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Accident avoidance by active intervention for Intelligent Vehicles

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Collision Avoidance based on Camera and Radar Fusion

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interactIVe Summer School

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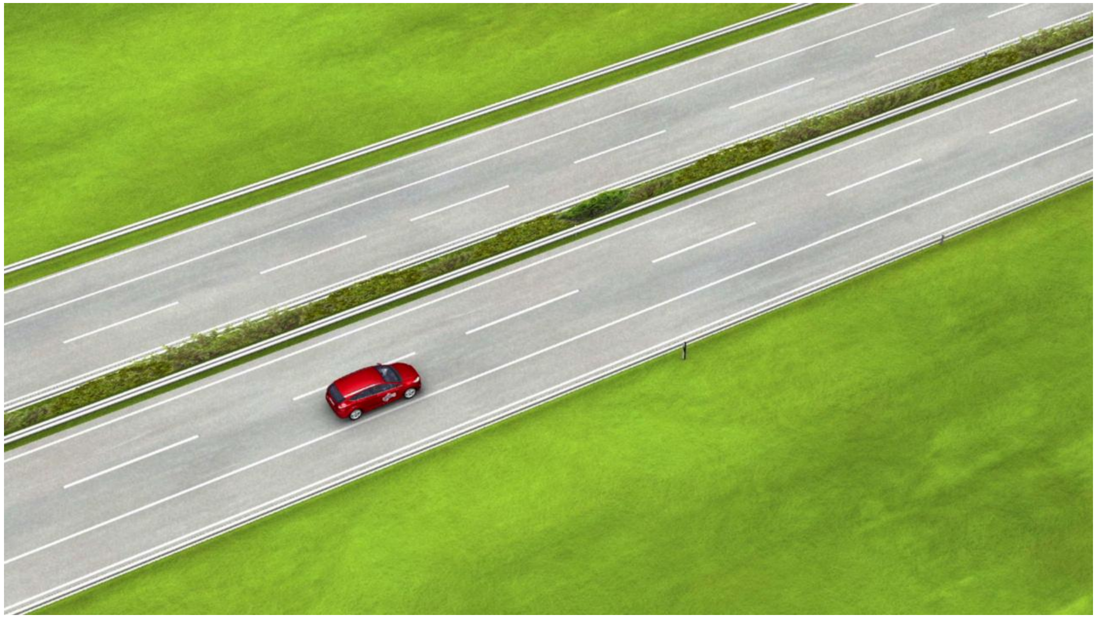
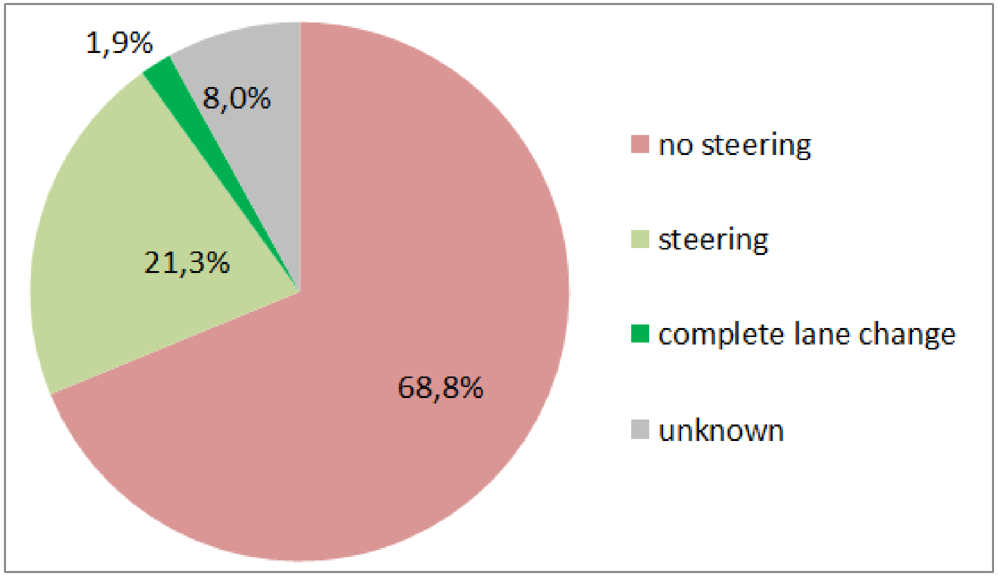
Agenda

- Motivation
- Perception requirements for collision avoidance
- Situation classification and threat assessment
- Longitudinal and lateral control
- Implementation of collision avoidance in interactIVe test vehicle
- Summary



Evasive Steering in Rear End Collisions, GIDAS Data

- Analysis of the German In-Depth Accident Study, GIDAS indicate, that from all accidents resulting in personal injuries about **10%** are frontal collisions of passenger cars against the rear of another vehicle

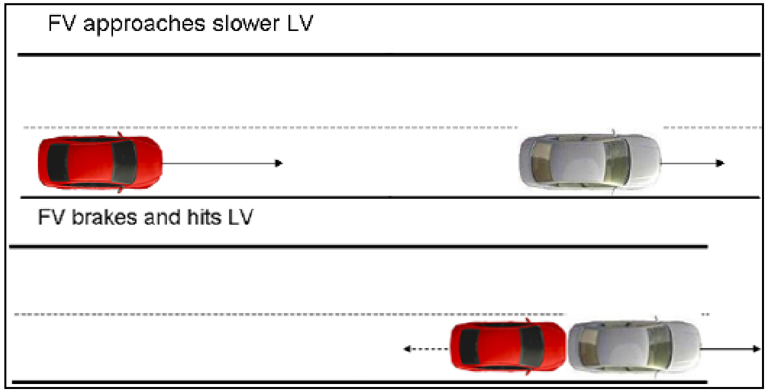


Less than one quarter of the following car drivers involved in these accidents tried to avoid the collision by steering

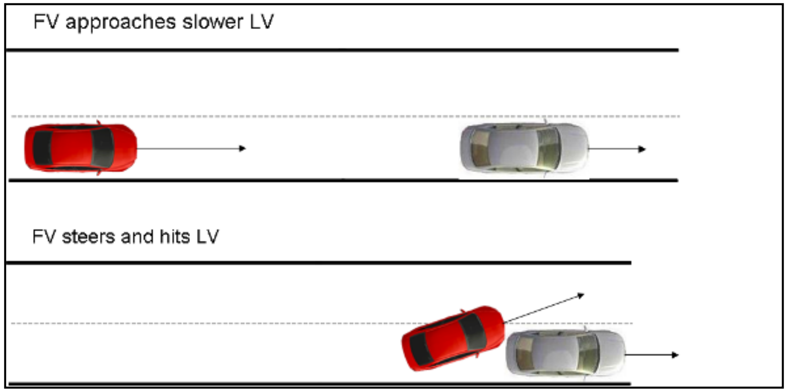
From accident data obviously no statement can be derived about successfulness of evasion maneuver

