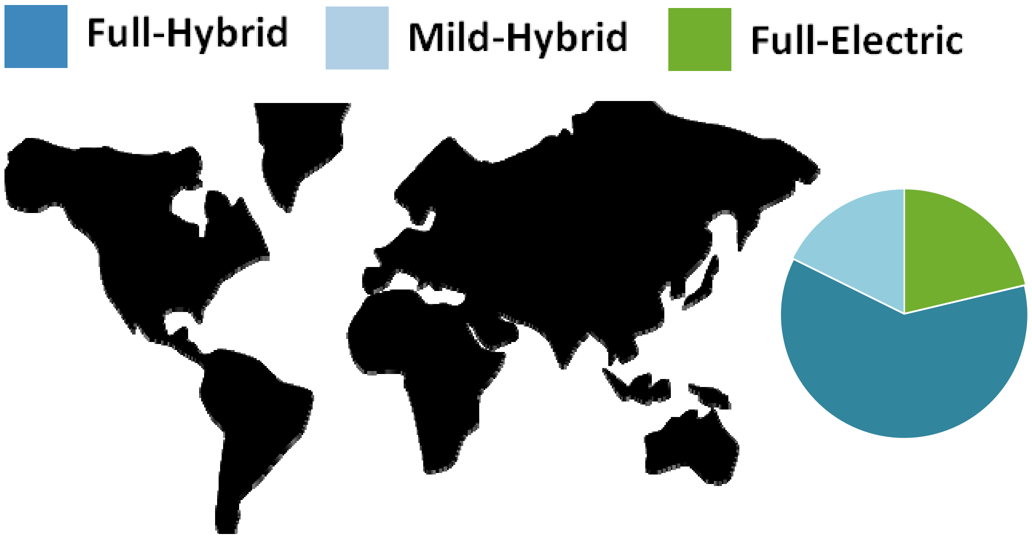
5th February 2020

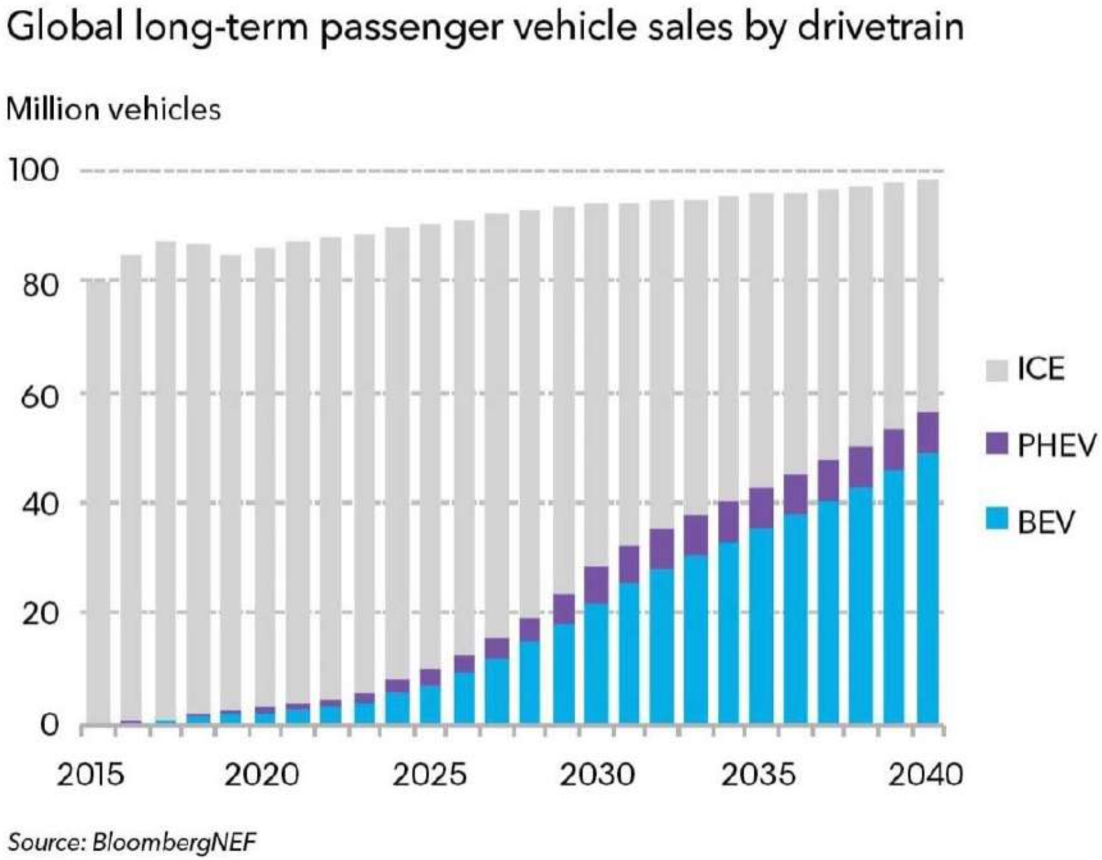
Agenda

- Introduction
- Research Motivation and Goals
- Literature Background
- Scenario Definition
- Discussion of Results
- Implications & Conclusions
- Future Research

Low Impact Vehicles Market

2017 Market





Still high vehicle costs!!

Low Impact Vehicles Market & Supply Chain

- Supply chain design and configuration key points to reduce low impact vehicle production costs and make them more competitive on the market (Chan, 2011).
- Supply Chain of critical components ⇒ Lithium-Ion Batteries (LIBs) (Heinicke and Wagenhaus, 2015; Gao et al., 2019).
- Battery pack high value component accounting up to 40% of the total costs (Giannetti et al., 2016).

LIBs Critical Factors

- Battery and Electric Engine Raw materials
  - High supply concentration

in developing or protectionist countries

(Dem. Rep. of Congo, China, Chile).

Battery components

What can be done?

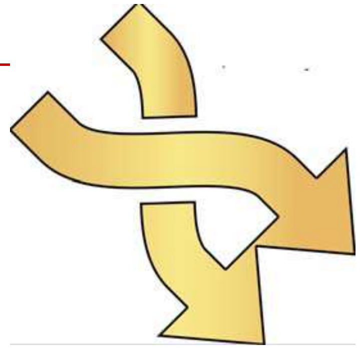
Value Chain dominated by Asian countries
and specialized companies

Transportation and Storage Conditions

Literature

- LIB supply chain:
  - Component procurement and logistics issues as well as associated risks (Helbig et al., 2018; Pelletier et al., 2017).
  - Battery end of life management (Hao et al., 2017;Tosarkani and Amin, 2018).
- Electric/hybrid vehicle production supply chain:
  - Adoption dynamics of electric/hybrid vehicles, associated benefits and marketing mechanisms (Cagliano et al., 2017; Hagman et al., 2016).
  - Electric/hybrid vehicles production strategies (Zhang and Zhang, 2015; Gu et al., 2017).

What’s Missing?



- Investigating the intersection between:
  - electric/hybrid vehicle production supply chain;
  - electric/hybrid vehicle propulsion battery supply chain.

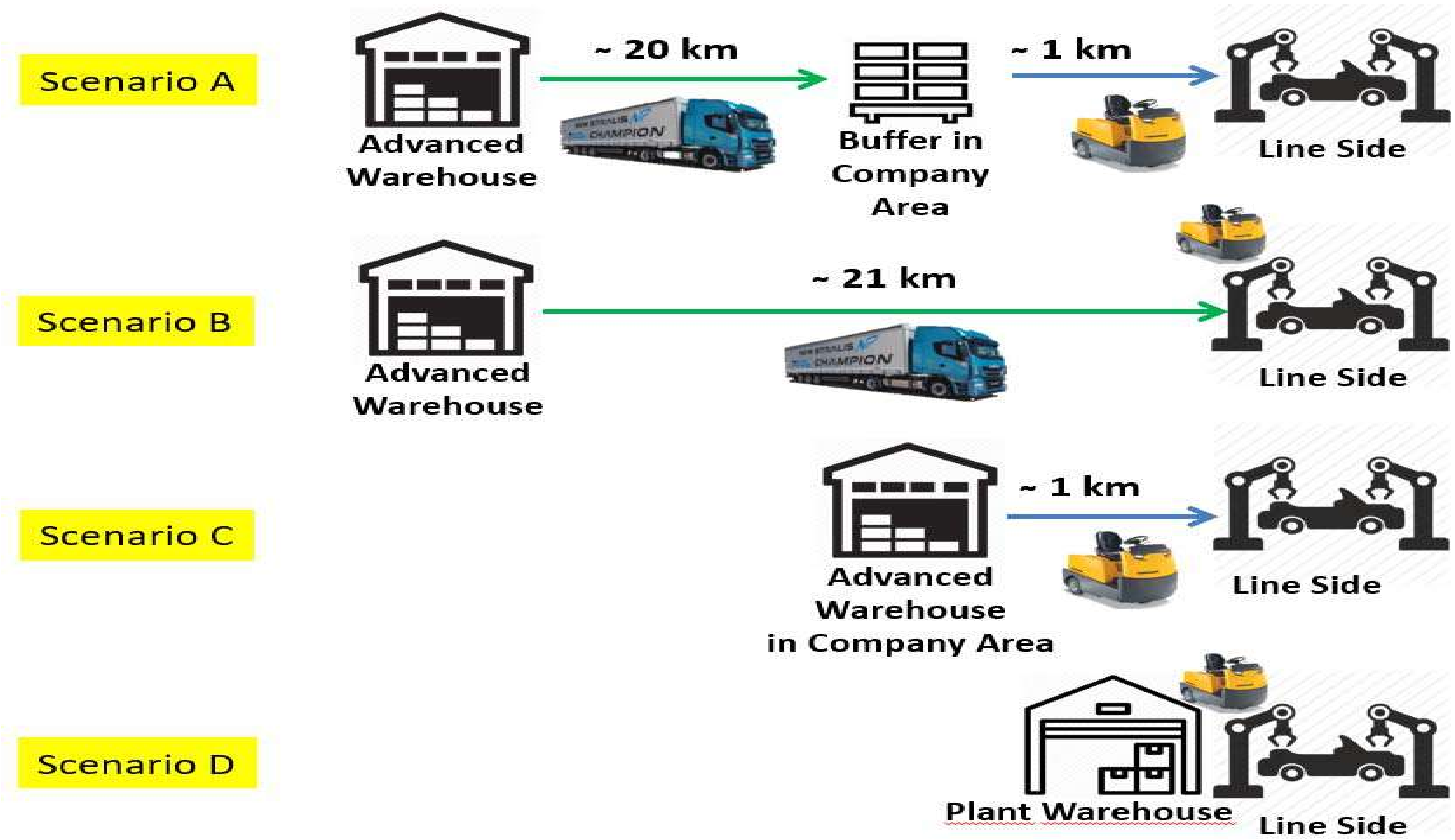
- *Designing the portion of the vehicle propulsion battery supply chain associated with the transportation and storage processes between LIB manufacturers and carmakers.*

Objective of the Research

- Providing a contribution for enhancing knowledge on logistics systems associated with low impact vehicle production.

- Supporting both researchers and practitioners in designing suitable logistics networks for battery procurement by vehicle manufacturers.

Scenario Definition

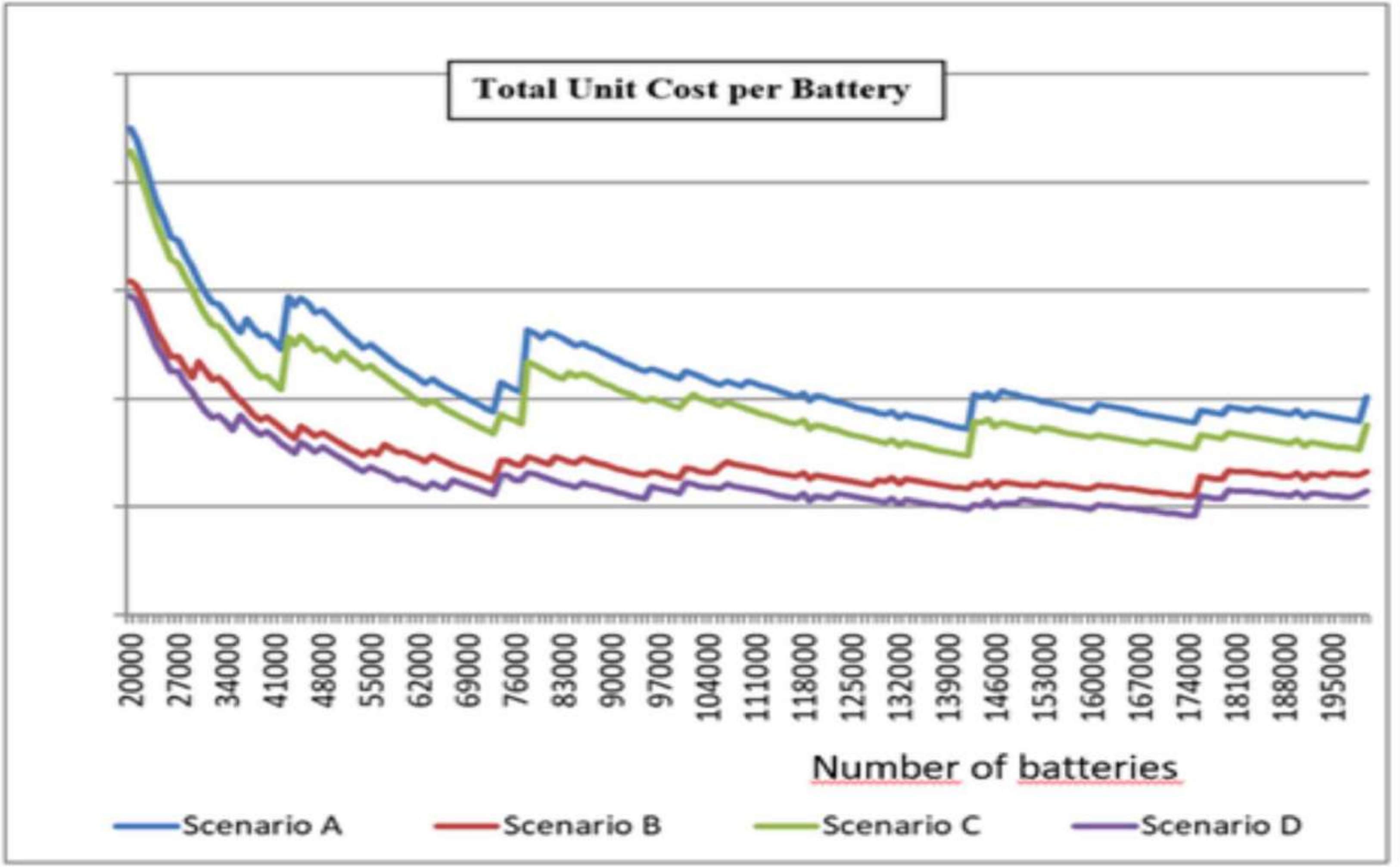


Rafele, C., Mangano, G., Cagliano, A.C. and Carlin, A. (2020), "Assessing batteries supply chain networks for low impact vehicles", International Journal of Energy Sector Management, Vol. 14 No. 1, pp. 148-171.

Findings

- **Material Handling cost**: computed by multiplying the number of towing tractors and forklift and their unit rental cost  
- **Labour cost**: amount of time required to perform all the operations times the hourly resource costs
- **Transportation cost**: - from the battery supplier to the Advanced Warehouse/ manufacturing plant or from the Advanced Warehouse to the plant computed according to the maximum capacity of a truck, equal to 56 batteries. 
- **Warehouse operations and renting costs** for the facility defined by an external service provider – the same for all the scenarios-.

Findings



Total Unit Cost per Battery
20000
27000
34000
41000
48000
55000
62000
69000
76000
83000
90000
97000
104000
111000
118000
125000
132000
139000
146000
153000
160000
167000
174000
181000
188000
195000
Number of batteries
Scenario A
Scenario B
Scenario C
Scenario D

Findings

- Scenario A shows the highest unit costs: the Advanced Warehouse 20 Km far away from the plant with increasing number of trips
- Scenario C is cheaper since trucks are headed from the Advanced Warehouse directly to the car manifacturer
- In Scenario B the Advanced Warehouse is next to the production line, thus lower number of towing tractor is required
- Scenario D is the cheapest one since there is a direct flow between the supplier and the production site

Implications and Conclusions

- This contribution might help the car maker to define and evaluate some different supply chain configurations for introducing low impact vehicles into their range of product or for enhancing their actual traction batteries supply chains.
- A method to calculate the unit cost for batteries is provided for companies that want to develop economical and financial analysis in order to implement studies on the subject.

Implications and Conclusions

- This work can encourage the research about supply chain for low impact vehicles and their components, that over the next years are going to become crucial in the future forms of mobility.
- The present research adds new elements to existing literature by affirming how an organized logistics network is likely to positively influence the manufacturing cost and drive the company strategy.

Future Research

- Defining scenarios with more low-impact vehicle models and more automated operations inside the warehouse.
- Analyzing advantages, disadvantages, and implications of alternative LIBs make or buy strategies by car manufacturers.

THANK YOU FOR YOUR ATTENTION!

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Cars@PoliTO

Integrated ICE-ATS management in HEVs

PhD Student: Federico Miretti
Academic Tutors: Daniela Misul, Ezio Spessa

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Center for Automotive Research and Sustainable mobility

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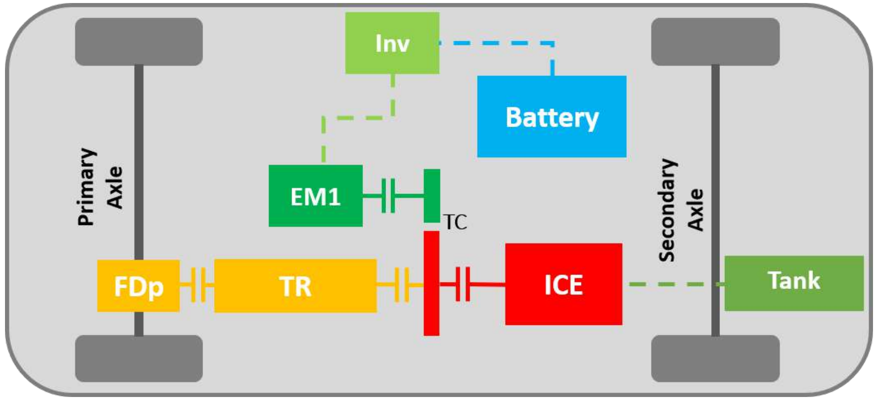
Objectives

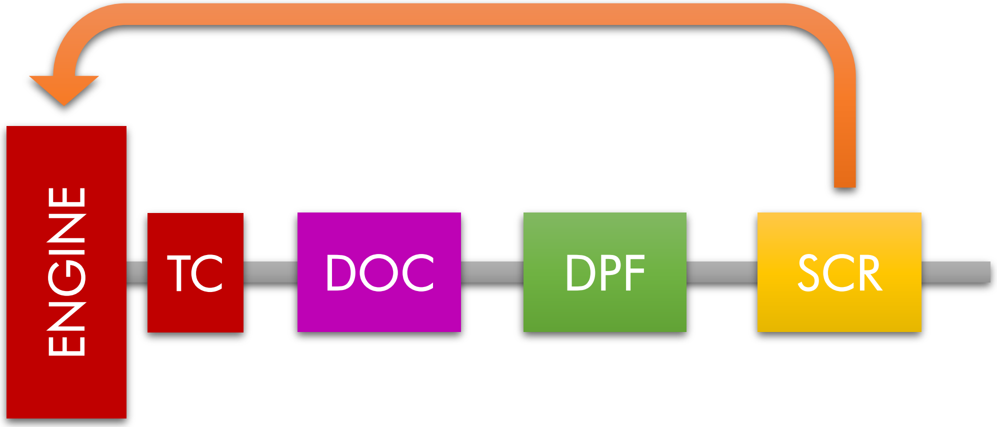
Control Strategy optimization

To develop a HEV (Hybrid Electric Vehicle) Control Strategy optimization tool **for Diesel-Electric Heavy Duty** applications, which includes the effects of the **After-Treatment System**.

HEV Optimal Design

To develop an **HEV optimal design tool** based on the optimal Control Strategy.





Background

Hybrid Electric Vehicles

Future emissions targets can only be met with the adoption of electrified powertrains.

Hybrid Electric Vehicles (HEVs) allow strong reductions in emissions while avoiding the shortcomings of Battery Electric Vehicles (BEVs) in terms of recharging time and driving range.

Diesel-Electric HEVs

For heavy duty applications, **Diesel-Electric** powertrains have the highest potential among HEVs for CO2 emissions reduction.

However, **pollutants** emissions from Diesel engines (particularly NOx) can only be met by the adoption of **an After-Treatment System** (ATS), even for HEVs.

Background

HEVs Control Strategy

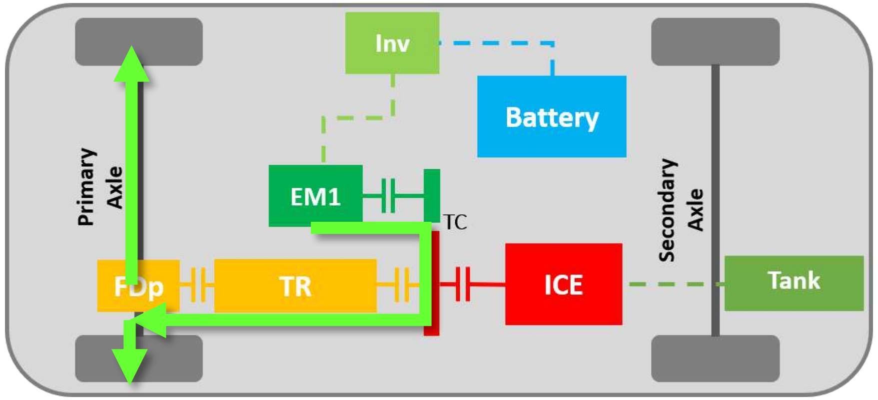
HEVs can satisfy the driver's power demand using several combinations of its power sources (the engine and the electrical machines).

A high-level powertrain controller, the **Energy Management System**, defines the **Control Strategy**: it selects the operating mode and (if needed) defines the powersplit.

