interactIVe

Accident avoidance by active intervention for Intelligent Vehicles

Vehicle Dynamics Model & Path Stability Control Algorithms

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interactIVe Final Event

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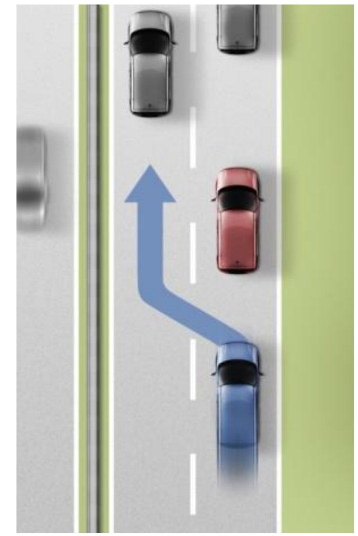
Introduction - integrated collision avoidance and vehicle path control for passenger cars and commercial vehicles

- Development of integrated collision avoidance (INCA) and vehicle path control for passenger cars and commercial vehicles.
- “Vehicle path control” module dynamically evaluates a collision free trajectory in rapidly changing driving scenarios.
- 3 demonstrator vehicles:
  - Ford Focus
  - Volvo S60
  - Volvo FH13



- Partners:

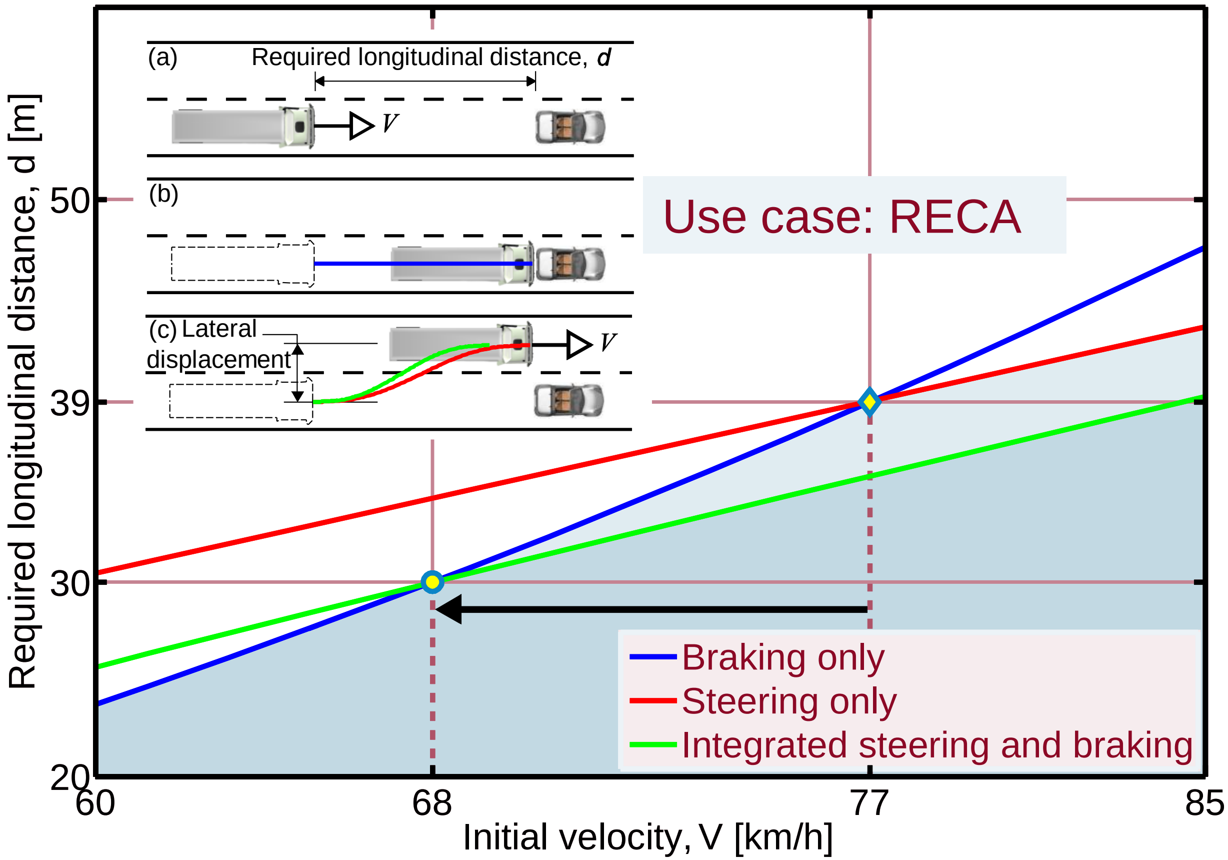
CHALMERS, Ford, ICCS, VOLVO, VOLVO, DELPHI