Rear End Collision Avoidance Accident Scenarios

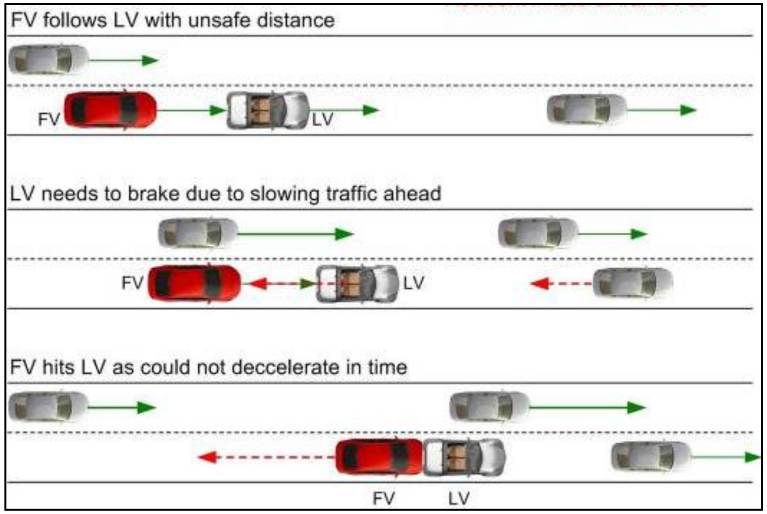
- Late Reaction - Braking



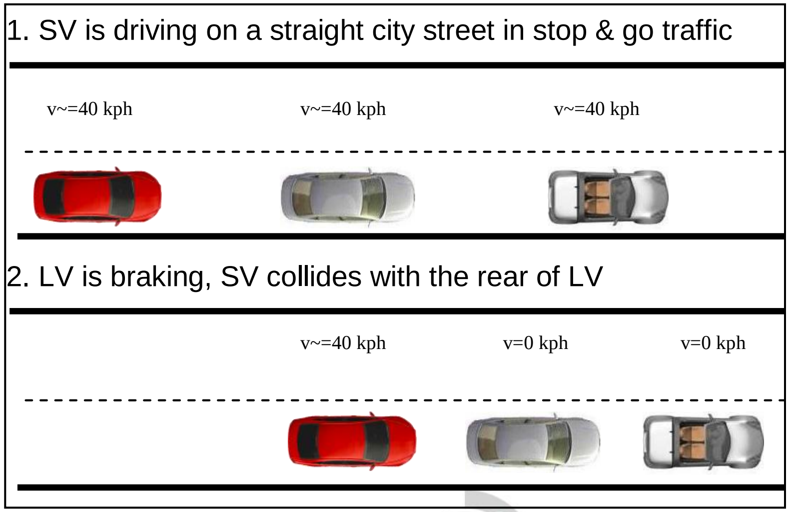
- Late Reaction - Steering



- Following Distance too low



- No Reaction



Perception Requiements

- Reliable detection and tracking of target (incl. stationary targets)
- Relevant Information about target
  - Distance (<150 m)
  - Relative longitudinal velocity
  - Relative longitudinal acceleration
  - Relative lateral distance
  - Relative lateral velocity
  - Target width

  neither radar only or camera only can provide all information with required accuracy ➔ radar and camera fusion
- Other important information
  - Side objects availability and motion state
  - Road class and geometry
  - Lane information
  - Host vehicle motion state
  - Road friction coefficient

Situation Classification and Threat Assessment

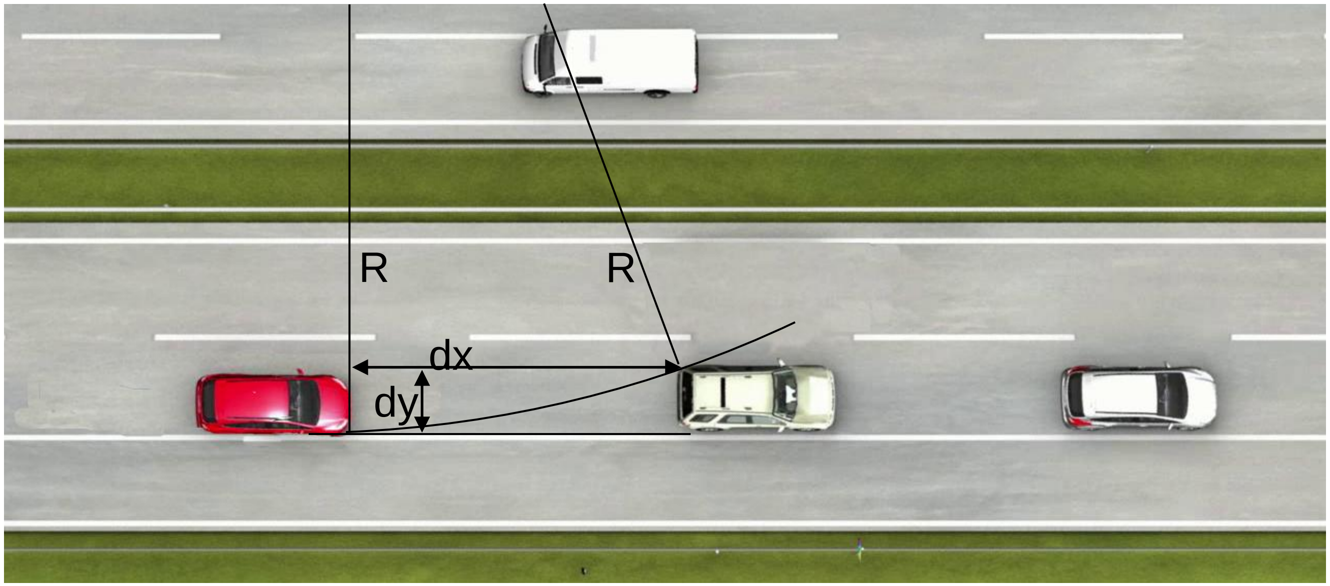
- For each object detected the last point in distance is determined
  - where a rear end collision can be avoided by braking
  - where a rear end collision can be avoided by steering

- The most critical object is the one with the highest last braking / last steering distance

- Determined values can be compared to driver's last braking / last steering distance from driver study on driver behavior in rear end collision situations (see presentation in T04)

