GTAA 2014 - Orléans

Smart and Green Autonomous Vehicle Controller: Enhancement of Regeneration and Powertrain Strategy

S. GLASER, D. GRUYER,, O.ORFILA (IFSTTAR / LIVIC)

S. AKHEGAONKAR (INTEDIS, IBISC / UEVE)

F. HOLZMANN (INTEDIS, Germany)

L. NOUVELIERE (IBISC / UEVE et IFSTTAR/LIVIC)

eFuture

- Funded by the European Commission (grant no. 258133)
  - Duration 3 years
    (until September 2013)
  - Budget ca. 7 Mio. Euro
  - Funding ca. 4 Mio. Euro
  - 6 partners from 4 countries
    4 from industry
    2 research institutes
  - Coordinator:
    Intedis, Würzburg
- Develop a safe and efficient electric vehicle

Outline of the presentation

- Motivations
- Enhanced ACC
- Module integration
- Simulation / Experimental results and discussion

Motivations

- Existing technology
  - Adaptive Cruise Control is now widely spread
  - Communications and navigation devices now fit in everyone pockets !
- Electric vehicle is still a challenge
  - Limited Range
  - Regenerative capacity

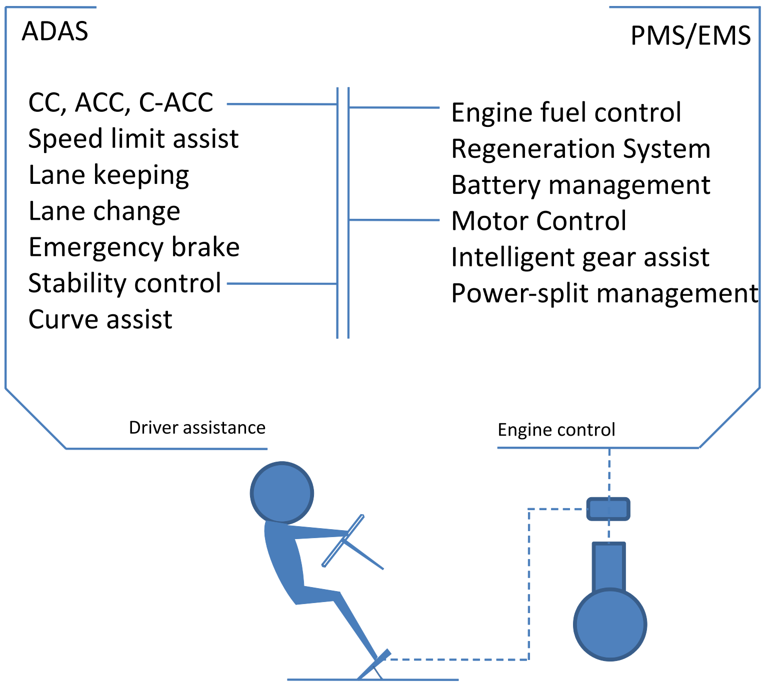
Traditional method

Limited communication between ADAS and energy management systems

Present

Acceptable because advanced functionalities are in development stage

Architecture development is in a transitional state