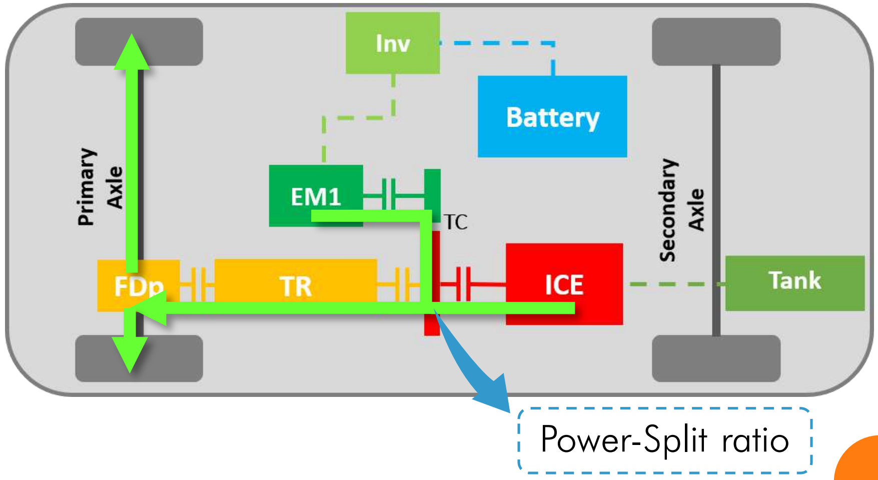
The EMS strongly influences GHG and pollutants emissions.

The EMS design is a challenging task and it is tailored to a specific vehicle design.

Pure Electric



Power-Split



Background

HEVs Optimal Design

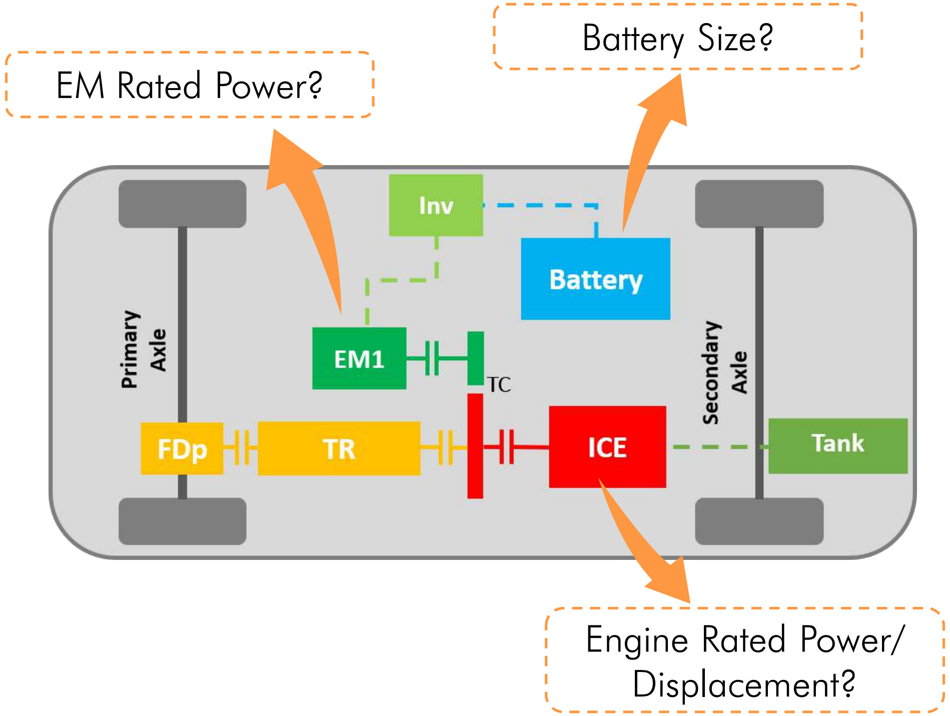
To **select the best hybrid architecture** and perform preliminary component sizing, a set of layouts is tested by **simulation over a regulatory driving cycle**.

To do so, we need do define a Control Strategy for each layout.

Control Strategy Optimization

In order to compare fairly the powertrain layouts under analysis without having to tailor a dedicated Control Strategy on each of them, they are evaluated based on their **optimal Control Strategy**.

The optimal (in terms of emissions) Control Strategy is evaluated for each layout using a **Dynamic Programming algorithm**.



Methods

The HEV Optimal Design Tool

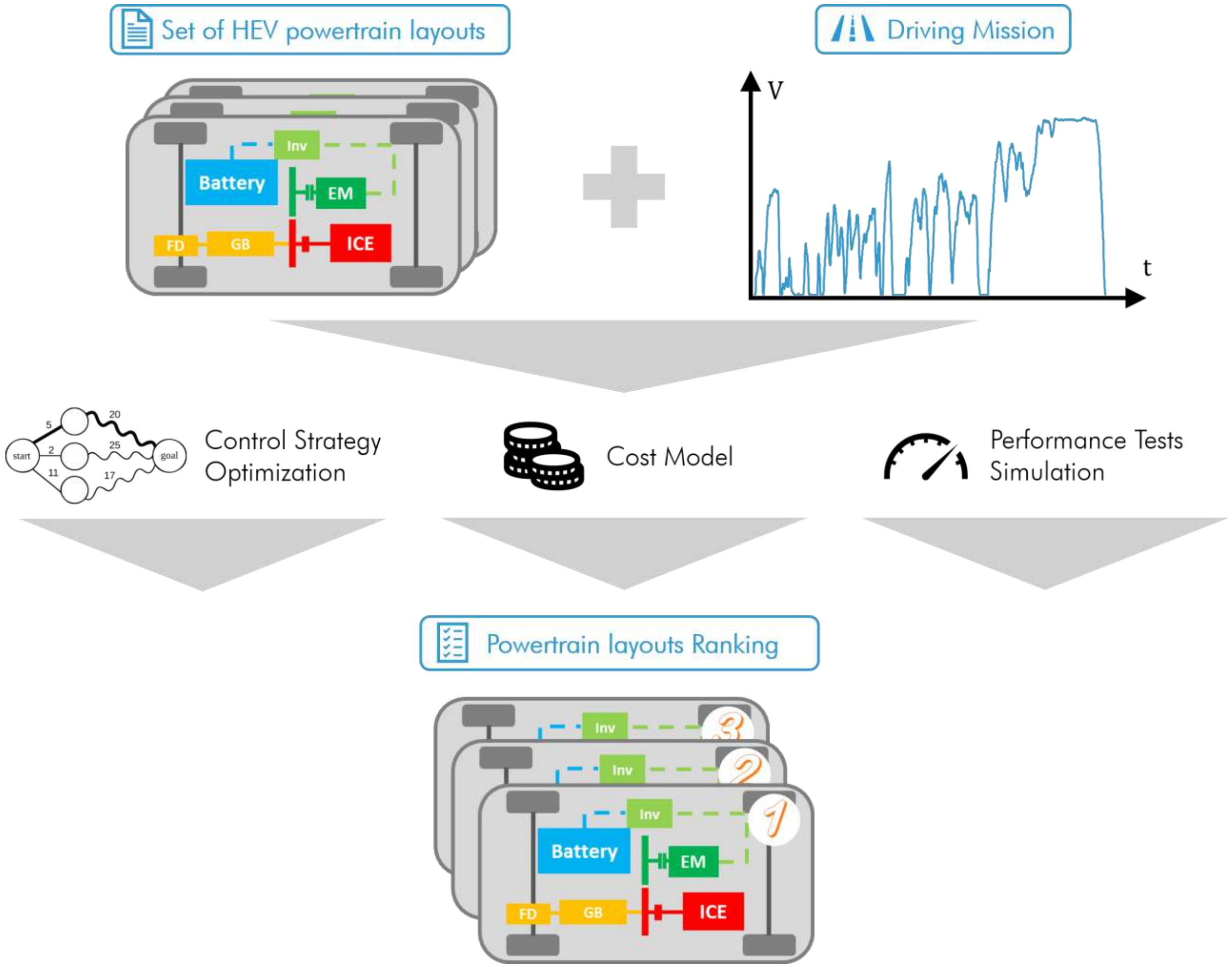
The HEV Optimal Design Tool rapidly compares a list of HEV powertrain layouts based on their emissions.

Inputs:

- A list of **layouts**, each defining the powertrain **components** by their **size** or some other defining parameter.
- A driving cycle.

Outputs:

- Emissions
- Cost



Methods

Dynamic Programming: set up

The optimal Control Strategy is evaluated using a Dynamic Programming algorithm.

The problem is divided in **N stages** (e.g. time intervals).

A **cost function** is defined which depends on the current state and control variable.

A **state update** model is defined, also depending on the current state and control variable.

Constraints are set on the **admissible state and control variables**.

$g_k(x_k, u_k)$	Instantaneous Cost
$x_{k+1} = f_k(x_k, u_k)$	State Update equation
$J(x_0, u_0, \dots, u_{N-1}) = g_N(x_N) + \sum_{k=0}^{N-1} g_k(x_k, u_k)$	Total Cost. $g_k(x_k, u_k)$ is the cost related to a single step.
$J^*(x_0) = \min_{\substack{u_k \in U_k(x_k) \\ k=0,\dots,N-1}} J(x_0, u_0, \dots, u_{N-1})$	Optimal cost
$J_k^*(x_k) = \min_{u_k \in U_k(x_k)} \{g_k(x_k^*, u_k) + J_{k+1}^*(f_k(x_k, u_k))\}$	Dynamic Programming Recursive Algorithm

Methods

Principle of Optimality

If $\{u_0^*, u_1^*, \ldots, u_{N-1}^*\}$ is the optimal control sequence, then $\{u_k^*, \ldots, u_{N-1}^*\}$ is optimal for the tail subproblem defined from stage k to the last.

Dynamic Programming Algorithm

First compute the optimal cost for the tail subproblem for the last stage.

Then use this solution to compute the optimal cost for the tail subproblem for the last two stages.

… and so on.

$$g_k(x_k, u_k)$$

Instantaneous Cost

$$x_{k+1} = f_k(x_k, u_k)$$

State Update equation

$$J(x_0, u_0, \ldots, u_{N-1}) = g_N(x_N) + \sum_{k=0}^{N-1} g_k(x_k, u_k)$$

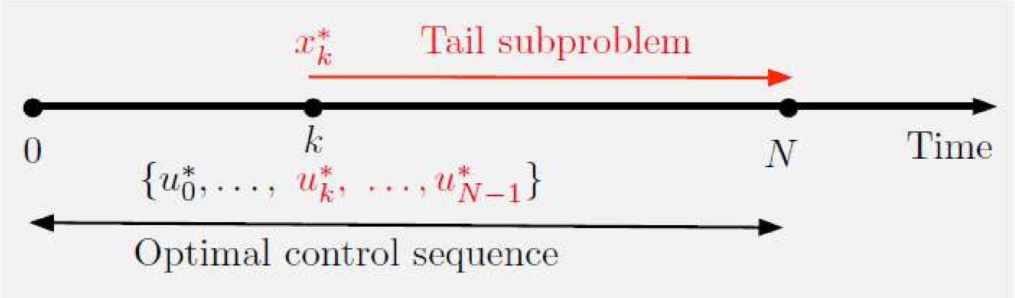
Total Cost. $g_k(x_k, u_k)$ is the cost related to a single step.

$$J^*(x_0) = \min_{\substack{u_k \in U_k(x_k) \\ k=0,\ldots,N-1}} J(x_0, u_0, \ldots, u_{N-1})$$

Optimal cost

$$J_k^*(x_k) = \min_{u_k \in U_k(x_k)} \{g_k(x_k^*, u_k) + J_{k+1}^*(f_k(x_k, u_k))\}$$

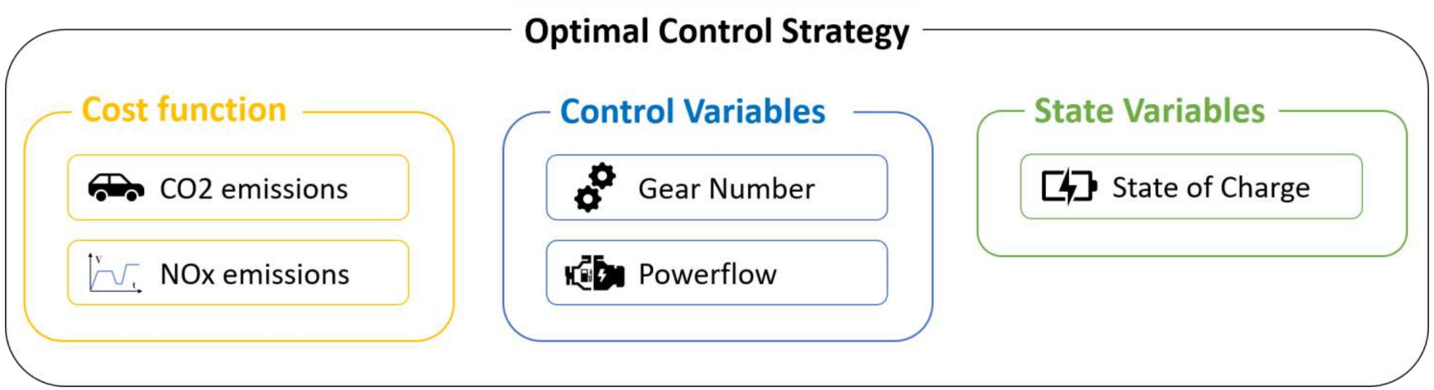
Dynamic Programming Recursive Algorithm



Principle of Optimality illustration [1]

[1] Bertsekas, Dimitri P. *Reinforcement learning and optimal control*. Athena Scientific, 2019.

Methods



Control Strategy Optimization

Cost function:

- CO_2 emissions
- CO_2 /NOx emissions trade-off

State variable:

- Battery State-of-Charge

Control variables:

- Powerflow
- Gear Number

Constraints

- SOC must stay in a certain range
- Final SOC must be equal to initial SOC
- Components speed/power are limited

Methods

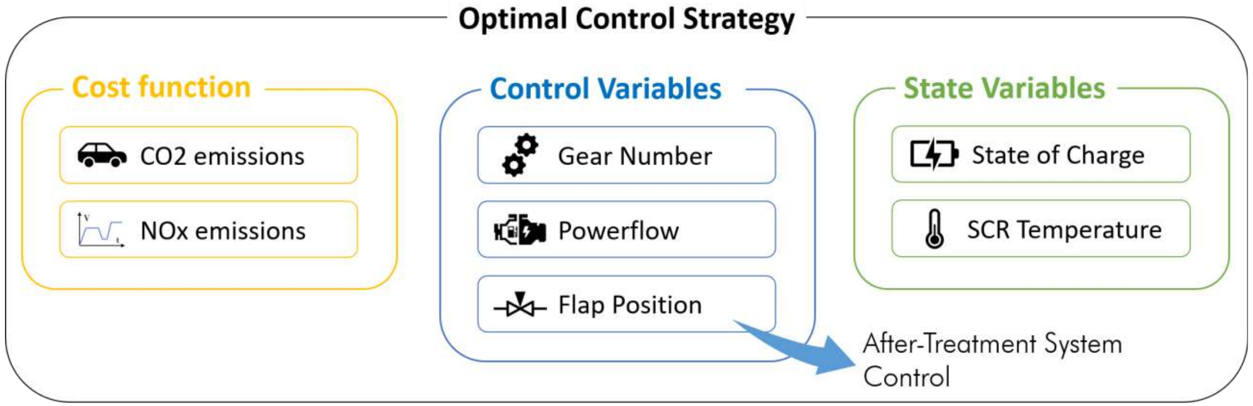
After-Treatment System Integration

The After-Treatment System must be integrated into the HEV Optimal Design Tool.

Selective Catalytic Reducer (SCR) must be kept at an operating temperature.

First, a physical model for the ATS must be developed:

- Good accuracy
- Low computational cost
- Low calibration effort.



The Control Strategy must take into account the SCR.

- Cost function: CO_2 emission
  Constraint: the SCR temperature stays in a certain temperature range.
- Cost function: CO_2-NOx emissions trade-off. NOx are dependent on the SCR temperature.

Conclusions

Preliminary results

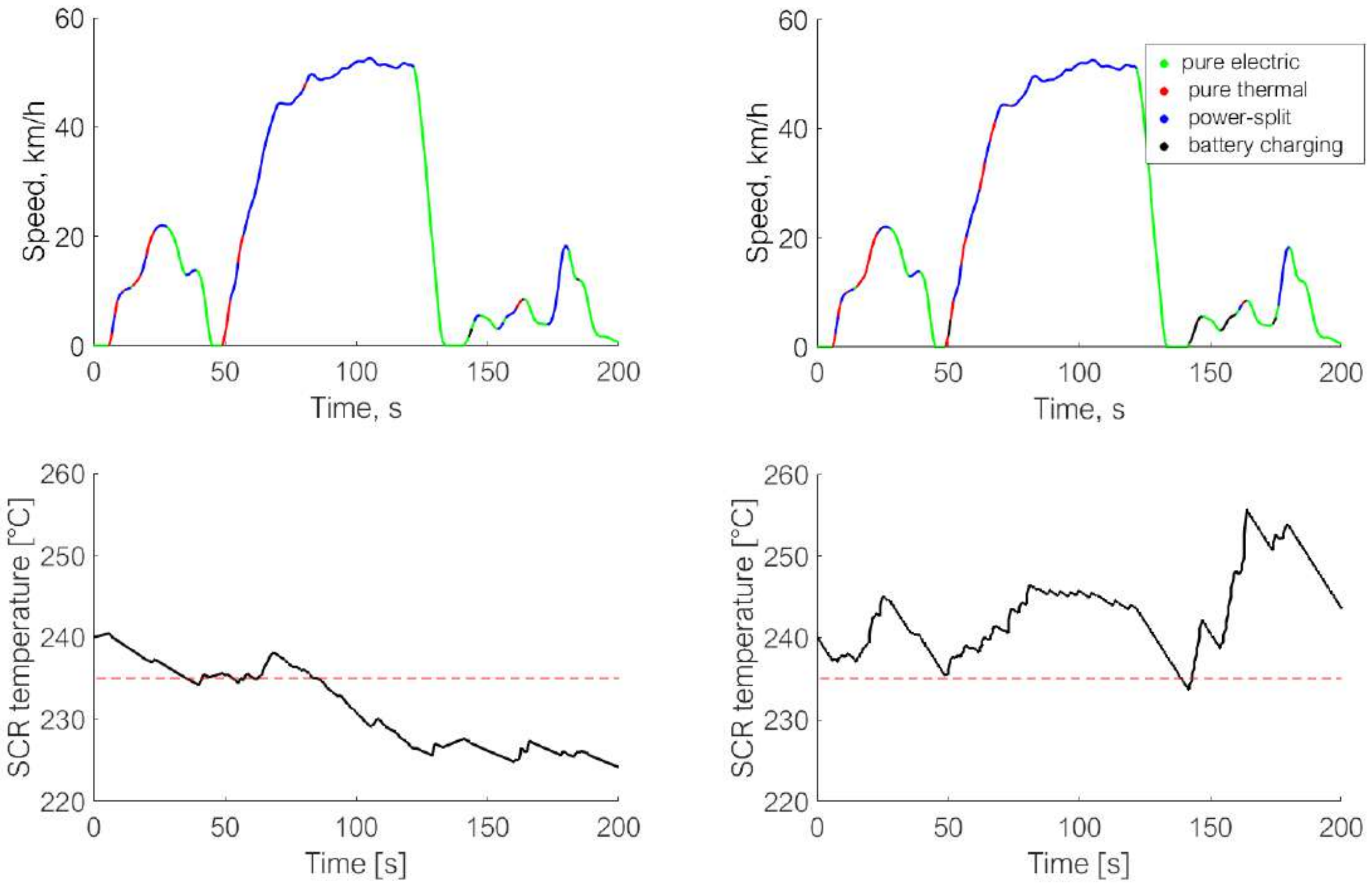
The optimal Control Strategy is strongly affected when a constraint on the SCR (Selective Catalytic Reducer) temperature is set.

In this figure, there is no additional control variable (no flap control); the vehicle handles the constraints by a different choice of the powerflow.

Future work

Introduce the flap control and quantify its benefits.

Investigate CO_2 /NOx emissions trade-off.