Examplary Determination of last Steering Distance for a Stationary Target

Examplary Determination of last Braking/Steering Distance for a Stationary Target



$$R^2 = dx^2 + (R - dy)^2$$

$$\Rightarrow dx = \sqrt{2Rdy - dy^2}$$

$$R = \frac{v^2}{a_{\max}} = \frac{v^2}{\mu \cdot g}$$

$$\Rightarrow dx_{steering} = \sqrt{2\frac{v^2}{a_{\max}}dy - dy^2}$$

$$dx_{braking} = \frac{v^2}{2a_{\max}}$$

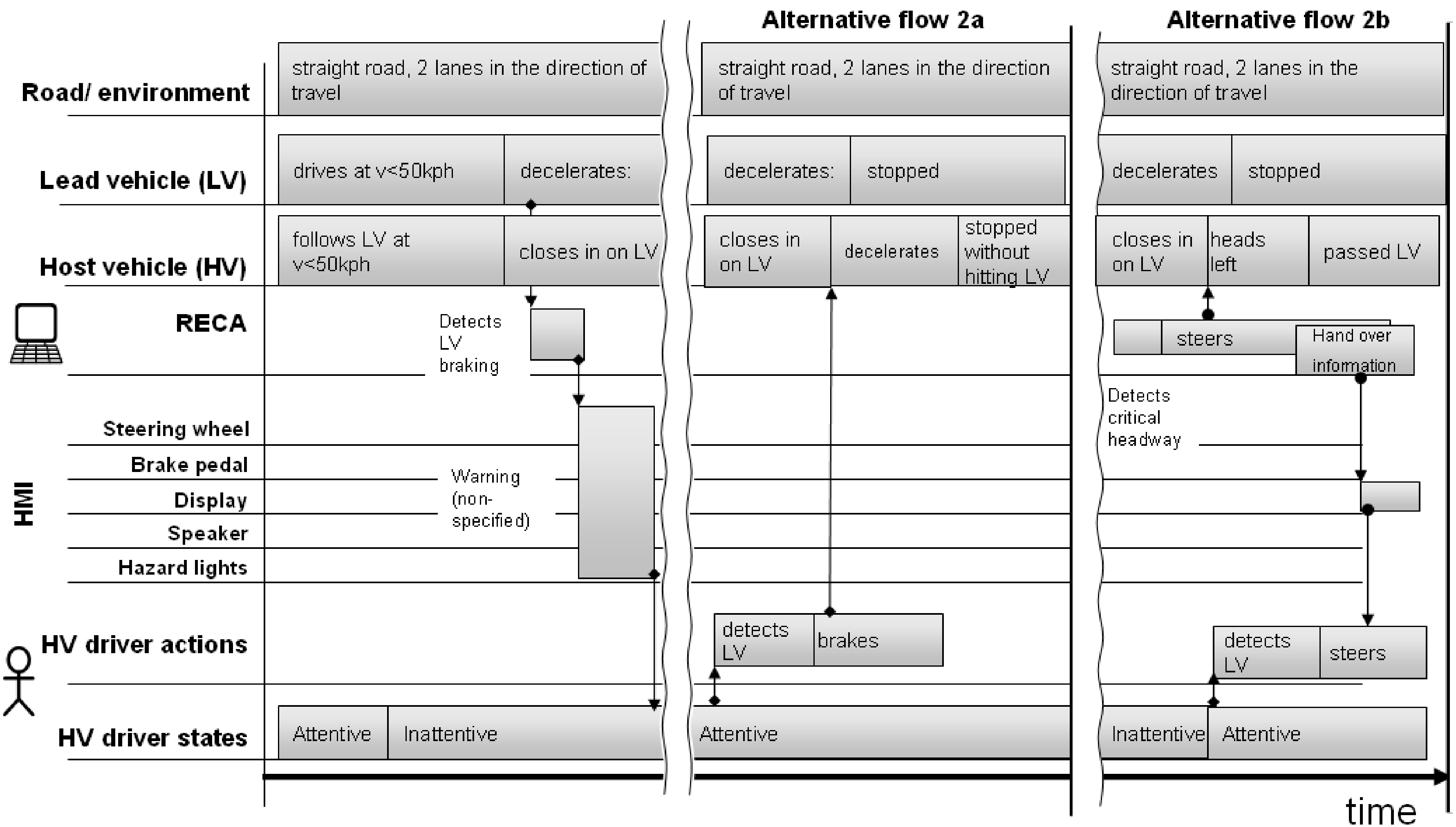
with $a_{\max} = \mu \cdot g$

Longitudinal and Lateral Control

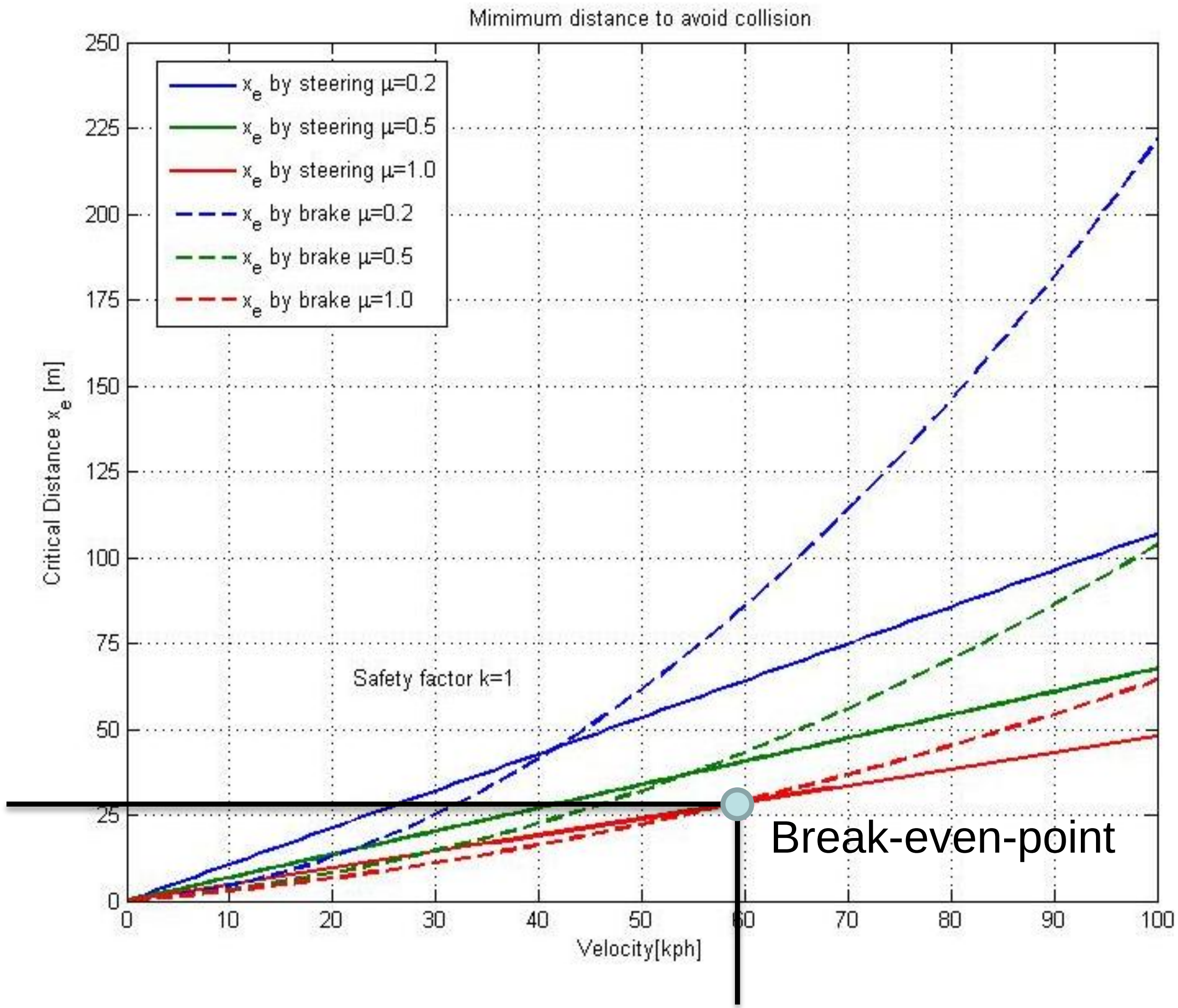
- Once an imminent threat is identified different actions can be considered:
  - Warning the driver
    - Visual warning (e.g. LED bar)
    - Acoustic warning
    - Haptic warning (e.g. force feedback accelerator pedal, brake jerk)
  - Autonomous collision avoidance
    - Automated braking
    - Automated steering

