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Accident avoidance by active intervention for Intelligent Vehicles

Decision Making and Threat Assessment for Automotive Collision Avoidance

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interactIVe Summer School

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Overview

- Introduction
- Threat Assessment and Decision Making Methods
- Pedestrian Detection with Full Auto Brake
- Intersection Collision Avoidance
- Road Way Departure Avoidance
- Outlook

Cars are driven by people….

It is important to understand that accidents are not inevitable.

Most collisions are caused by simple mistakes, like momentary inattention.

How can we help and support the driver to avoid real-world accidents?

Safety and Driver Support Technologies

Manual Drive

Supported Drive

Inform driver on:
- Speed
- Distances
- Road
- Driver State

Automated Drive

Take over part of the driving task.

Integrated Safety

warn, intervene and protect

Technology that is relatively invisible, but is there when you need it.

interactive

State of the Art

- Many vehicles are equiped with Automatic Emergency Braking systems. Refer to the EuroNCAP: www.euroncap.com/results/aeb/survey.aspx

City System | **Inter-Urban System** | **Pedestrian System**

- The actual performance of these different systems is well-documented by e.g. the German ADAC www.adac.de/infotestrat/tests/assistenzsysteme/notbremsassistent

Decision Making and Threat Assessment

- A Collision Avoidance system is intended to help in critical situations, but should not disturb the driver during normal driving conditions.

  - An intervention is given and it should have. True Positive
  - An intervention is *not* given and it should *not* have. True Negative
  - An intervention is given and it should *not* have. False Positive
  - An intervention is *not* given and it should have False Negative

Decision Making and Threat Assessment

Typical measures that are used for judging whether a collision is about to happen are *e.g.*:

- Time to collision
- Headway
- Needed longitudinal acceleration
- Time to lane crossing
- Needed lateral acceleration

Note: *all need to make assumptions on the future motion of the host vehicle and the target(s).*

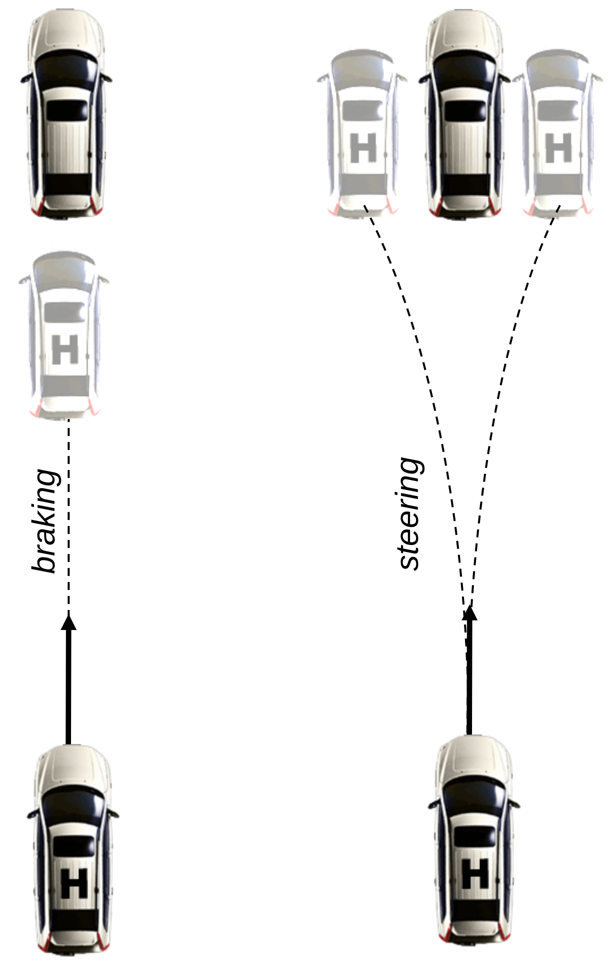
Threat Assessment

TTC at which braking has to be commenced

$$ttc_{brake} = -\frac{\tilde{p}_{x,brake}}{\tilde{v}_{x,0}} = \frac{\tilde{v}_{x,0}}{2a_{x,host}}$$

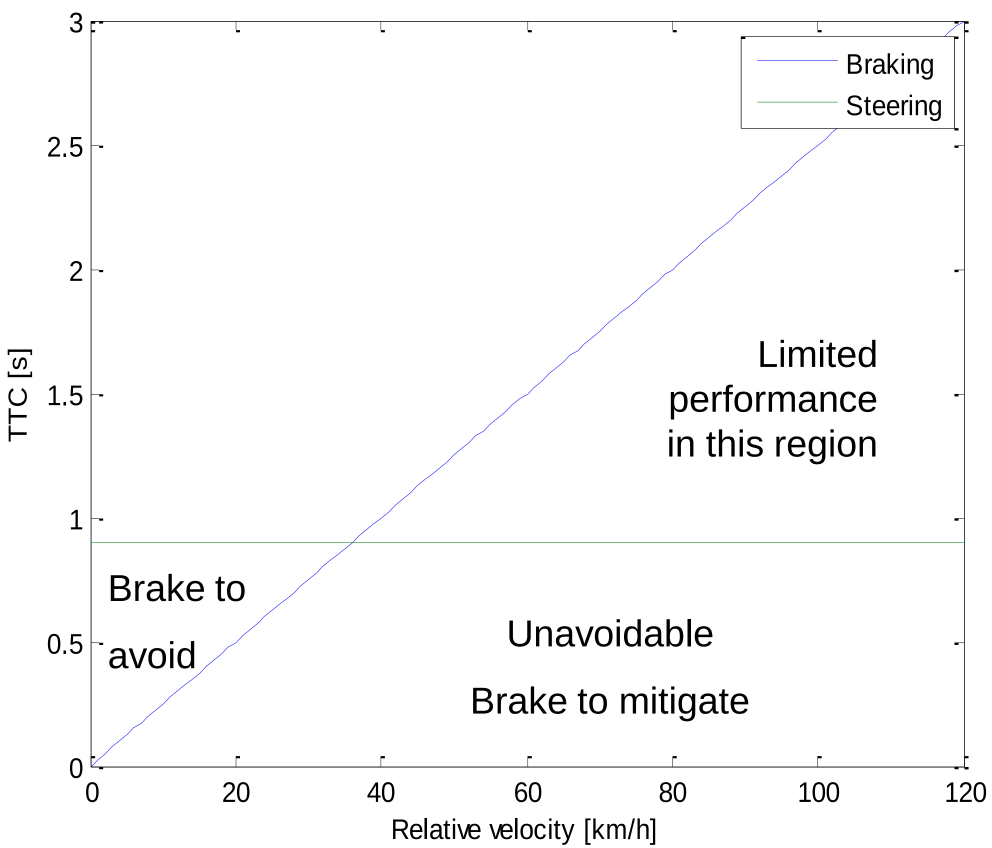
TTC at which steering has to be commenced

$$ttc_{steer} = \min\left(\sqrt{\frac{2}{a_{y,host}}\left(y_0 \pm \frac{w_{host} + w_{target}}{2}\right)}\right)$$