(a) No constraint on SCR temperature

(b) Constrained SCR temperature

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February 05, 2020 – Presentation

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Project Manager UMLS and Supervisor
Prof. Guido Perboli

Background

- Master Degree in Engineering and Management at Politecnico di Torino
- Ph.D. in Computer and Control Engineering at Politecnico di Torino
  - Research Topic: Business models and operations management in last mile and e-grocery for Smart Cities applications
  - Ph.D. Visiting at the Centre interuniversitaire de recherche sur les réseaux d'entreprise, la logistique et le transport (CIRRELT), Montréal (Canada)
- Member of the workgroup on business models for mobility of the Urban Mobility and Logistics Systems (UMLS)
- Post-Doc researcher at DAUIN

Main research topic

- **Development and implementation of a multi-disciplinary approach to deal with the urban freight transportation and last-mile logistics:**

  - **Integration of traditional business models with new business models related to vehicles with low-environmental impact and new delivery options (e.g., cargo bike and locker);**

  - **Support to the decision-making processes, incorporating uncertainty**
    - **capacity planning problem**

Emerging challenges in urban freight transportation

- **Paradigm shifts**
  - **From an intra-business (material) logistics to a Demand-Driven Logistics**
- **Multi-actor complex system**
  - **Shippers, carriers, administrations, customers**
  - **Different goals and objectives**
- **Common and scares resources**
  - **Freight vehicles share and compete with people mobility for the use of infrastructure and resources**
- **Large scale problems**
  - **About 4000 delivery/day in a medium-sized city (*Rosano et al., 2019*)**
  - **Atomization of parcel flows (*Morganti, 2014*)**
- **Sustainability**
- **Planning issues**

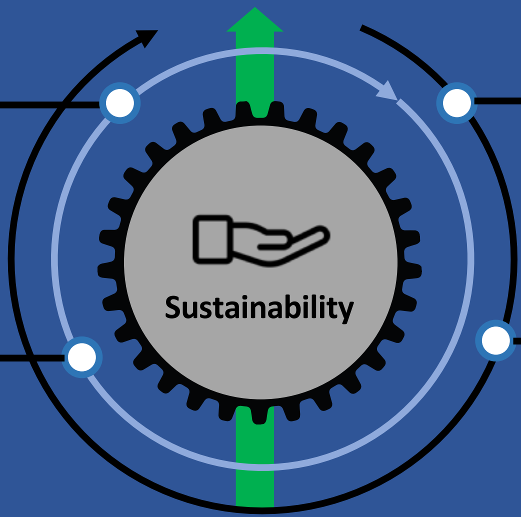
Sustainability

PEOPLE

- Public health and safety
- Accessibility
- Livability

ENVIRONMENT

- Environmental protection
- Social costs



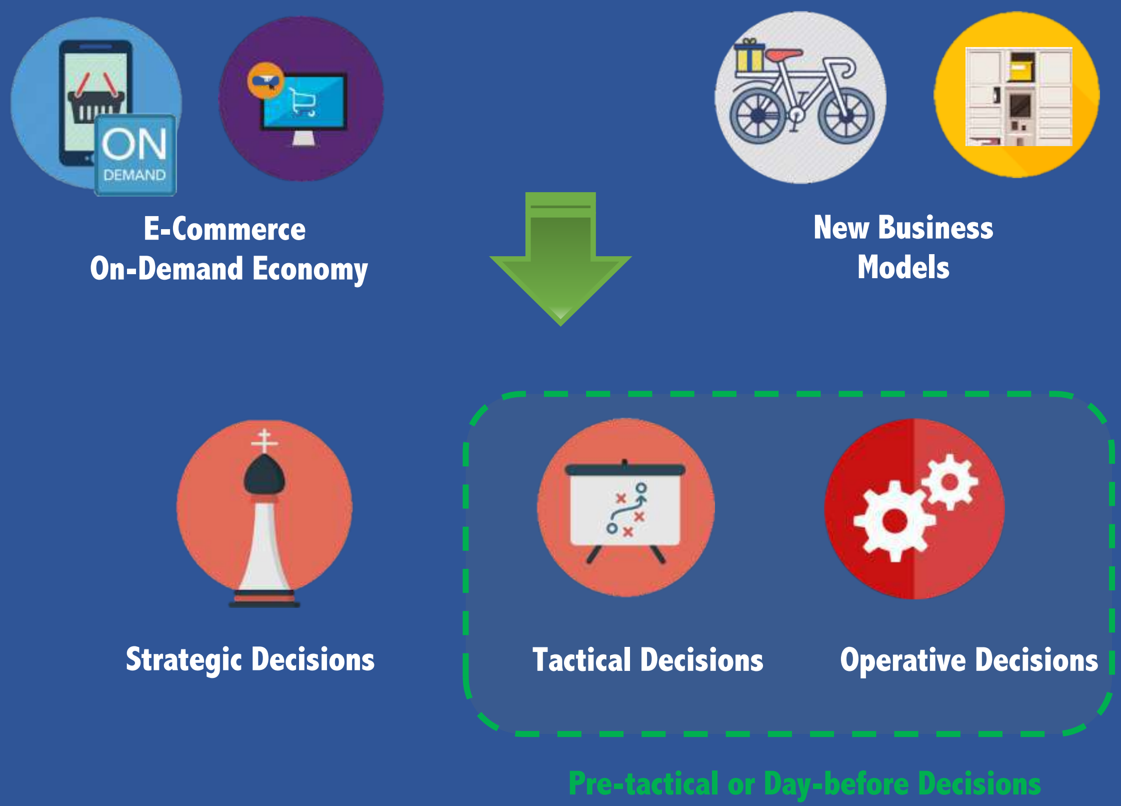
ECONOMY

- Profits
- Cost-efficiency and effectiveness

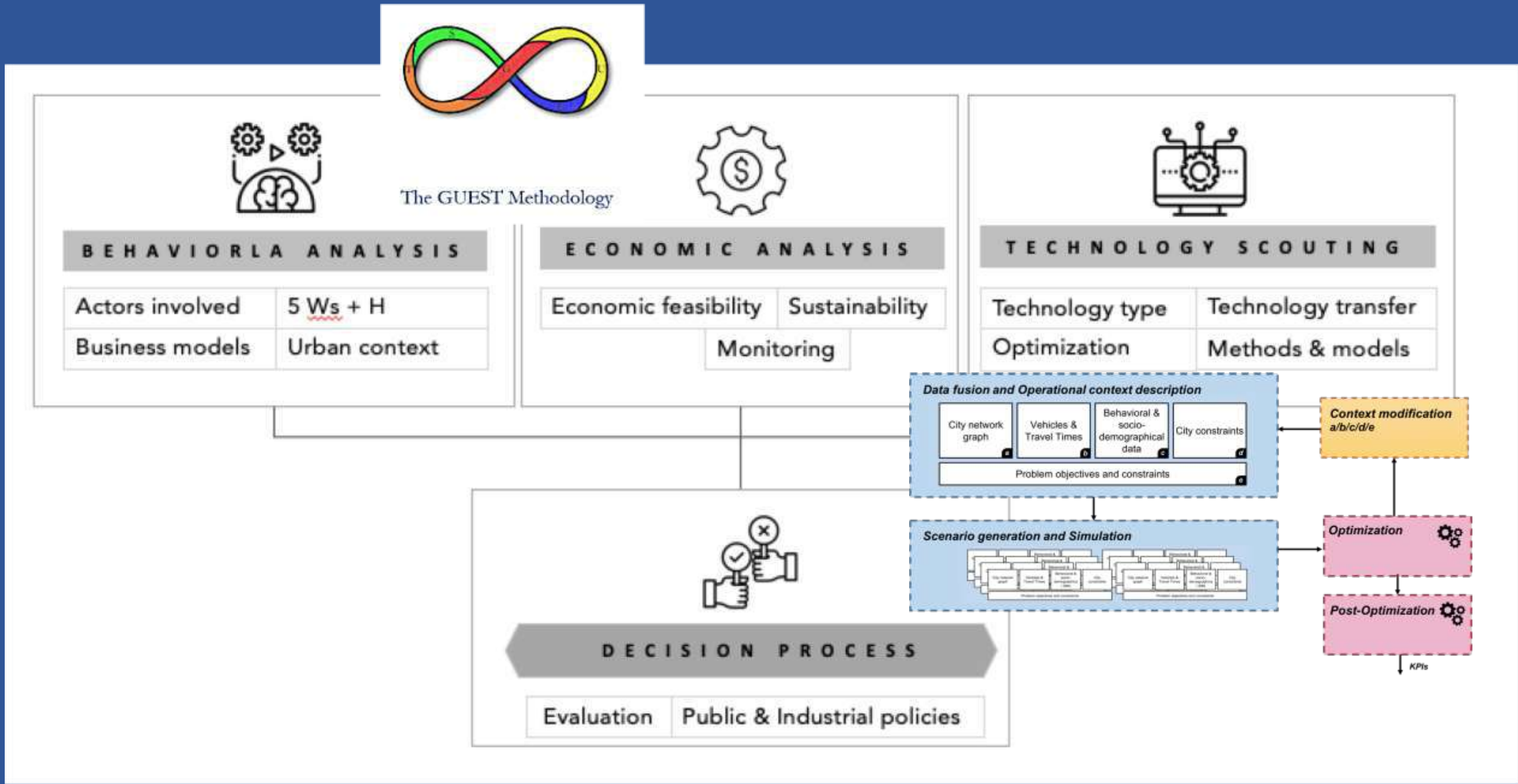
CITY

- Sustainable development
- Attractiveness
- Lean government

Planning issues



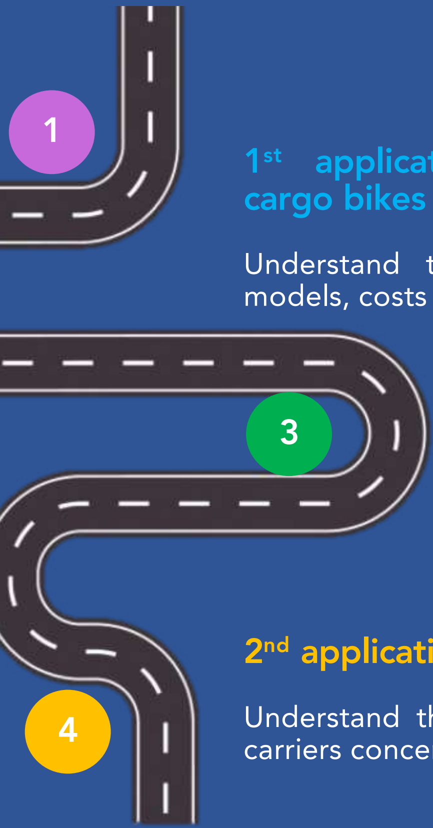
A new multi-disciplinary approach



Roadmap

Intermodal Transportation

Understand how intermodal systems can be repurposed at a logical level on the urban freight transportation



1st application: Mixing traditional vans, cargo bikes and lockers. Business models

Understand the actors involved, their business models, costs and revenues structures

1st application: Mixing traditional vans, cargo bices and lockers. Simulation-optimization

Apply simulation-optimization to extract mixed-fleet policies

2nd application: Tactical capacity planning

Understand the relationship between shipper and carriers concerning multiple type of capacity

Mixing traditional and green business models

- **Introduction of new delivery options and green vehicles (e.g., cargo bikes, electric vehicles, lockers)**

Mitigate effects of reducing marginal revenues

Reduce environmental issues

Is this integration easy and always positive?

Increase efficiency of delivery activities

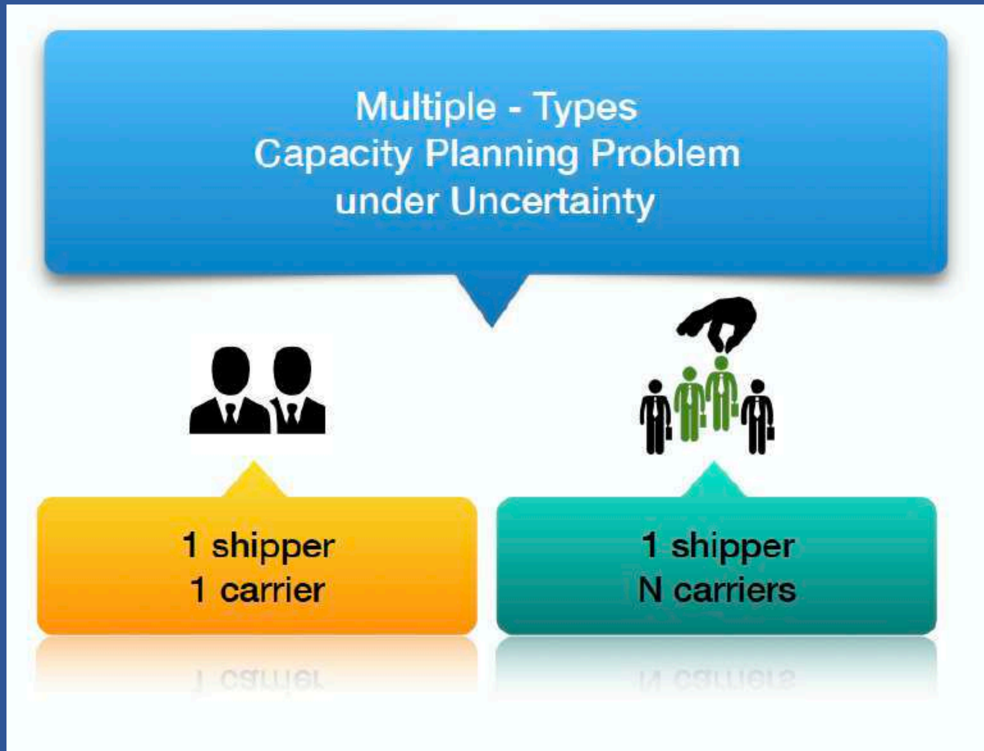
Mixing traditional and green business models

- **Significant reduction of negative externalities thanks to the introduction of green vehicles and new delivery options**
- **However, stakeholders have to consider not only the environmental impact**
  - **Risk of cannibalization between traditional and green business models**
  - **Loss of efficiency for the traditional models**
    - **- 80% in the case cargo bike + van**
    - **- 38% in the case locker + van**
- **Although green vehicles and new delivery options are beneficial for the environment, their adoption must be carefully assessed and supported by a <u>continuous process of planning</u>**

Tactical capacity planning

- **The outsourcing of logistics activities in the last mile segment makes needed a complex planning activity**
- **Enterprises answer to the growing requests for fast and cheap deliveries of goods**
- **Need of securing/contract sufficient distribution capacity in the next period of activity**
- **Uncertain environment**
  - **Demand fluctuation**
  - **Additional (future) capacity, when needed**
  - **Availability of contracted capacity**

Tactical capacity planning



Tactical capacity planning

- **Stochastic Variable Cost and Size Bin Packing Problem with Capacity Loss SVCSBPPL**
- **Two-stage stochastic programming formulation with recourse**
  - **First stage: tactical decisions**
    - **selection a priori of the capacity to be made available**
  - **Second stage: operational decisions**
    - **recourse actions (acquisition of additional capacity on the spot market, rearranging the loads or the storage of goods)**
- **Solution strategy**
  - **Progressive Hedging heuristic (Rockafellar and Wets, 1991; Crainic et al., 2016)**

Research objectives

- Is considering the loss of capacity (actual volume of bins as stochastic) relevant in our contexts?
- What is the impact of uncertainty? Is it useful to build a stochastic programming model?
- Which is the relationship between the problem characteristics and the structure of the capacity plan?
- Carrier selection problem

CARS @ Festival della Tecnologia

Conclusions and Future research

- **Need to find factual solutions to the urban freight transportation issues**
- **Rethink and Optimize the urban freight transportation through tools for the policy assessment**
    - **Not only technology and models**
    - **Qualitative tools for a global vision of the system**
  - **Simulate in silica the whole system and then decide**
- **How the dynamics change after introducing other green vehicles or unprofessional users ”Uberization of the last-mile”?**

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February 05, 2020 –PhD Presentation

PhD Student:
Stanislav Fedorov

Supervisor:
Guido Perboli

Urban Logistics and Last Mile applications: models and methods to deal with uncertainty

Outline

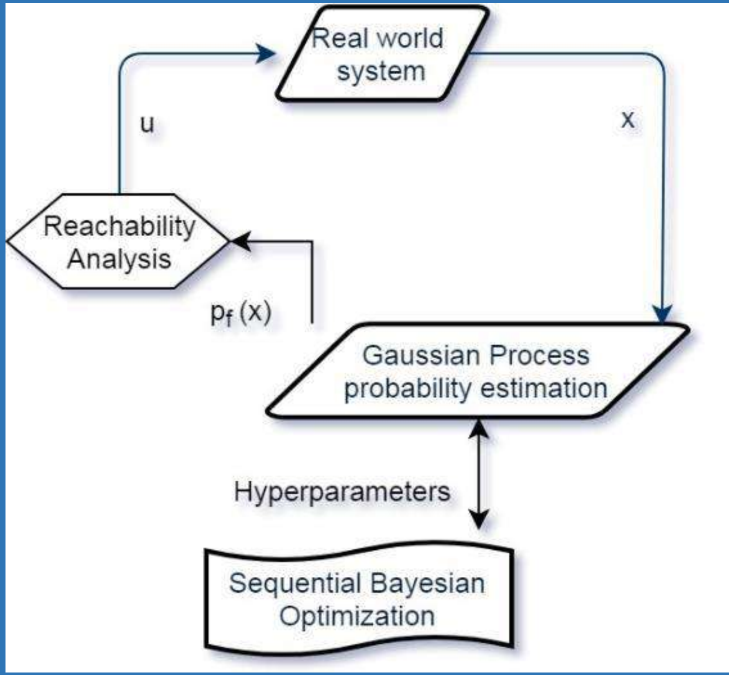
- My background
- Why this topic is important?
- PhD objectives

My background

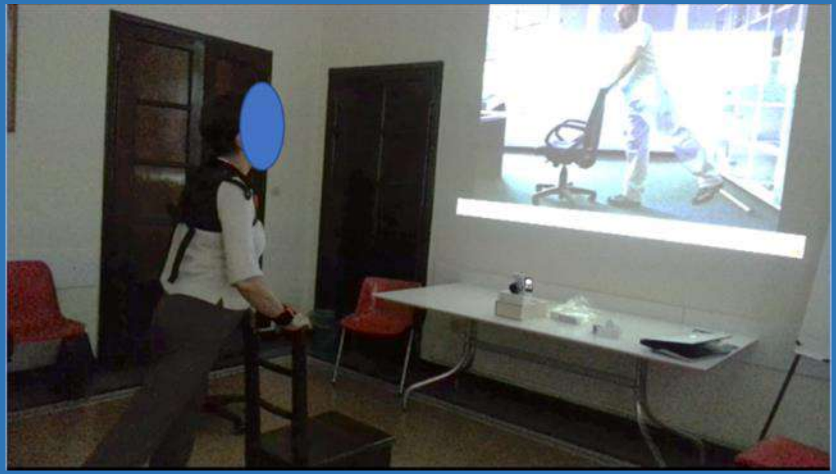
As a student:

- Erasmus Mundus Joint MSc "MathMods" Mathematical Modelling
- Reachability Based Safe Learning for Optimal Control Problem, MSc Thesis.

  - Reachability analysis
  - Constrained reaction time
  - Gaussian Processes model
  - “Reinforcement Learning” framework

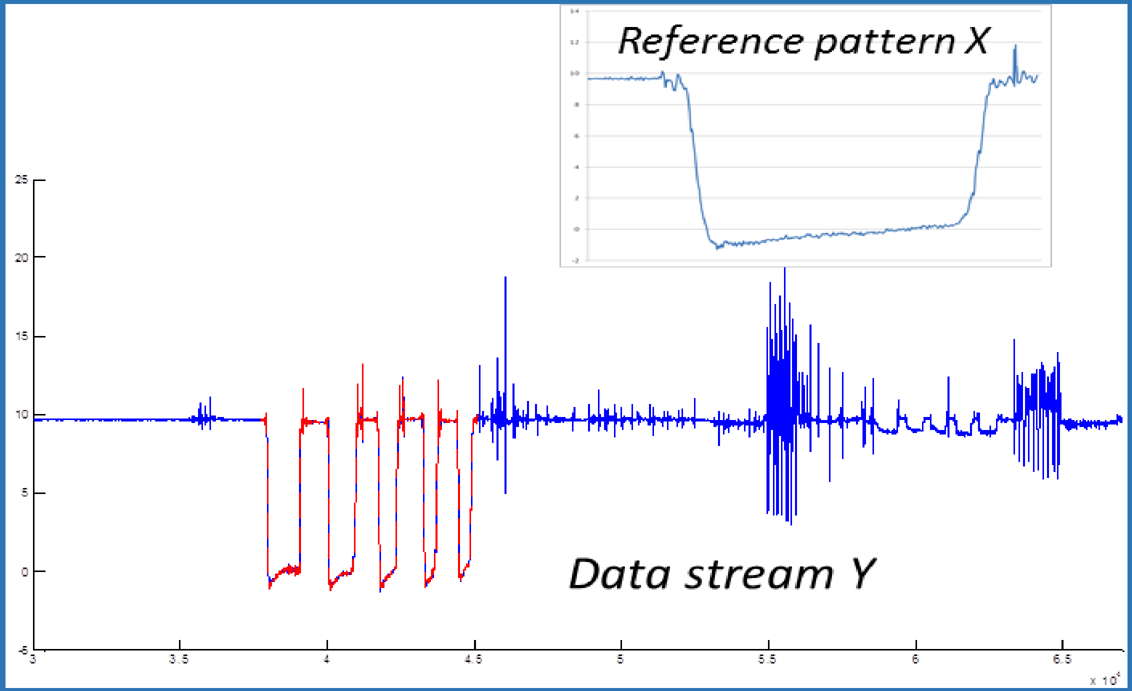


My background

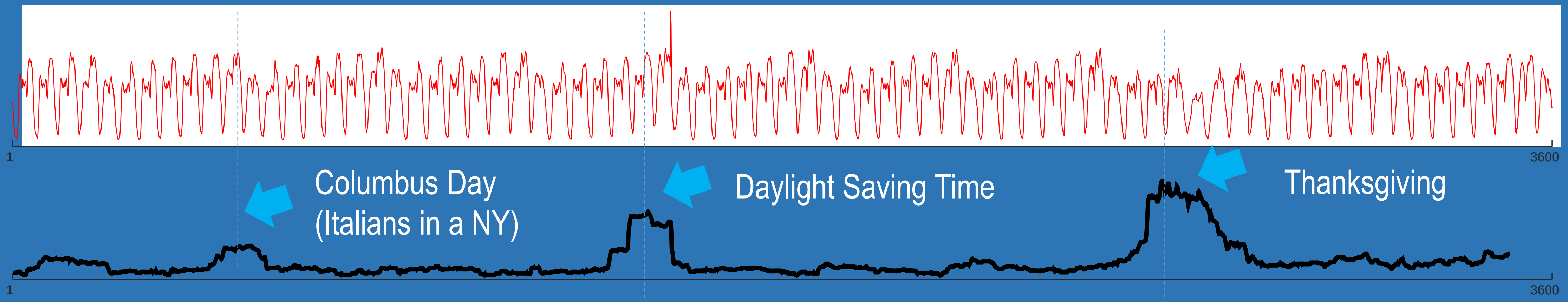


As a researcher:
- Fellowship in Milano, Bicocca
- Efficient Kernel-based Subsequence Search for User Identification from Walking Activity
  Candelieri A., Fedorov S., Messina V. (2019)

- Dynamic Time Wrapping measure
- Construct the Kernel
- Bayesian Optimization for subsequence identification



Why this topic is important?



The datasets is Taxi demand, in New York City, in three months of the year (From Eamonn Keogh, 100 Questions in Data Mining)

Interesting question:

How we can use this kind of data for the Urban Logistics Optimization?

- Preprocessing the data for identify the habitant patterns
- Quickly adaptable model (react to changes constantly)
- Incorporate the obtained knowledge into the logistics model to bias it towards realistic solutions

PhD objectives

Subject: Bilevel stochastic optimization problems for Urban Mobility and City Logistics

- Tariff policies / service levels costs
- Reaction of the users/customers

In details:

- Preprocessing the data for identify the habitant patterns
  - Kernels, Sophisticated Measures, Computer Science
- Quickly adaptable model (react to changes constantly)
  - Recent advances in probabilistic learning frameworks, diversity in distribution functions, Applied Math
- Incorporate the obtained knowledge into the logistics model
  - Bilevel programing, Hybrid model, open field
- Apply for the promising problems:
  - Last Mile Delivery, EV Charging Networks, Power Grids
- Collaboration with CIRRELT, Montreal and INRIA, Lille

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PhD Student: HEGDE Shailesh

Supervisor: Prof. AMATI Nicola

February 05, 2020 –PhD Presentation

PhD Program in Mechanical Engineering – XXXV Cycle

Funded by PoliTo and Mechatronics Laboratory within Dayco Project

Outline

- Control strategies for Mild Hybrid powertrain (*in cooperation with Dayco Europe S.r.l*).