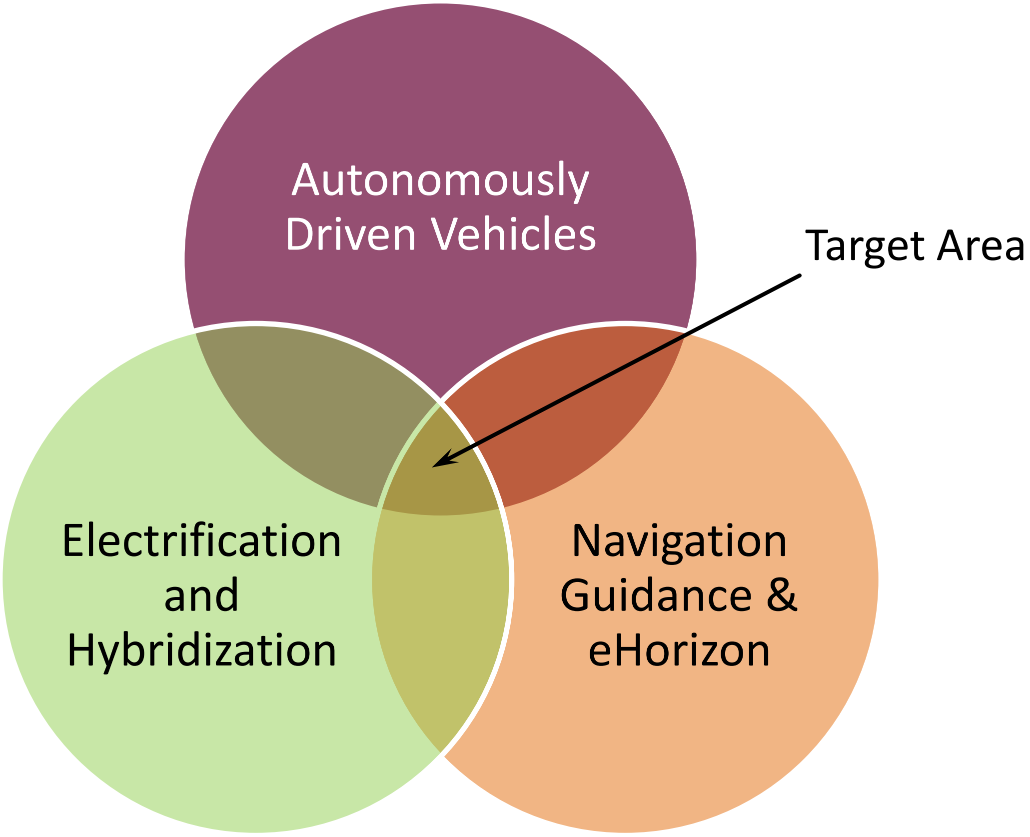
Future

Incompatible

Inadequate

Inherently unable to support
and process incoming environment data

Technologies that will set the prerequisites



Defining properties for the next generation of vehicle controllers

They are already here!

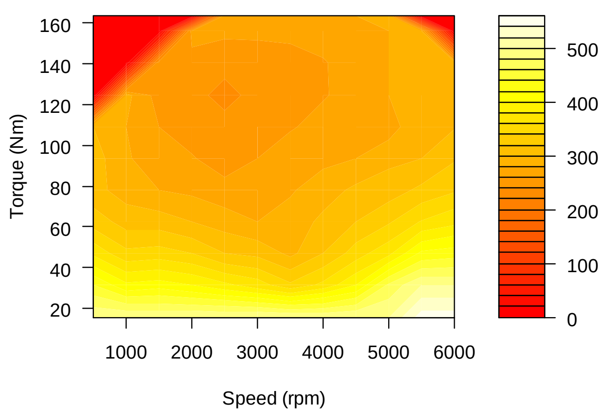
Eco-driving rules

- Ensure proper gear selection
- Shift into a higher gear early
- Leave vehicle in gear when braking
- Maintain a steady speed at highest possible gear
- Look ahead and anticipate traffic flow
- Switch off engine at short stops
- Make use of in-car fuel saving devices such as on-board computers and dynamic navigation to avoid traffic jams

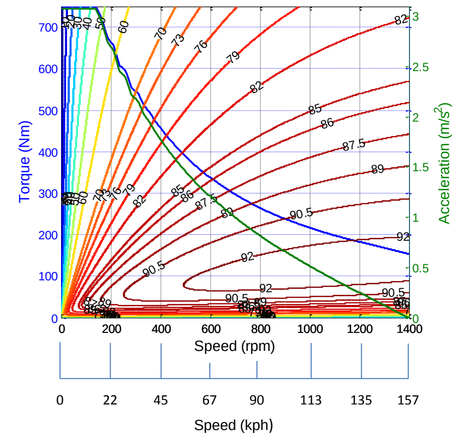
Electrification and Hybridisation

Green Energy

- Serial, Parallel, Power-split hybrids
- Efficiency
- Emissions
- Driving Range
- Component cost
- Oil independence
- BEV HEV PHEV



ICE η= 0-30 %



eMotor η= 70-95 %

Energy density

Oil : 16 km/kg*

Battery: 0.7 km/kg*

*Approximate Estimation

Navigation Guidance & eHorizon

Navigation & Guidance

Approx. Location

Approx. movement properties

ICT	Information Communication systems
ITS	Intelligent Transportation systems
V2V	Vehicle to vehicle communication
V2I	Vehicle to infrasture communication

