Accident Avoidance by Evasive Manoeuvres

Challenges and steps towards technical solutions

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Accident Avoidance by Evasive Manoeuvres

Motivation

- **Relevance of rear end crashes with injuries in 2006:**

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

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

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

- No Steering
- drivers steer left
- driver steer right
- driver reaction unknown

- typical evasion situation (vehicle in front braking or closing speed >30kph)
- evasion optional
- traffic in evasive path
- No evasive space available

(n=635 accidents: rear end crashes with car as main causer, hitting opponent from the rear)
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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

- Rear-end collision on highway
  - Braking to full stop (w/o steering): 22%
  - Braking to full stop & steering: 6%
  - Evasion (w/o braking): 9%
  - Collision: 12%
  - Collision despite steering: 27%

- Entering vehicle @ intersection
  - Braking: 32%
  - Collision: 17%
  - Collision despite steering: 7%
  - Evasion: 19%

- Lane changing vehicle up-front
  - Braking: 16%
  - Braking & steering left: 4%
  - Braking & steering right: 12%
  - Collision: 4%
  - Collision despite steering: 24%

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

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*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.
Guideline: An evasive manoeuvre shall not be undertaken unless the collision is unavoidable by braking.

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Topography of evasive maneuvers

- **risk of rear end collision**
  - $v<v_G$
    - no space for evasion
    - timely warning
    - driver braking
    - collision avoidance
  - $v>v_G$
    - evasion possible
    - tailored warning
    - 30%
    - driver evasion
    - straight driving
    - 26%
    - autonom. evasion
      - evasion support
      - autonom. evasion
      - motivate evasion
      - braking support
      - emergency braking/collision
      - collision avoidance
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**
  - $v < v_G$: No space for evasion
  - $v > v_G$: Evasion possible

- **Driver Braking**
- **Autonomous Braking**
- **Evasion Support**
- **Collision Avoidance**
- **Emergency Braking/Collision**
- **Straight Driving**
- **Motivate Evasion**

- **Timely Warning**
- **Tailored Warning**

- **26%**
- **30%**
Accident Avoidance by Evasive Manoeuvres

Accident avoidance by evasion – System pattern

<table>
<thead>
<tr>
<th>Emergency Evasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction zone</td>
</tr>
<tr>
<td>Evasion zone</td>
</tr>
<tr>
<td>Finish zone</td>
</tr>
</tbody>
</table>

- Driver reaction
- Driver lead evasion
- Safety zone
- System reaction + Warning
- Driver reaction, support
- Supported driver lead evasion
- Braking distance
- System reaction
- System lead evasion
- Hand over zone
- Safety zone

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

ESS – window for initiation of support

Reaction time
Decreasing number of options for driver to avoid collision
Unavoidable

Risk of rear-end collision

Time to Collision
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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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
Thank you for your attention.

Questions?

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