Accident Avoidance by Evasive Manoeuvres

Challenges and steps towards technical solutions

Dr. Michael Fausten
Abteilungsleiter Vorentwicklung
Chassis Systems Control
Robert Bosch GmbH
michael.fausten@de.bosch.com
Accident Avoidance by Evasive Manoeuvres

Motivation

- Relevance of rear end crashes with injuries in 2006:

<table>
<thead>
<tr>
<th>Number of rear end crashes</th>
<th>Share in all accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>500,000</td>
<td>28%</td>
</tr>
<tr>
<td>284,000</td>
<td>32%</td>
</tr>
<tr>
<td>266,000</td>
<td>16%</td>
</tr>
<tr>
<td>49,200</td>
<td>15%</td>
</tr>
</tbody>
</table>

Source: NHTSA/NCSA, IATSS, DESTATIS Year 2006, UNECE accident report, own calculation, EU27

- Rear end crashes with injuries are very relevant
- Between 80% and 90% of all rear end crashes are caused by cars

Source: Youtube.com
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Options of accident avoidance by evasion

Driver reaction in rear end crashes with injuries.

Availability of adequate conditions for collision avoidance by evasion in rear end crashes.

(n=635 accidents: rear end crashes with car as main causer, hitting opponent from the rear)
**Accident Avoidance by Evasive Manoeuvres**

**Steering as a reaction in critical situations***

* As a result of a study in cooperation with Daimler AG’s driving simulator **. Number of persons participating in the study: 70

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<table>
<thead>
<tr>
<th>Scenario</th>
<th>27%</th>
<th>12%</th>
<th>9%</th>
<th>6%</th>
<th>52%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear-end collision on highway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>22%</strong></td>
</tr>
<tr>
<td>Entering vehicle @ intersection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>17%</strong></td>
</tr>
<tr>
<td>Lane changing vehicle up-front</td>
<td><strong>4%</strong></td>
<td><strong>4%</strong></td>
<td><strong>12%</strong></td>
<td><strong>16%</strong></td>
<td><strong>64%</strong></td>
</tr>
</tbody>
</table>

- Braking to full stop (w/o steering)
- Braking to full stop & steering
- Evasion (w/o braking)
- Collision
- Collision despite steering

**Steering and evasion are drivers’ options in order to avoid collisions**

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**Chassis Systems Control**

**from: H. Schittenhelm, Fahrverhalten und Reaktionszeiten in kritischen Situationen, VDI-Bericht 1911, Düsseldorf, 2005**

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Evasive Steering: Studies with untrained drivers

Evasion CarClinic:
- Tests carried out with 35 untrained test drivers
  - Approx. 26% tried to evade the suddenly appearing obstacle
  - All test persons applied the brakes

Reaction of test drivers:
- Evasion attempt with braking: 9 drivers / 26%
- No reaction (collision): 2 drivers / 6%
- Full braking (no collision): 24 drivers / 68%
Threshold speed for evasion vs. braking depends on assumed maximum lateral acceleration.

The assumed maximum lateral acceleration is not necessarily the physical limit acceleration.

Real evasion usually is situated outside the driver's comfort zone.
Topology of evasive maneuvers

- **risk of rear end collision**
  - $v<v_G$
    - no space for evasion
    - timely warning
      - driver braking
      - collision avoidance
    - autonom. braking
  - $v>v_G$
    - evasion possible
  - 30%}

**Guideline:** An evasive maneuver shall not be undertaken unless the collision is unavoidable by braking.
Accident Avoidance by Evasive Manoeuvres

Topology of evasive maneuvers

- **risk of rear end collision**
- **v<vsub>G**
  - timely warning
  - driver braking
    - collision avoidance
  - autonom. braking
- **v>vsub>G**
  - evasion possible
  - tailored warning
  - driver evasion
    - evasion support
    - collision avoidance
  - straight driving
    - autonom. evasion
    - motivate evasion
    - emergency braking/collision
    - braking support
    - collision avoidance
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Challenges for automatic evasion maneuvers

- Detection of oncoming traffic
- Detection of fast following traffic
- Detection of blind spot
- Detection of geometry of evasive path
  - e.g. Width of obstacle, width of evasion lane, …
Topography of evasive maneuvers

