Advanced Driver Assistance Systems for increased Traffic Safety

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Agenda

• Introduction
  – Traffic Safety
    – Classification of ADAS

• Sensors for environment perception

• Examples of ADAS
  – Current automotive applications
  – Current off-road applications
  – Future automotive applications
Traffic Safety
Terminology

Active Safety

Normal
Accident Avoidance
Pre-Crash

Passive Safety

In-Crash
Post-Crash

Introduction

Sensors

Examples

Pre-Crash Accident Avoidance

Ca. 2,6 s vor dem Unfall

Ca. 1,6 s vor dem Unfall

Ca. 0,6 s vor dem Unfall
Traffic Safety
Accident Statistic vs. Target of European Commission

Measure for traffic safety:
Number of accidents and hereby injured or killed people

50% Reduction (3rd RSAP)

50% Reduction (4th RSAP)
Traffic Safety
Accident Statistic vs. Target of European Commission

[Bar chart showing accident statistics over time]
Traffic Safety
Accident Statistic vs. Target of European Commission
Traffic Safety
Accident Statistic vs. Target of European Commission

Introduction

Examples
Traffic Safety
Basics for the Deduction of Measures

- Accident research and analysis
  - When, where, why and under which circumstances do accidents happen?
  - Type, severity, frequency, reconstruction, … of accidents

- Biomechanics
  - How do these accidents affect the human body?
  - Type, severity, frequency, … of injuries

- Active Safety
  - Reduce the number of accidents

- Passive Safety
  - Minimise the effects of accidents
Traffic Safety
Accident Research and Analysis

• Accident reasons

- Human Error 93.5%
- Environment/Weather 4.6%
- Technical Defect 0.7%
- Other 1.2%

Other sources mention up to 5 % due to technical defects

Source: Volkswagen GIDAS database
Analysis of 16,544 accidents
Traffic Safety
Accident Research and Analysis

- Distribution of 3966 technical defects in 2009 (Germany)

Traffic Safety
Deduction of Measures

- Passive safety in former times

- Deformated A-pillar
- Steering wheel intrusion
- Rear displacement of front wall
- Deformated door
Passive Safety Protection of Passengers in the Past and Today

- aggressive form of steering wheel
- square-edged instrument panel
- displacement of steering wheel
- floor room intrusion
- knee protector pads
- side airbag
- telescopic steering column
- front airbag
Traffic Safety
Deduction of Measures ⇒ Accident Risk Reduction

• Vehicle
  – Vehicle design (chassis concept, quality of safety relevant parts, etc.)
  – Vehicle concept (control panel, climatisation, lighting, viewing angle, seat position)

• Driver
  – Driver condition (stress, exhaustion, driver attention etc.)
  – Driver behaviour (choice of speed for cornering, choice of distance for following, etc.)

• Infrastructure / environment
  – Road conditions
  – Road lighting
  – Crossroad concept
  – Signing (speed limit/ ban on overtaking)

• Legislation
  – Speed controls
  – Minimum distance between two vehicles
Traffic Safety
Deduction of Measures ⇒ Accident Risk Reduction
Traffic Safety

Deduction of Measures ⇒ Accident Risk Reduction

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  – Vehicle design (chassis concept, quality of safety relevant parts, etc.)
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• Legislation
  – Speed limits
  – Minimum distance between two vehicles
Traffic Safety

Deduction of Measures

- Human errors and possible technical solution
  - Driver has to realise (detect) the situation (viewing angle, i.e. vehicle in blind spot?) ⇒ Lane Change Assist
  - Driver has to assess the situation in the right way (risk of collision, critical situation) ⇒ Collision Warning
  - Driver has to judge the situation in the right way („It will be close, but I will go through“) ⇒ Emergency Braking
  - Driver has to react in the right way (full brake power, evasion manoeuvre)
  - Vehicle has to convert driver’s reaction (sufficient high deceleration/lateral acceleration) ⇒ ABS
  - Street condition has to realize the deceleration/lateral acceleration (friction factor, unevenness) ⇒ Road Friction Tester
Traffic Safety
... is not the only target of ADAS

- **Comfort**
  - Increase of driving comfort
  - Relieve the drivers from monotone tasks

- **Traffic efficiency**
  - Improved utilisation of the road capacity
  - Avoidance or faster dissolution of traffic jams

- **Effects on the environment**
  - Decrease of fuel consumption
  - Decrease of emissions (e.g. CO₂, CO, NOₓ, Particles)
  - Reduction of traffic noise
Traffic Safety
... is not the only target of ADAS

- CO\textsubscript{2} emission of new licensed passenger cars

![Graph showing CO\textsubscript{2} emissions for Diesel and Petrol vehicles from 2006 to 2008.]