Threat assessment

Time at which collision becomes unavoidable



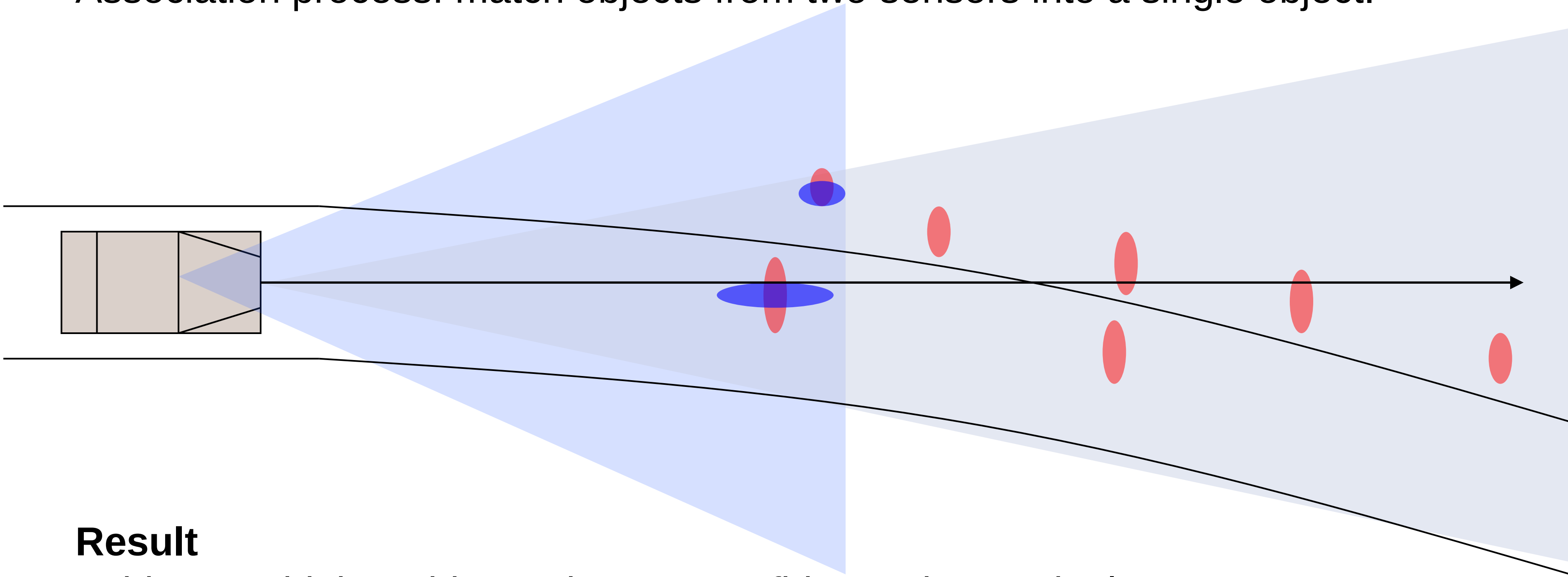
TTC steer

TTC brake

Pedestrian Detection with Full Auto Brake

Sensor Fusion

Association process: match objects from two sensors into a single object.



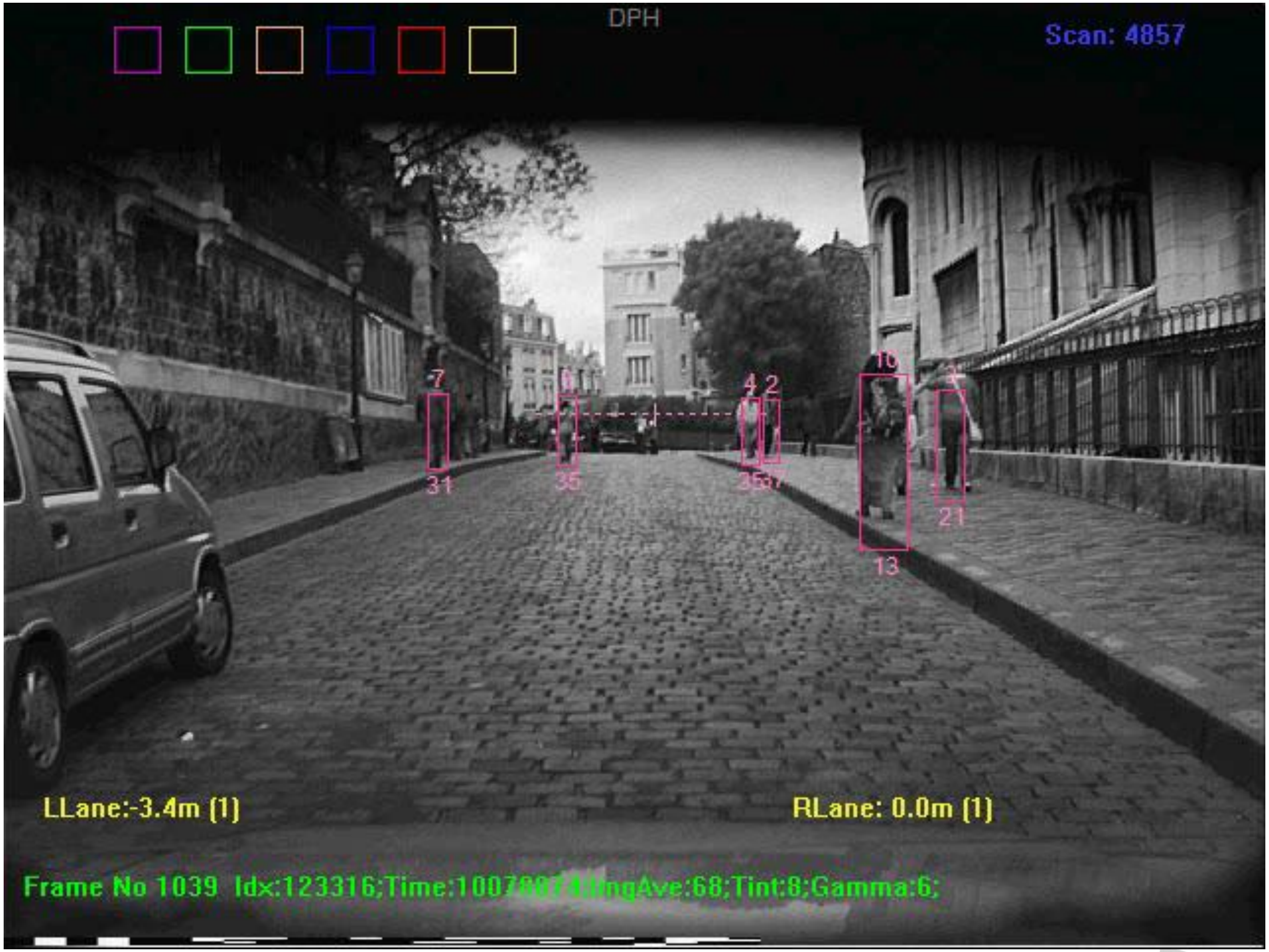
Result

Achieves a higher object existence confidence than a single sensor system

Allows activation on stationary vehicles by discrimination of stationary objects (poles, mailboxes….) reducing false activation frequency.