Approaching road conditions

DSRC communication with traffic signals

Beyond Horizon events

Right of space usage

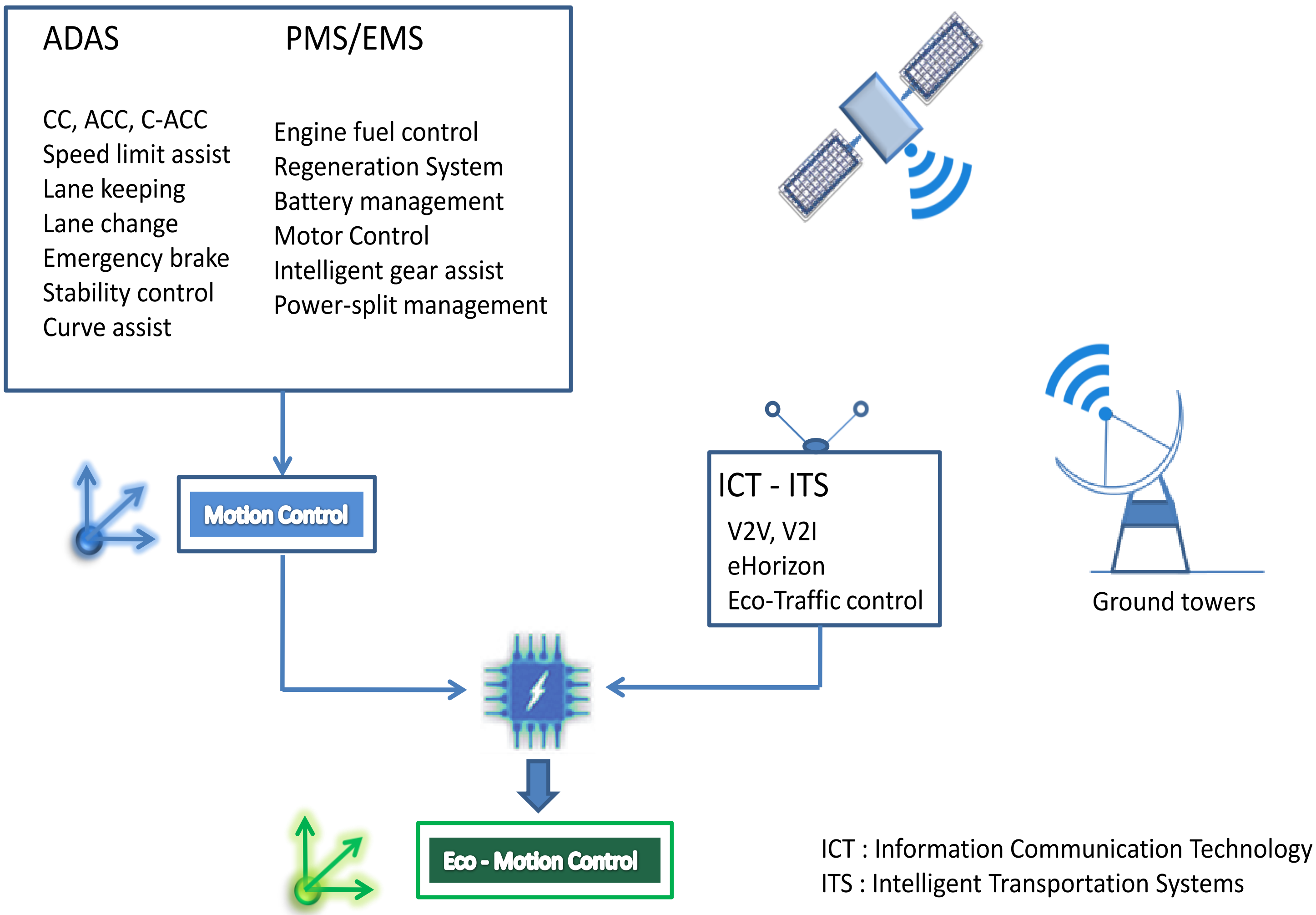
Emergency brake warning

Confirmation for overtaking maneuver

Unavoidable collision warning

Vehicle breakdown warning

eco-Motion Control



Outline of the presentation

- Motivations
- Enhanced ACC
- Module integration
- Simulation / Experimental results and discussion

From ACC to Enhanced ACC

- Conventional ACC
  - Detects the front vehicle
  - Manages speed and relative distance
    - Safety and confort constraints
    - Generate acceleration demand
  - Detailed in ISO norms
- Enhanced ACC
  - Takes into account regenerative aspect during deceleration
  - Does not compromise safety
  - On an Automotive ECU

When can we regenerate?

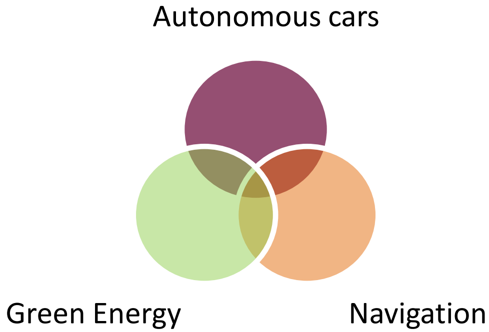
- Regeneration is related with limited braking

Digital Map integration

  - Use case 1 : Speed limit change
  - Use case 2 : Sharp curve that needs speed adaptation
  - Use case 3 : Vehicle following
- Safety aspect
  - Low impact : use case 1 and 2
  - High impact : use case 3

Environment perception enhancement

Smart and Green ACC (SAGA)

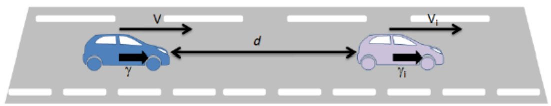


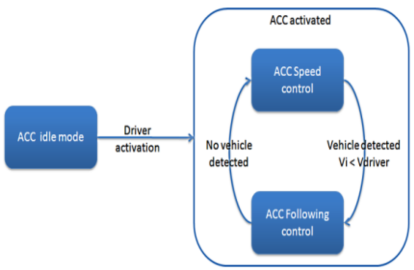
SAGA function is an autonomous longitudinal vehicle motion controller which actively optimizes safety and efficiency

- E-Horizon
- Vehicle position, velocity, altitude, headway spacing…
- Distance to destination, traffic situation, speed limits…
- Gradients, dangerous road curves…
- Energy optimisation and cruise control Green ACC
- SAGA : Complete automatic longitudinal vehicle controller