To develop realtime realizable control strategies for Mild Hybrid powertrain [P0, P2, P2-P0] , Rapid control prototyping and Hardware in the Loop testing.

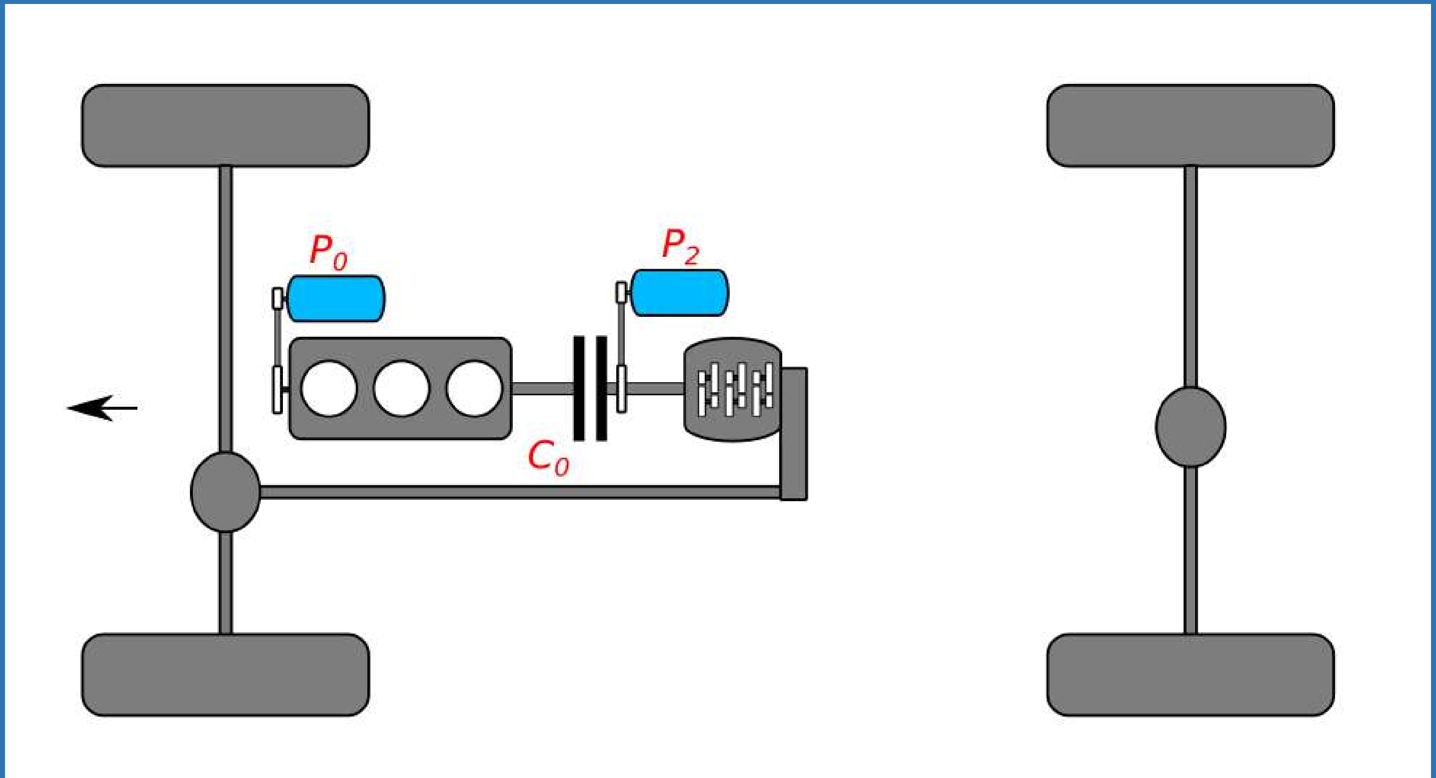
- Controller development for Torque vectoring and stability improvement (*Hiperform H2020 Project*).

Design of control strategies for in-wheel motors in pure Electric Vehicles (Torque vectoring and stability improvement in addition to energy savings).

- Design of Control Algorithms in automated vehicles exploiting V2x communication - SAVE Project (funded by FCA).

Control strategies for Mild Hybrid powertrain: Dayco project

Objective :
To develope various control strategies for P0, P2, P2-P0 configurations of Mild hybrid powertrain. The controller deployment in real time ECU and software refinement.



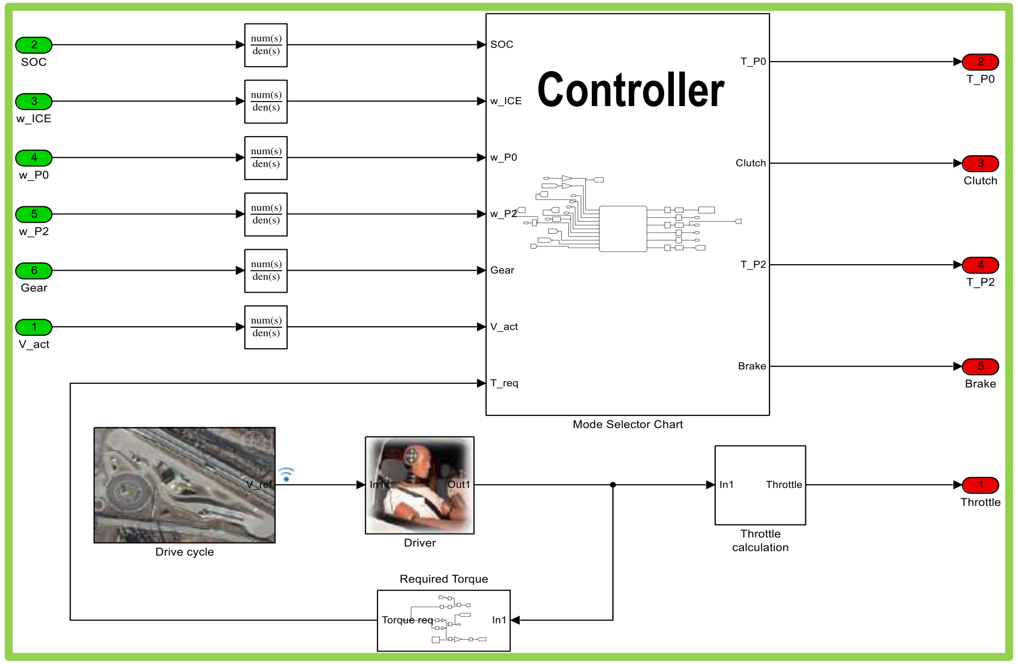
Controller types:

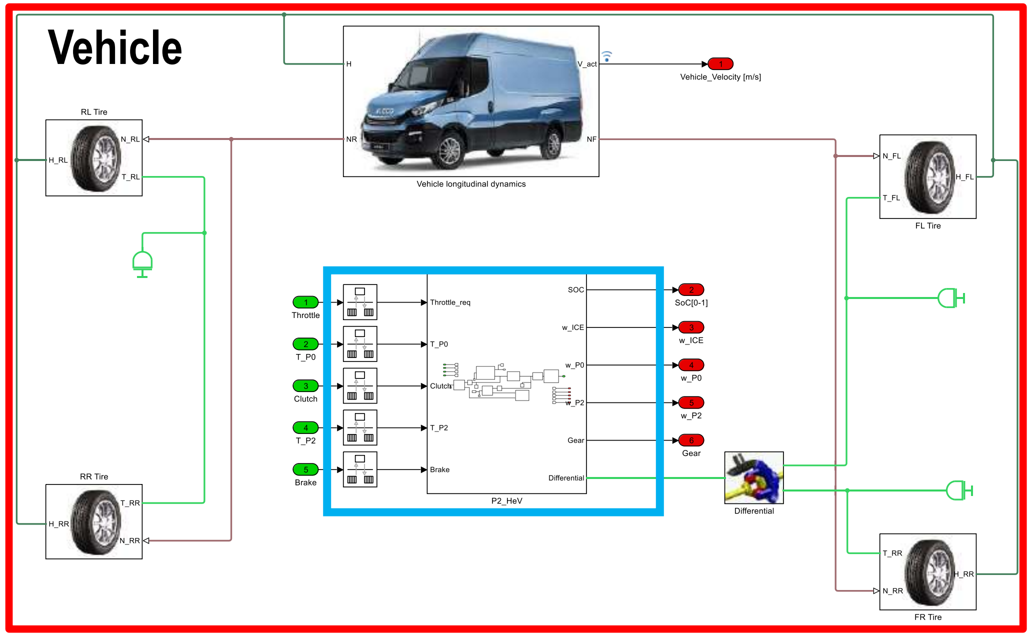
- Charge depleting strategy (CDS)
  - Design and simulation > RCP > HIL testing
- Equivalent consumption minimization strategy
  - Design and simulation > RCP > HIL testing
- Model Predictive Controller (Implicit)
  - Design and simulation > RCP
- Dynamic Programming
  - Design and simulation

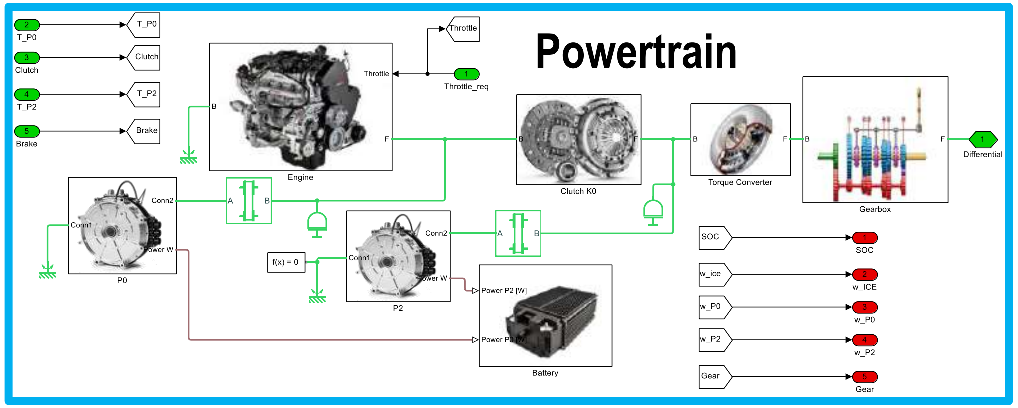
✓ Complete
✓ In progress
✓ Future work

Models

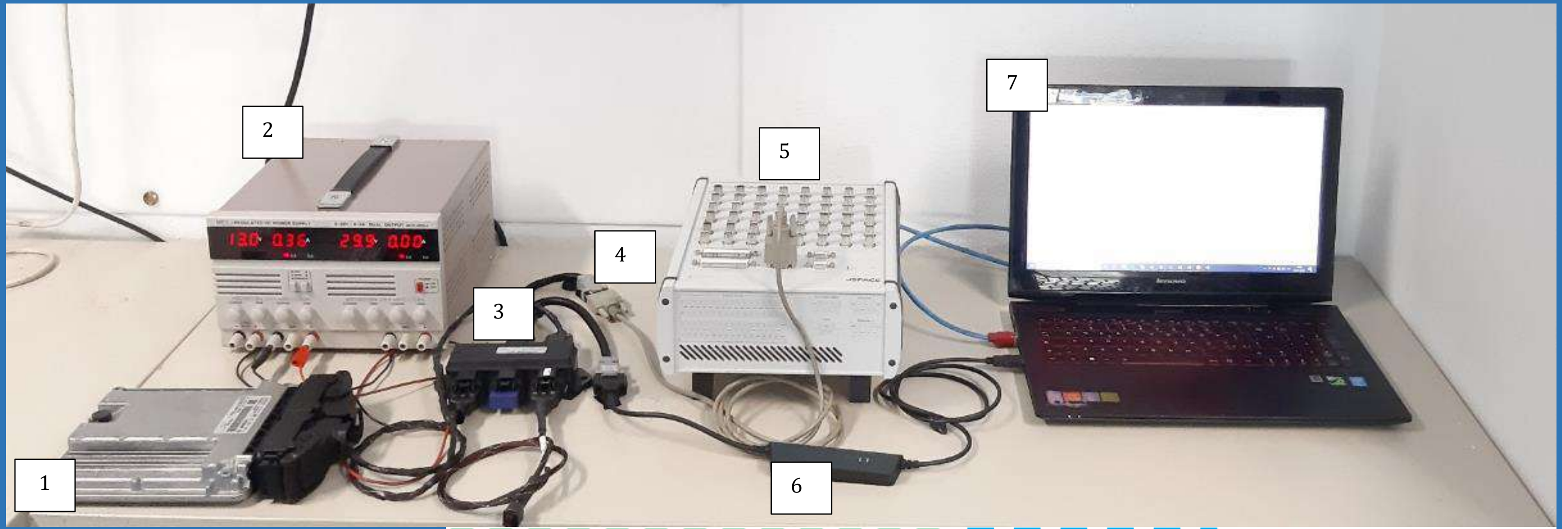

HIL_controller
V_act
SOC
w_ICE
w_P0
w_P2
Gear
Throttle
T_P0
Clutch
T_P2
Brake
HIL_plant
Vehicle_Velocity [m/s]
SoC[0-1]
w_ICE
w_P0
w_P2
Gear


Controller
SOC
w_ICE
w_P0
w_P2
Gear
V_act
T_req
T_P0
Clutch
T_P2
Brake
Mode Selector Chart
Drive cycle
Driver
Throttle calculation
Required Torque
Torque req
Throttle


Vehicle
Vehicle longitudinal dynamics
Vehicle_Velocity [m/s]
RL Tire
RR Tire
FL Tire
FR Tire
P2_HeV
Throttle
T_P0
Clutch
T_P2
Brake
SoC[0-1]
w_ICE
w_P0
w_P2
Gear
Differential


Powertrain
T_P0
Clutch
T_P2
Brake
Throttle
Throttle_req
Engine
Clutch K0
Torque Converter
Gearbox
Differential
P0
P2
Battery
SOC
w_ICE
w_P0
w_P2
Gear

Rapid Control Prototyping (RCP)



Hardware:

- Raptor GCM196 (Controller)
- dSpace MicroLabBox (vehicle Emulator)

Software:

Controller:

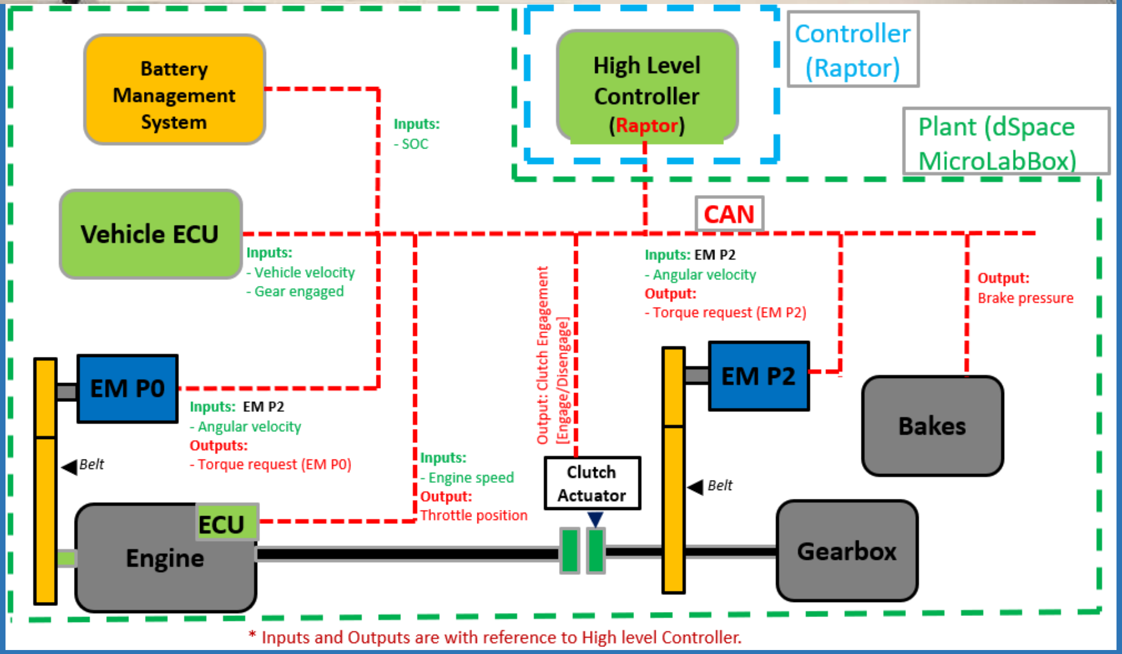
Controller code generation: Matlab/Simulink

Code deployment and Calibration: Raptor Cal

Vehicle Emulator:

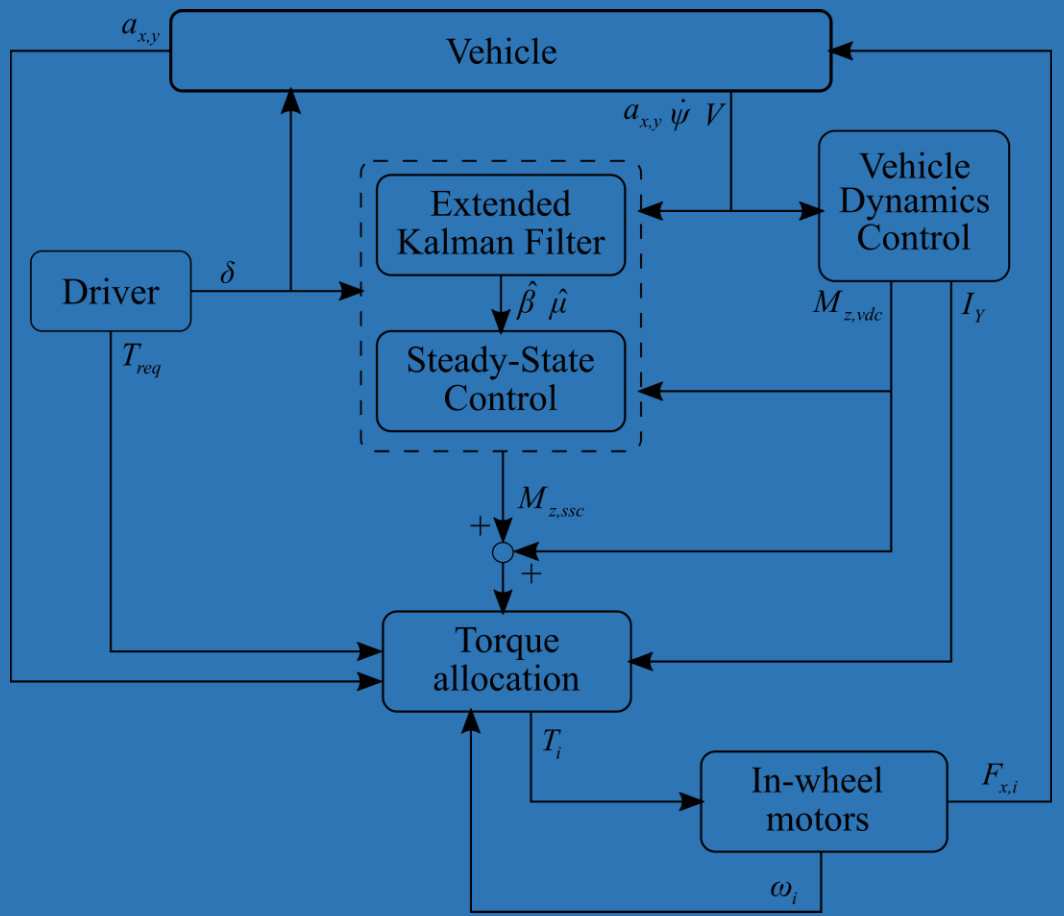
Code generation: Matlab/Simulink

Code deployment and Calibration: dSpace Controldesk



Control strategy for Torque Vectoring: **HiPerform H2020 project**

Objective: Design of control strategies for in-wheel motors in pure Electric Vehicles (Torque vectoring and stability improvement in addition to energy savings).
Controller : **Adaptive Linear Quadratic Regulator (ALQR).**
State estimator: **Extended kalman filter (EKF) / Neural Network.**



System Specification
- Vehicle Data
- On-board sensors
- Can-bus specification (dbc files)
- Inverters and motor data

System design
- Vehicle dynamics modeling (Simulink with validation from CarSim)
- Literature review of torque vectoring control architectures
- Functional Safety study
- Adaptive optimal control for Torque Vectoring (TV)
- CAN-bus signal integration

Software design
- Selection of HW (controller deployment feasibility study)
- TV-ECU definition (Raptor GCM 196)
- C code generation

HW/SW Integration
- Rapid Control Prototyping
- Control tuning

Vehicle Integration & Calibration
- Sensor calibration
- Model Calibration
- Control Refinement
- On-board diagnostic setup