Introduction - use cases

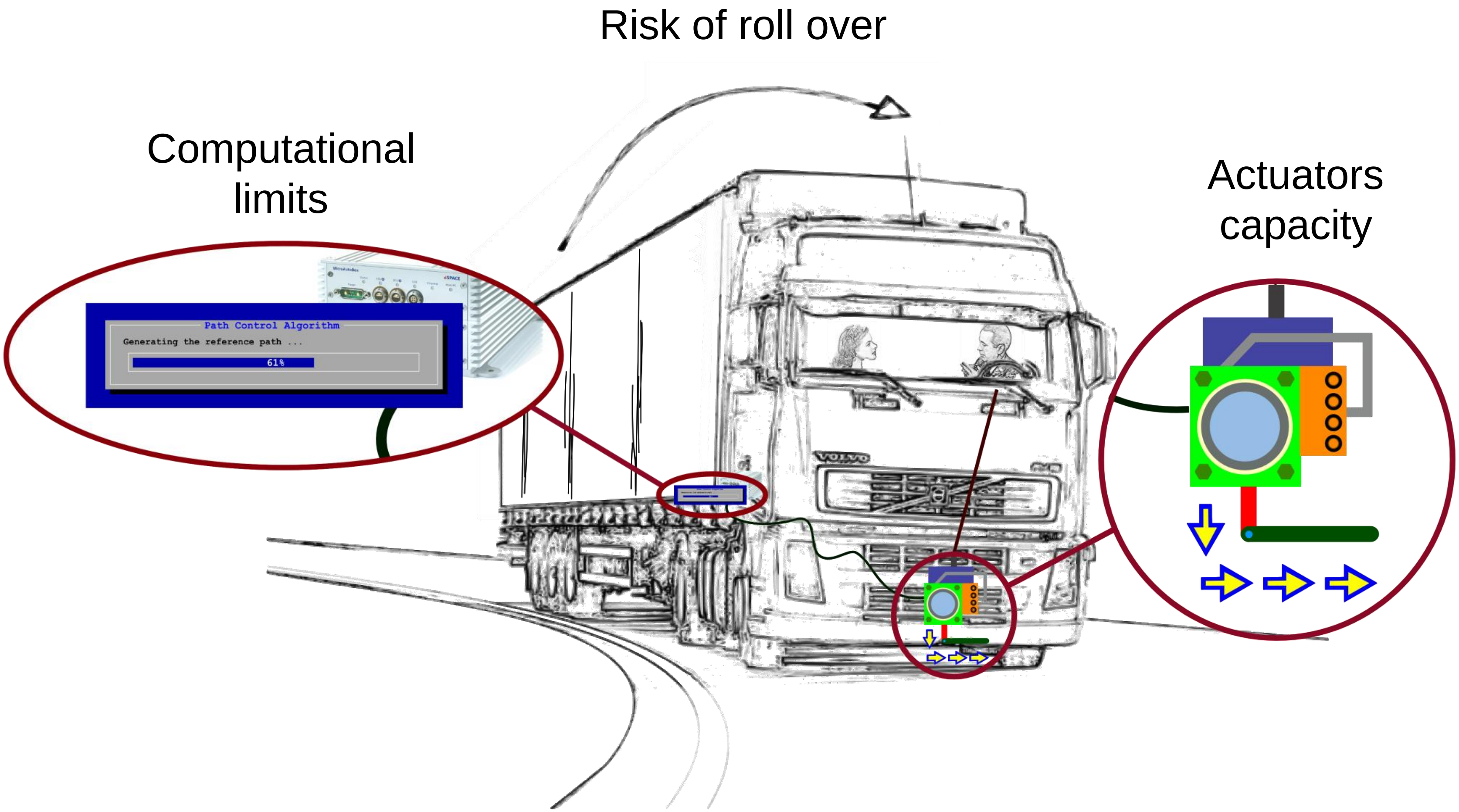
- Description of specific sequence of interactions between the driver and truck to achieve a specific goal.
- Functional requirements for the integrated collision avoidance applications,
- Prioritization based on:
    - accident statistics
    - use case complexity
- Generic intervention solution can be found in the prioritized use cases:
    - Rear-end collision avoidance (RECA)
    - Run-off road prevention (RoRP) on a straight road
    - Run-off road prevention (RoRP) in a curve

Introduction - motivations and challenges; actuator configurations

Performance of actuator configurations.