SAGA concept and applications

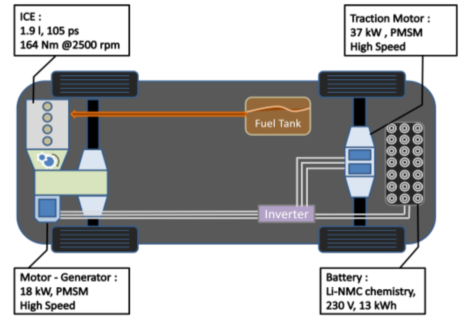
Following Headway: 2 s Sensor range: 150 m



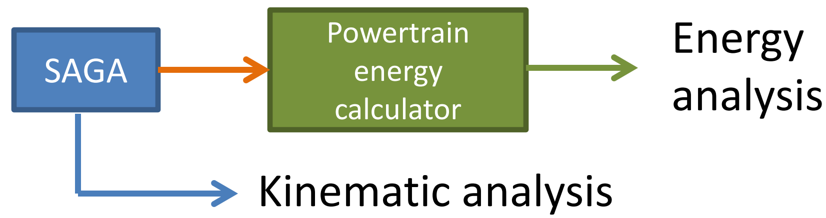


Speed control :
Acceleration : P control
Deceleration: SAGA regulated

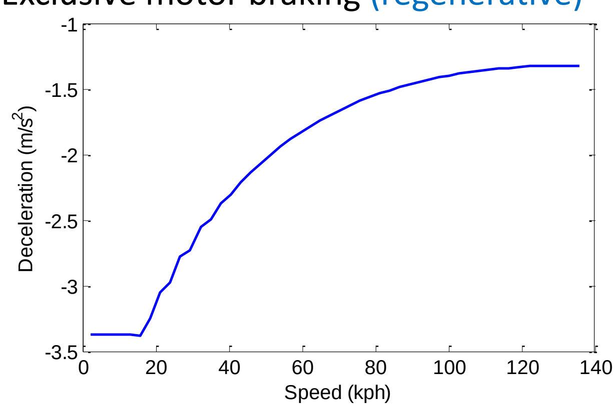
Vehicle following:
Acceleration: front vehicle controlled
Deceleration: SAGA regulated
D_sens: 150 m
Safe Headway: 2s



Through the road (TtR)
HEV : 7 kWh
PHEV : 13 kWh
1550 kg Hybrid
1350 kg Conventional



Exclusive motor braking (regenerative)



Max _deceleration = f(speed)

City driving: Motor braking sufficient
Small energy packets available for regeneration
50 kph to 0 kph -approaching traffic signal

Highway driving:
Motor braking insufficient (optimization required)
Attractive maneuvers for energy recuperation

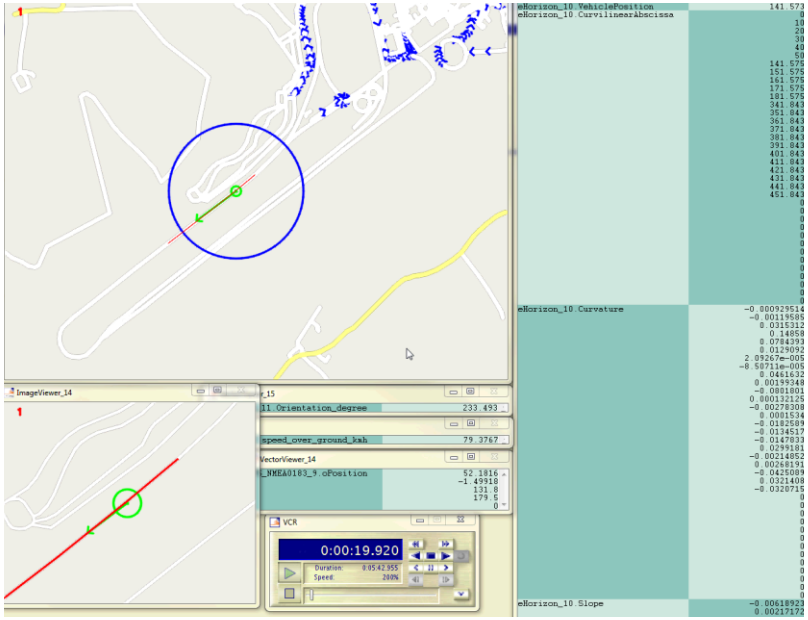
Approaching slow moving vehicle
Approaching speed limits
Approaching a curve

Outline of the presentation

- Motivations
- Enhanced ACC
- Module integration
- Simulation / Experimental results and discussion