Complete
In progress
Future work

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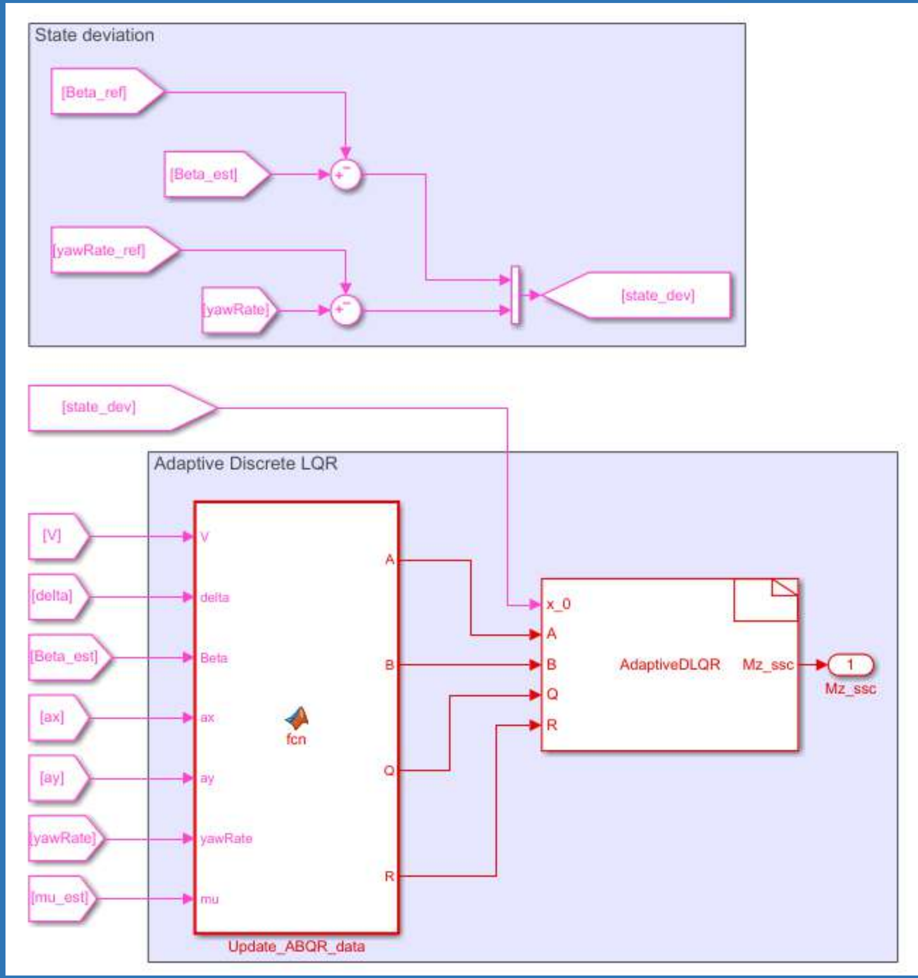
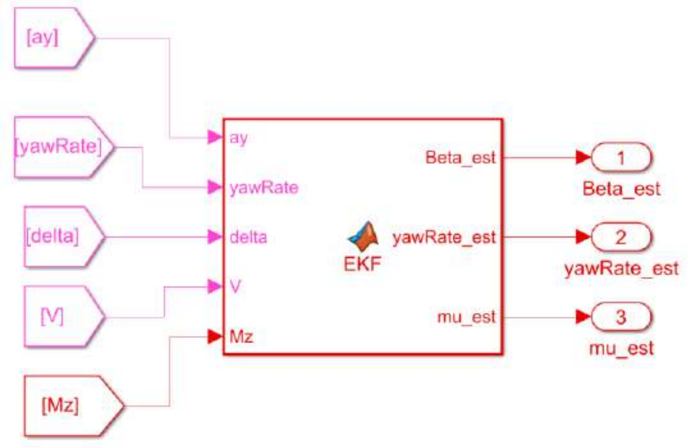
Control strategy for Torque Vectoring

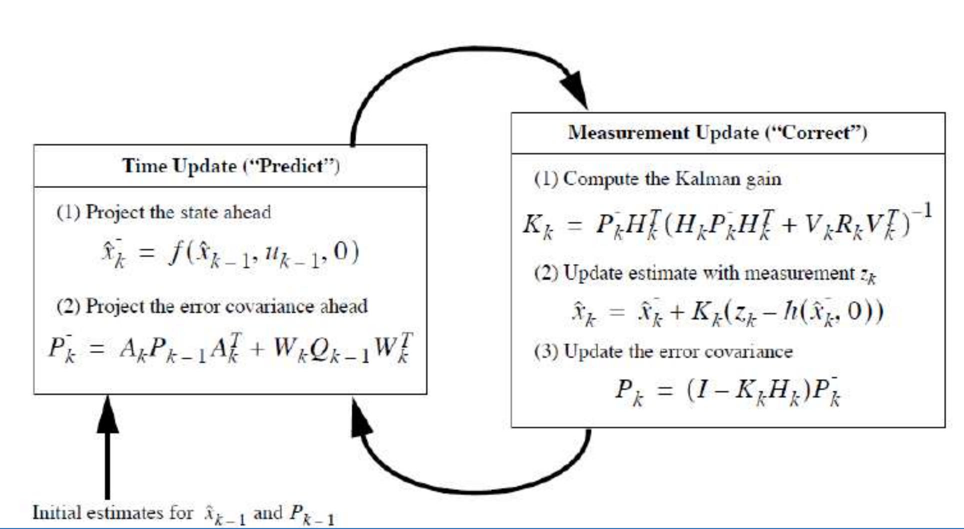
Controller: ALQR

$$\text{Min } J = \int (X'[Q]X + u'[R]u)dt,\ \ x = [\dot{\beta}, \dot{\psi}], u = Mz$$



State Estimator: Extended Kalman Filter

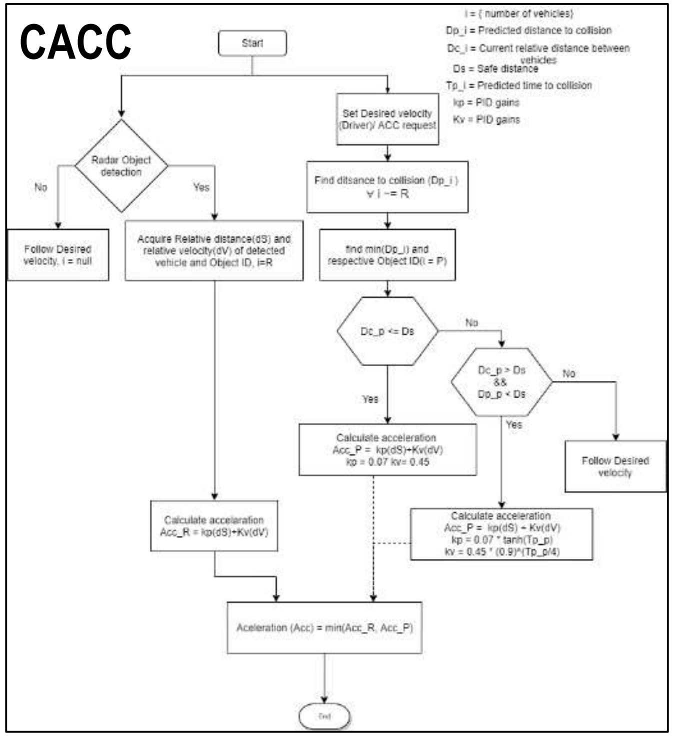


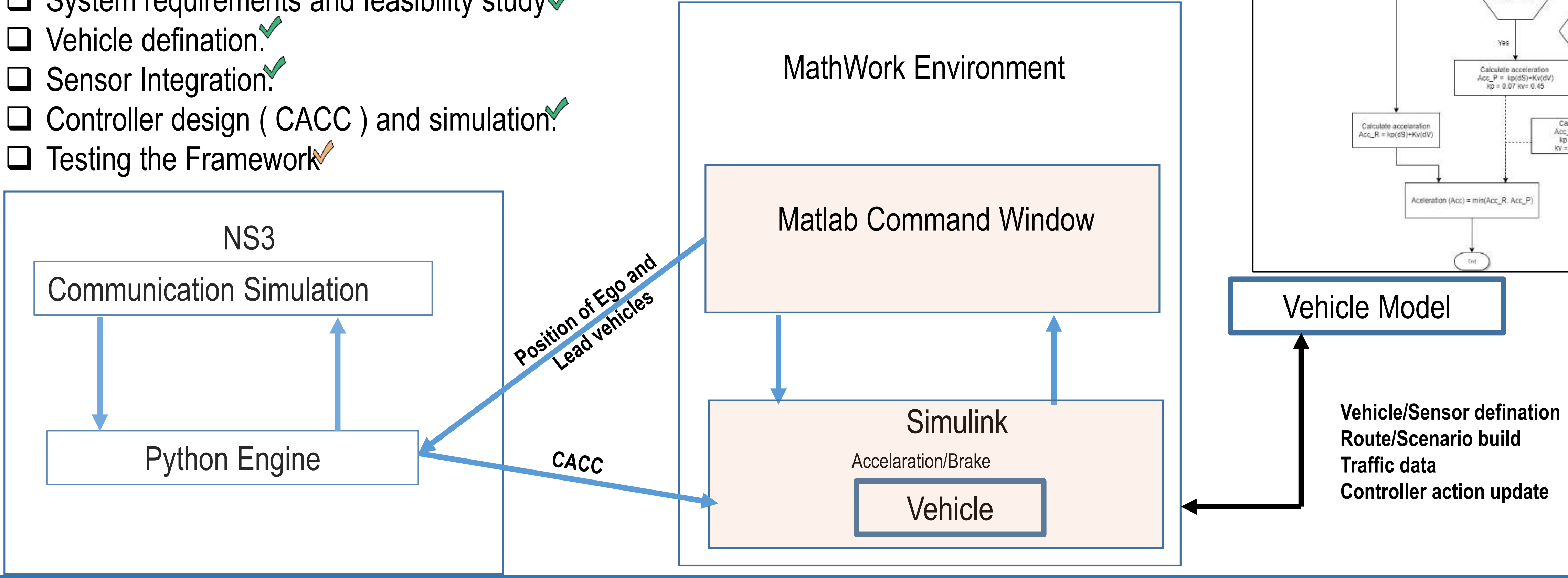


Control Algorithms in automated vehicles exploiting V2I communication : SAVE Project (CRF)

Objective : To develope a co-simulation framework to envelope vehicle connectivity, vehicle dynamics, on-board sensor, traffic mobility and scenarios.

- ❑ System requirements and feasibility study ✓
- ❑ Vehicle defination. ✓
- ❑ Sensor Integration. ✓
- ❑ Controller design (CACC) and simulation. ✓
- ❑ Testing the Framework ✓





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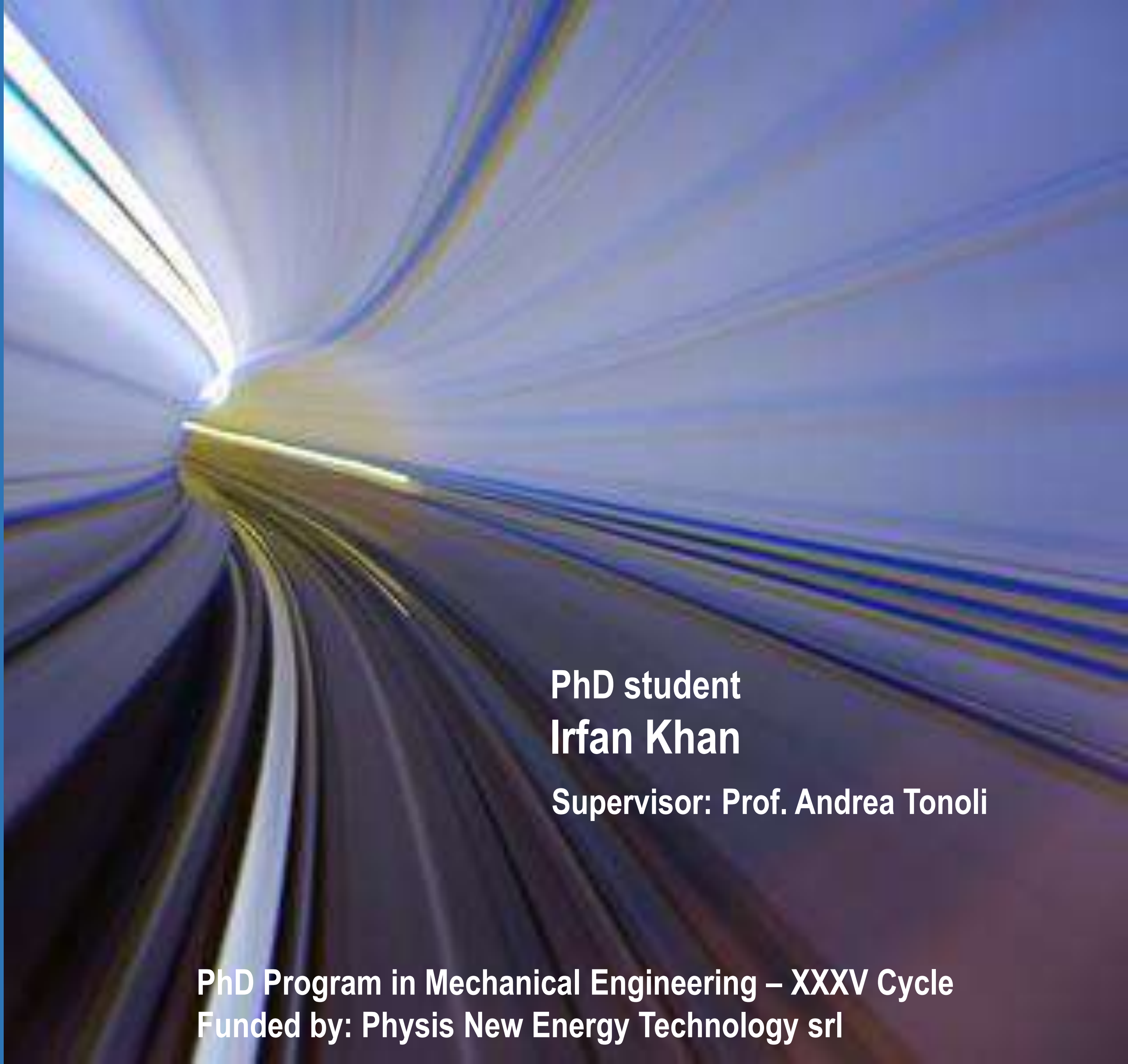
February 05, 2020 –PhD Presentation



PhD student
Irfan Khan
Supervisor: Prof. Andrea Tonoli

PhD Program in Mechanical Engineering – XXXV Cycle

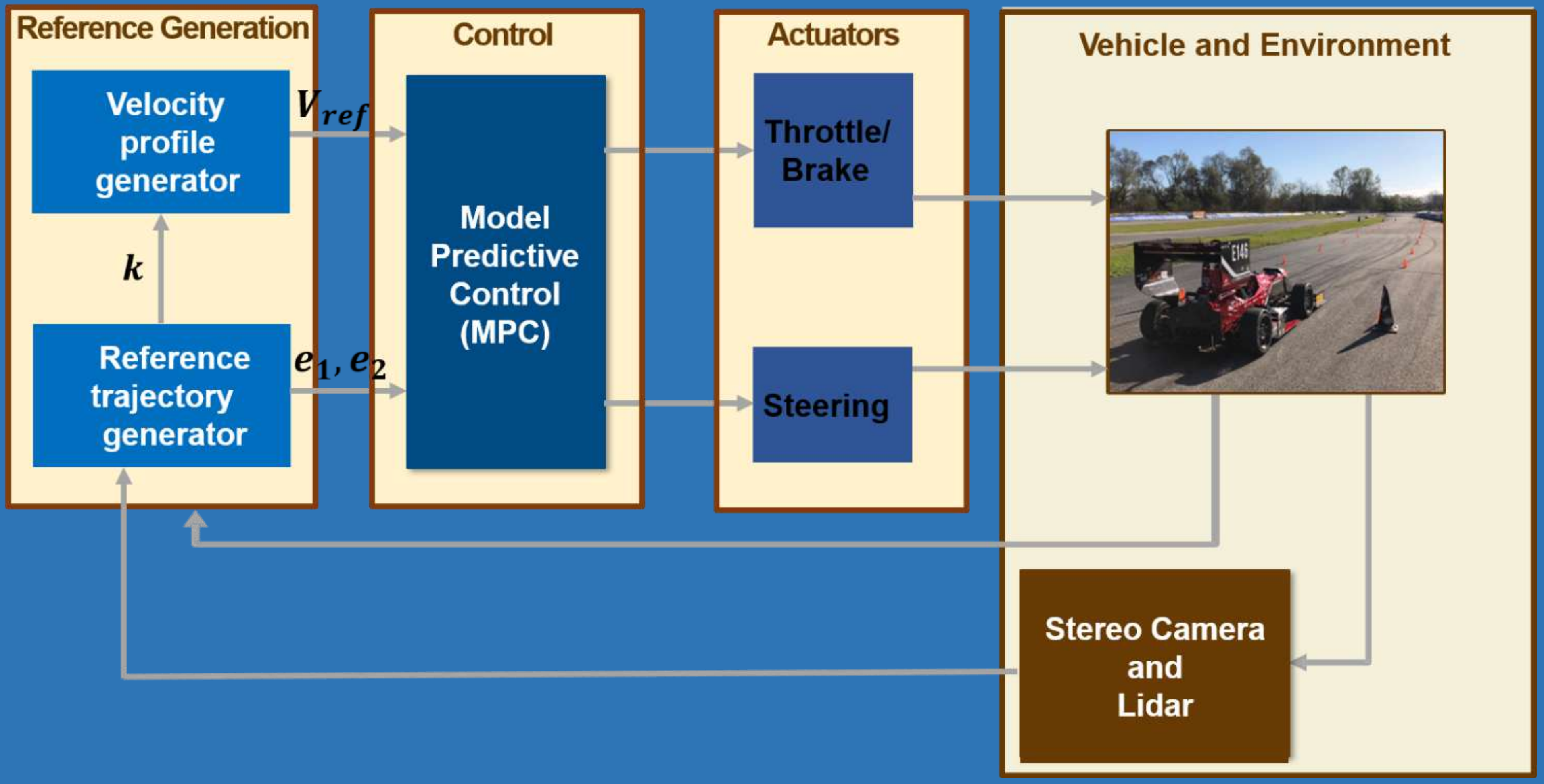
Funded by: Physis New Energy Technology srl

Research activities:

- **Autonomous Driving:**
  - Study, design and implementation of the control strategies for automated racing vehicles to improve the performance.
  - Design, construction and implementation of actuators for automated vehicles.
- **Powertrain electrification (P2 and P4 configurations):**
  - Integration of mechanical, electrical and electronic subsystems in terms of packaging, reliability and performances.
  - Implementation on real case studies.

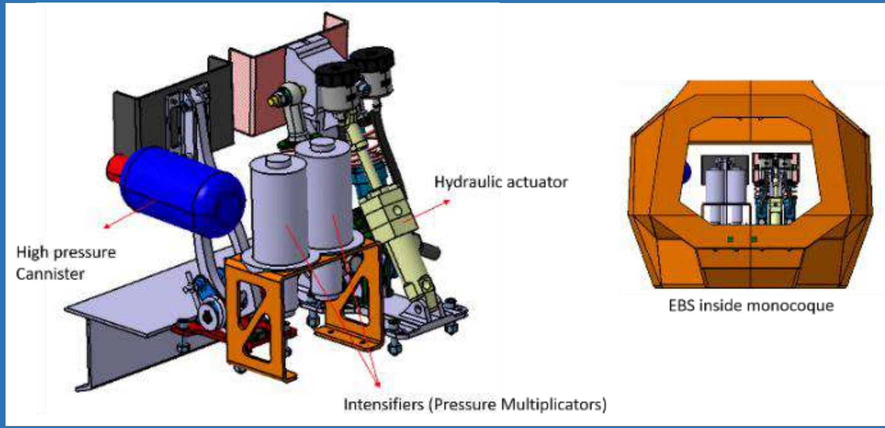
Autonomous Driving:

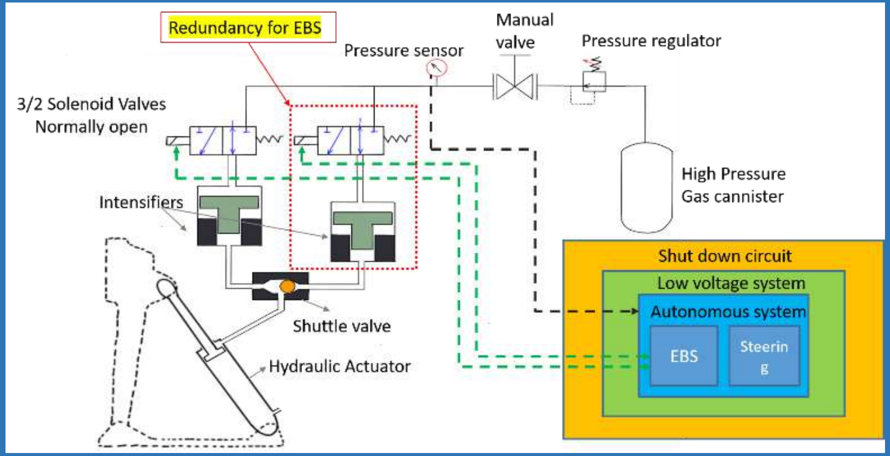
- The objective is the design and implementation of the control strategies for automated racing vehicles to improve the performance in terms of lap time.

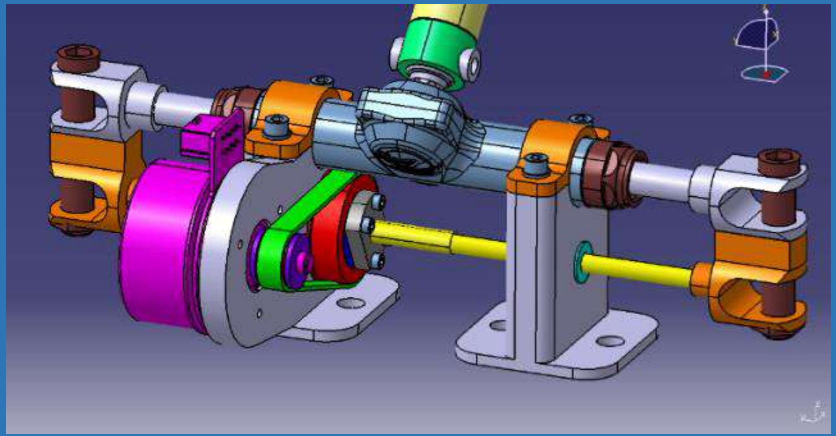


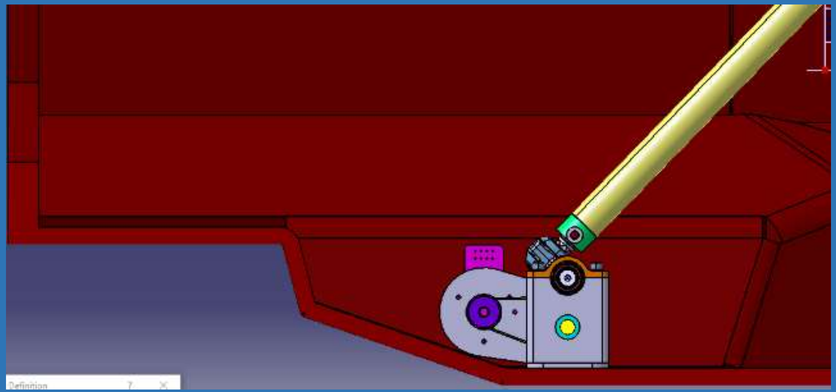
Steering and Braking Actuators

- The objective is the design, construction and implementation of actuators for automated vehicles.