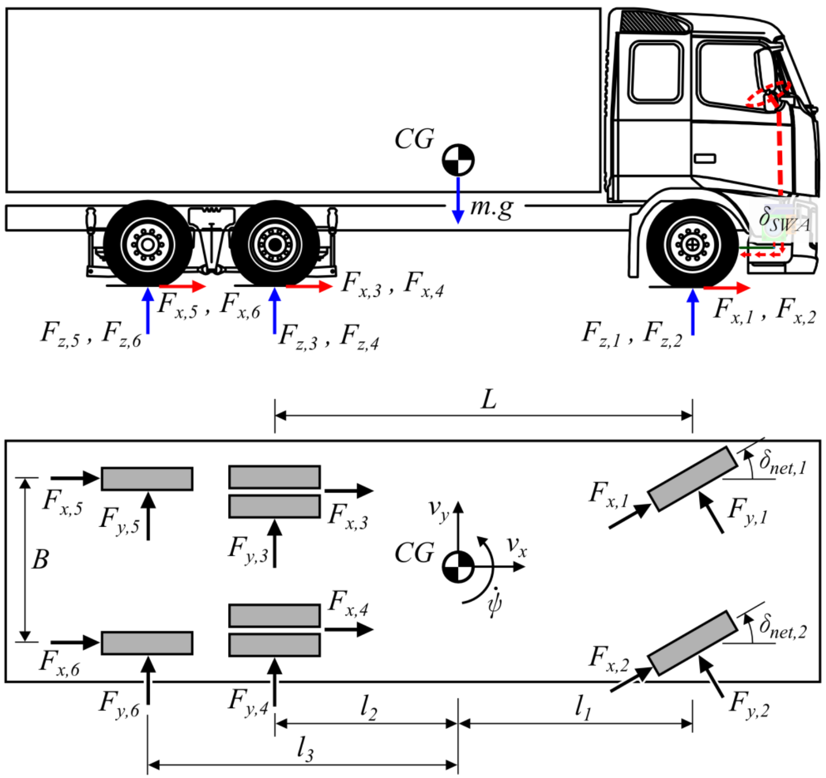


Introduction - motivations and challenges; practical constraints



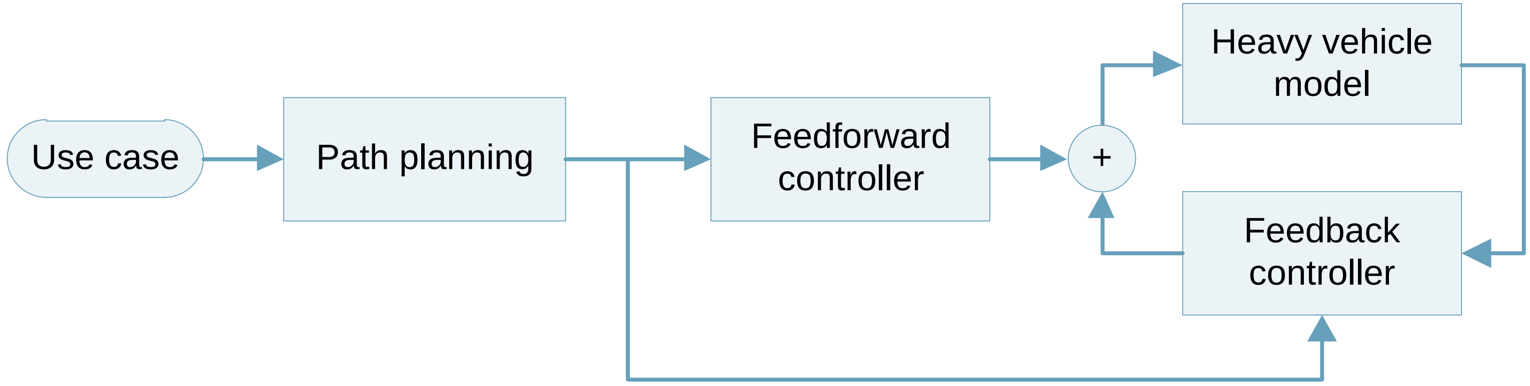
Heavy vehicle system dynamics

- A two-track vehicle model is used that:
  - captures the main dynamical properties of planar motion,
  - is customized for the current work.
- A simplified combined slip nonlinear tyre model that is suitable for investigating integrated steering and braking.