➔ In the following focus is set on autonomous collision avoidance

Flow of Events for autonomous Collision Avoidance

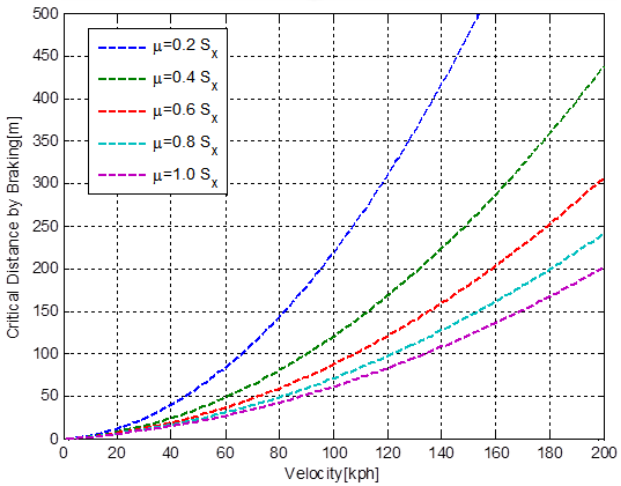


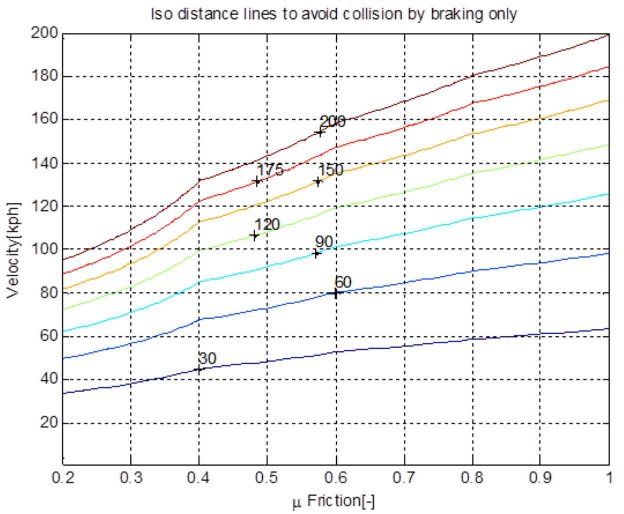
Braking Steering Decision for Stationary Target