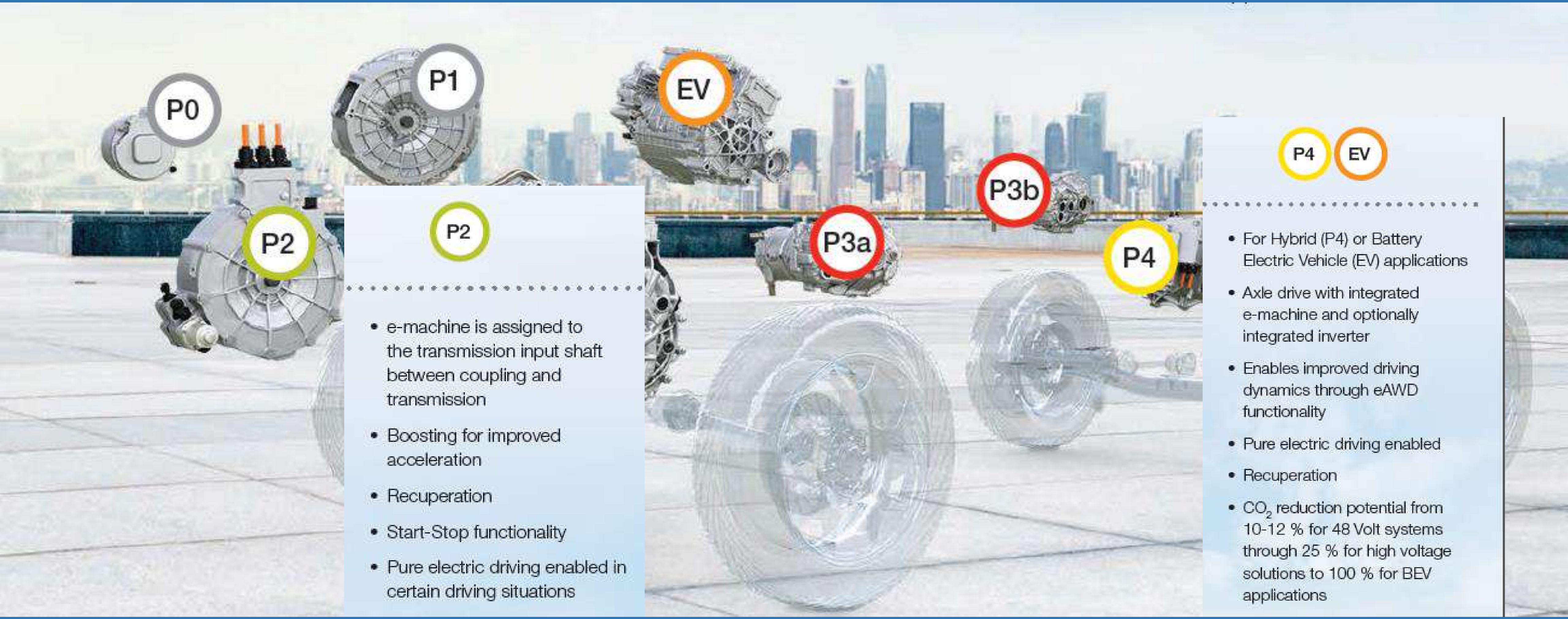




Design of Control strategies/Actuators → Simulation/HIL and Laboratory Tests → On vehicle implementation and testing

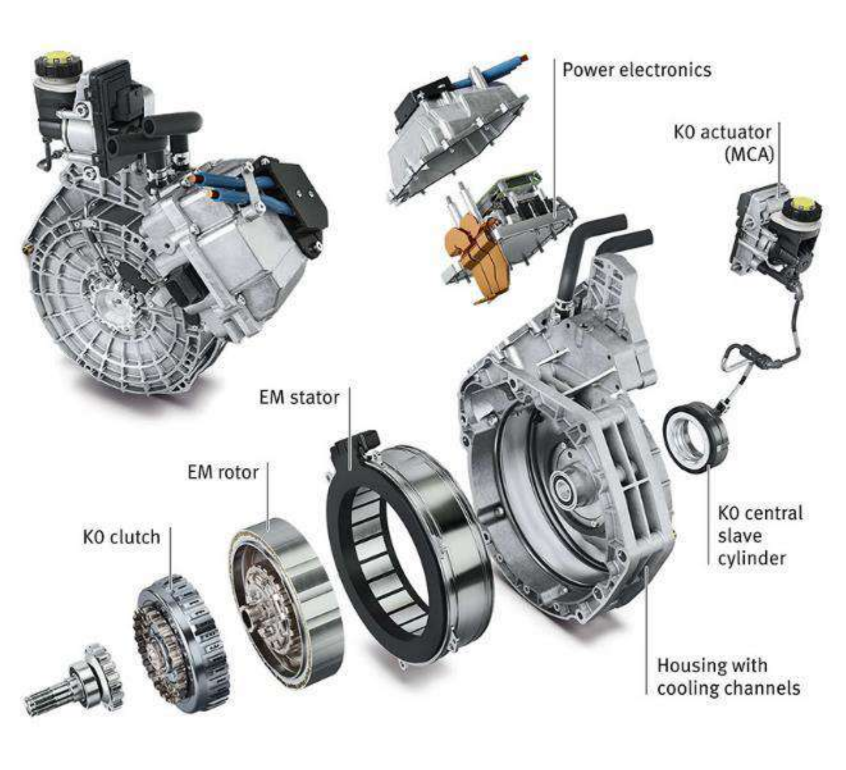
Powertrain Electrification:

- Hybrid powertrain architectures:

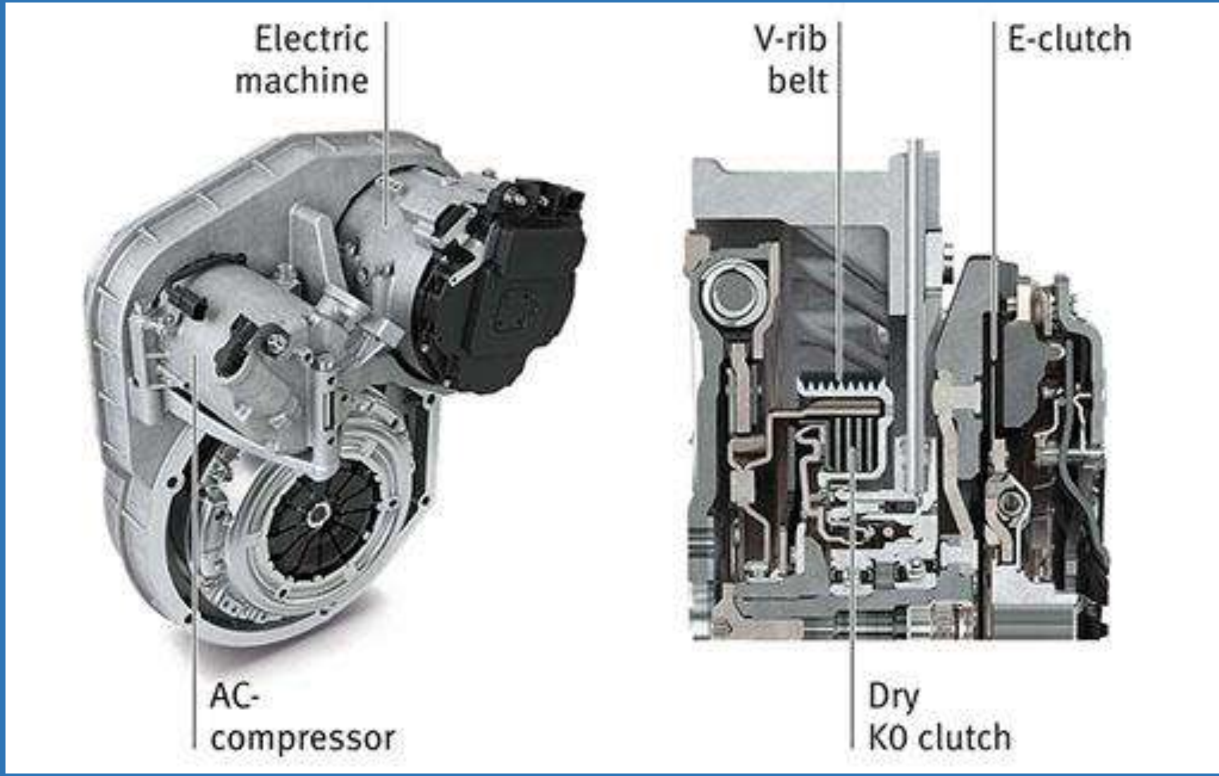


P2 Hybrid module

- The objective is the investigation of the most promising P2 solution in terms of (among the others) packaging, reliability, performances in traction and in regenerative braking, possibility to control unwanted torsional vibrations, cost/performance.



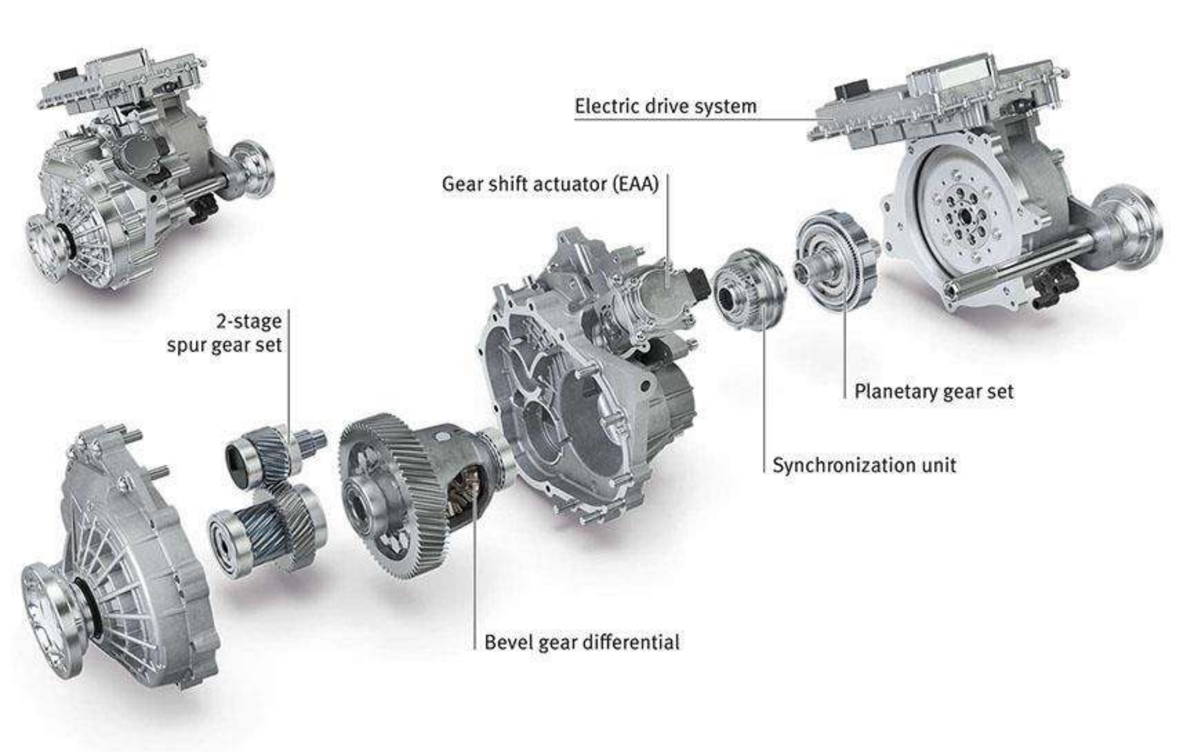
Coaxial P2 hybrid module



P2 hybrid module with parallel axis installation

P4 Hybrid module

- The objective is the integrated design of an innovative e-axle including: e-motor, SIC inverter, gear train and differential, cooling and lubrication system.
- The goal is to reach the highest level of integration so to develop an e-axle unit with unique characteristics in terms of: compact package, small weight, reduced parts count, optimized overall efficiency.
- Possibility to adopt to both P4 hybrid and full electric vehicles .



Electric axle for a P4 hybridization

Integrated Design → Simulation and Laboratory Tests → On vehicle test

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Center for Automotive Research and Sustainable mobility

PhD Student: Sara Luciani

Supervisor: Prof. Andrea Tonoli

PhD Program in Mechanical Engineering – XXXV Cycle
Funded by: IVECO SpA

February 05, 2020 –PhD Presentation

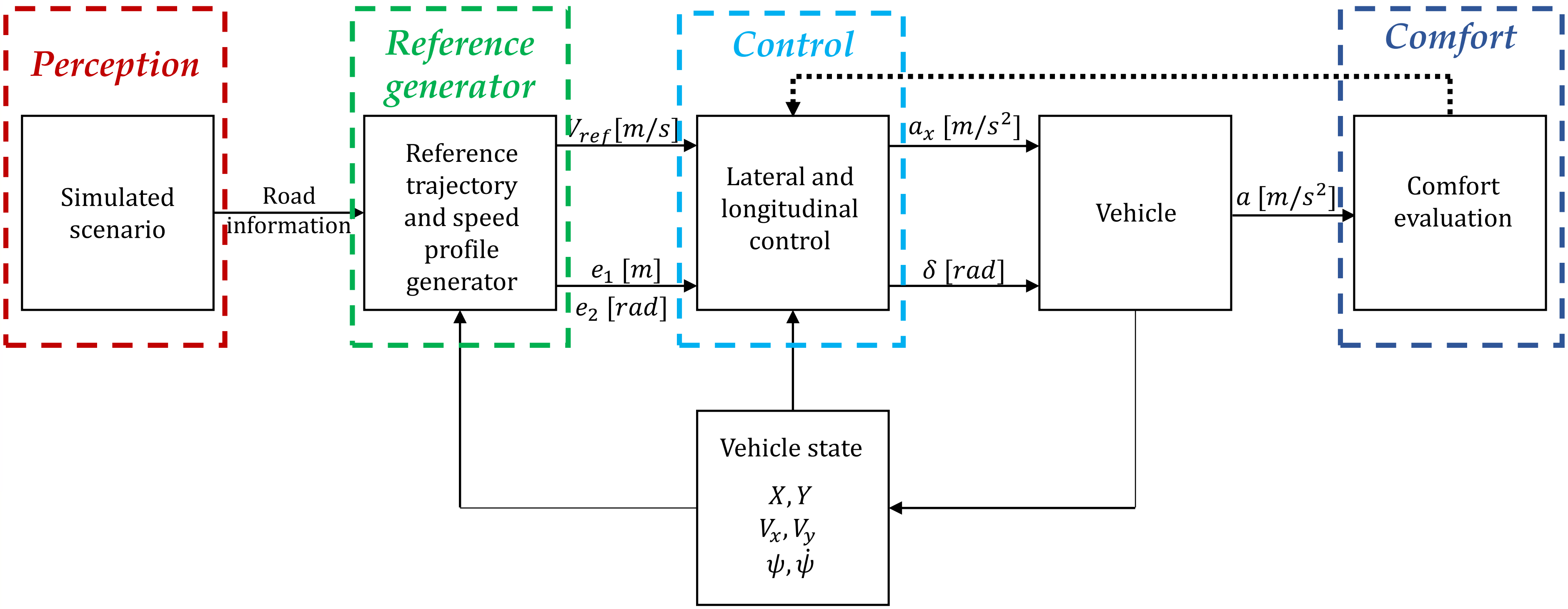
Research activities

- Development of control strategies for automated vehicles addressing the issue of the ***comfort***

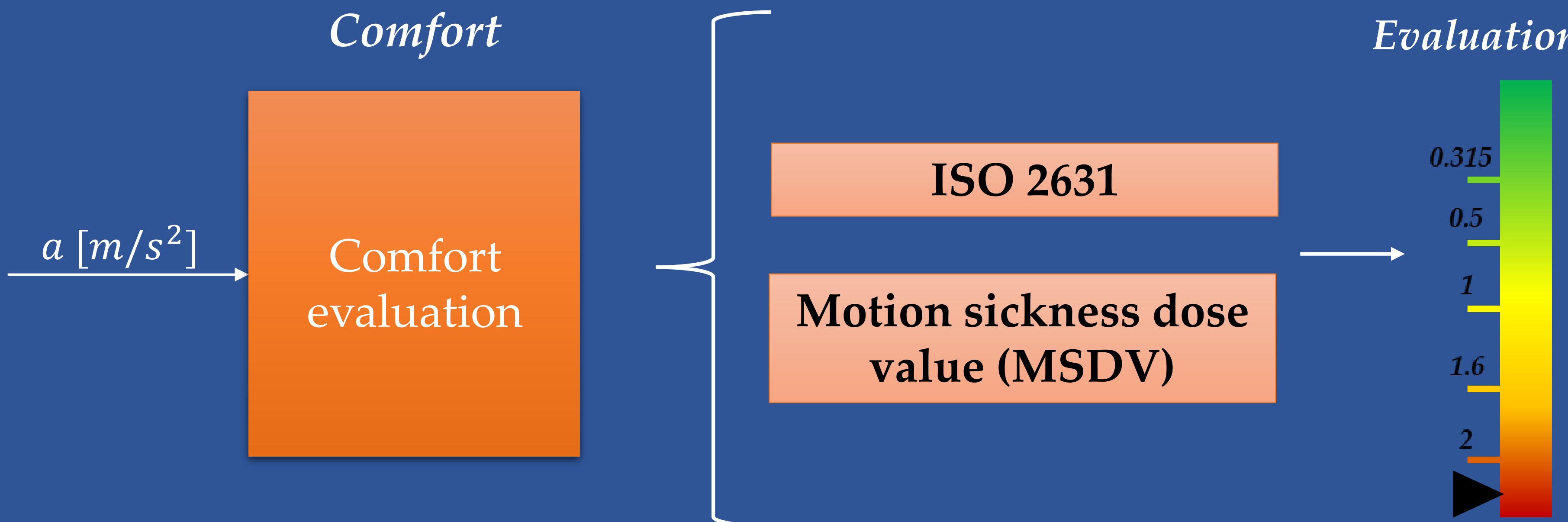
- Development of models to predict ***SOC*** (state of charge) and ***SOH*** (state of health) in batteries for commercial/industrial vehicles from model-based techniques to ANN (Artificial neural networks).

Development of control strategies for automated vehicles addressing the issue of the *comfort*

System architecture

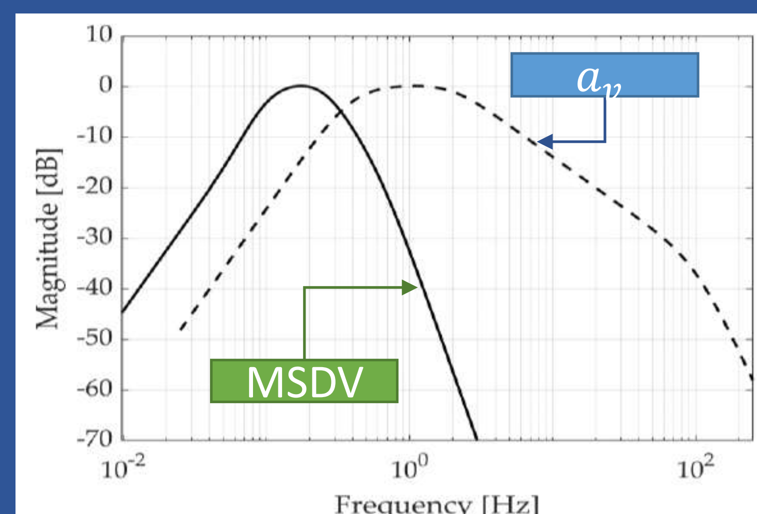


Comfort evaluation methods

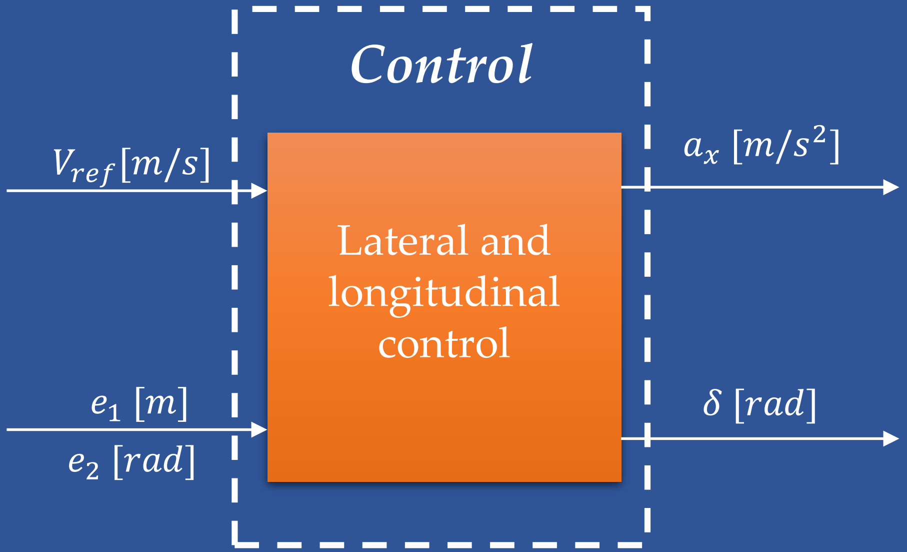


ISO 2631 $$a_{W_{i,RMS}} = \left(\frac{1}{T}\int_{t_0}^{t_f} a_{W_i}(t)dt\right)^{\frac{1}{2}}$$

MSDV $$MSDV = \sqrt{\int_0^{T_f} [a_w(t)]^2 dt}$$



Control design



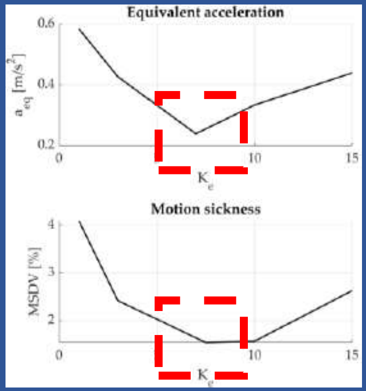
1. PID and non linear steering control
2. MPC and PID
3. MPC

Parameters optimization

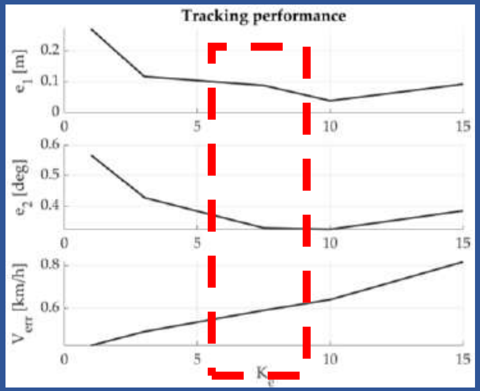
1. In each control strategies the characteristic parameters were optimized separately in order to achieve a trade-off between comfort evaluations (ISO 2631 and MSDV) and vehicle performances (lateral deviation, relative yaw angle and velocity tracking error).