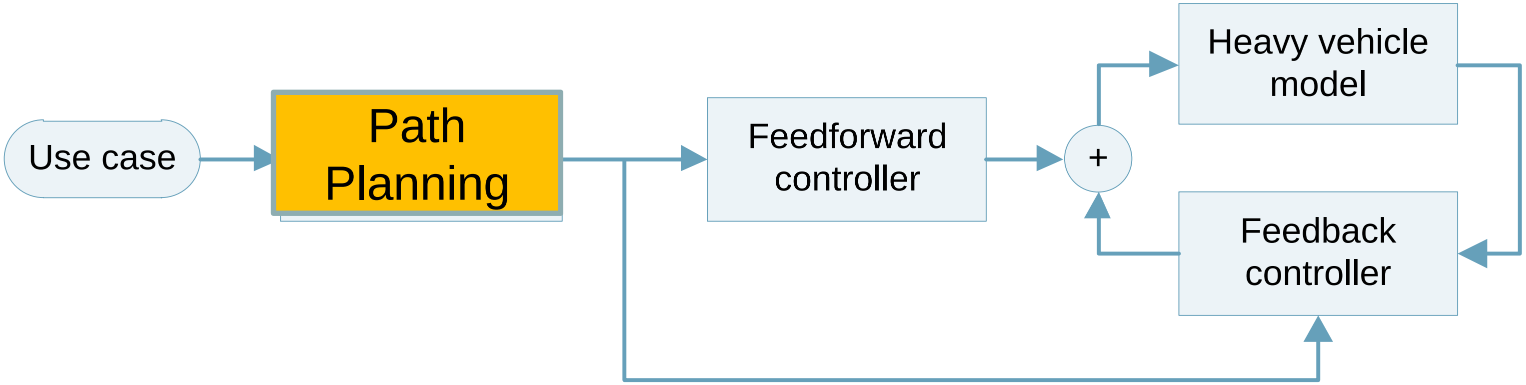


Path control algorithms - overview

- Path planning generates a reference path (considering roll over risk, actuators capacity, and computational limits).
- Feedforward steering input is calculated using a steady state one-track model and the reference path.
- Feedback controller with a lookahead concept implementation compensates for disturbances, unmodeled dynamics, and uncertainties.
- General overview of the whole algorithm:



Path control algorithms - path planning



Path control algorithms - path planning

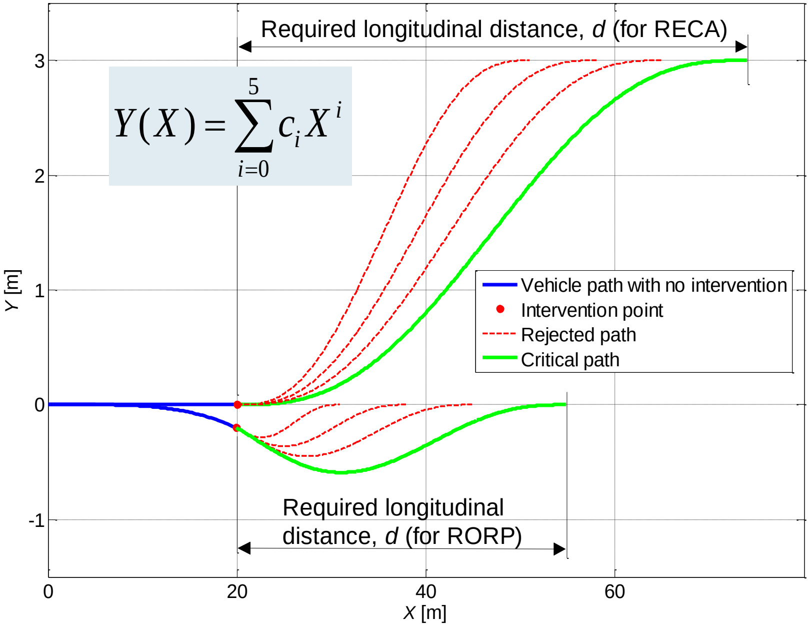
- Feasibility path:
  Steady state one-track model is used to consider constraints for planar motion on the reference path $Y(X)$:

$$R = \frac{\sqrt{(1+Y'^2)^3}}{Y''} \qquad a_y = \frac{V^2}{R}$$

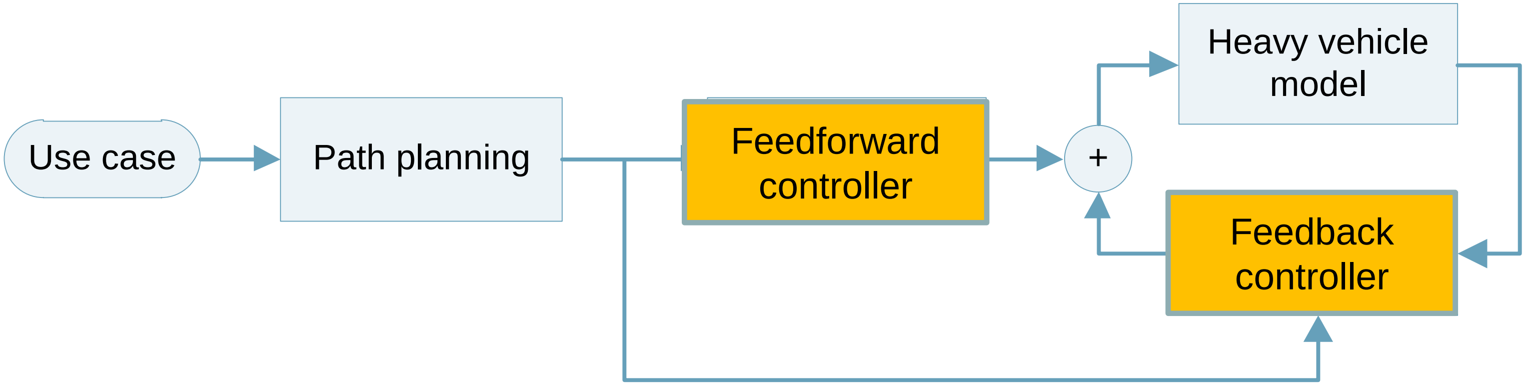
$$\delta = \frac{l_e}{R} + K_{us}\frac{a_y}{g} \qquad \dot{\delta} = V\frac{d\delta}{dX}$$

- Critical path:
  The shortest feasible escape path is determined through an iterative procedure.