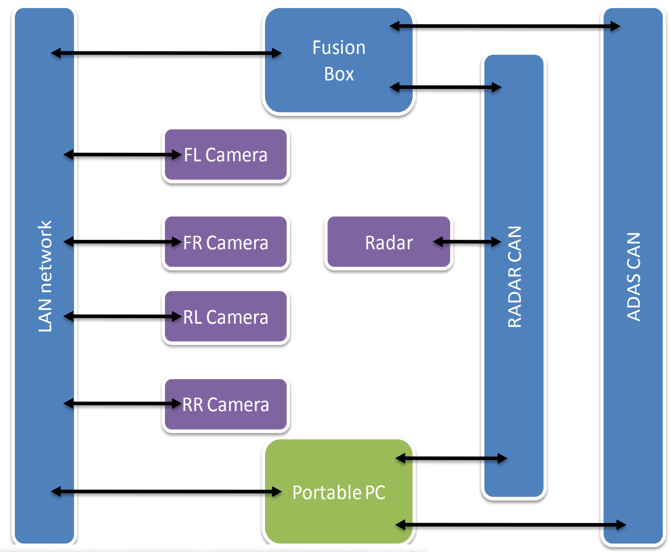
Digital Map integration

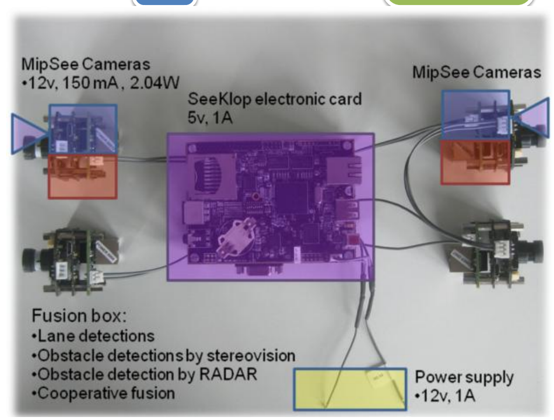
- Vehicle positionning
  - GPS
  - Vehicle sensors
    - Inertial
    - Steering angle
    - Wheel speed
- Digital Map
  - Digital infrastructure supported by caorto
  - Additional data
    - Road geometry
    - Speed limit
  - Automatic process for accurate data



Environment perception

- Front long range radar
  - Continental ARS 300
  - Relative distance and speed of front obstacle
- 4 cameras
  - Lane detection
  - Front near obstacles (stereo)
- Lane association of obstacles





In vehicle integration

Micro-controllers from Hella
integrate control functions (AUTOSAR),
feeded by perception modules

Vehicle from TMETC (modified eVista)

<u>eMotor (x2) :</u>

30 kW PMSM with 750 Nm peak torque
Integrated reduction gear

Outline of the presentation

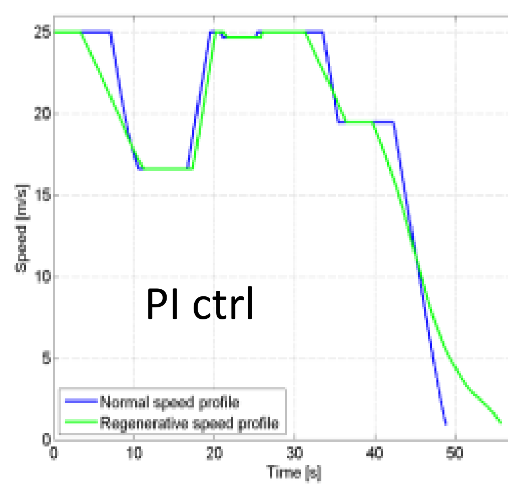
- Motivations
- Enhanced ACC
- Module integration
- Simulation / Experimental results and discussion

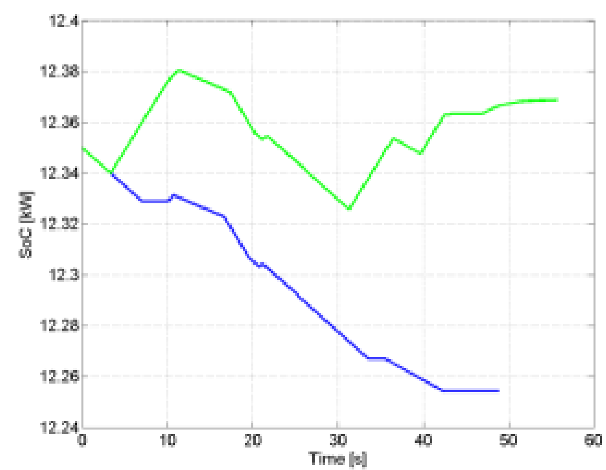
Digital map and speed profile

- Speed is limited by
  - Available road friction
  - Driver desired lateral / longitudinal acceleration
  - Regenerative deceleration

$$\begin{cases} \max\left(\frac{\mu^2_{lat_f}}{\lambda^2_{lat}\mu^2_{max}}+\frac{\mu^2_{lon_f}}{\lambda^2_{lon}\mu^2_{max}}, \frac{\mu^2_{lat_r}}{\lambda^2_{lat}\mu^2_{max}}+\frac{\mu^2_{lon_r}}{\lambda^2_{lon}\mu^2_{max}}\right) = 1 \\ \mu^2_{lon_r}+\mu^2_{lon_f} \le \left(\frac{\gamma_d(V)}{g}\right)^2 \quad (during\ deceleration) \end{cases}$$

$$\begin{cases} V^2 = \frac{g}{\rho_r}\left(\left(1-\frac{H}{L_f}\theta_r\right)\sqrt{\left(1-\frac{\theta_r}{\lambda_{lon}\mu_{max}}\right)}\lambda_{lat}\mu_{max} - \varphi_r\right) \\ 1 = \left(\frac{1}{\lambda_{lat}\mu_{max}}\frac{\frac{\rho_r V^2}{g}+\varphi_r}{1-\frac{H}{L_f}\left(\frac{V}{g}\frac{dV}{ds}-\theta_r\right)}\right)^2 + \left(\frac{1}{\lambda_{lat}\mu_{max}}\left(\frac{V}{g}\frac{dV}{ds}-\theta_r\right)\right)^2 \end{cases}$$