ISO 2631 vs. Ke

MSDV vs. Ke

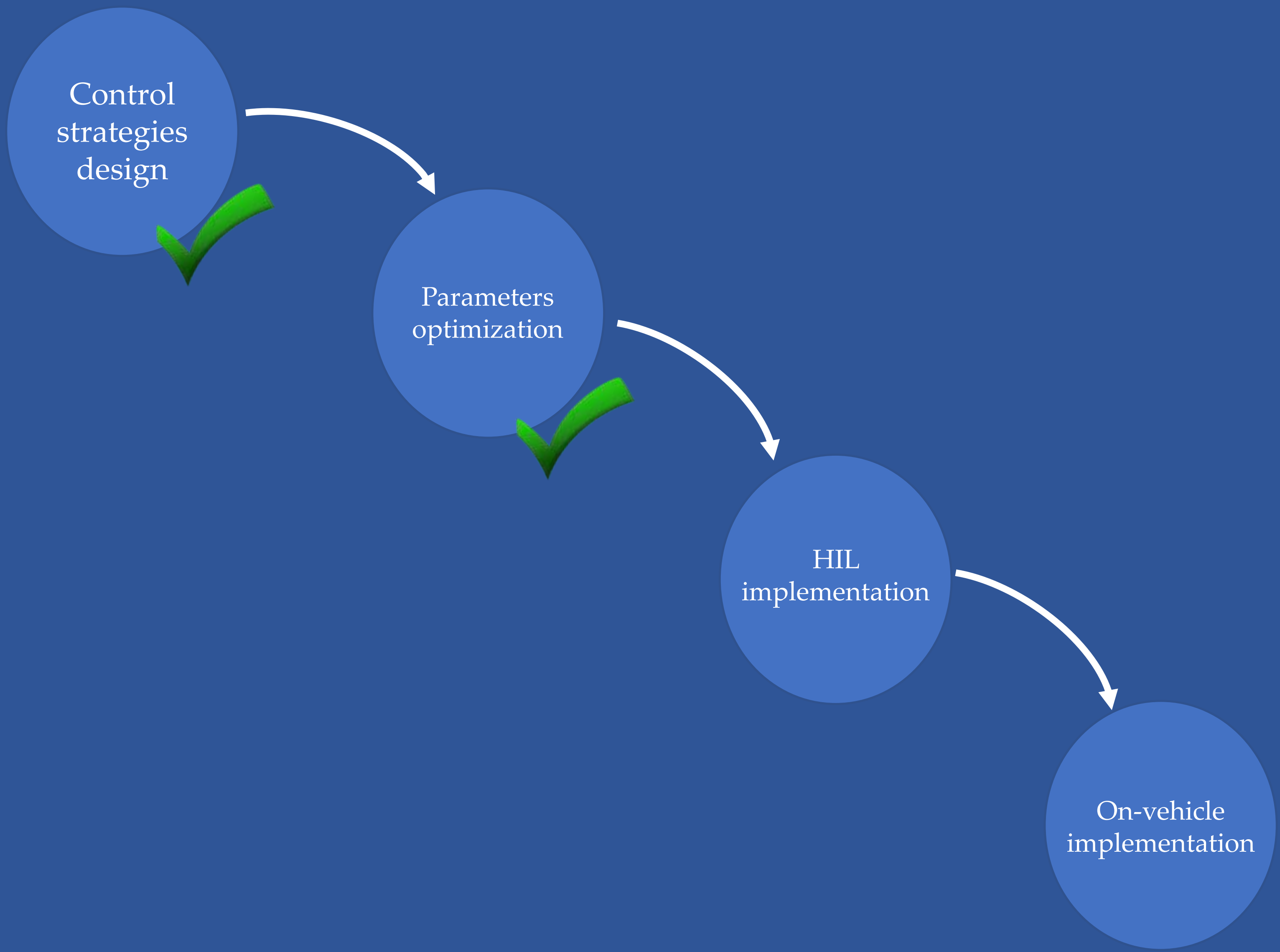


Mean errors vs. Ke



2. A multivariable optimization was performed by means of a genetic algorithm in order to obtain simultaneously the best trade-off between comfort evaluation (ISO 2631) and vehicle performances.

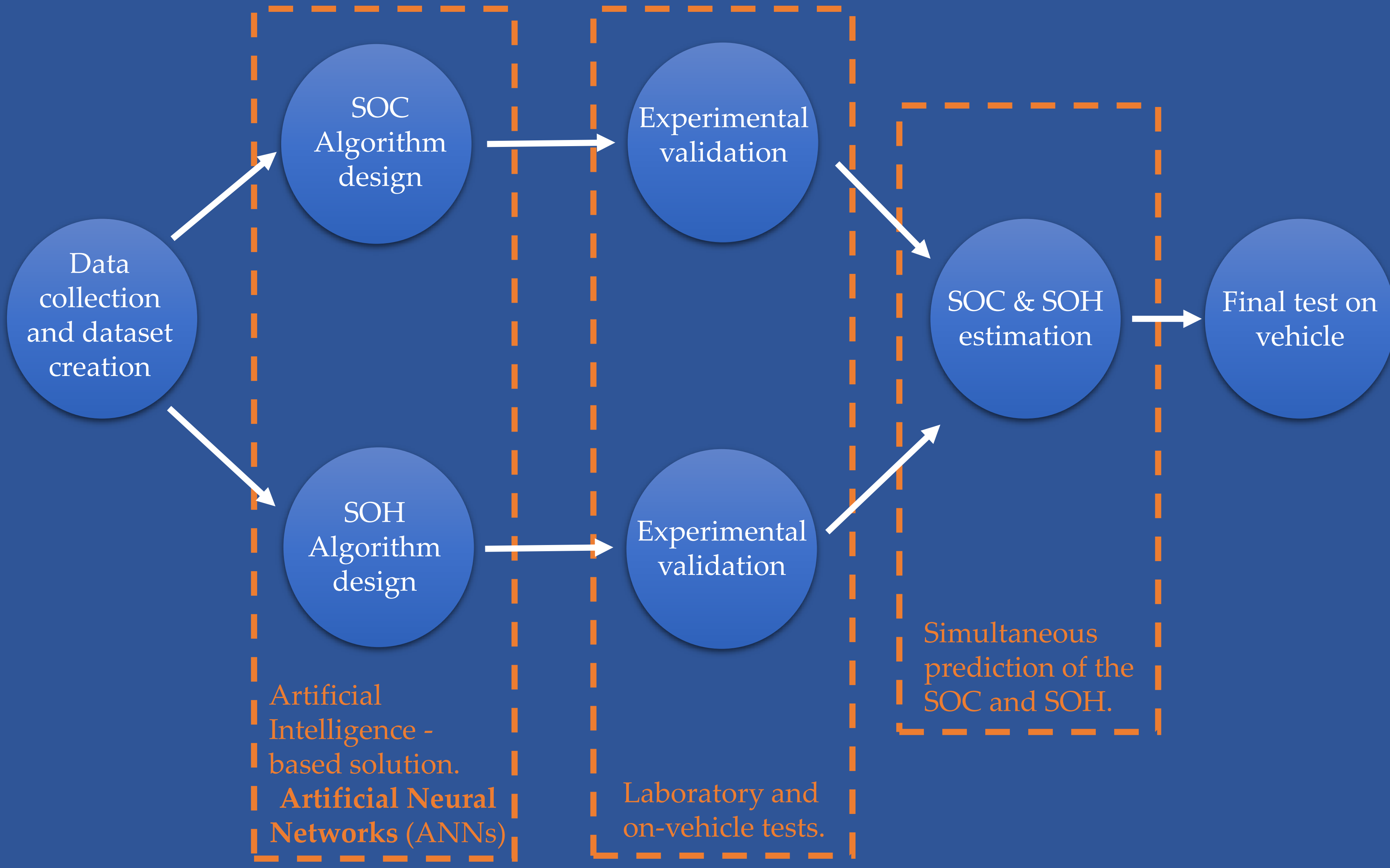
Future work


Control strategies design
Parameters optimization
HIL implementation
On-vehicle implementation

Development of models to predict ***SOC*** and ***SOH*** in batteries for commercial/industrial vehicles

Overview

The assessment of the level of the remaining available energy, indicated by the State of Charge (SOC), as function of the level of ageing suffered by the battery, indicated by the State of Health, (SOH) is of primary importance. These parameters cannot be directly measured with sensors and must be estimated by means of indirect approaches.


Data collection and dataset creation
SOC Algorithm design
SOH Algorithm design
Experimental validation
Experimental validation
SOC & SOH estimation
Final test on vehicle
Artificial Intelligence - based solution. **Artificial Neural Networks** (ANNs)
Laboratory and on-vehicle tests.
Simultaneous prediction of the SOC and SOH.

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February 05, 2020 –PhD Presentation

Hybrid Powertrain Design and Control based on Artificial Intelligence Solutions

PhD Student:
Alessandro **FALAI**

Supervisors:
Daniela **MISUL**
Ezio **SPESSA**

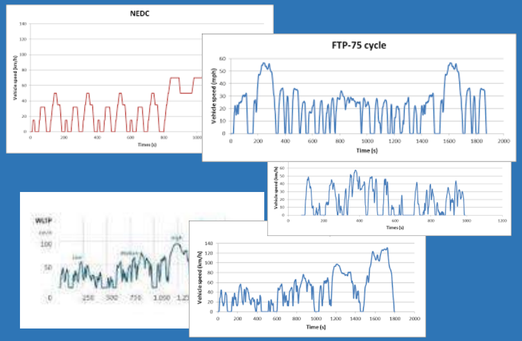
PhD program: Energetic

Outline

- ➢ **Objectives of PhD Research**
- ➢ **Machine Learning background**

Objectives of PhD Research

- Estimate the impact of the vehicle driving mission on the performance of the commercial vehicles, including the effects from main environmental conditions.



In an industrial project, a toolbox has been developed in order to identify the best powertrain layout for HEV in terms of costs, energy consumption, CO_2 and pollutant emissions (components sizing and weight of vehicle's powertrain) and a contemporary optimization of the operating strategy of ICE, EMS and SOC.

- Development of **real-time HEV controllers** that can be implemented on-board by means of machine learning and reinforcement learning solutions.
- Exploit **V2X technologies** to improve the controllers capability to achieve a better utilization of onboard energy

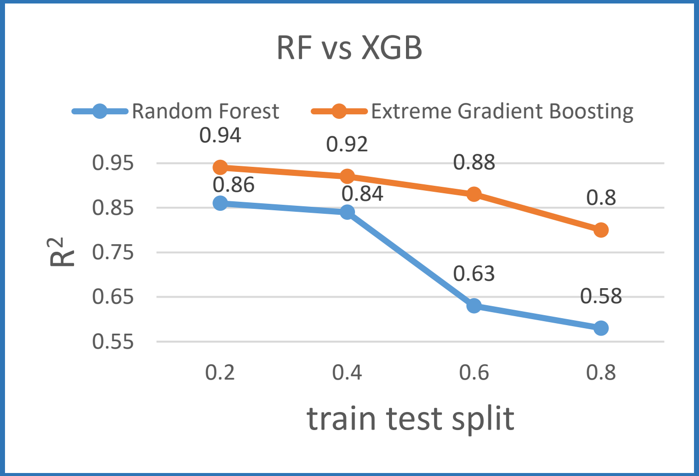
Machine Learning background

The interest on AI algorithms come from Master thesis and reasearch fellow activity, where single-output ML-based models for *soot* and *NOx prediction* in Diesel engines have been developed, in a passenger car and HeavyDuty frameworks.

→ Virtual Sensoring Application

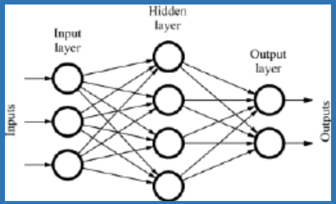
- ❑ *Random Forest*

- ❑ *ExtremeGradientBoosting (XGB)*



In order to realize a single model to predict both soot and NOx emissions, we are working on the development and validation of a *multiple-output sensor* based on:

- ❑ *Feedforward Neural Networks (multilayer perceptrons)*



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Research fellow

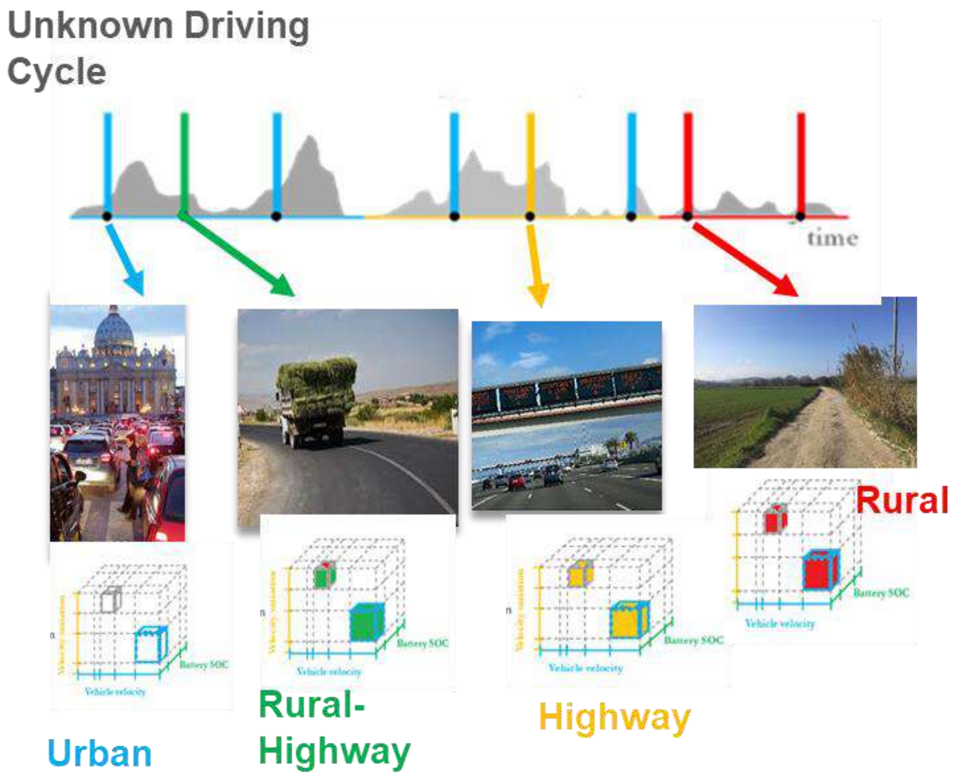
Alessia MUSA

Supervisors

Prof. Daniela MISUL
Prof. Ezio SPESSA

February 05, 2020

Thesis: Development of an adaptive real-time control strategy for (P)HEVs



Tailored Hybrid Emission Optimizer (THEO)

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February 05, 2020 – PhD Presentation

Research Fellow

Matteo Spano

Supervisors

Prof. G. Belingardi
Prof. D. Misul

Outline

- Brief Presentation
- Short Overview about the M.Sc. Thesis
  - Conclusion

Brief Presentation

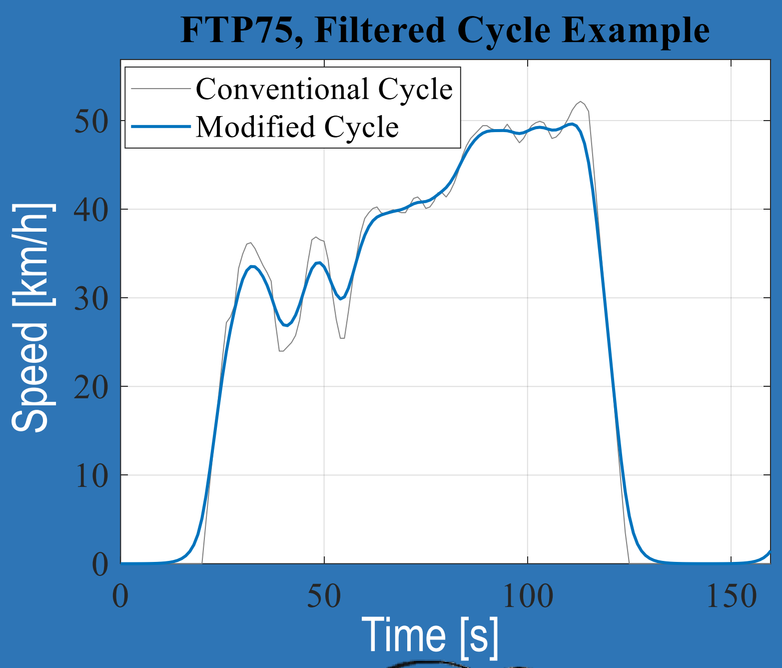
Master's degree in **Mechanical Engineering at the Politecnico di Torino**

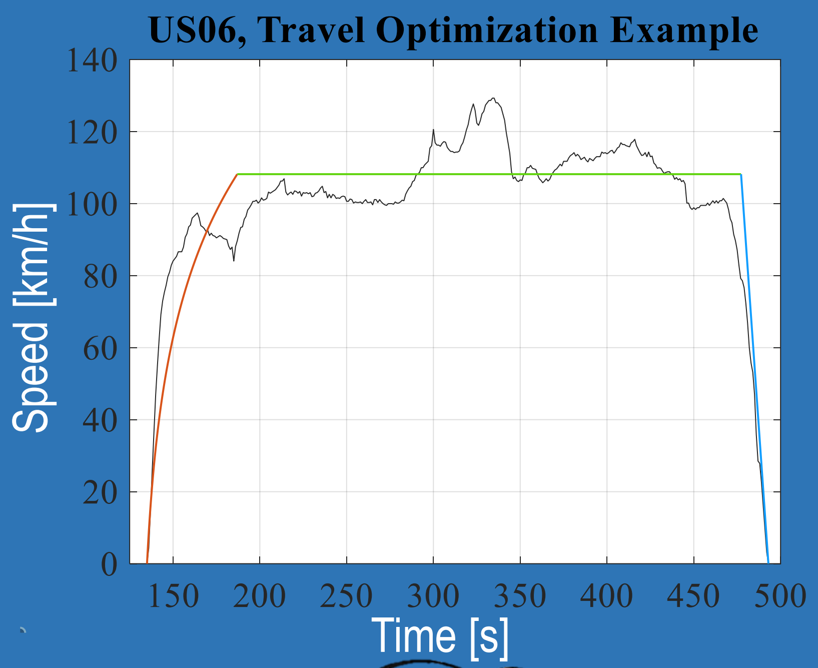
International Experience

University of Kentucky,	08-12/2016
Oakland University,	03-09/2019

Thesis

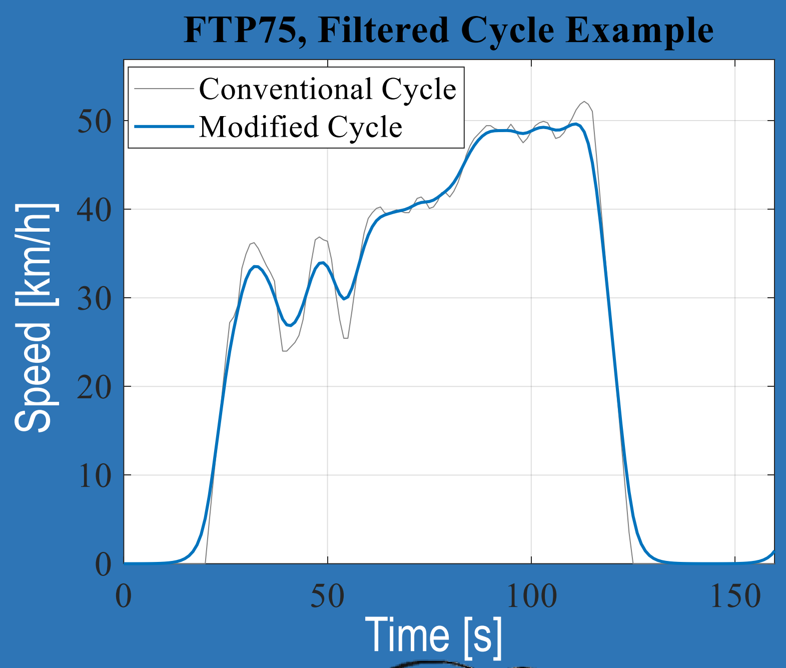
What could be the driving behavior of an automated driving vehicle?

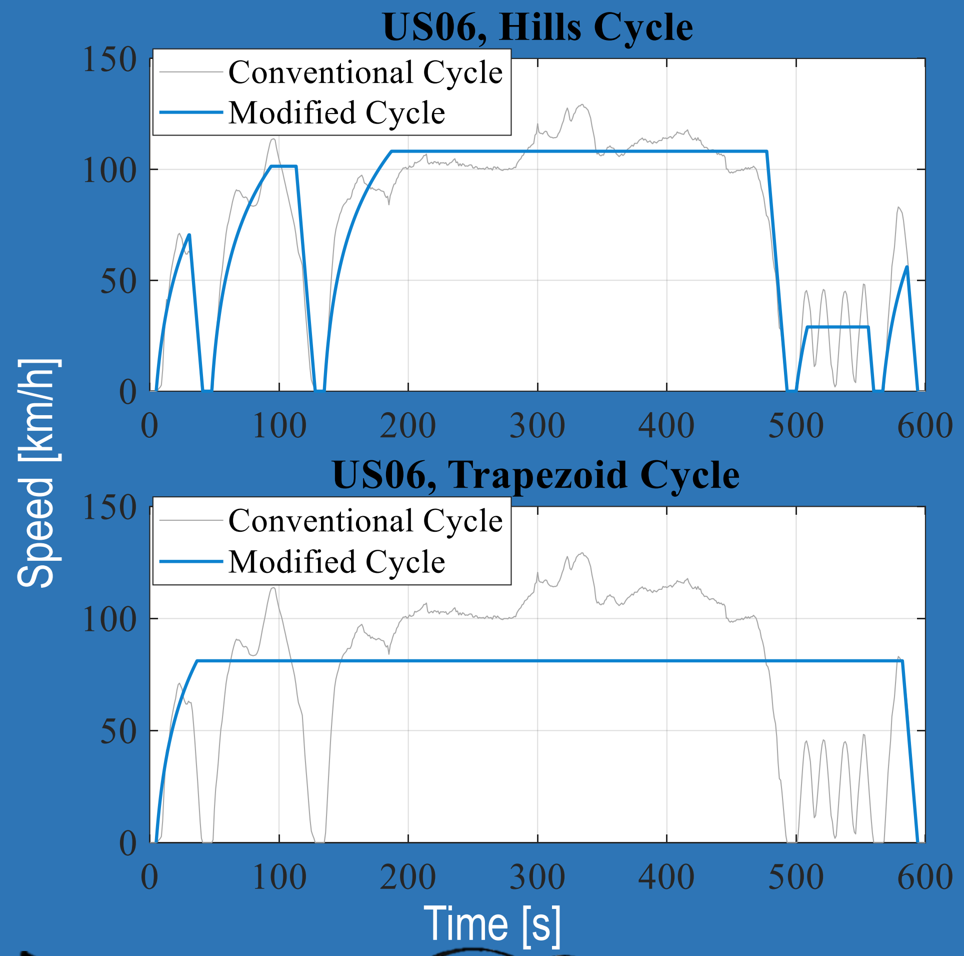




Thesis

What could be the driving behavior of an automated driving vehicle?