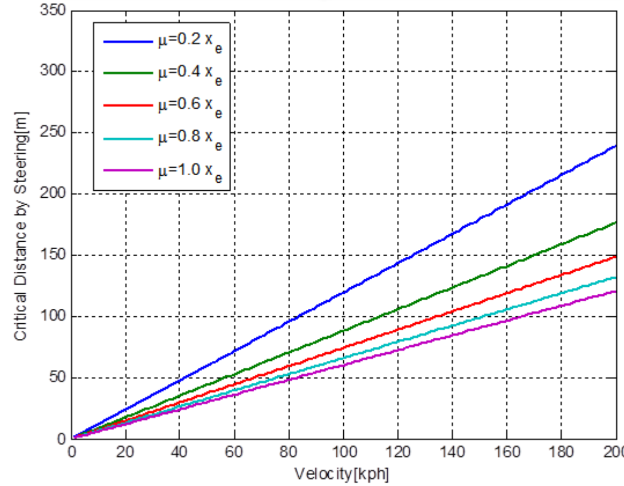
Braking Steering Decision

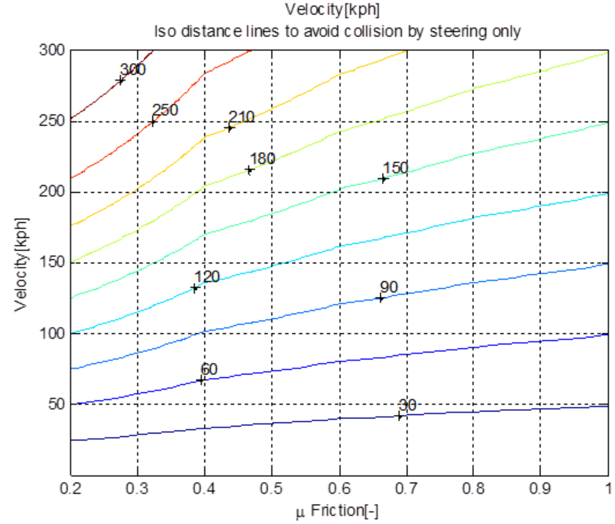
Braking Distance





Steering Distance



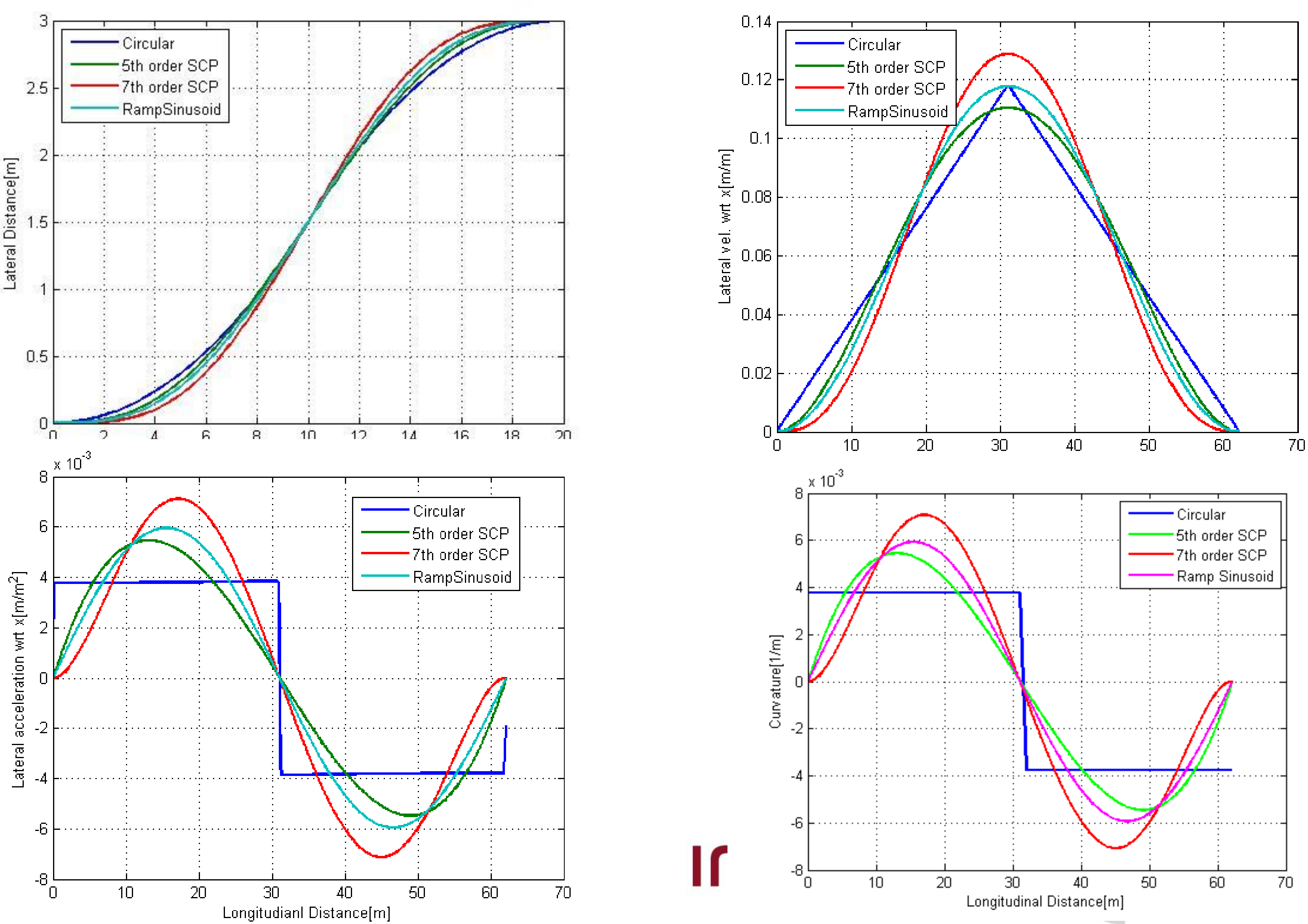


Trajectory Planning

Different types of lane change paths are available with its advantages & disadvantages

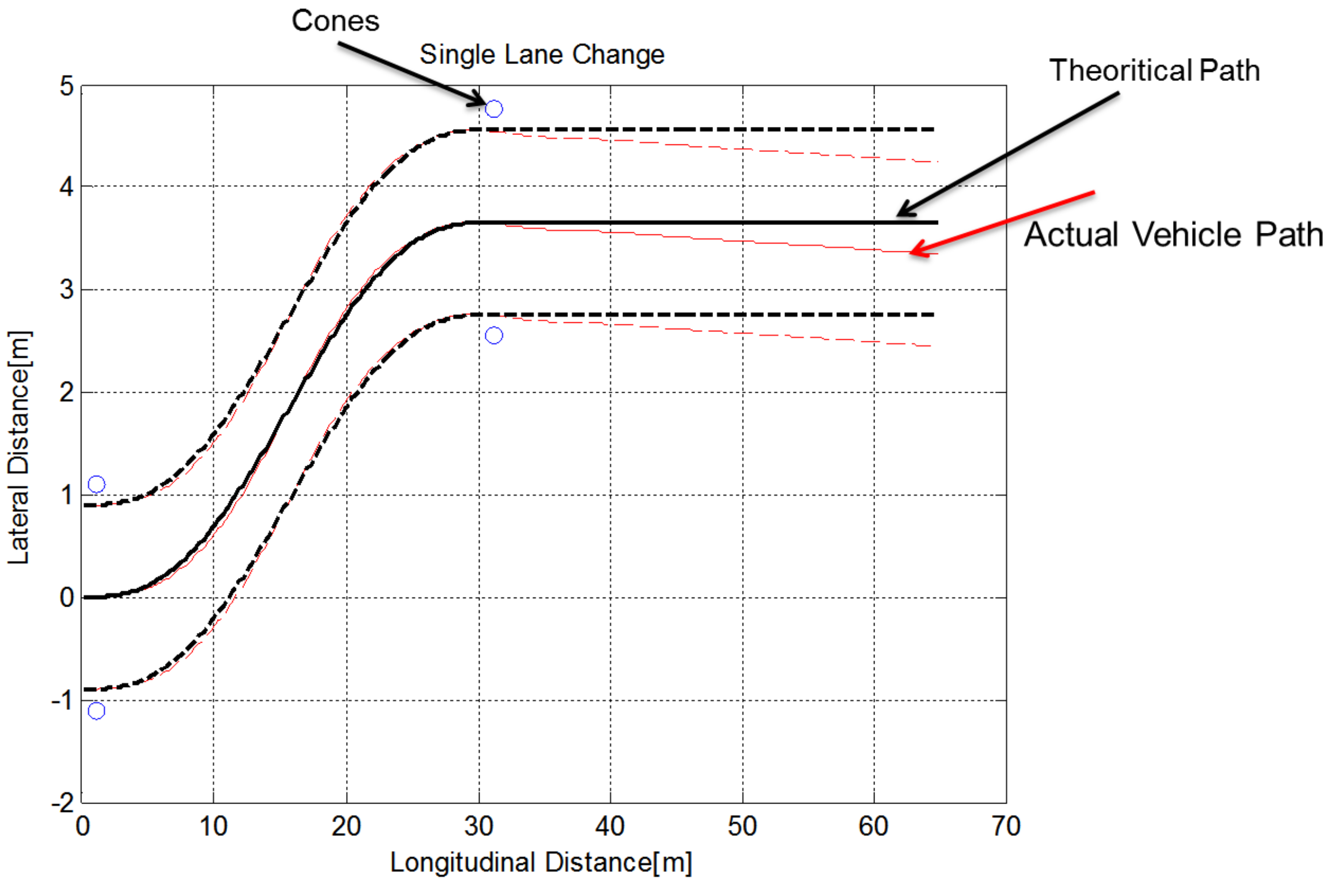
- Circular Curve
- Ramp Sinusoid
- Cubic Spirals
- Acceleration Profile
- Single Cartesian Polynomials
- Polar Polynomials
- B-Spline