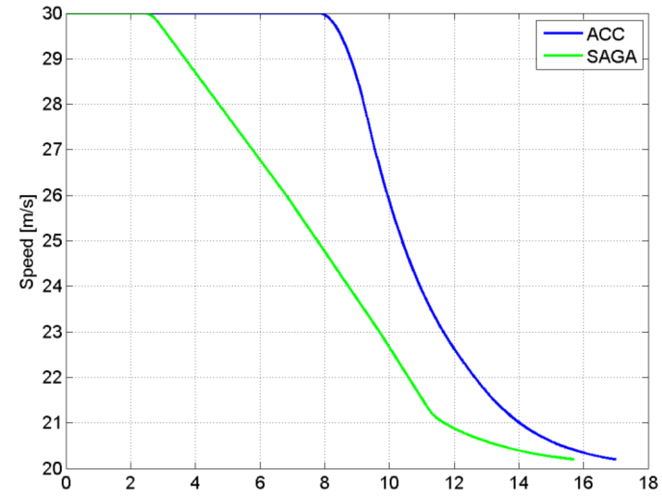


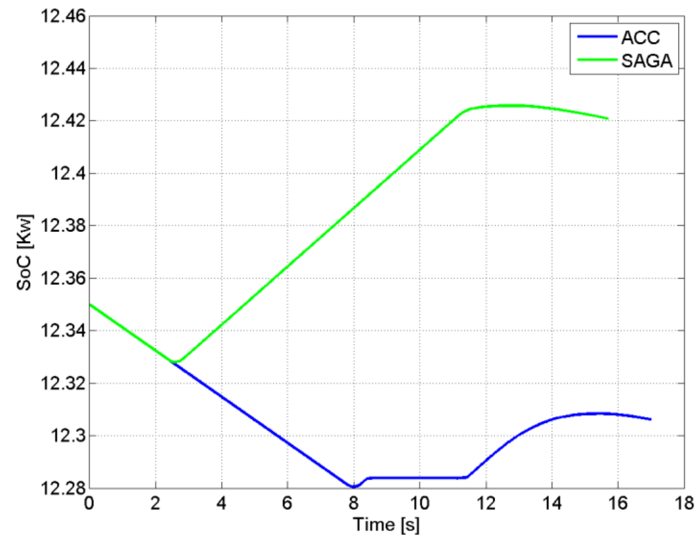


Perception and dist. regulation

- Several strategies are evaluated and must achieve safety constraints
  - Only regenerative braking
    - long time headway
  - Regenerative braking and Emergency braking
    - headway close to ACC headway,
    - strong deceleration
  - Regenerative braking and conventional braking
    - Acceptable time headway