Provides enhanced data for the objects-lateral position, extension and range.

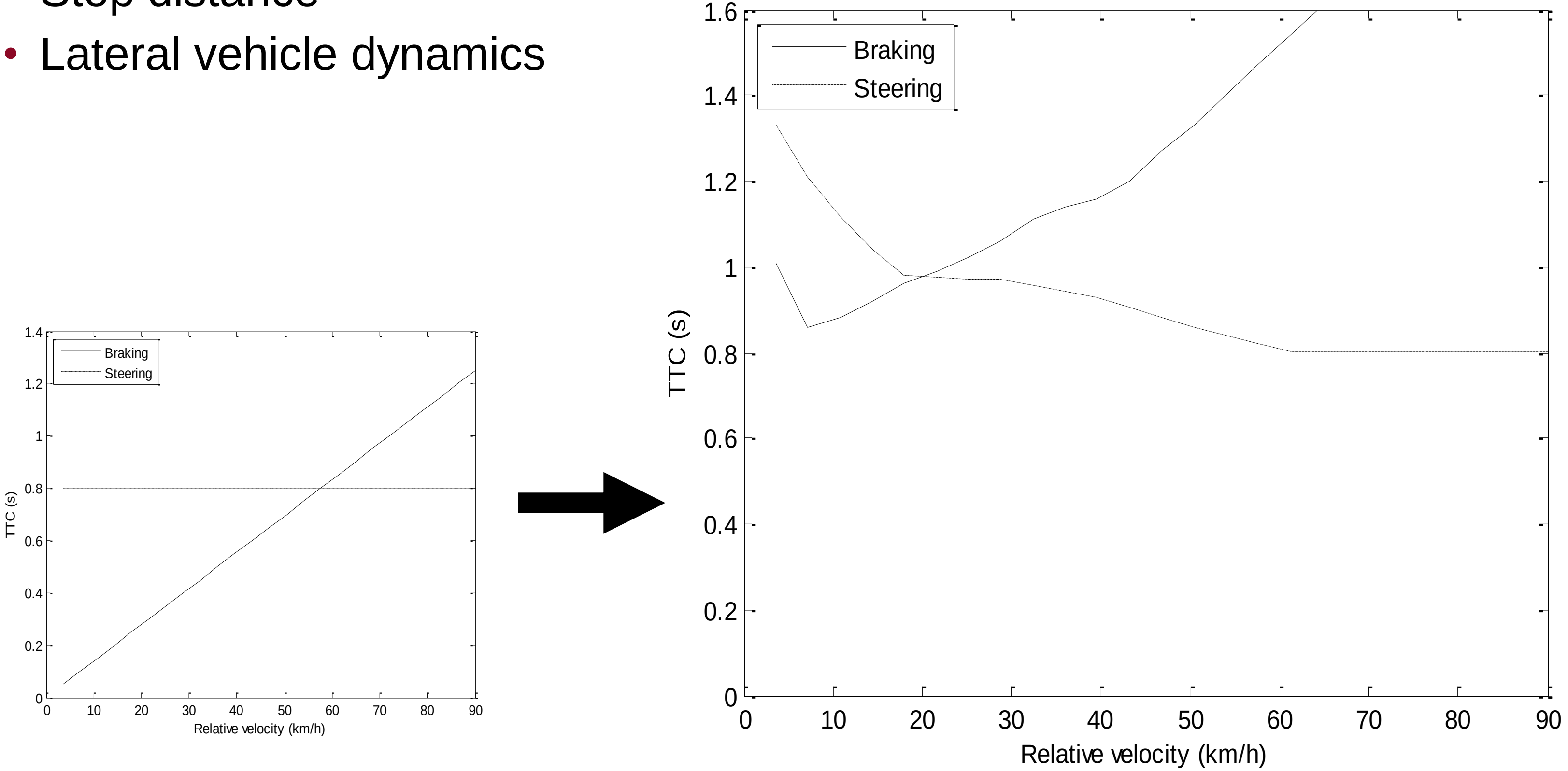
Real-life Situations



Threat Assessment and Decision Making

Improvements of vehicle model:

- Brake system dynamics
- Stop distance
- Lateral vehicle dynamics



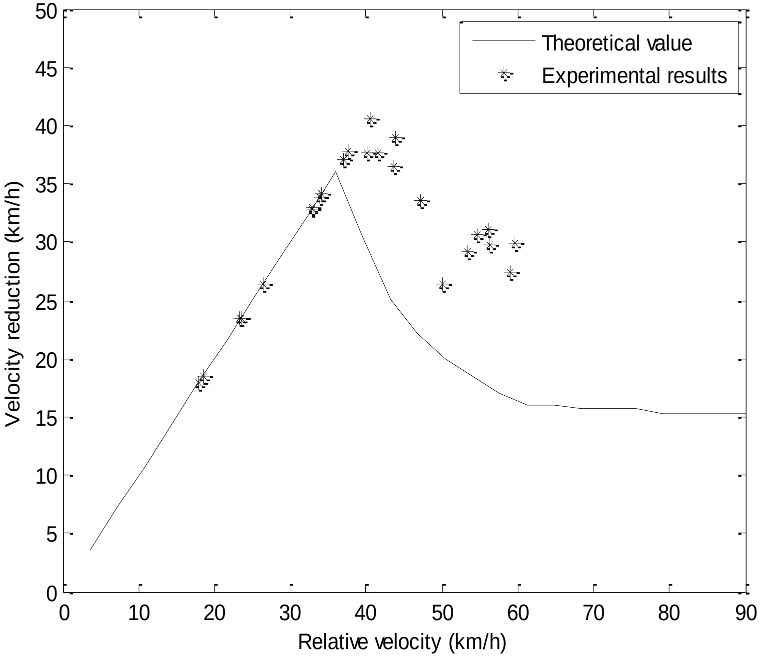
Test – Robustness Requirements

- In order to verify requirement a large field test was initiated where data has been collected from different parts of the world using correct sensor hardware

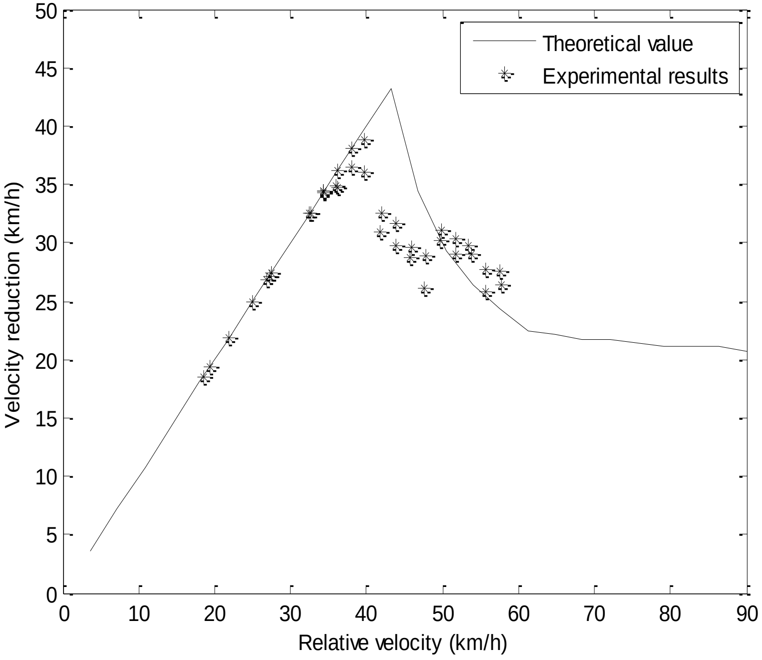
- Data has been recorded using expeditions, taxis, local dealers etc.