Trajectory Planning



Trajectory Planning

Single Lane change at 70kph(65kph real)



Reference Generation

Let the polynomial be φ(x)

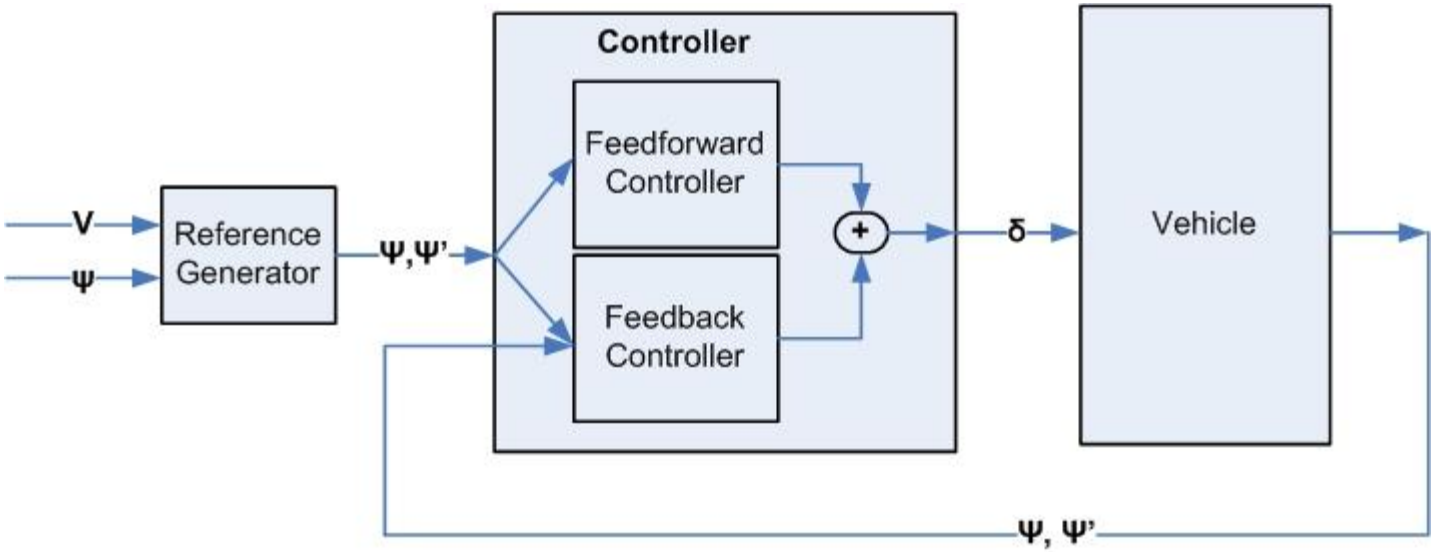
$$\phi(x) = a_0 + a_1 x + a_2 x^2 + \cdots + a_5 x^5$$

Desired reference signals are required;

1. Yaw rate
2. Yaw Angle
3. Curvature
4. Lateral Acceleration

Control Design

$$\delta = \delta_{FF} + \delta_{FB}$$



Control Design

Feed-forward Loop:

$$\delta_{FF} = \frac{L}{R} + \frac{m}{l}\left(\frac{l_r}{C_f} - \frac{l_f}{C_r}\right)\frac{V^2}{\rho}$$

Feed-back Loop:

Linear PD controller is designed for yaw rate and yaw angle.

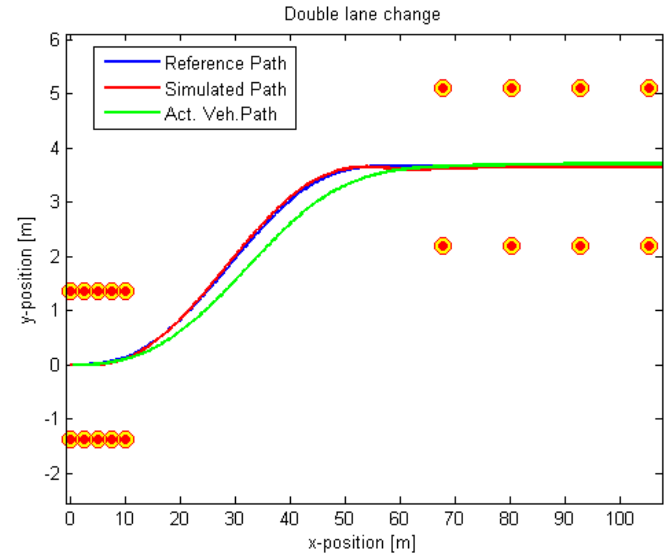
Constraints:

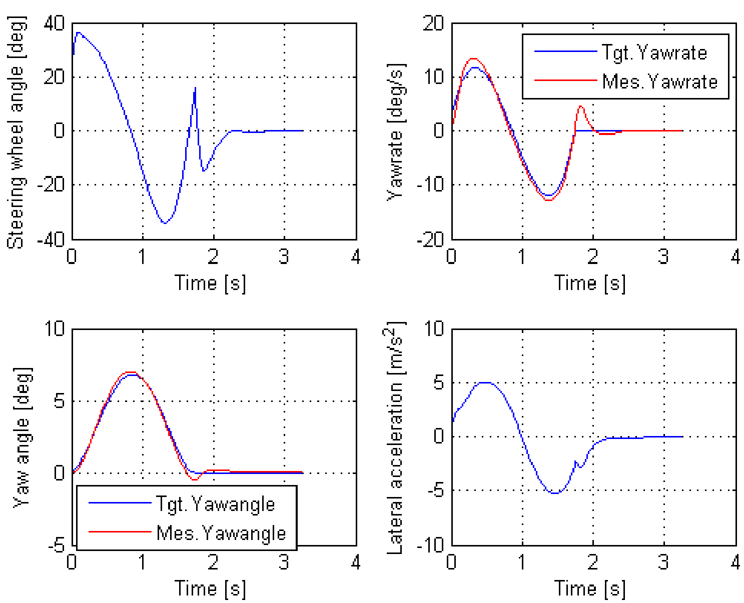
The constraints are as follows

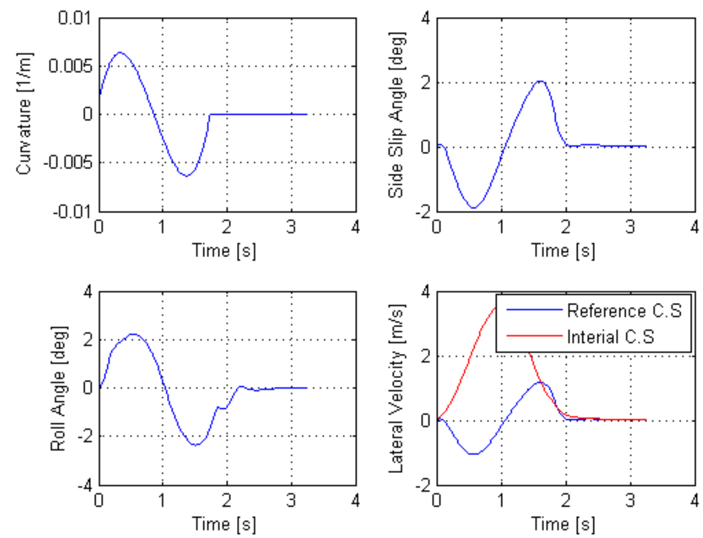
$$\psi_{start} = \psi_{end} = 0$$
$$V_{y,start} = 0$$