- **Risk of rear end collision**
  - **\( v < v_G \)**
    - Timely warning
      - Driver braking
      - Autonom. braking
      - Evasion support
  - **\( v > v_G \)**
    - Evasion possible
      - Tailored warning
      - Straight driving
        - Autonom. evasion
        - Motivate evasion
        - Emergency braking/collision
        - Collision avoidance
Accident Avoidance by Evasive Manoeuvres

Accident avoidance by evasion – System pattern

<table>
<thead>
<tr>
<th>Emergency Evasion</th>
<th>Reaction zone</th>
<th>Evasion zone</th>
<th>Finish zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver reaction</td>
<td>Driver lead evasion</td>
<td>Safety zone</td>
<td></td>
</tr>
<tr>
<td>System reaction + Warning</td>
<td>Supported driver lead evasion</td>
<td>Braking distance</td>
<td></td>
</tr>
<tr>
<td>Driver reaction, support</td>
<td>System lead evasion</td>
<td>Hand over zone</td>
<td></td>
</tr>
</tbody>
</table>

Warning w/o support | Warning w/ support | Autonomous

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Evasive Steering Support (ESS) - Principles

critical driving situation

potential driver intention: avoidance by evasion

evasion support triggered by driver

evasion likely to be chosen

reaction time decreasing number of options for driver to avoid collision unavoidable

risk of rear-end collision

Time to Collision

ESS – window for initiation of support
Technical characteristics – Support strategy

The driver steers on the optimal evasion trajectory

**What ESS does:**

- ESS provides no support at all as long as the driver does not decide to perform an evasive maneuver

The driver overreacts

**What ESS does:**

- **Corrective torque** on the steering wheel

The driver underreacts

**What ESS does:**

- Supports the driver during evasion with **additional torque** on the steering wheel

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**Optimized trajectory**

**Drivers reaction without ESS**

**ESS controller deviation**

**Direction of ESS torque intervention**
Accident Avoidance by Evasive Manoeuvres

Demonstrations: over and under-reaction

1. Driver under-reacts (with ESS)

2. Driver over-reacts (with ESS)

ESS corrects the driver’s insufficient input in case n°1 and the excessive reaction in case n°2. In both cases the right amount of steering torque is finally input. The obstacle is safely avoided.
Effect and benefit of ESS

Method
- Internal study using prototype vehicle
- Number of persons participating: 41
- Evasion maneuver with 60 kph

Result
- The Maximum steering wheel angle reached 25% earlier (Mean values)
  - higher steering wheel angular velocity
  - More calm steering behaviour

Drivers’ steering reaction is improved by ESS
Result of the improved steering behaviour

- Same lateral position is reached 60 [cm] earlier
  - Increased degree of freedom to avoid a collision with the obstacle

Evasion trajectory is improved by ESS
Safety decomposition of ESS

- Introduction of functional limitations
- Limitations guarded by (actuator-)ECU with ASIL ≥ x

Guard interfaces are essential for functional safety
Evasive Steering Support (ESS) – Comparison

**ESS by Torque**

- **ESS by (steering) torque as haptic support**
- Limited steering torque below safety level guarantees controllability by driver
- Can be combined with partial braking intervention

**ESS-B by brake**

- **ESS by (brake) yaw torque directly improves vehicle handling**
- Limited yaw torque below safety level guarantees controllability by driver
- Can be combined with partial braking intervention
Accident Avoidance by Evasive Maneuvers

Development strategy for evasion functions

- Autonomous Accident avoidance
- Semi-autonomous support

Objects w/ Distance, Closing velocity, Azimut, (TTI)
- EBA
- ESS-T/B

+ Rear Supervision
Integr. Braking and Steering

- AEB

+ Lat. Position, width
Adaptive path for evasion

- Evasion for narrow objects

+ Object type

- Evasion on pedestrians

+ Rear/ Side Supervision
Radar Radar Radar Stereo Video (or Radar+Mono-Video) + Rear/Side Radar
Brake Steering
Brake &Steering

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Thank you for your attention.

Questions?

Dr. Michael Fausten
Abteilungsleiter Vorentwicklung
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michael.fausten@de.bosch.com