Test - Positive performance

Velocity reduction, test track data:



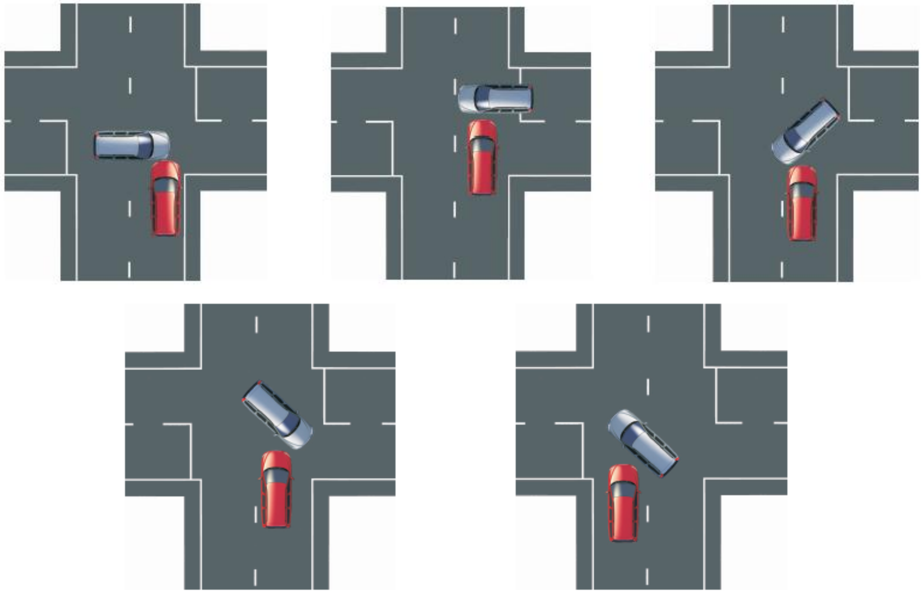
vehicles



pedestrians

Intersection Collision Avoidance

- Current collision avoidance systems are tailored to specific scenarios
- We need a system for general traffic scenarios, including intesections.

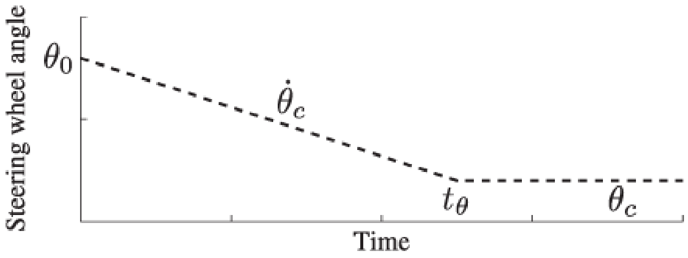


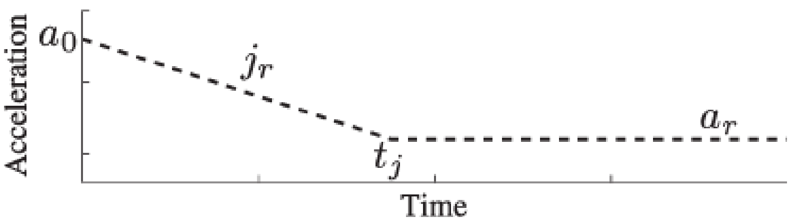
Threat Assessment and Decision-Making

- Assume that we have estimates of obstacle locations over time.

Concept:

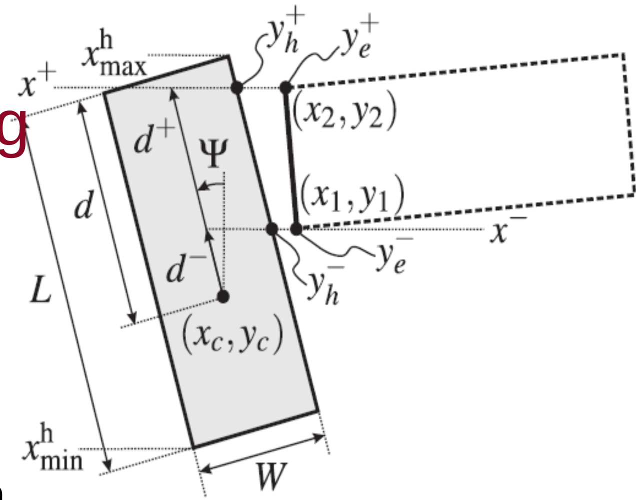
- Assess how the driver can maneuver to avoid a collision. Assume driver preferences for accelerations and steering inputs.





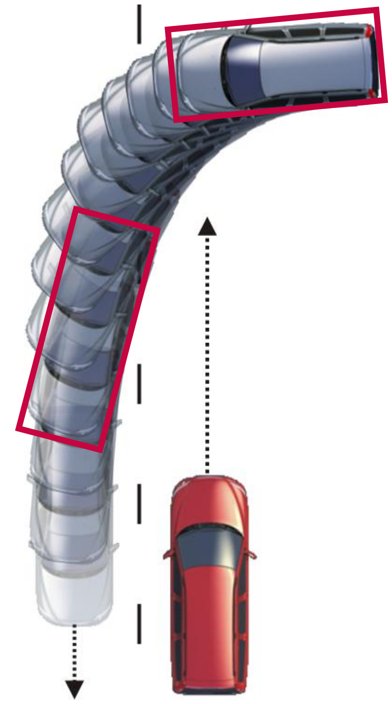
- Apply the brakes automatically if hard braking is the only option to avoid

Threat Assessment and Decision-Making

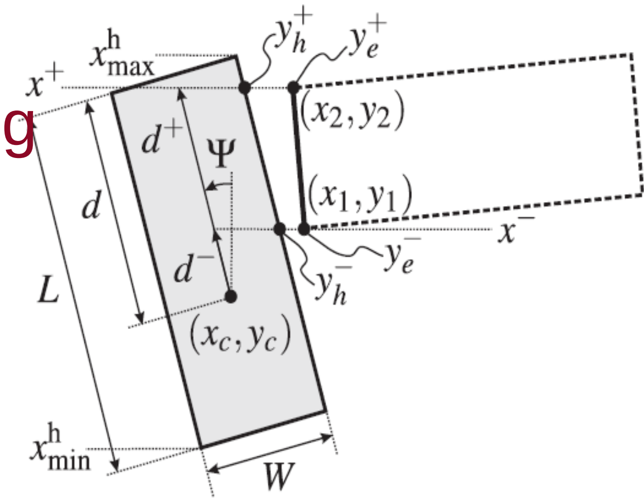


Decision-making in four steps:

1. Describe the perimeter of the object with a polygon
2. Estimate how the driver can maneuver to avoid colliding with the polygon during a prediction horizon
   - Divide the polygon into edges
   - Assess how each edge can be avoided by either steering / braking / accelerating
   - Join the solutions to assess how the driver can steer / brake / accelerate to avoid the entire polygon



Threat Assessment and Decision-Making

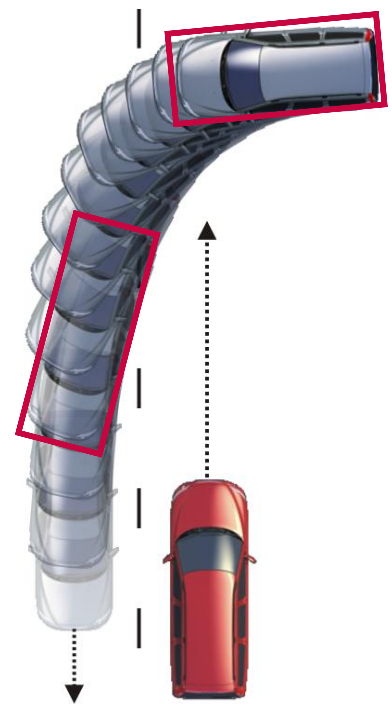


3. Apply the brakes if hard braking is the only option to avoid a collision

4. During a brake intervention:

    - Repeat the assessment at each time step to estimate the required deceleration. Control the brakes.

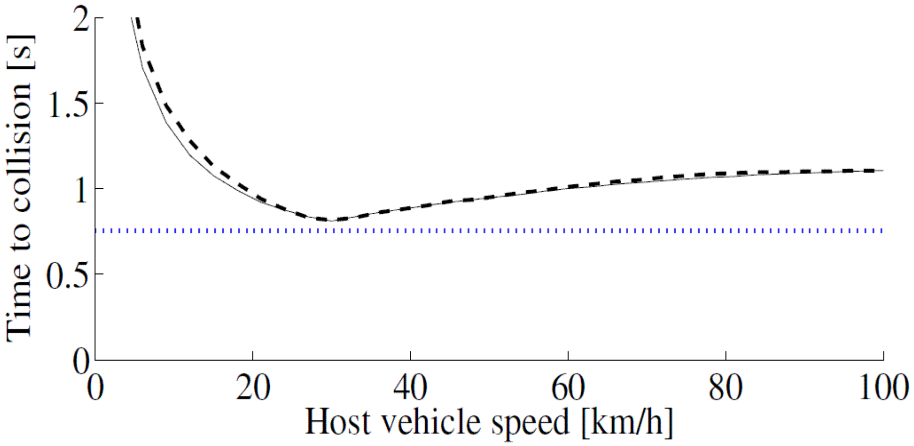
    - Actuator limitations are included in the assessment



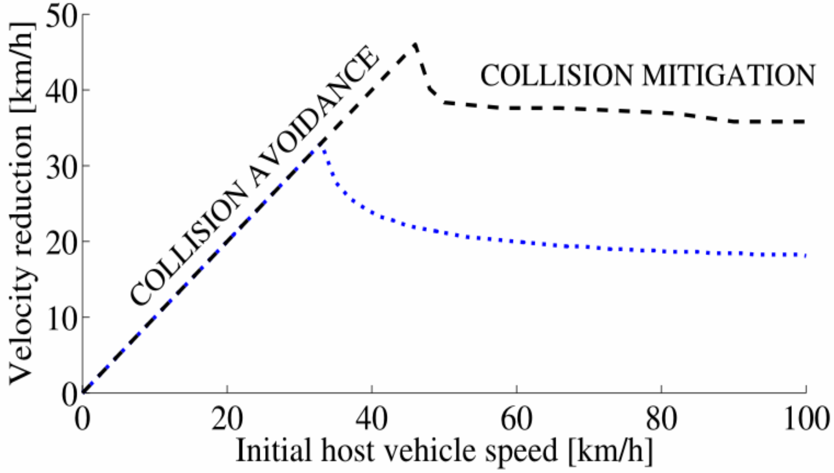
Theoretical Results

- Improved speed reduction / avoidance possibilities
- Does not need to be re-designed when sensors are added
- Can assist drivers in any collision scenario

Stationary, rear-end. TTC for steer to avoid



Potential velocity reduction

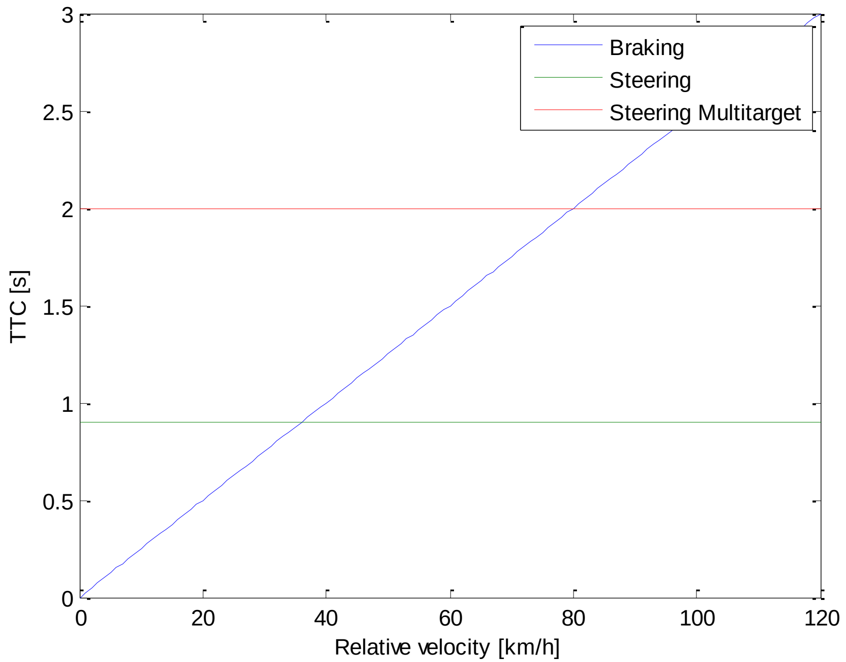


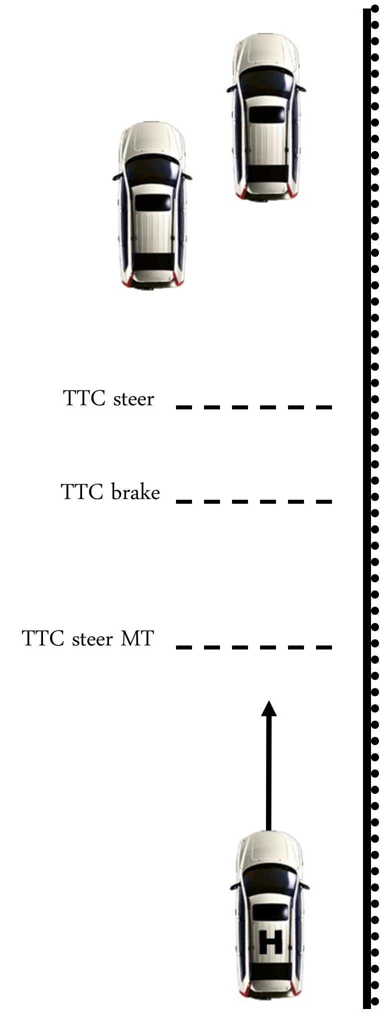
Dotted = Initial model Solid = Brute force with a detailed vehicle model **Dashed = New algo.**