Examplary Simulation Results

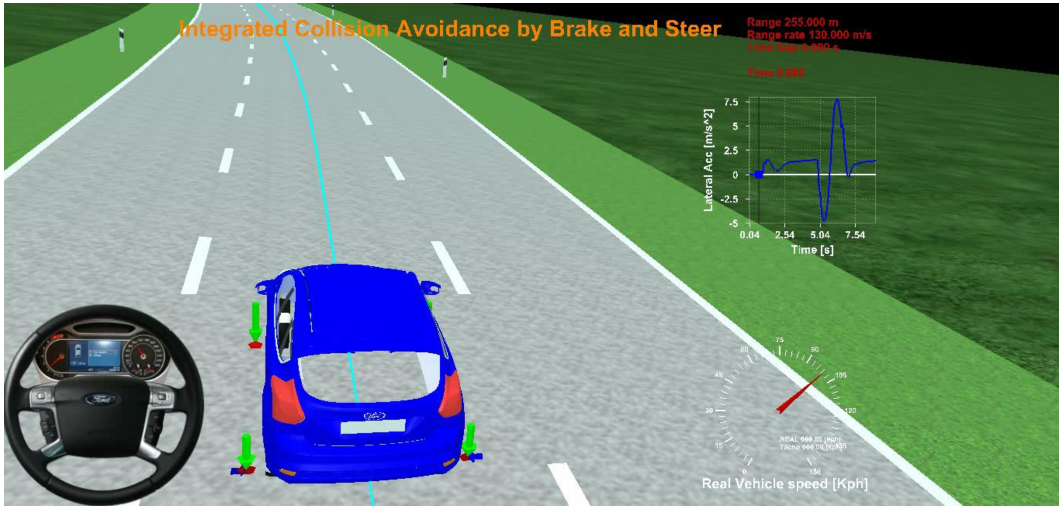
Driving conditions:
Vehicle Velocity : 120kph
Road friction : 1.0