Conclusions

- CAVs could bring substantial fuel economy Improvements
- Hybrid vehicles show higher fuel economy values when compared to the conventional configurations

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February 05, 2020 –PhD Presentation

PhD Student

Dario Fiumarella

Supervisors

Prof. Giovanni Belingardi

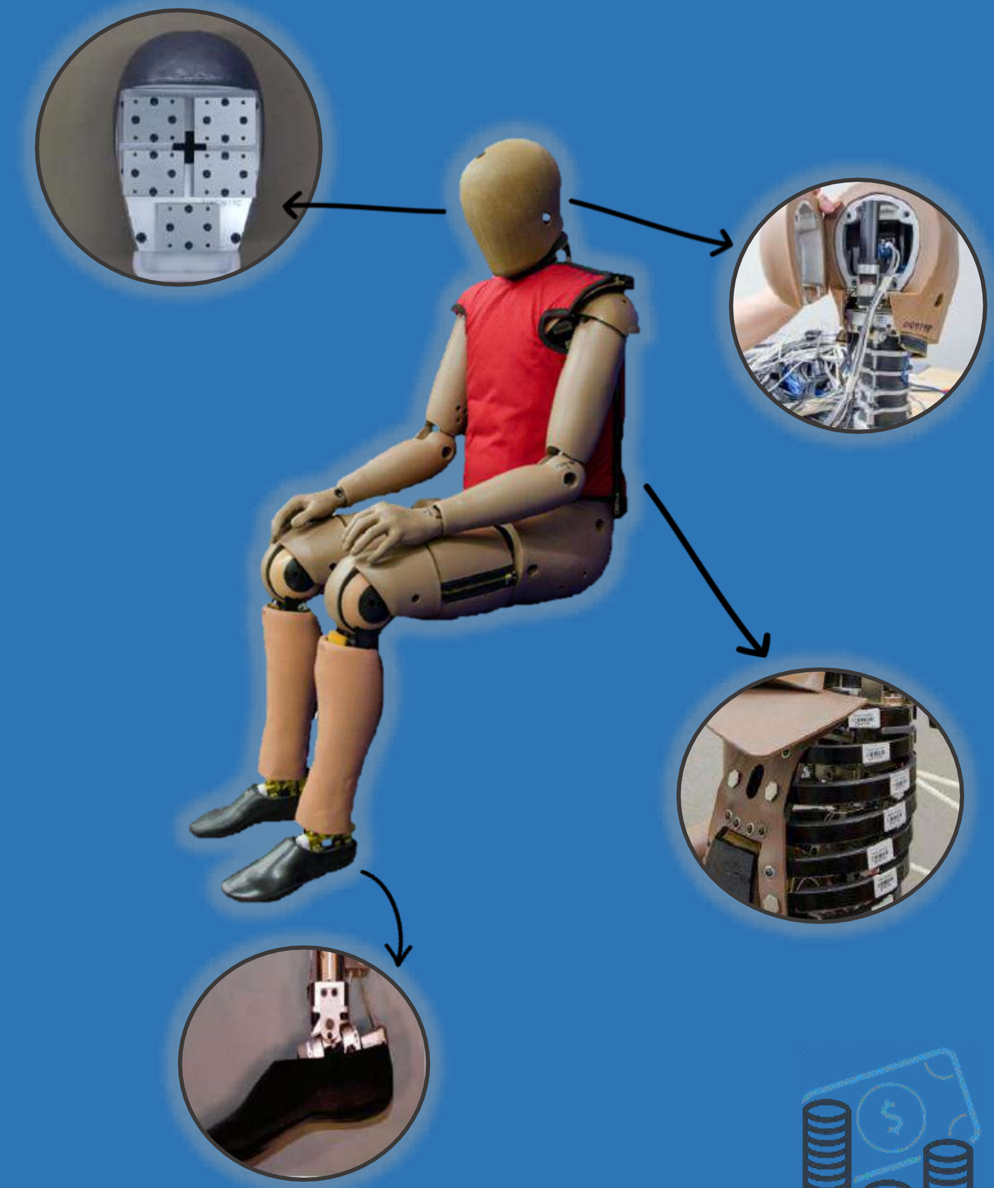
Prof. Alessandro Scattina

PhD in Mechanical Engineering

Outline

- Thor Dummy
- FE models
- Positioning
- Simulation
- Conclusion

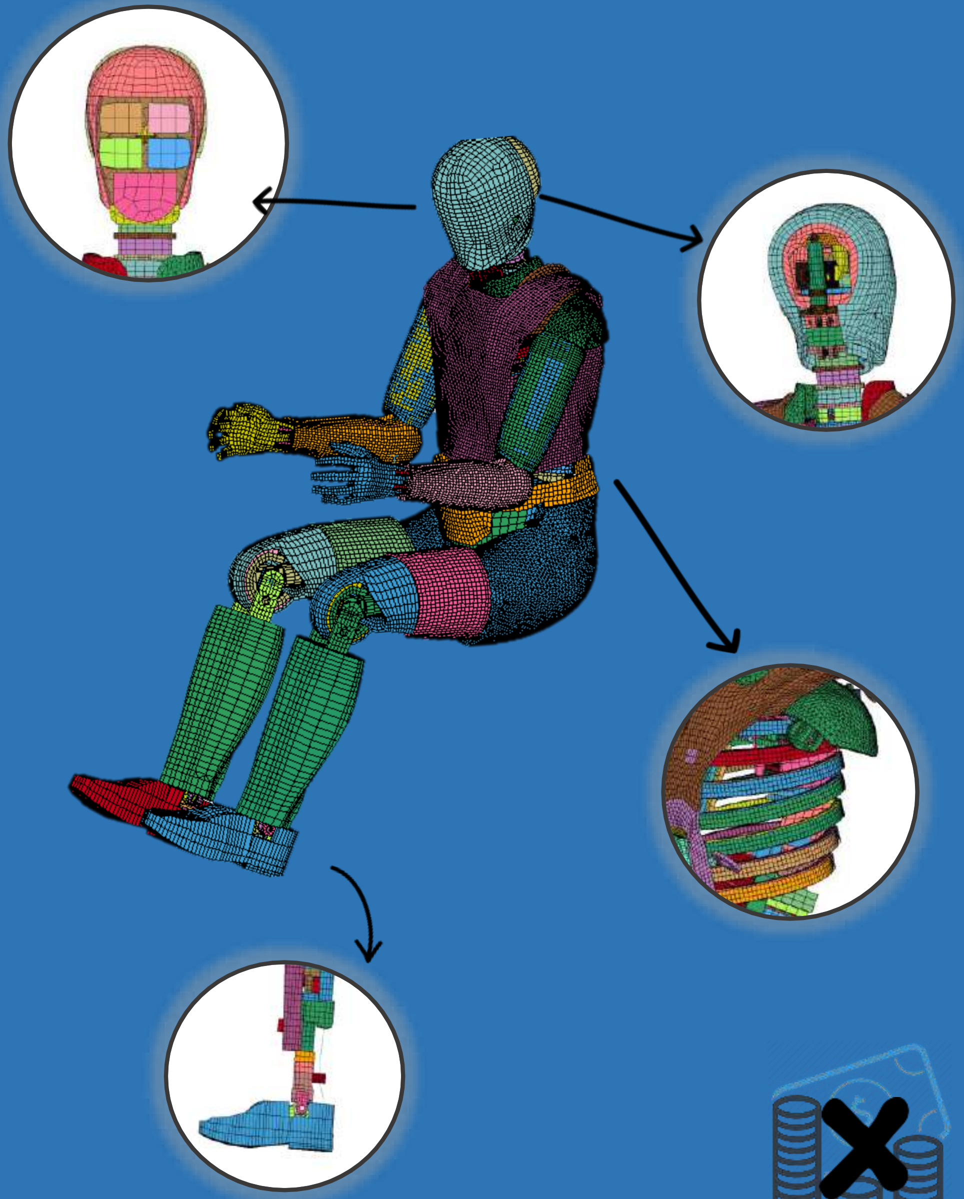
Thor Dummy

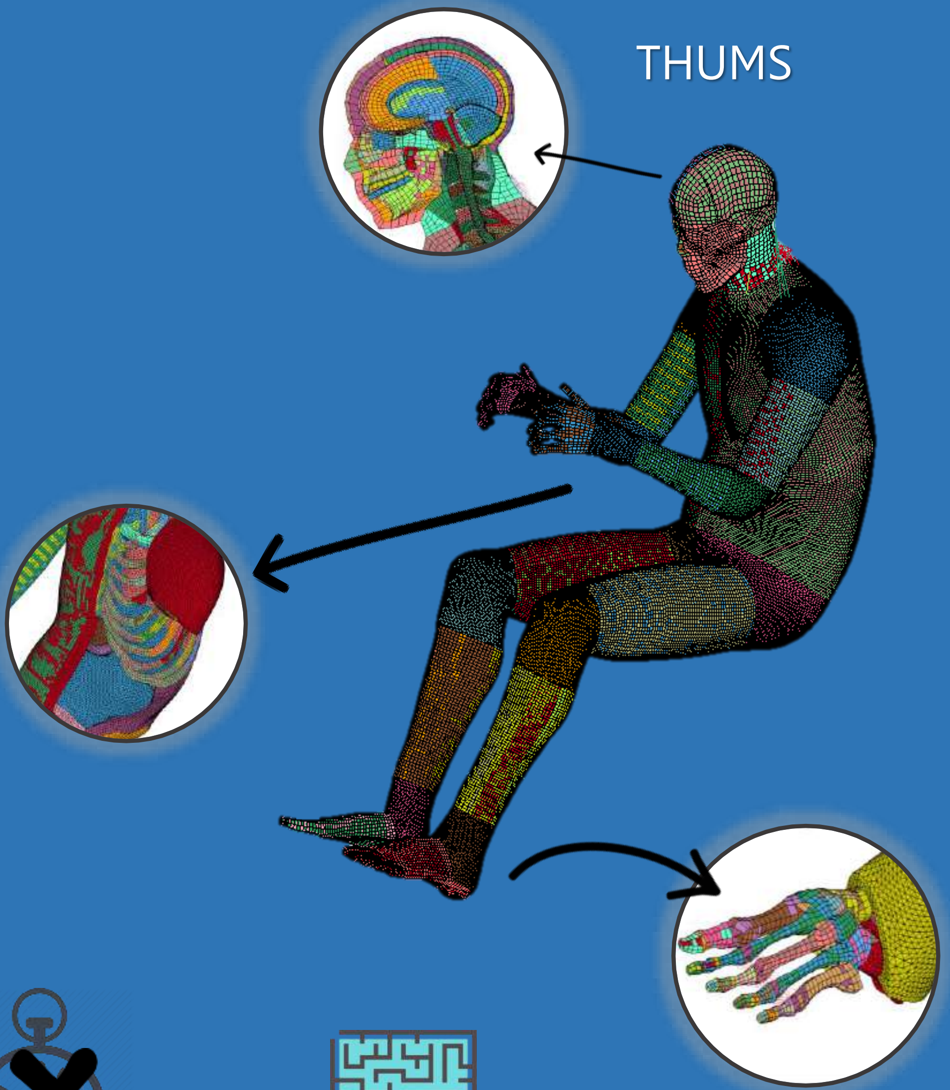


Acceleration during Impact

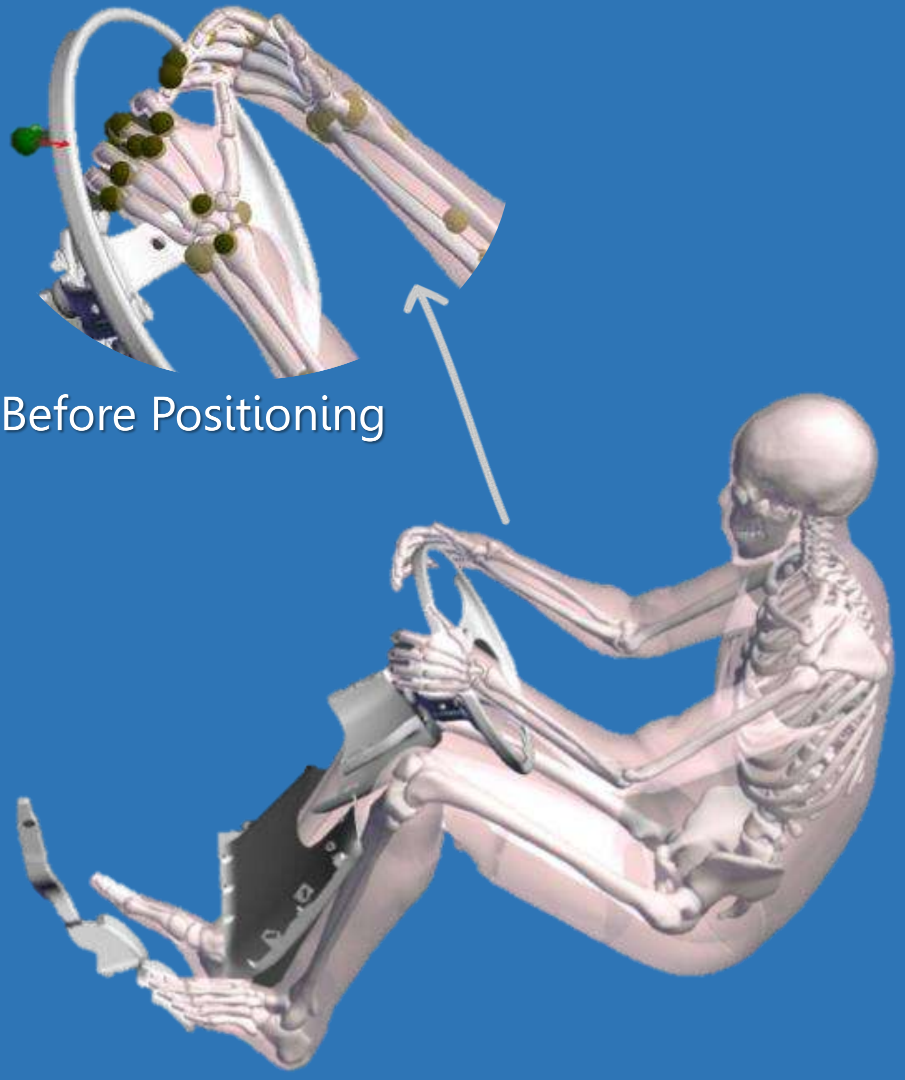
Head Injury Metrics
HIC

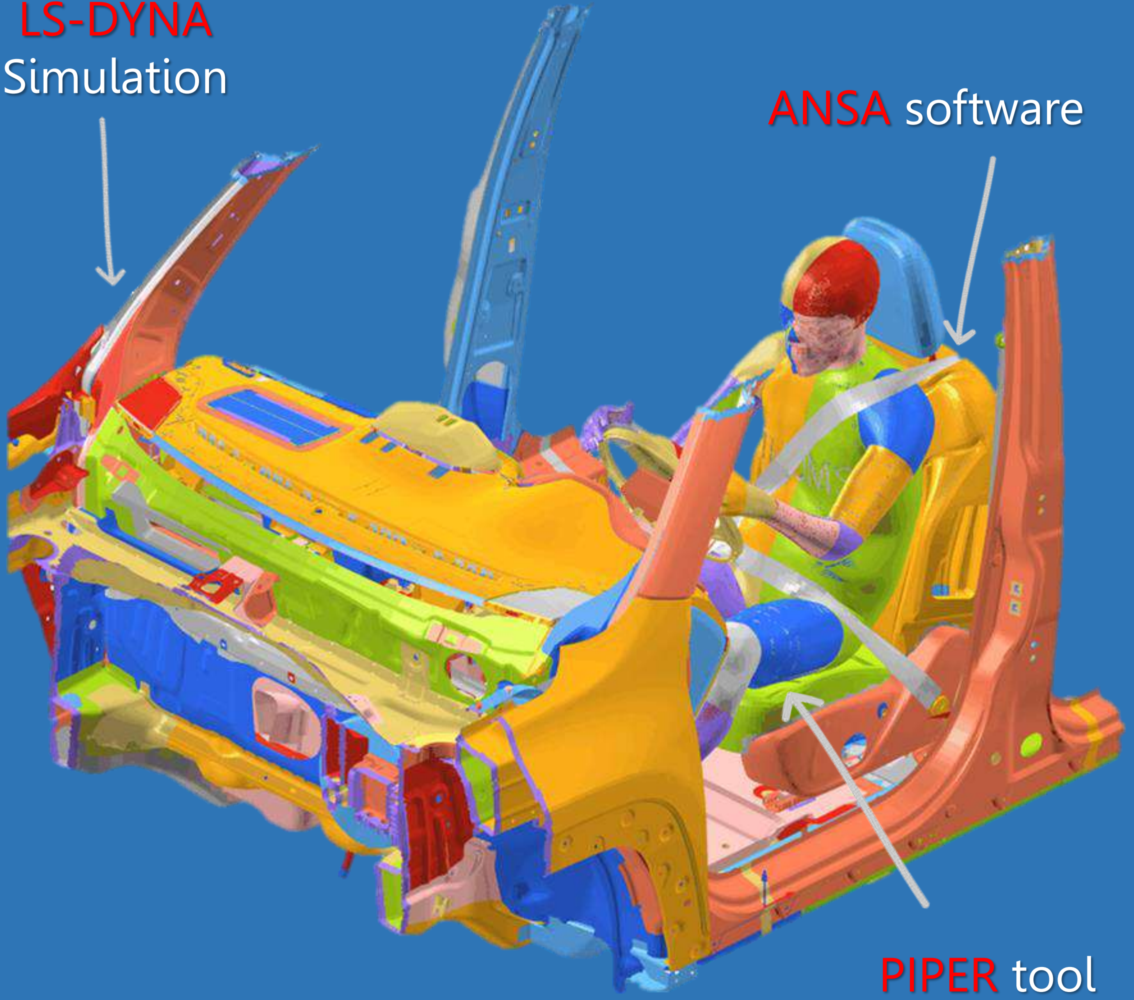
FE Models



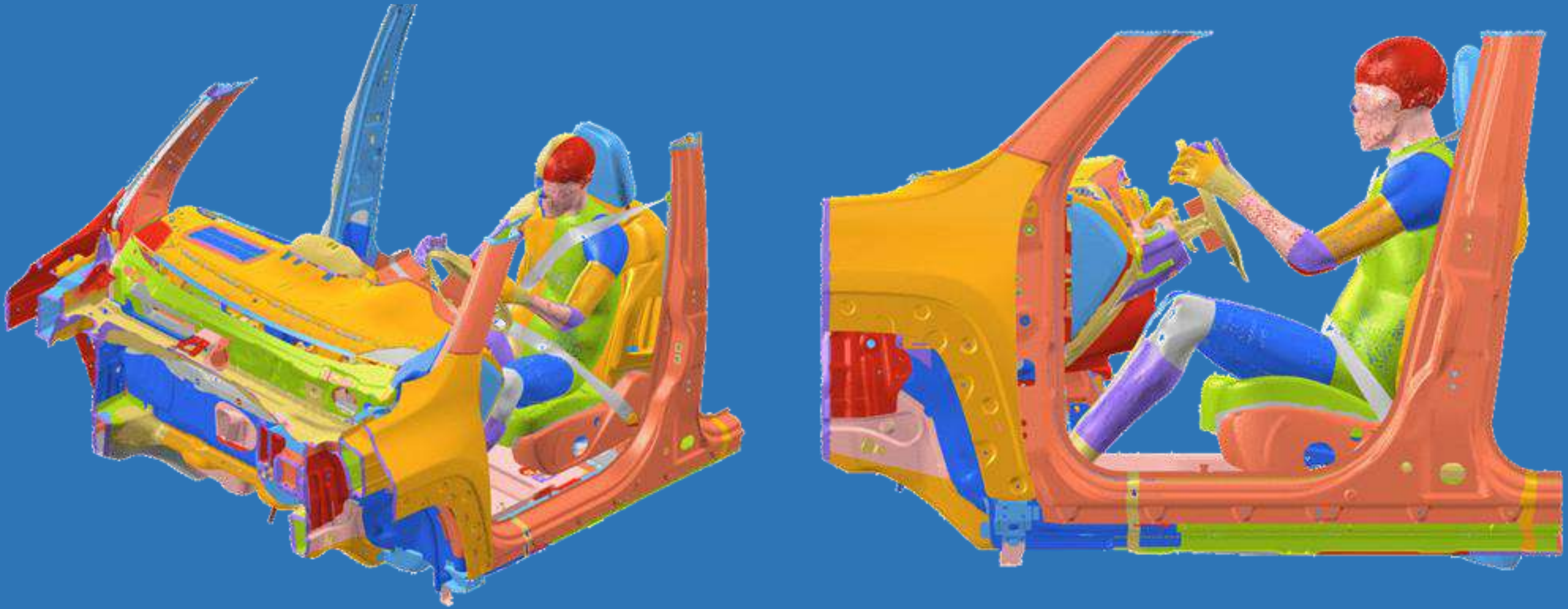


Thums Positioning





Crash **Simulation**



Conclusions

- ✓ HBM ensures a better correlation with Real Crash Events
- ✓ Direct Injury evaluation (Stress-Strain based metrics)
- ✗ Higher Simulation time

Future Works

- ? Different OOPs for Autonomous Vehicles
- ? Study of the fractures and internal organ injury
- ? Lateral Impact Simulation

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Thank You for Your Attention

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