APPLICATIONS IN TRAFFIC ACCIDENT RESEARCH TO IMPROVE VEHICLE SAFETY

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1. Necessity of traffic accident research
2. Application assisted accident investigation
3. Data analyses for research on traffic safety
4. Pre-crash simulation to enhance traffic safety
5. Conclusion
Applications in Traffic accident research to improve vehicle safety
Necessity of traffic accident research

Accident research in the 1920s

Early “accident research” in Dresden

Source: Youtube
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Necessity of traffic accident research

Accident scenario in Germany

- Car occupants benefit from active and passive safety
- Numbers of accidents & casualties are stagnating since some years
- In 2016 persons:
  - Fatalities 3,206
  - Seriously injured 67,426
  - Slightly injured 329,240

→ In-depth accident studies are absolutely essential to improve vehicle safety
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Necessity of traffic accident research

Documentation of real traffic accidents

Accident data analysis

Reconstruction and Simulation

Naturalistic driving study

Area of studies

- Automotive engineering
- Transportation engineering
- Medicine

System assessment

Institute for Traffic Accident Research at Dresden University of Technology

Education
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Necessity of traffic accident research

GIDAS – German In-Depth Accident Study, since 1999

General information

Approximately 2,000 accidents/year

Accident sketch

Technical investigation

Medical investigation
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Necessity of traffic accident research

Criteria

- Only accidents with personal damage

Investigation area

- Hanover
- Dresden

Source: Google Maps & GIDAS

Database

- Accident level: ~33,000 accidents
- Vehicle level: ~60,000 vehicles
- Personal level: ~77,000 persons
- Ø 3,500 single information/accident
Structure

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Application assisted accident investigation

Some examples

OpenStreetMap (OSM) for accident sketch

Coding of injuries

Signal processing of measurements
Structure

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Data analyses for research on traffic safety

Databases

Access and processing

Source: ESV 2017 – Bakker, Spitzhüttl et al.: “IGLAD - International harmonized in-depth accident data”
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Mathematical models – Injury Risk Functions (IRF)

What is it?
Model to describe the probability of the occurrence of a specific event (e.g. to be at least seriously injured) as a function of one or several influencing parameters (e.g. collision speed) for a given population.
→ Substantial tool for the assessment of vehicle safety systems

How is it calculated?
Based on real (accident) data, calculating the maximum likelihood estimation with an underlying logistic distribution

\[ p = \frac{1}{1 + e^{-z}} = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n)}} \]

\( \beta_0 \ldots \beta_n \) – regression coefficients
\( x_1 \ldots x_n \) – independent variables
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Mathematical models – Injury Risk Functions (IRF)

What is it used for?

Real accident:
$v_{\text{coll}} = 50 \text{ km/h}$

Accident with system (e.g. AEB):
$v_{\text{coll}} = 40 \text{ km/h}$
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Mathematical models – Injury Risk Functions (IRF)

Multidimensional
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Calculation of deformation frequencies

- Normalized car dimensions and discretization into voxel
- Accumulation of accident deformations for 1000 passenger car

→ Analyzation of potentially safe places for sensitive and/or dangerous energy storage (e.g. battery or gas)
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ACEA Safety Model

Sequence of a traffic accident:

- $t_{crit}$: critical event
- $t_u$: collision unavoidable
- $t_0$: collision

**Phase 1**: Normal driving
**Phase 2**: Incident-Phase
**Phase 3**: Pre-Crash-Phase
**Phase 4**: In-Crash-Phase
**Phase 5**: Post-Crash-Phase

**Safety Levels**:
- Active safety
- Integral safety
- Passive safety
- Tertiary safety
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**VUFO Accident Simulation Toolbox (VAST)**

- Sketch
- External data
- Preparation
- Road
- Vehicle
- Action

Source: Mathworks.com
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Example accident – Sketch

Accident scene
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Example accident – Simulation

real accident situation

real accident situation

with ADAS System
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Evaluation of opponent’s position at specific TTC

* TTC = 400 ms
* TTC = 200 ms
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Point of no return \( t_u \) when a collision is unavoidable

Circle of forces / „Kamm'scher Kreis“

„Handbuch Fahrerassistenzsysteme, Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort“

(1) - Max. deceleration
(2) - Steering to the left
(3) - Steering to the right
(4) - Max. deceleration + Steering to the left
(5) - Max. deceleration + Steering to the right
(6) - Max. acceleration + Steering to the left
(7) - Max. acceleration + Steering to the right
(8) - Max. acceleration
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Point of no return $t_u$ when a collision is unavoidable

- Criticality as a function of time
  - continuous
  - differentiable
- No knowledge about the exact function
- $f(t_u) = 0$
  - no analytical solution possible
  - approximation by iterative process and variable integration step size

→ Efficient 2-step-approximation method
  1) Fixed step size of 1s
  2) Bisection method
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Point of no return $t_u$ when a collision is unavoidable – Generic rear-end collision

$t_u = f(\Delta v, \mu)$; $v_{obj} = 40$ km/h
$\Delta v = 2 \ldots 100$ km/h, $\mu = 0.1 \ldots 1.0$

$t_u$ comparison of simulation and literature
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Naturalistic driving study (NDS) → Incidents and Events
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Naturalistic driving study (NDS)

Real scenario

Recording

- Camera
- Accelerometer
- Rotation rate sensor
- GPS
- Sender and receiver device
- Processor und ring memory

Position

Movement

Video
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Naturalistic driving study (NDS)

Real scenario

Simulation
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Naturalistic driving study (NDS)

Ground truth labeling with

Automated Driving System Toolbox
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Naturalistic driving study (NDS)
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Naturalistic driving study (NDS)

<table>
<thead>
<tr>
<th></th>
<th>Driver 1</th>
<th>Driver 2</th>
<th>Driver 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger car</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
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<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
<tr>
<td>Camping van</td>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
<td><img src="image9" alt="Graph" /></td>
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<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
</tr>
</tbody>
</table>

Driver 1:
- Large scatter range
- Significant difference between passenger car and camping van
- High accelerations

Driver 2:
- Marginal difference between passenger car and camping van
- Experienced driving

Driver 3:
- Low scatter range
- Higher acceleration in passenger car

Naturalistic driving study (NDS)

2015
- Renault Espace: Marital-problems
- Suzuki Swift: Divorce
- Renault Megane: New relationship
- VW Caddy: Responsibility for children

2016
- Renault Megane: Crisis in relationship

2017
- Renault Laguna: On-Off relationship
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Naturalistic driving study (NDS)

Real driving behavior

Driver models

Automated driving

Individual sets of driving parameters

Extraction of driving profiles

Train ADAS and HAD
AGENDA

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Conclusion

- Assurance of traffic safety must be a very high society target. Human errors must not lead to fatalities in a modern traffic environment!

- In contrast to past trends, recent statistics show a stagnation in the accident numbers.

- The development of Highly Automated Driving needs some more efforts to ensure a safe and modern concept of movement.

- Therefore it is very important to improve on crucial aspects of
  - ensuring functional safety
  - study real world scenarios
  - progress on perception infrastructure to support vehicle systems.
THANK YOU FOR YOUR ATTENTION!

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