- EU Goal 2015: Limitation CO\textsubscript{2} Emission 120g/km
- EU Goal 2020: Limitation CO\textsubscript{2} Emission 95g/km

Source: VOL09
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  - Classification of ADAS
- Sensors for environment perception
- Examples of ADAS
  - Current automotive applications
  - Current off-road applications
  - Future automotive applications
Classification of ADAS

... according to the course of traffic
Classification of ADAS
... according to the type of assistance

- **Information**
  - acoustic
  - visual
  - haptic

- **Warning**
  - acoustic
  - visual
  - haptic

- **Intervention/takeover of the driving task**
  - accelerator/brake pedal
  - steering
  - transmission
Classification of ADAS
... according to the driving task

Driving Task

**Navigation level**
\[ t = 10 \text{ s} \ldots \times \text{h} \]

The driver decides the route inside an existing road network. During the drive the navigation engages itself to the perception of the necessary information for keeping the route and if necessary to an adjustment of the route due to changed boundary conditions.

**Guidance level**
\[ t = 1 \text{ s} \ldots 10 \text{ s} \]

The driver adjusts the driving manner to the road situation perceived by him and the surrounding traffic. The guidance level contains subtasks e.g. the lane-keeping, the following, the overtaking and the reaction to traffic signs. The tasks of this level can be divided into lateral and longitudinal guidance.

**Stabilisation level**
\[ t = 0 \text{ s} \ldots 1 \text{ s} \]

The driver converts the chosen driving strategy into vehicle-specific control variables, e.g. steering action, position of accelerator, brake und gear. A permanent adjustment of the actual value to the desired value of the velocity and the lane takes place. For the driver „stabilisation“ means the avoidance of uncontrolled internal dynamic of the vehicle.
Classification of ADAS
... according to the driving task

Level of driving task

- **Navigation**
  (route choice)

- **Guidance**
  (course and speed choice)

- **Stabilisation**
  (actuation of steering wheel, throttle and brake pedal)

Asisstance System

- Navigation System
- ADAS
  (e.g. ACC, LDW)
- Chassis Control Systems
  (e.g. ABS, DSC)

Analogy

1. **1st**
   - Feel
   - Equilibrium organ
   - Inertial sensors

2. **2nd**
   - See
   - Eyes
   - Radar, Camera

3. **3rd**
   - Communicate
   - Ear & Mouth
   - C2X, GNSS

Needed Sensors
Agenda

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Sensors for environment perception

Overview

- **Long-Range Radar**
  - Far field ≤200m

- **Infrared**
  - Night View

- **Video**
  - Middel field ≤80m

- **Ultrasonic**
  - Ultranear field ≤4m

- **Video**
  - Rear range

*source: Bosch*
Sensors for environment perception

History of Radar Technology

- Traffic radar equipment in Dresden 1961
- Display unit is integrated in vehicle

source: German Traffic 07/1961
Sensors for environment perception
Long Range Radar

- RADAR = Radio Detection And Ranging
- Example: Bosch 3rd generation

**Performance data** (compared to LRR2)
- Field of View: 30° (16°)
- Range: 0.5...250m (1.5 ...200m)
- Object separation
  - By distance: 1m (2m)
  - By velocity: 0.6m/s (1.2 m/s)
  - By angle: ~4° (none)

**Technology**:
- 77 GHz Silicon Germanium MMIC (world’s first)
- Flexray communication (world’s first)
- Package advantages (world’s smallest)
- Lead free
Sensors for environment perception

Lidar

- LIDAR = **Light Detection And Ranging**
- Example: Omron and Hella

<table>
<thead>
<tr>
<th>Model</th>
<th>OMRON gen3</th>
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<tbody>
<tr>
<td>Wavelength</td>
<td>905 nm</td>
</tr>
<tr>
<td>Eye protection</td>
<td>Class 1 (IEC825)</td>
</tr>
<tr>
<td>Radiated power:</td>
<td>12W (Peak) 5mW (Average)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Hella IDIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>905 ... 920 nm</td>
</tr>
<tr>
<td>Eye protection</td>
<td>Class 1 (IEC825)</td>
</tr>
<tr>
<td>Radiated power:</td>
<td>50W (Peak)</td>
</tr>
<tr>
<td>Coverage</td>
<td>±16° (Azimuth/hor.) 3° (Elevation/vert.) multiray</td>
</tr>
<tr>
<td>Number of rays</td>
<td>16</td>
</tr>
<tr>
<td>Min. curve radius</td>
<td>100 m</td>
</tr>
<tr>
<td>Range</td>
<td>1 ... 150 m</td>
</tr>
<tr>
<td>Size LxWxH</td>
<td>105 x 105 x 76.5 mm²</td>
</tr>
<tr>
<td>Velocity Accuracy</td>
<td>1 km/h</td>
</tr>
</tbody>
</table>
Sensors for environment perception
Laser Scanner