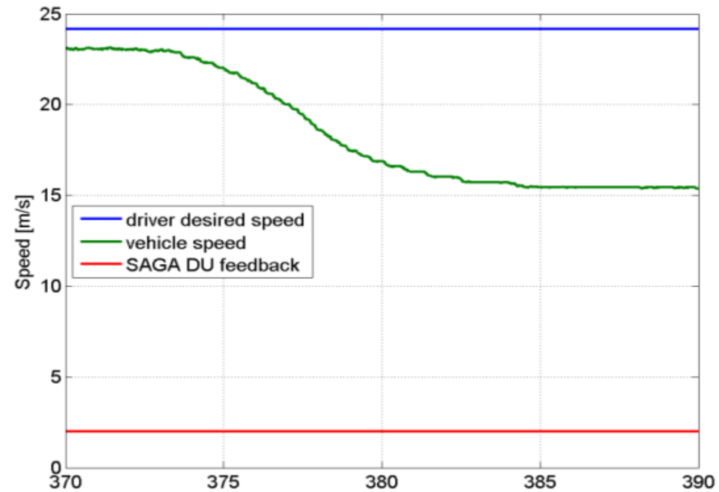
Vehicle following a slower vehicle

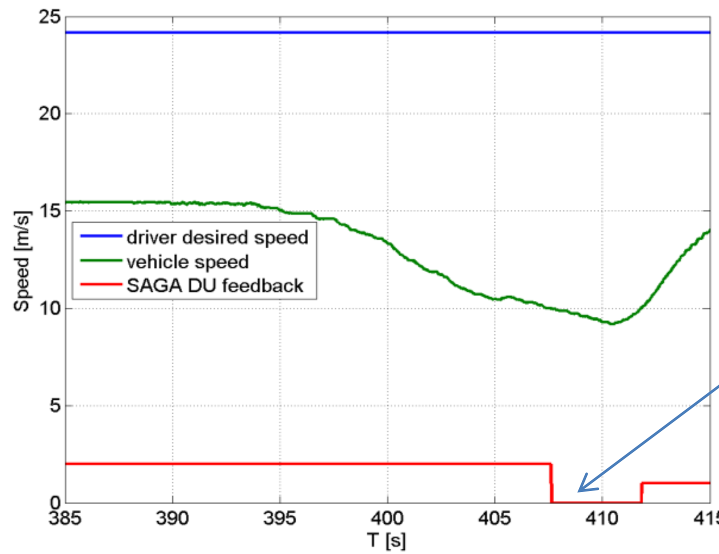




In vehicle integration

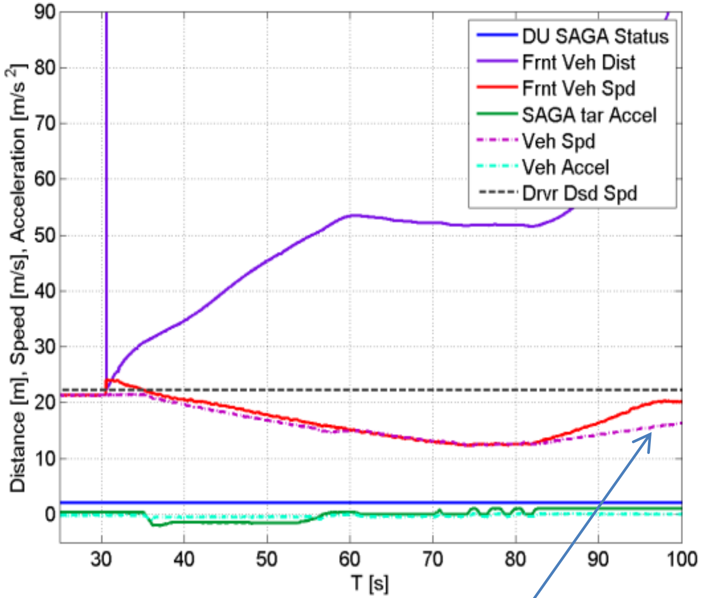
- Speed profile impact
  - Speed limit change from 90 to 50 km/h
    - Smooth deceleration generated by the controller using information from digital map
  - Sharp curve
    - Computation of safe speed, deceleration to reach it, out of the speed range





SAGA desactivated (v < 10)

In vehicle integration



SAGA decelerates lower than lead vehicle for enrgy efficiency reason

- A front vehicle cuts in our lane
  - Deceleration (smooth) to reach safe distance
  - Acceleration of the lead vehicle, our vehicle accelerates (small acceleration)

Smart and Green ACC: Results and Strategies

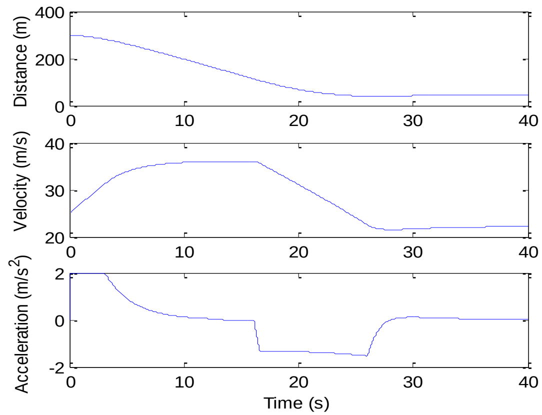
SAGA deceleration 130 - 80 kph, pure motor braking

Sensing distance = 150 m, safe headway 2 s

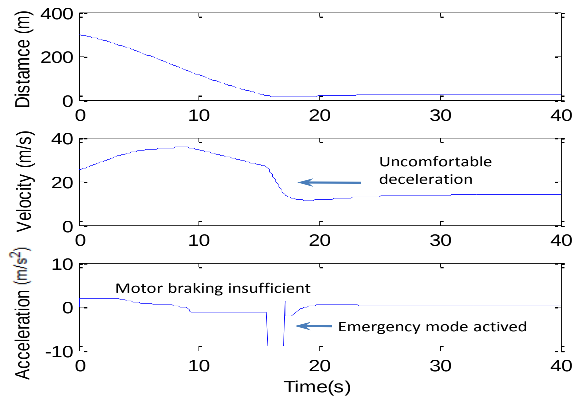
Headway distance

Ego vehicle velocity

Ego vehicle Acceleration



SAGA deceleration 130 - 50 kph, threshold braking, Emergency mode below 1.5s



Threshold braking

Use motor brake exclusively

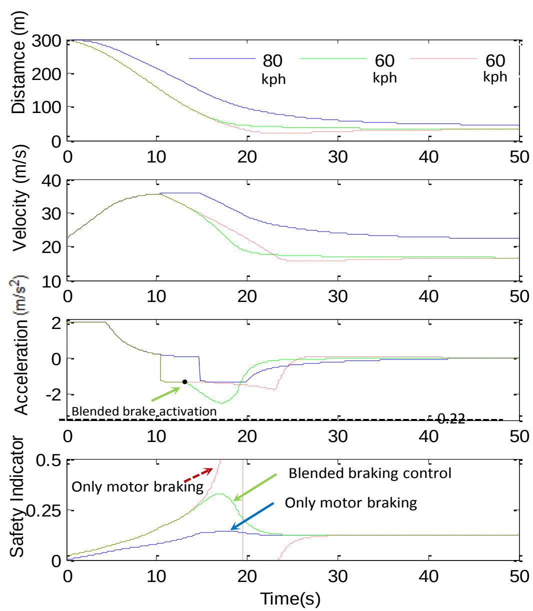
If headway falls below 1.5 s apply emergency brakes