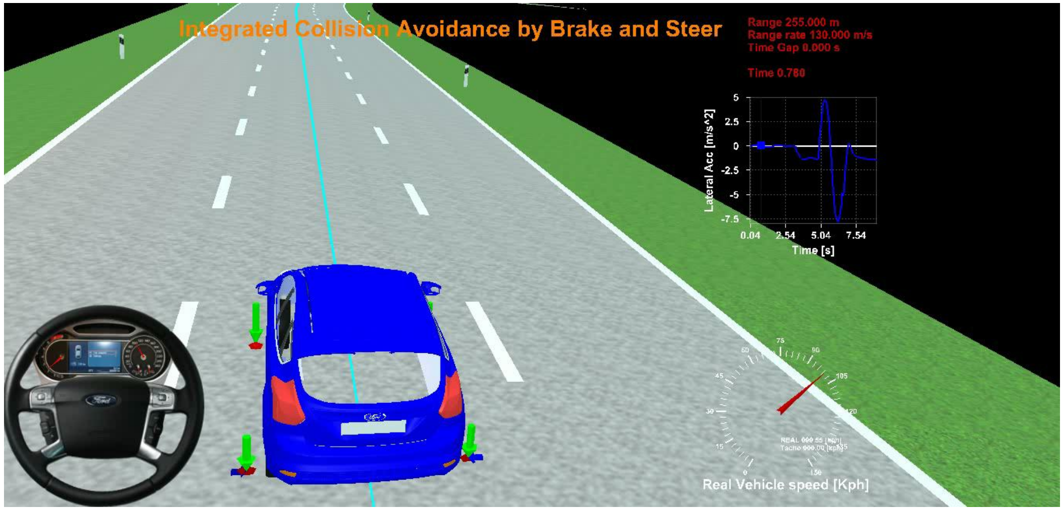




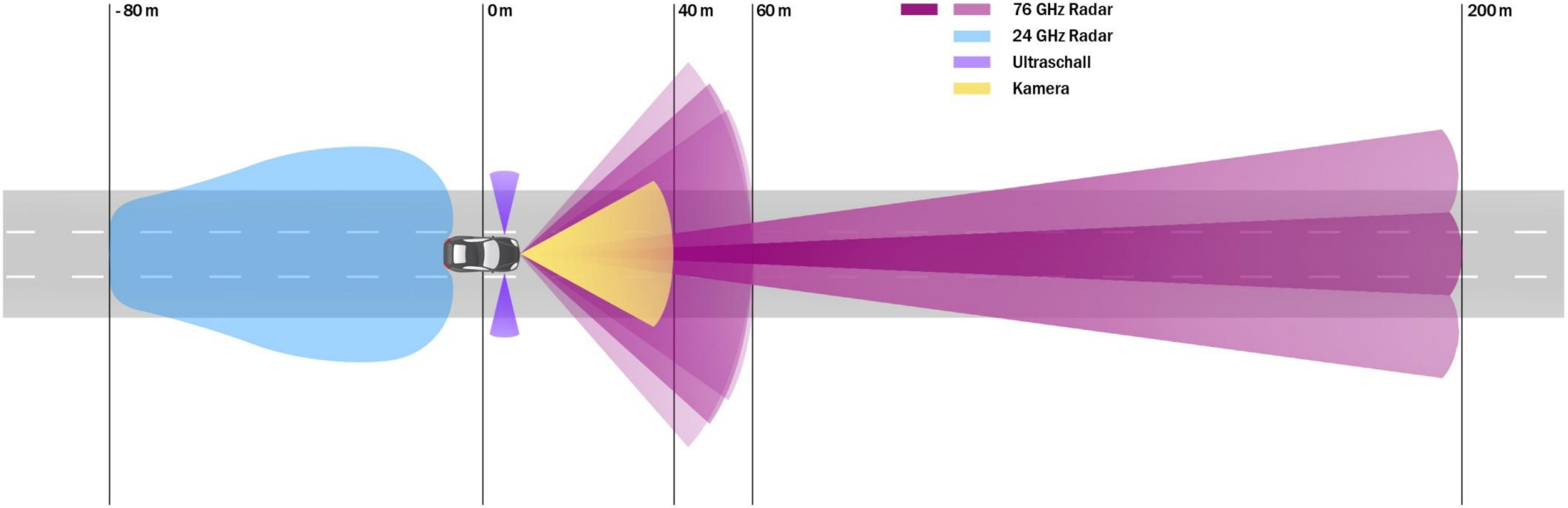


Simulation of autonomous Rear End Collision Avoidance

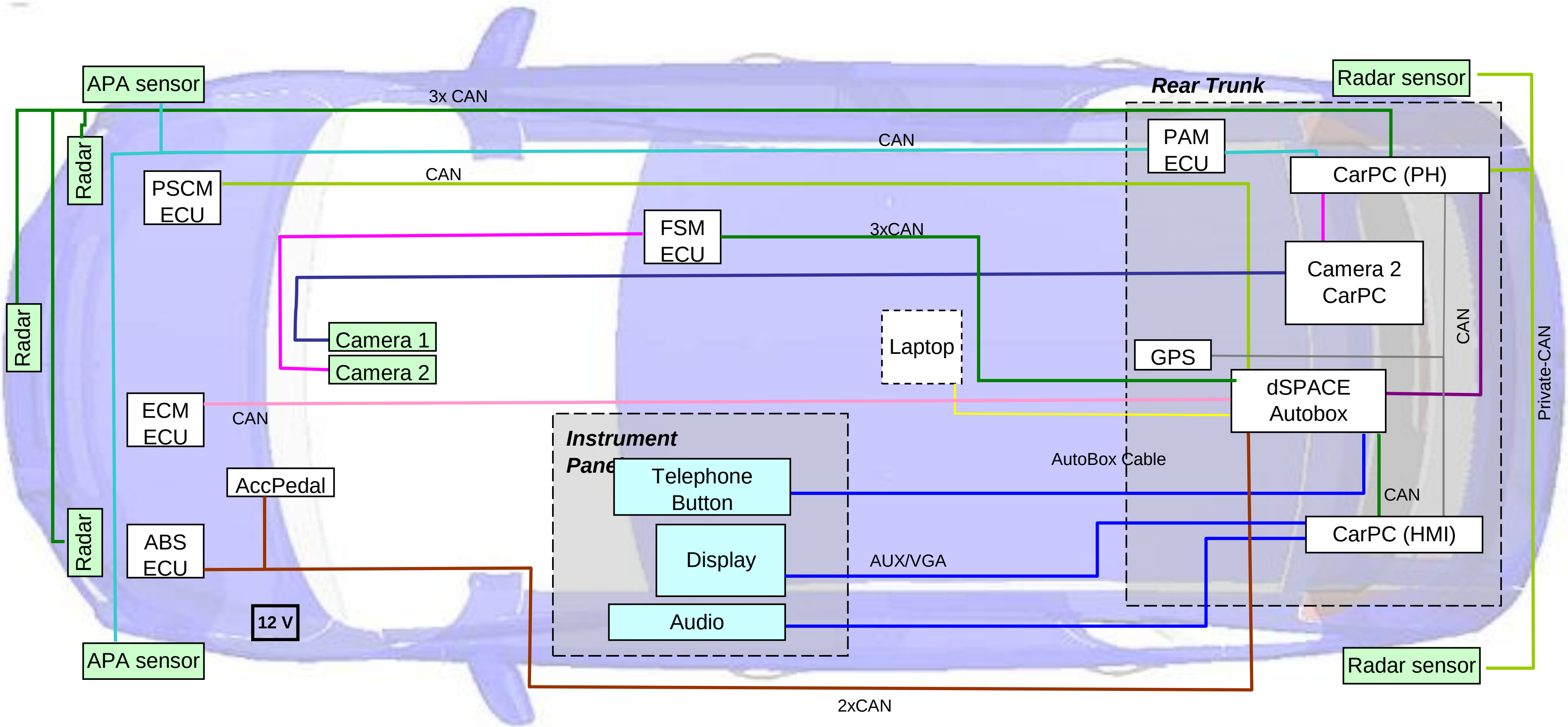




Sensor Configuration in Ford Demonstrator Vehicle



Vehicle Architecture



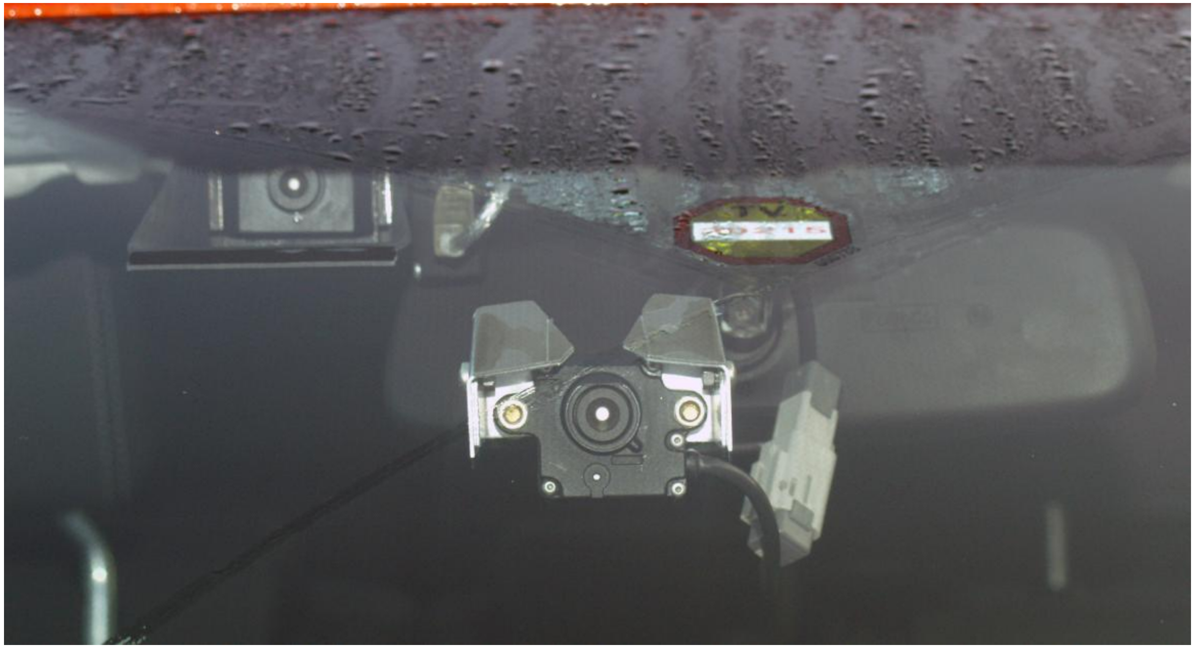
Installed Sensors in Ford Demonstrator Vehicle

Three ESR 76 GHz radars at front:

Two 24 GHz radars at rear:

Installed Sensors in Ford Demonstrator Vehicle

Two cameras at front (Fusion Camera and Delphi):



Autonomous Collision Avoidance with Dummy Target

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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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