- **LASER** = Light Amplification by Stimulated Emission of Radiation
- Example: Ibeo Lux
  - Scanning Frequency: 12.5 Hz (25 Hz)
  - Horizontal angle: 100 ° field of view
  - Range: 0.3 m to 200 m
  - Resolution: range 4 cm, angle 0.125 ° to 1 °
  - 4 parallel and simultaneous scanning layers
  - Size: H85 x W128 x D93
  - Weight: Approx. 1kg
  - Built-in processing
  - Laser class 1
  - Ethernet- and CAN-Interface
Sensors for environment perception
Comparison of radar with laser sensors

Advantages

- **Radar**
  - not sensitive to dirt
  - direct velocity measurement
  - hidden installation possible
  - no interferences with other sensors
  - low output power
  - small antenna because of combined emitting and receiving

- **Laser**
  - low price
  - point of view adaptation
  - no interferences with other sensors
  - no health impairment

Disadvantages

- expensive
- no visibility measurement
- blind flight possible at bad sight
- sensitive to dirt
- installation influences styling
- indirect velocity measurement
- sensitive to bad weather condition
Sensors for environment perception
Systems for image processing

- CMOS camera (Complementary Metal Oxide Semiconductor)
- CCD camera (Charge Coupled Device)
- Example Mobileye:
  - Resolution: 480×640 pixels
  - Field of View: 47 °
Sensors for environment perception

Ultrasonic

• Used in park distance control systems

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0.2 – 1.5 m</td>
</tr>
<tr>
<td>Position Accuracy</td>
<td>0.02 m</td>
</tr>
<tr>
<td>Relative Velocity</td>
<td>-5 m/s – +5 m/s</td>
</tr>
<tr>
<td>Velocity Resolution</td>
<td>0.5 m/s</td>
</tr>
<tr>
<td>Object Detection Time</td>
<td>100 ms</td>
</tr>
</tbody>
</table>

Sources: DENSO, Bosch
Sensors for environment perception
Comparison of different sensor systems

<table>
<thead>
<tr>
<th></th>
<th>Radar</th>
<th>Lidar</th>
<th>Laser scanner</th>
<th>Ultrasonic</th>
<th>Image processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>++ (77 GHz)</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>+ (24 GHz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy long. distance</td>
<td>0 (77 GHz)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>+ (24 GHz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral resolution</td>
<td>-</td>
<td></td>
<td>0</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Multiple targets</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Measurement process</td>
<td>Reflexion</td>
<td>Reflexion</td>
<td>Reflexion</td>
<td>Reflexion</td>
<td>Triangulation</td>
</tr>
<tr>
<td>Measurement at bad weather or dirty sensor</td>
<td>+ +</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Hidden mounting</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Sensors for environment perception
Vehicle-to-vehicle/infrastructure communication

- Communication technology:
  - Wireless LAN IEEE 802.11.p
  - GSM, GPRS, UMTS UTRA TDD
  - HiperLAN
  - CALM
  - Bluetooth
  - Self-contained solutions based on 434 MHz, 868 MHz, 2.4 GHz, 5.8 GHz, 24 GHz

- Abbreviations:
  - V2V (C2C)
  - V2I (C2I)
  - V2X (C2X)
Sensors for environment perception
Global Navigation Satellite Systems

• Examples: GPS, Galileo, Glonass
  – Position Accuracy: 10 m
• Enhanced Position Accuracy:
  – DGPS: up to 0.3 – 2.5 m
  – RTK-GPS: up to 2 cm
Sensors for environment perception
Digital Map & Map Matching

- Improve the accuracy of satellite navigation and “Dead Reckoning”
- Positioning system gives coordinates, which do not correspond exactly to those of a street on the map
- Itinerary is compared to the course of the road on the digital map
- Map Matching algorithm corrects the position
- Pseudo positioning system, because it determines the position through the coordinates of knots (junctions) or points (beginning or end of curve)
Sensors for environment perception
How does the world look like for sensor technology?