Blended braking 130 kph – 80/60 kph

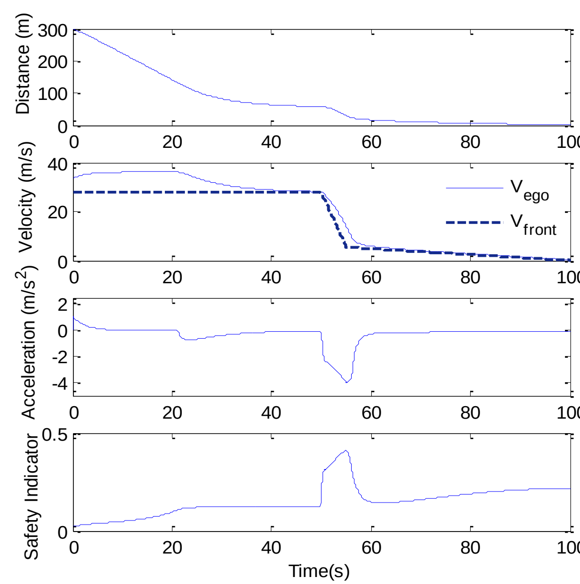
Use motor brake exclusively at entry

Constantly evaluate the safety status with Safety Indicator (S.I.)

At S.I. limit of 0.22 supply excess deceleration by blending motor and conventional braking



SAGA deceleration, sudden front vehicle braking



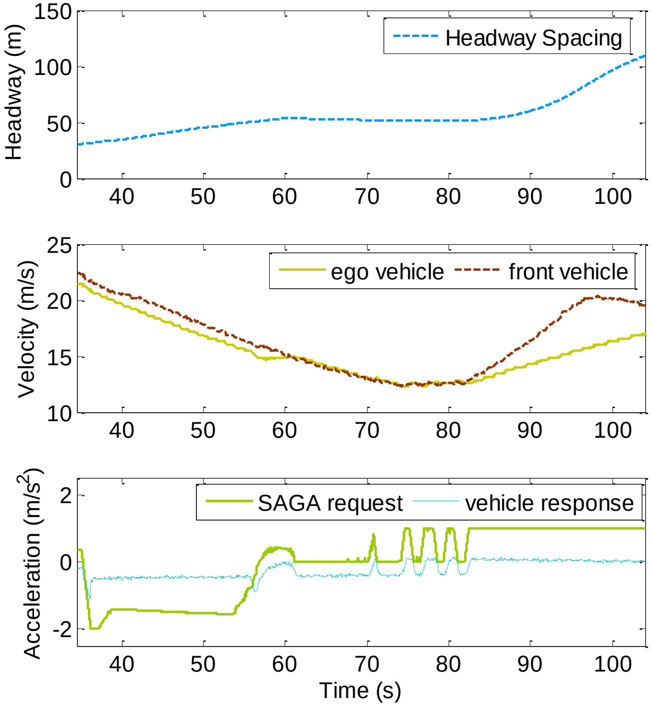
Blended braking strategy test for sudden deceleration of front vehicle

Speed equalisation @ 100 kph

Front vehicle decelerates intensively till 30 kph in 5 s

SAGA successfully manages the maneuver without compromising safety

Smart and Green ACC: Testing



Demonstrated the functional behaviour of SAGA system

- Front vehicle detected
- Deceleration command
- Following mode

Conclusion

- Energy optimized ADAS function, taking into account safety and energy efficiency
- Integrated in car ECU
- Enhanced perception and Digital Map integration

- Evaluation of green ADAS and engine test cycle (NEDC…) ?

References

Sagar Akhegaonkar, Sebastien Glaser, Lydie Nouveliere, Frederic Holzmann, "Smart and Green ACC: As Applied to a Through the Road Hybrid Electric Vehicle", Advanced Microsystems for Automotive Applications 2014 - Smart Systems for Safe, Clean and Automated Vehicles, Springer International Publishing, pp 15-27, ISBN No: 978-3-319-08086-4, 2014.

Sebastien Glaser, Sagar Akhegaonkar, Olivier Orfila, Lydie Nouveliere, Frederic Holzmann, "Smart And Green ACC, Safety and efficiency for a longitudinal driving assistance", Advanced Microsystems for Automotive Applications 2013 - Smart Systems for Safe and Green Vehicles, pp 123-135, ISBN No: 978-3-319-00476-1, 2013.

R. Potarusov, L. Nouvelière, O. Orfila, S. Glaser, "Smart and green adaptive cruise control for an electric vehicle: first results", 7th IFAC Conference on Manufacturing Modelling, Management, and Control, Volume VII, Part I, pp 596-601 – ISBN No 978-3-902823-35-9, ISSN No 1474-6670, 2013.

lydie.nouveliere@ibisc.univ-evry.fr