Constraint	Value
Max. lateral acceleration, $a_{y,\max}$	3 m/s2
Max. steering wheel angle, $\delta_{\max}$	800 deg
Max. steering wheel angle rate, $\dot{\delta}_{\max}$	430 deg/s
Max. torque on the steering actuator, $T_{\max}$	25 Nm



Path control algorithms - feedforward and feedback controller



Path control algorithms - feedforward and feedback controller

- Feedforward control:
  Steady state one-track model is used to calculate the steering input:

$$\delta_{\mathrm{FF}} = \frac{l_e}{R_{\mathrm{ref}}} + K_e \frac{a_{y,\mathrm{ref}}}{g}$$

where

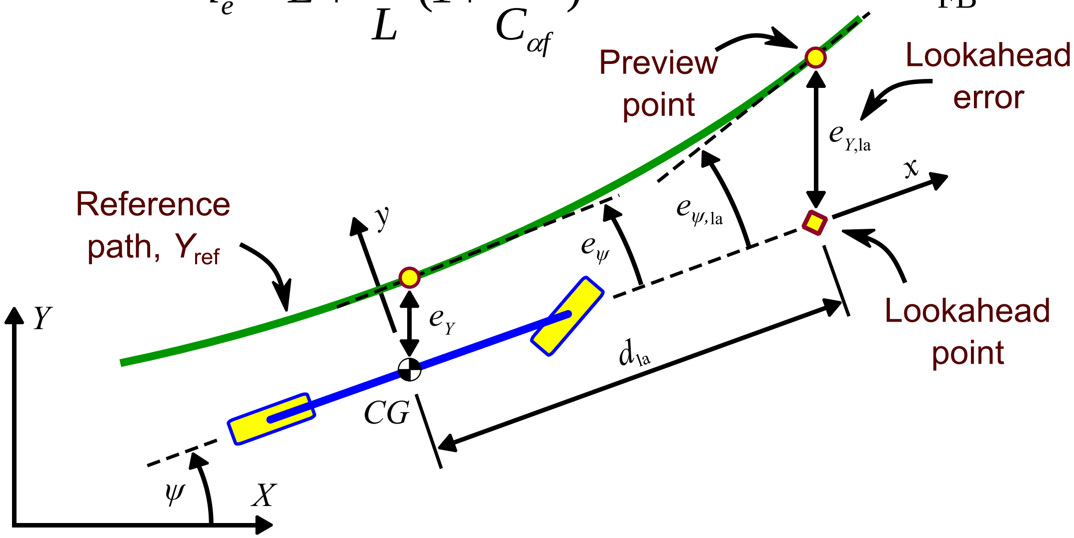
$$l_e = L + \frac{\Delta^2}{L}\left(1 + \frac{C_{\alpha r}}{C_{\alpha f}}\right)$$

- Feedback control:
  Lateral position PID control:

$$\delta_{\mathrm{FB}}^{Y} = K_{PY} e_{Y,\mathrm{la}} + K_{IY} \int e_{Y,\mathrm{la}} d\tau + K_{DY} \dot{e}_{Y,\mathrm{la}}$$

Yaw angle PD control:

$$\delta_{\mathrm{FB}}^{\psi} = K_{P\psi} e_{\psi,\mathrm{la}} + K_{D\psi} \dot{e}_{\psi,\mathrm{la}}$$