Test Results

Further development

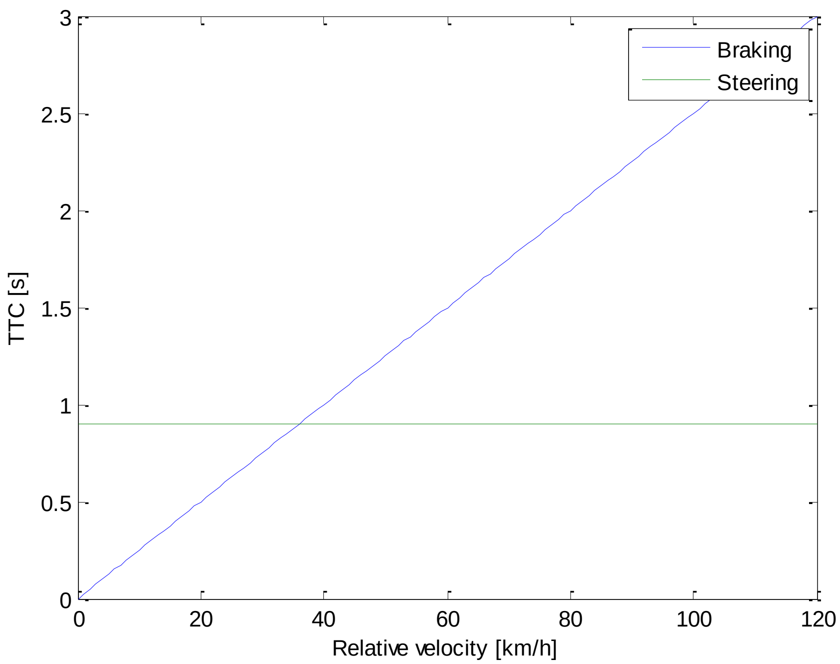
- Multi-target Threat Assessment

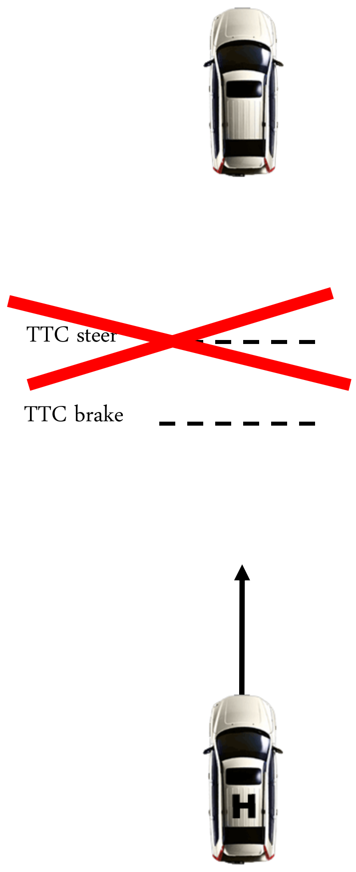




Further development

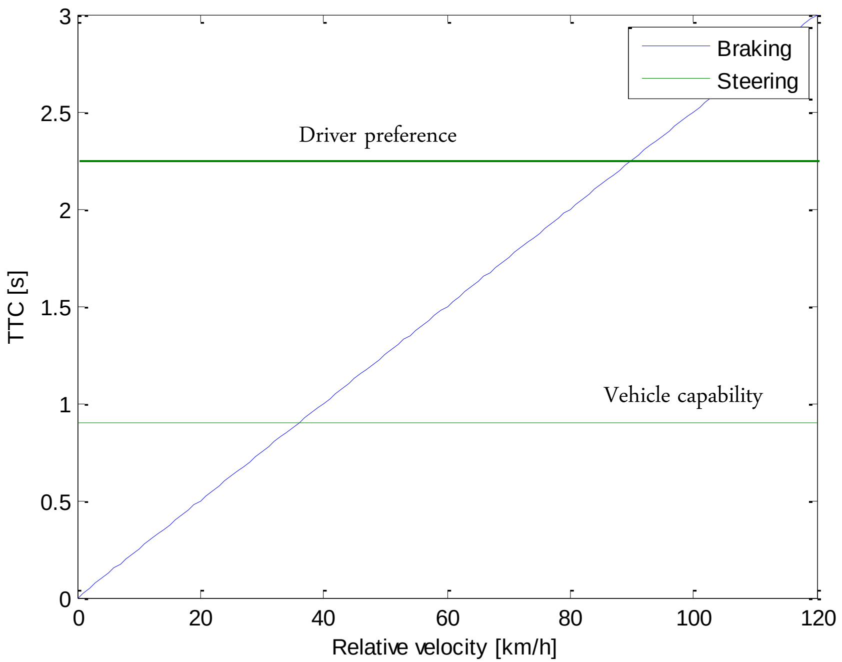
- Driver monitoring
  - Distracted drivers will not do evasive maneuvers