• Distance sensors
Sensors for environment perception
How does the world look like for sensor technology?

- Distance sensors + image processing “1G”

- lane marking (ego position, lane width, lane markings, curvature)

- distance and velocity
Sensors for environment perception
How does the world look like for sensor technology?

- Distance sensors + image processing “2G”

- Pedestrian
- Lane marking (ego position, lane width, lane markings, curvature)
- Signage
- Distance, velocity and width
Sensors for environment perception
How does the world look like for sensor technology?

- Distance sensors + image processing “2G” + C2C
Sensors for environment perception

How does the world look like for sensor technology?

- Distance sensors + image processing “2G” + C2C + digital map

![Diagram of sensor technology application in a junction with vehicles, track, signage, and pedestrian.]
Agenda

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• Sensors for environment perception

• Examples of ADAS
  – Current automotive applications
  – Current off-road applications
  – Future automotive applications
Current automotive applications

First developments in the 1950's

the first field test of a radar-based distance measurement in the 50th's
Current automotive applications
First C2C

Source: ADASE 2 AIDER CARTALK WORKSHOP
Current automotive applications

Automatic tunnel drive
Current automotive applications

First lateral guidance system

Driving on a guide wire
Current automotive applications

Example: BMW 7 series

- BMW Night Vision
- Adaptive curve light
- Front light assistant
- ACC S&G
- Head-Up Display
- Lane Departure Warning
- Speed-Limit Display
- Lane Change Warning
- Side View, Rear View Camera
- Park Distance Control (PDC)
- BMW Assist
- Dynamische Stabilitäts Control (DSC), Brake assistant
- Rain sensor including drive light and wiper control
- Adaptive Brake light
- Active steering

Source: BMW
Current automotive applications
Night Vision - Far Infrared Radiation (FIR)

- Passiv Night Vision System
- Infrarotsensitive camera in vehiclefront
- Thermal radiation (7-12 µm) of objects are detected
- Warm objects are indicated as black-white picture
- Especially pedestrians and bikers are detected in cold environment
- Range up to 300 m
- No additional receptor/ transmitter required
Current automotive applications
Night Vision - Near Infrared Radiation (NIR)

- Active Night Vision System
- Infrarot radiator in vehiclefront, acceptor camera can be integrated in vehiclefront in any order
- Wavelength in the range of 780-1000 nm (near infrared radiation)
- Infrarot radiation is reflected on objects
- Important objects (road markings, traffic signs etc.) are dedicated definitly
- Further applications are possible (pedestrian detection)
- IR-emitter is halogen bulb with optical filter (future: IR-LDEs)
Current automotive applications
Night Vision 2

- Based on FIR Technology with additional detection of pedestrian and bikers
- Objects are classified
- Driver is warned in case of positive detection
- Detection field depends on vehicle velocity

Quelle: BMW, Autoliv, ATZ
Current automotive applications
Adaptive light (Variable light dissipation at intersections)

standard

new

Source: Hella
Current automotive applications
Semi-autonomous parking
Current automotive applications
Adaptive Cruise Control (ACC)

- Facts and figures:
  - First use 1995 in Japan
  - Introduced in Europe 1999 in Mercedes vehicles
  - In 2002 integration of ACC systems in heavy duty vehicles
  - Radar with 76-77 GHZ or Lidar
  - Today available at over 20 vehicle manufactures
Current automotive applications
Adaptive Cruise Control (ACC)
Current automotive applications

ACC Stop&Go

• Facts and figures:
  • Introduced in Europa 2005 by Daimler in S-Class
  • Other OEMs bring ACC S&G to the market (e.g. BMW 5 and 7)
  • Detection of surrounding using 24 GHz Radar Sensors
  • Maximum deceleration of up to 4 m/s²
  • Automatic acceleration after standstill if front vehicle accelerates within 3 seconds

Quelle: Daimler
## Current automotive applications

### Launch of ACC systems

<table>
<thead>
<tr>
<th>Year</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>Mondeo, CR-V, Legend, Accord</td>
</tr>
<tr>
<td>2000</td>
<td>Megane, Espace, Vel Satis, Sonata</td>
</tr>
<tr>
<td>2002</td>
<td>Primera, Phaeton, Touareg, Passat CC</td>
</tr>
<tr>
<td>2004</td>
<td>Range Rover Sport, Discovery, IS, S80</td>
</tr>
<tr>
<td>2006</td>
<td>XK8, XJ-Type, S-Type, XK</td>
</tr>
<tr>
<td>2008</td>
<td>S80, XC 70, V70, XC 60, Focus</td>
</tr>
<tr>
<td>2010</td>
<td>Galaxy, S-Max, Mondeo, A8</td>
</tr>
</tbody>
</table>