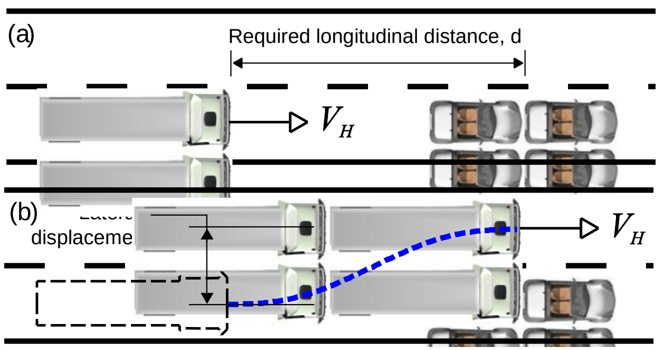


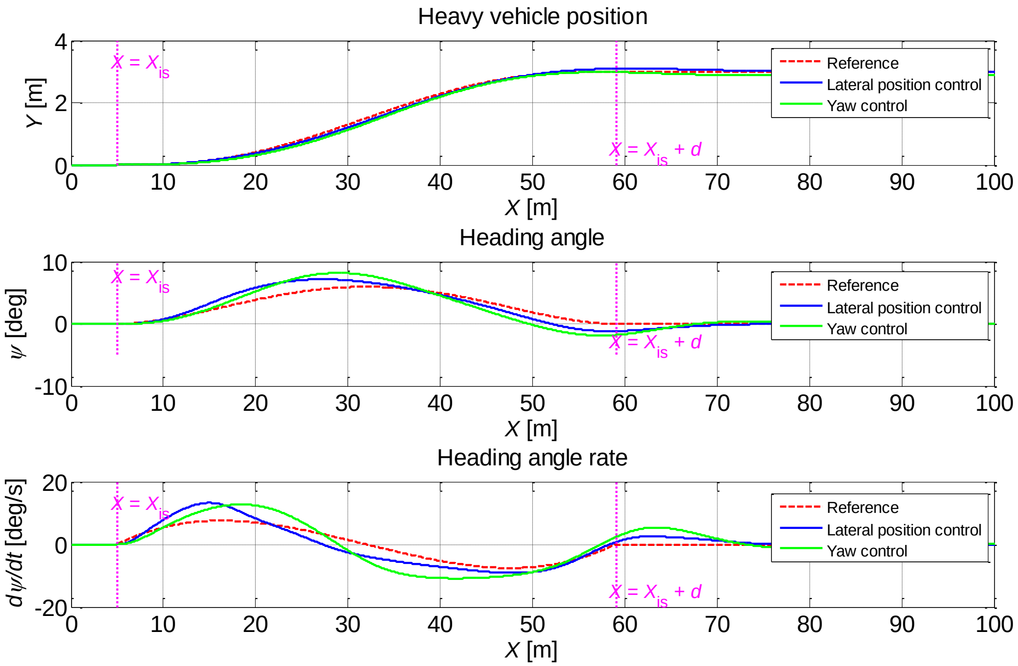
Total feedback:

$$\delta_{\mathrm{FB}} = \delta_{\mathrm{FB}}^{Y} + \delta_{\mathrm{FB}}^{\psi}$$

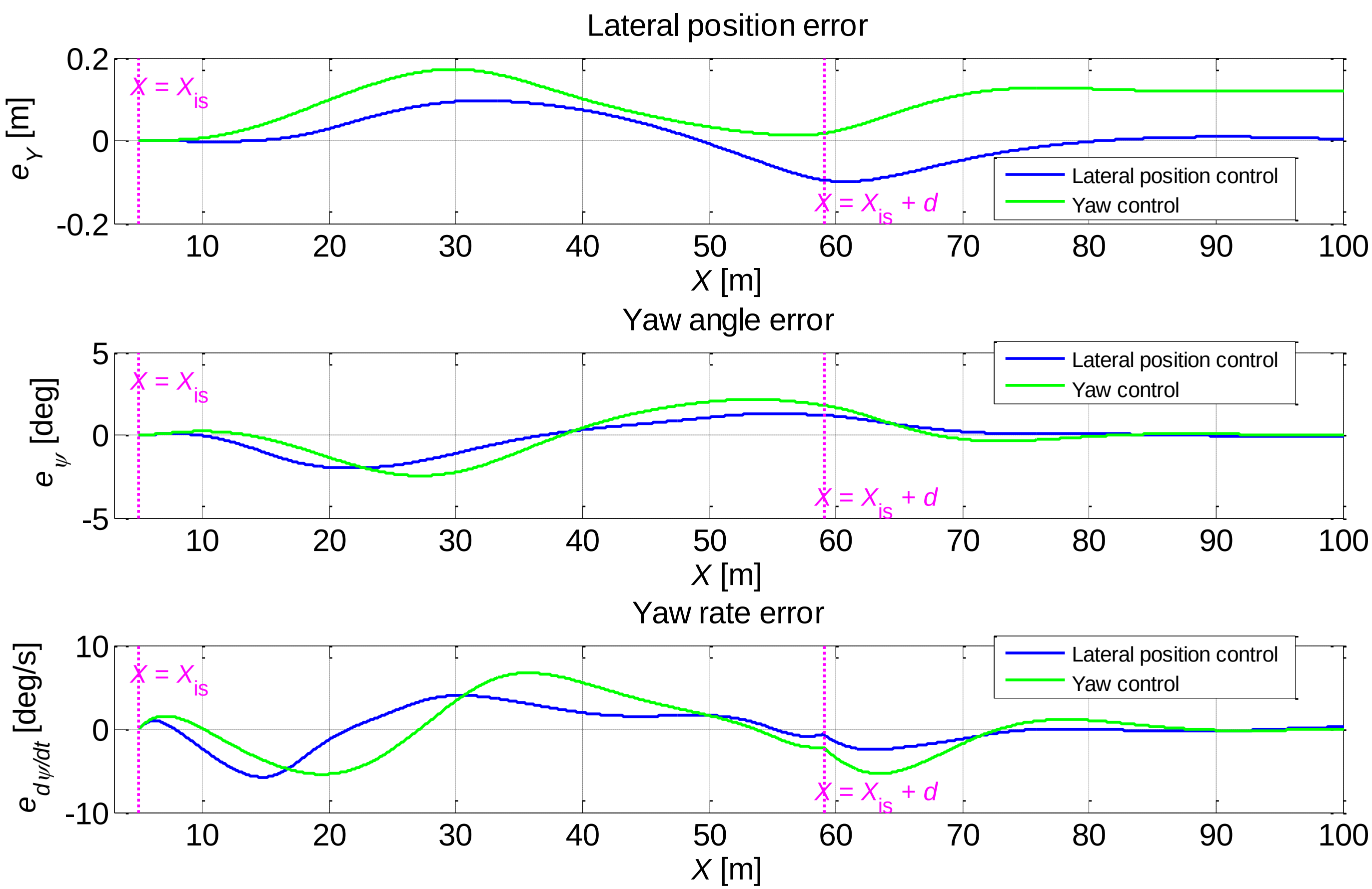
Simulation results - RECA manoeuvre by steering