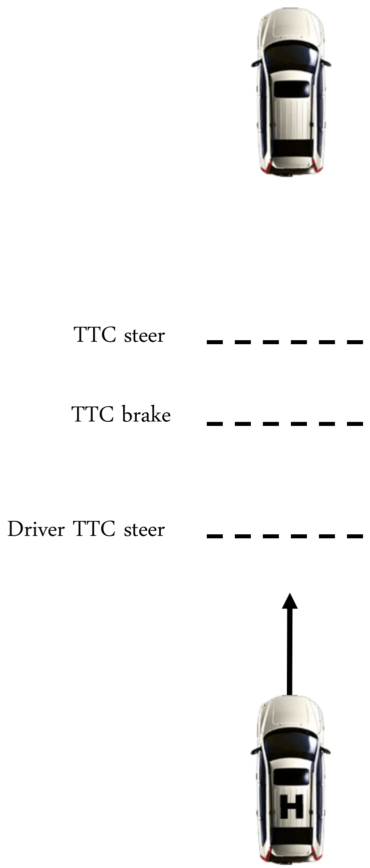




Further development

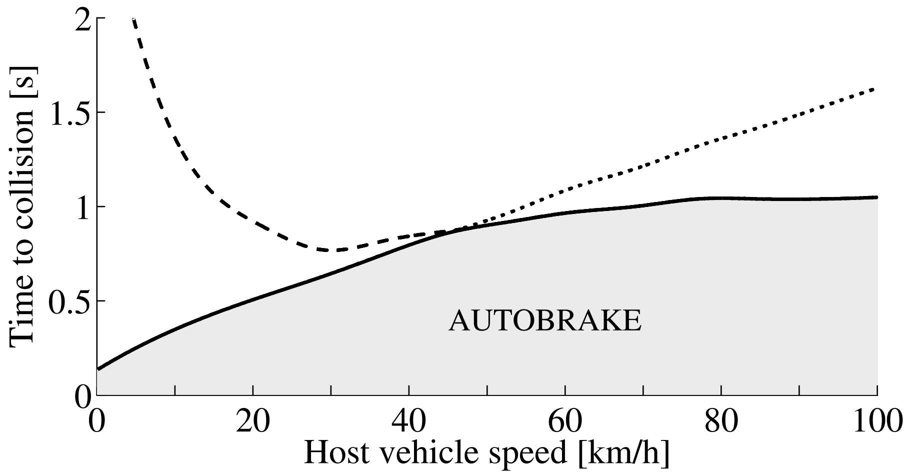
- Driver adaptation

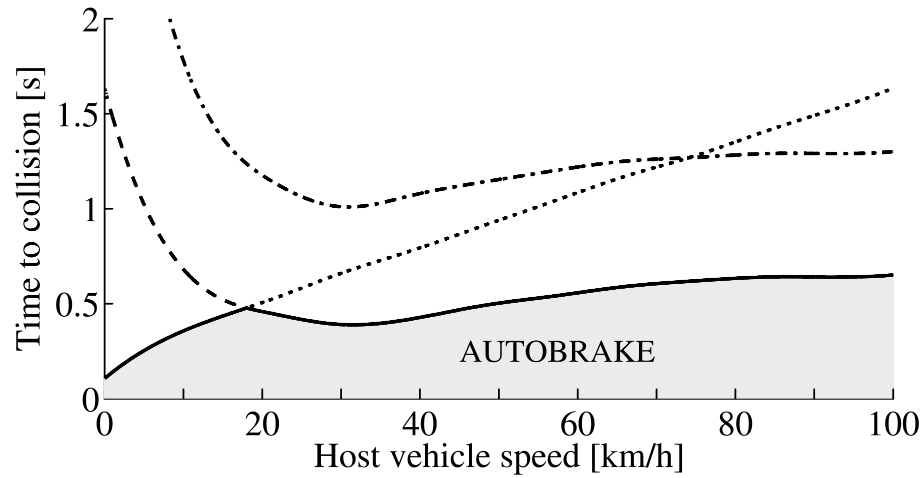




Further development

- Collision Avoidance by Steering
  - Rear-end collision with stationary vehicle and 0 resp. 1.5 m offset.





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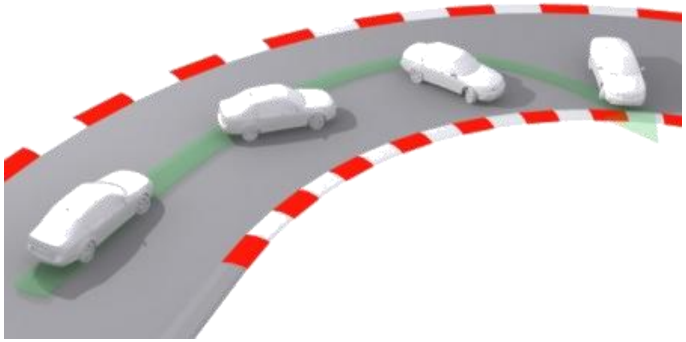
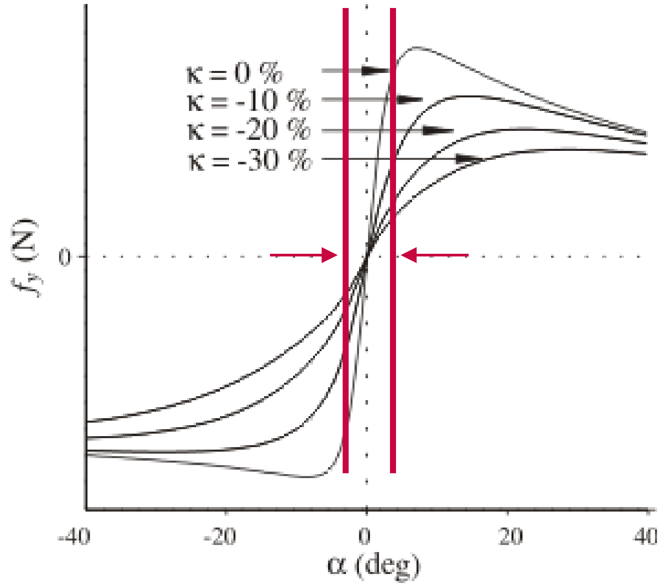
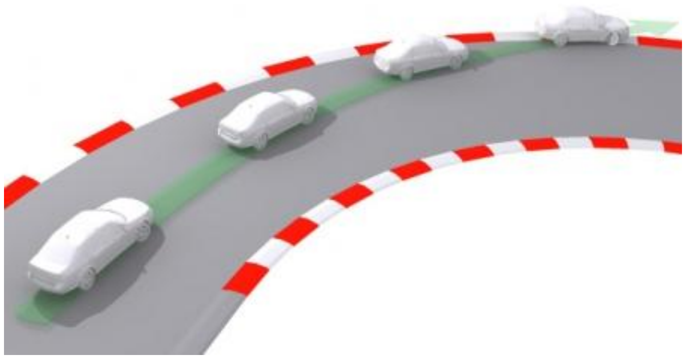
Roadway Departure Avoidance

Loss of control





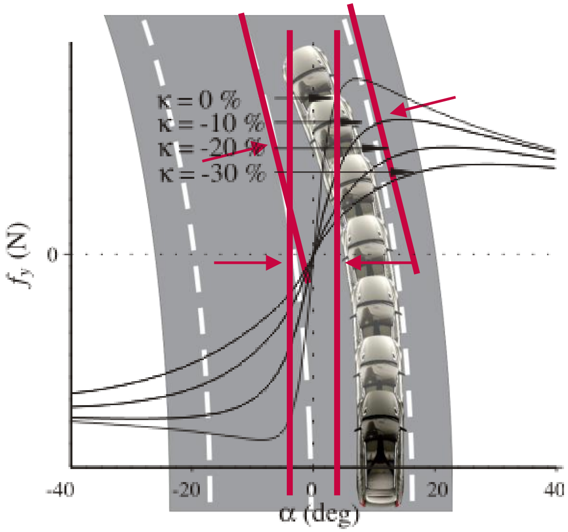


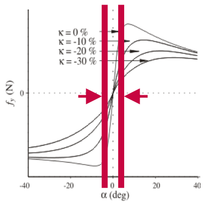
- The driver usually operates in linear region