### ACC and ACC S&G

- Sonata
- Megane, Espace
- Primera
- Phaeton
- Touareg
- Passat CC
- Range Rover Sport, Discovery
- IS, S80, XC 70, V70, XC 60
- XK8, XJ-Type, S-Type, XK
- S80, XC 70, V70, XC 60
- Galaxy, S-Max, Mondeo
- Stilo
- C5, C6
- 300c
- STS
- 7er, 6er, 5er
- Q7, 7er, 6er, 5er
- A4, A5, A6

---

*Note: The table lists the models for which ACC systems were launched.*
Current automotive applications
From ACC to ACC Stop&Go to CMbB

ACC Stop&Go must be able to detect non moving targets safely

Collision Mitigation / Avoidance by Braking

Collision Warning

Traffic Jam Assistant

ACC

Stop & Go

Velocity range

0 - 200 kph

Possible deceleration

0 - 1g

0,2 g

Examples

Introduction

0,2 g
Current automotive applications

Euro NCAP Advanced Reward - Volvo City Safety
Current automotive applications

Euro NCAP Advanced Reward - Audi Side Assist
Current automotive applications

Euro NCAP Advanced Reward - Mercedes Pre-Safe Brake
Current automotive applications
Euro NCAP Advanced Reward - Peugeot Connect SOS

EURO NCAP advanced
2010 Reward for Peugeot Connect SOS
Current automotive applications

Euro NCAP Advanced Reward - Volkswagen Lane Assist
Current automotive applications

Autonomous Driving Trucks

- Introduction of autonomous driving trucks on factory premises for the transport of euro-pallets
- Realised since March 2001
- Max. driving velocity: 5 km/h

- Sensors: Laserscanner for obstacle detection
- Rubber foam bumper as emergency-off buttons
- Distance between activation of emergency-off and complete standstill of the vehicle in wet road conditions: 0.4 m
- Truck can be driven as normal vehicles by human driver
Current automotive applications

Autonomous Driving Trucks
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Current off-road applications
Guidance of agricultural machinery
Current off-road applications
Wheel Loader
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Future automotive applications

Platooning

- Electronic coupling of two or more trucks
- Distance between vehicles from 5 to 15 m
- System takes over longitudinal and lateral control
- Possible lane changes performed by the system

- Advantages:
  - Reduction of fuel consumption up to 17%
  - Reduction of occupied road space
  - Relaxed driving for the coupled drivers
Future automotive applications

Obstacle warning

- On basis of vehicle-vehicle-communication
- Warning of traffic jam end
- Construction sites
- Accident sites
- Local dangers: icy road, oil on road
- Message is delivered from vehicle to vehicle
Future automotive applications
ecoACC (predictive control)
Future automotive applications
Autonomous Lane Change Assistant

- Vehicles communicate and cooperate with each other
- Vehicle 1 asks for cooperation
- Vehicle 2 keeps lane and accelerates to generate space for vehicle 3
- Vehicle 3 brakes and tries to change lane
- Vehicle 4 is not relevant in this case and keeps on the same lane
Future automotive applications
Intersection assistant

• On basis of vehicle-vehicle-communication
  – Disadvantages: no early pedestrian detection

• Realisable through image processing or laser scanner
  – Disadvantage: no detection of hidden vehicles

• ⇒ Combination of systems ideal
Future automotive applications

Intersection assistant ... can’t always help
Future automotive applications
"Vision Zero": Accident free road traffic

Source: Autoliv
Future automotive applications
Burden: Legal aspects

The development of ADAS has to consider the Wiener Convention from 1968:

ARTICLE 13

Speed and distance between vehicles

1. Every driver of a vehicle shall in all circumstances have his vehicle under control so as to be able to exercise due and proper care and to be at all times in a position to perform all manoeuvres required of him. He shall, when adjusting the speed of his vehicle, pay constant regard to the circumstances, in particular the lie of the land, the state of the road, the condition and load of his vehicle, the weather conditions and the density of traffic, so as to be able to stop his vehicle within his range of forward vision and short of any foreseeable obstruction. He shall slow down and if necessary stop whenever circumstances so require, and particularly when visibility is not good.
Contact

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