- Rear-end collision avoidance by steering: a single lane change manoeuvre.
- Speed: V_H = 80 km/h
- Lateral displacement: b = 3 m
- In order to add safety margin to the manoeuvre, required longitudinal distance can be increased.

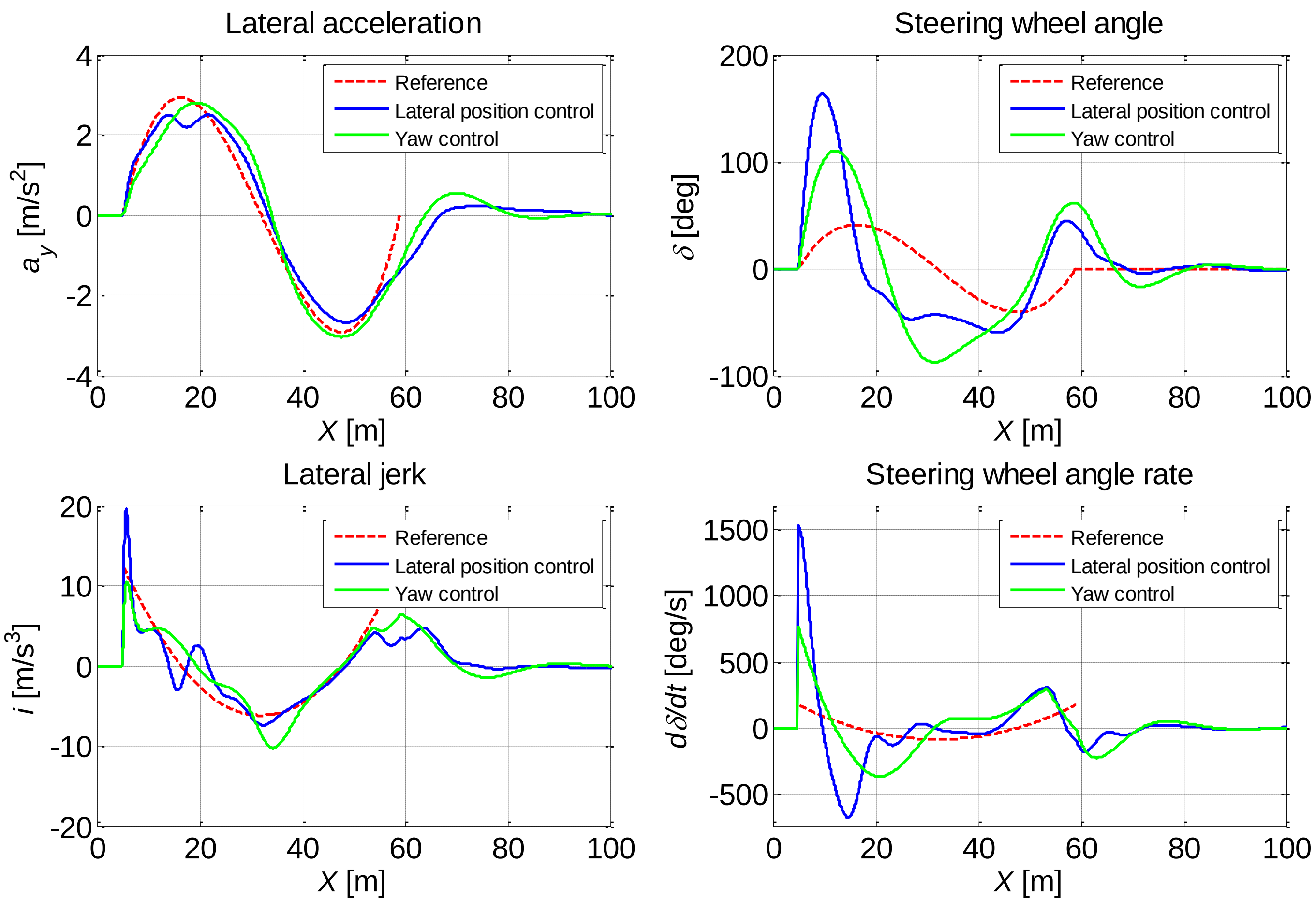




Simulation results - RECA manoeuvre by steering; position & yaw errors



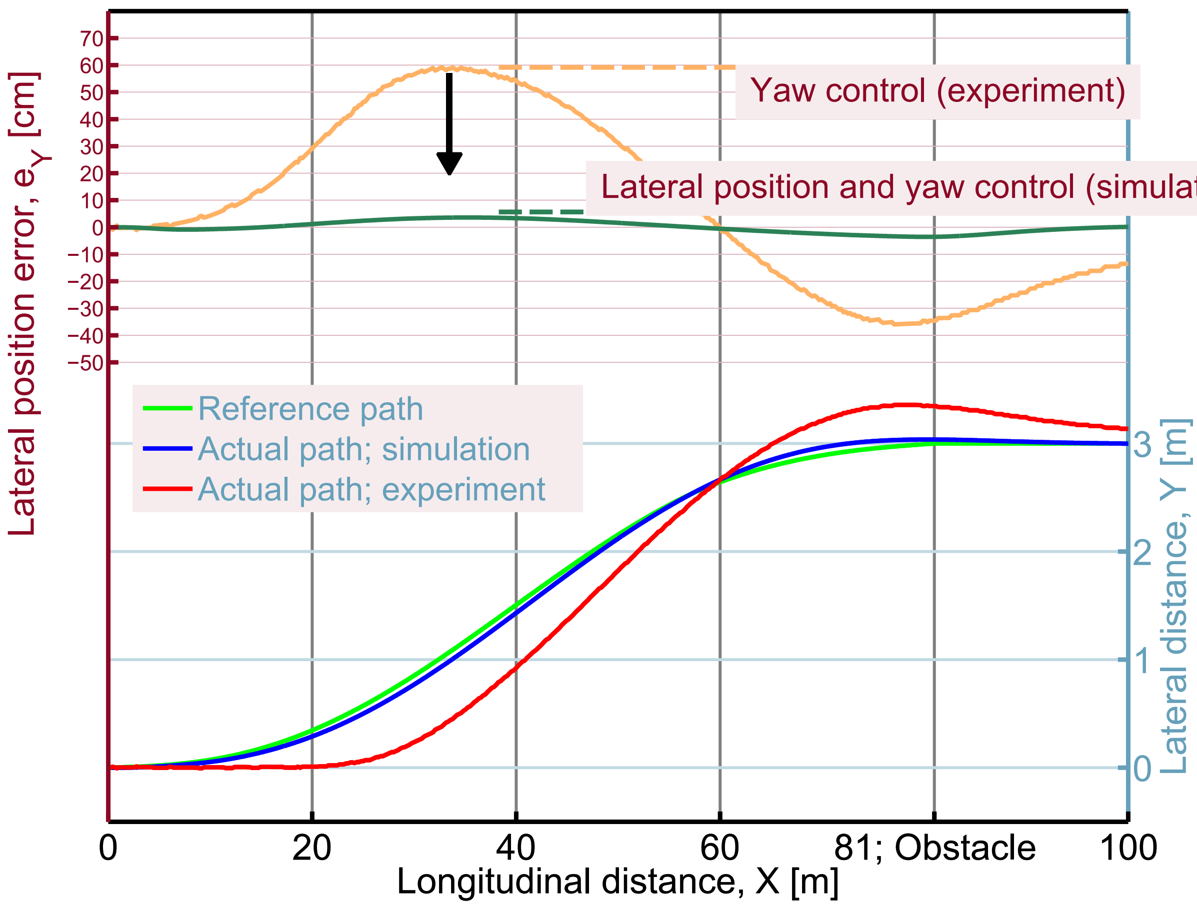
Simulation results - RECA manoeuvre by steering; vehicle states



Experiments - overview

- A series of tests were performed in the handling area of the Hällered Proving Ground.
- One of the experiments is also simulated in simulation environment with the same parameter settings, and the results are compared.
- The controller in simulation environment benefits by the lateral position information and can give the best results whereas the feedback controller in truck has access only to limited in-vehicle information, *i.e.* yaw rate.

Experiments - comparing test data with simulation (50% safety margin)



Future work

- Implement the lateral displacement controller in a truck or high fidelity simulation model and evaluate the performance.
- Consider transient feedforward control.
- Further validation of the path controller with a high fidelity simulation model.
- Thorough investigation of the integrated steering and braking, and corresponding validation through experiments.
- Follow up publication of the latest achievements.

Conclusions

- A heavy vehicle system dynamics model together with a robust path controller are developed as a simulation tool. The tool is flexible and can easily be extended for future studies and investigations.
- The yaw controller is implemented on the demonstrator truck, and successful experiments are performed for two use cases, RECA and RoRP on a straight road.
- Earlier achievements of the work resulted in a publication in IEEE Intelligent Vehicle Symposium, 2012.
- Deliverable D5.1 | Vehicle Dynamics Model & Path Stability Control Algorithms, is public and available for download on the interactIVe website http://www.interactive-ip.eu/publications/deliverables

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Accident avoidance by active intervention for Intelligent Vehicles

Thank you.

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SEVENTH FRAMEWORK PROGRAMME

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