Electronic Stability Control

- Utilizes feedback control, but no preview

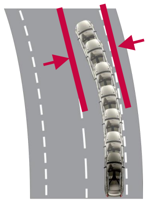
Threat Assessment Problem

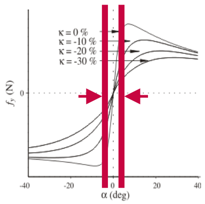




Threat Assessment Problem

|Slip angle front |	≤	Slip limit
| Slip angle rear |	≤	Slip limit
| Deviation centerline vehicle corner 1 |	≤	Half the lane width
| Deviation centerline vehicle corner 2 |	≤	Half the lane width
| Deviation centerline vehicle corner 3 |	≤	Half the lane width
| Deviation centerline vehicle corner 4 |	≤	Half the lane width





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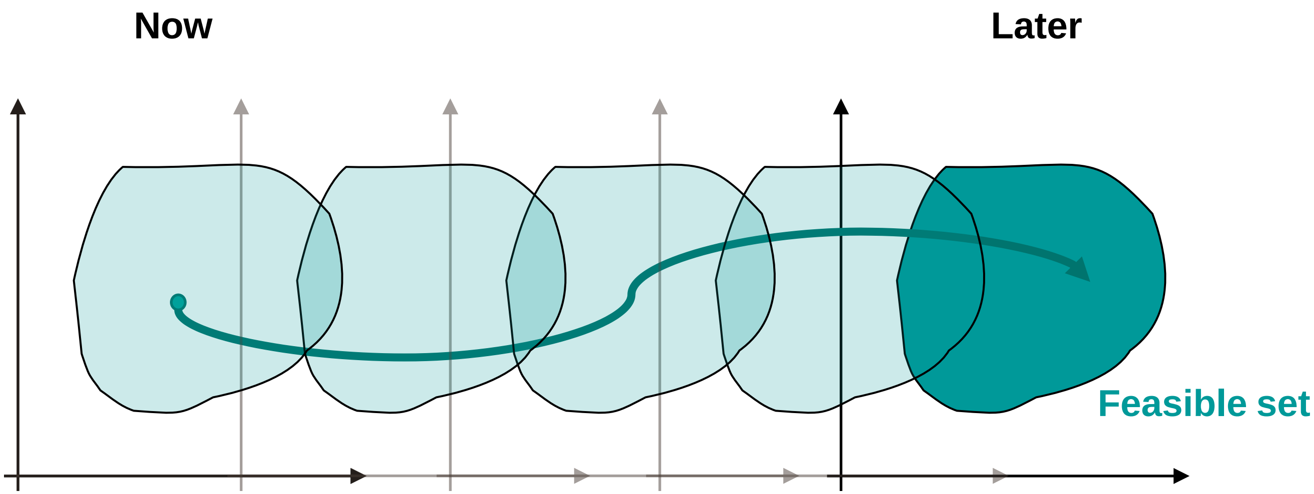
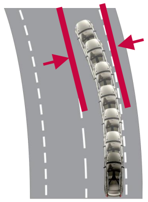
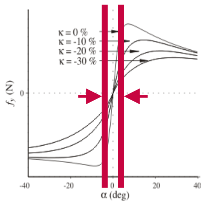
Threat Assessment Problem

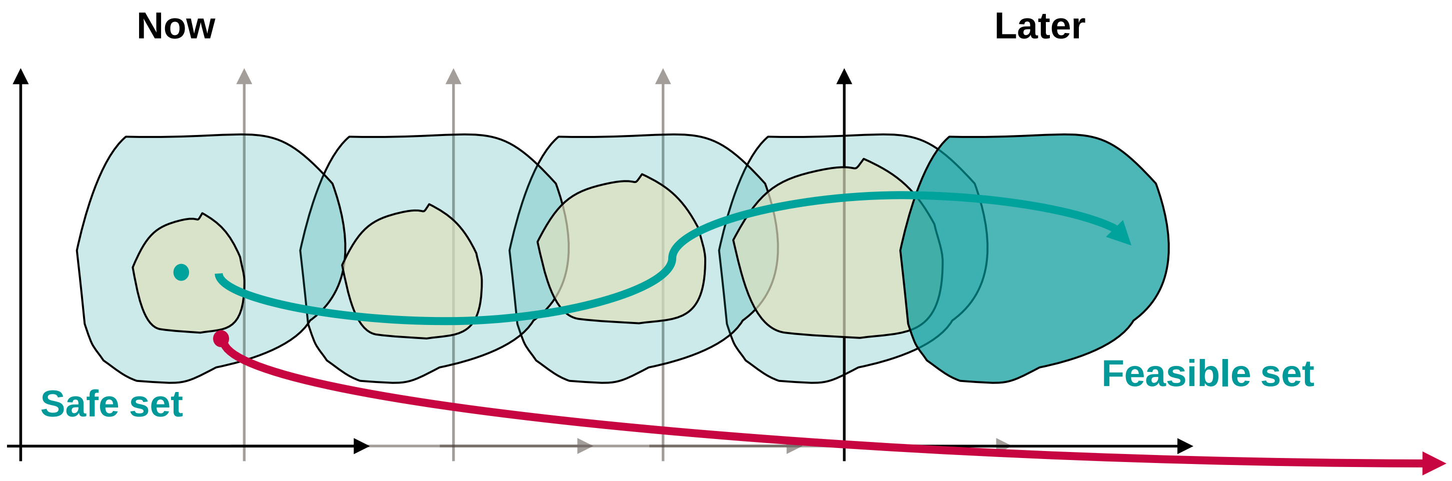


Given estimates of vehicle state and surrounding environment, can we find an admissible sequence of control signals s.t. the vehicle state evolves within the prescribed constraints?





Reachability Analysis Based Approach



1 Select terminal target set

2 Compute sequence of *safe sets*

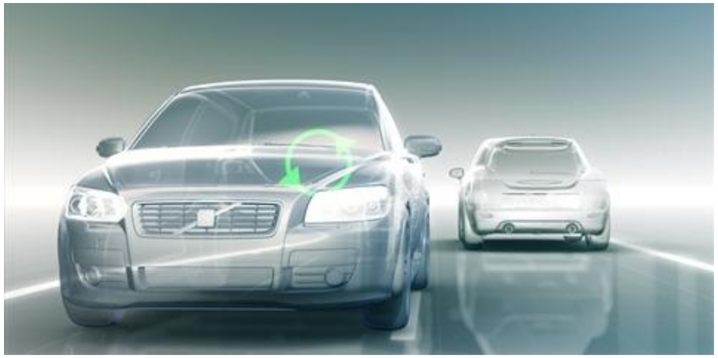
3 Check whether current state is inside

Experimental Tests – system off

Experimental Tests – system on

Outlook

- The revolution of automotive collision avoidance systems has just started.
- Further development is needed in support the driver in all stages and in all collision types:
  - Dealing with sensing and prediction uncertainty.
  - Provide earlier interventions through threat assessment and decision making with larger prediction horizon, *e.g.* using adaptive driver models and multiple-target emergency escape paths
  - Deal with roadway departures (straying and loss of control)



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Accident avoidance by active intervention for Intelligent Vehicles

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Thank you.

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SEVENTH FRAMEWORK PROGRAMME

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