Environmental Sensing

Modul 5 Chapter 8

Lecture I

Some of the following slices are not translated in English

If the user is not fluent to the German language, he/she should apply the following web site

www.leo.org/english

Lehrgebiet Fahrzeug-meßtechnik und Elektronik

Chair for Automotive measurement technology and electronics

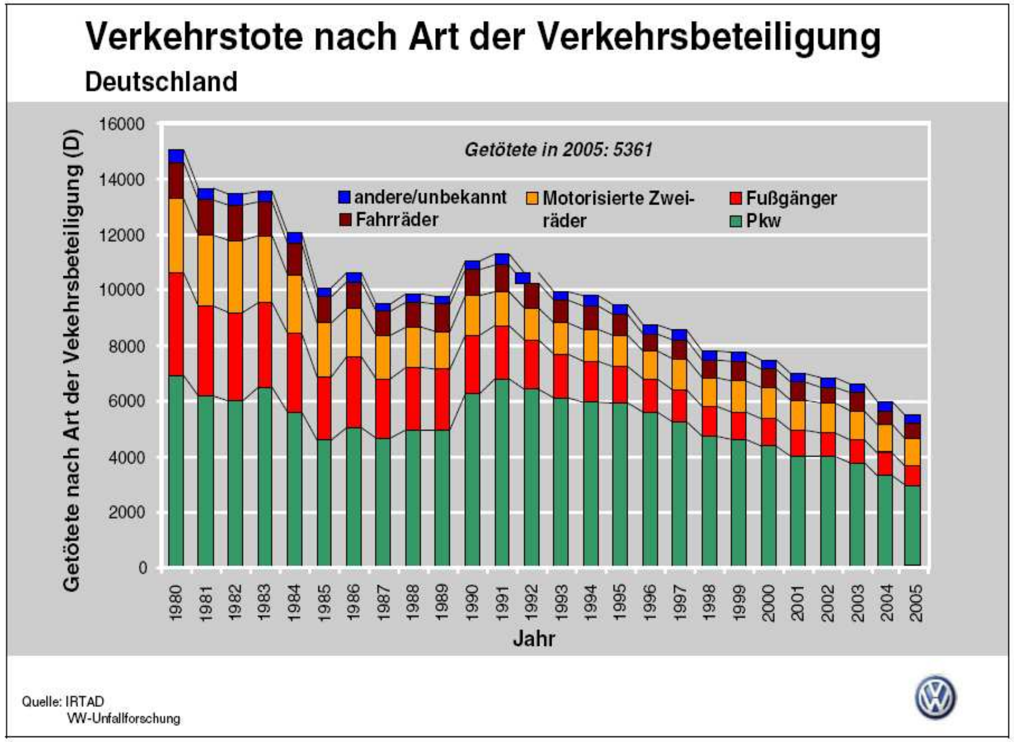
Content

Lecture I

1. Introduction
2. Driver Assistance Systems (overview)
3. Lateral/Side Sensing and Control Systems
4. Longitudinal Sensing and Control Systems
5. Sensors
6. Wave
7. Principles of measurement
8. Concrete systems

Introduction

- Success in the traffic safety
- The result of an increasing traffic (higher density) is a decreasing part of killed persons.



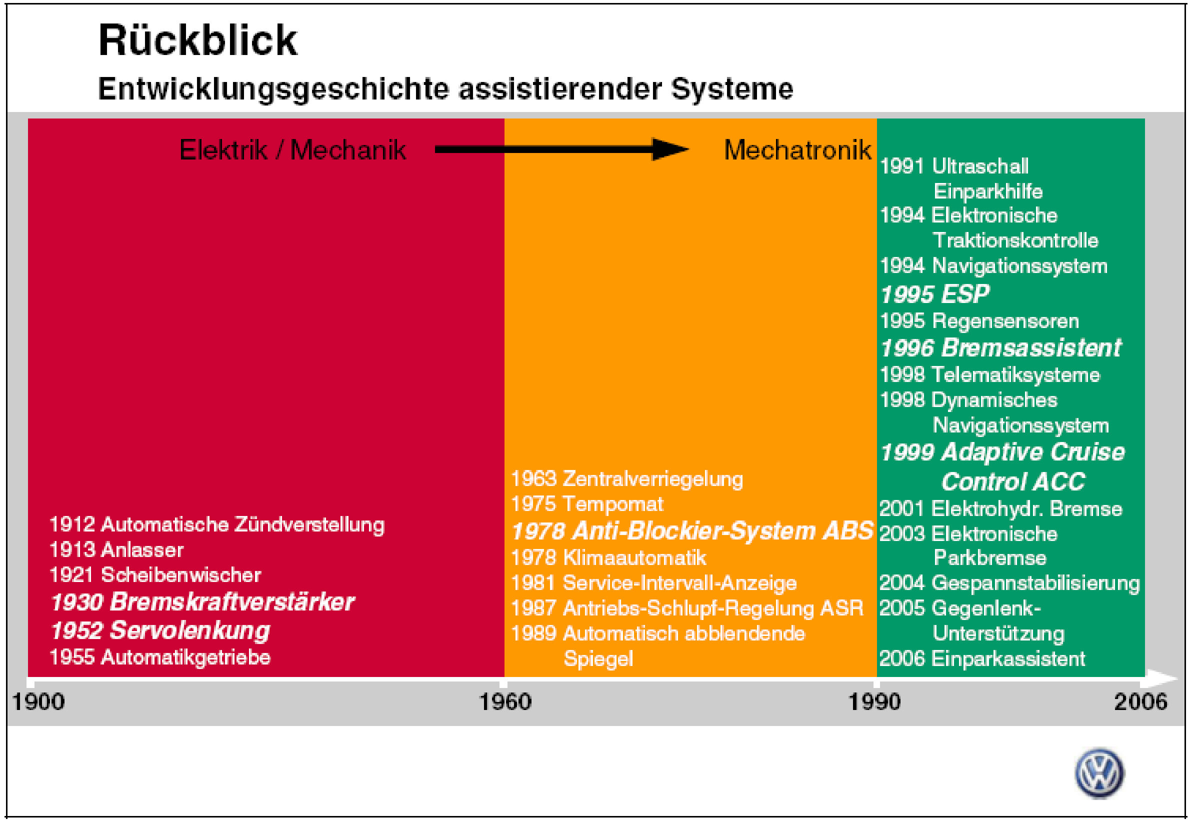
... but why?

More Safety (ABS, BAS, ESP)

Killed People (Type of participation)
Green: Cars
Red: Pedestrian

Introduction

- Review: What was invented in the past time?
- How did that work?



History of the assistance Systems

- Only electric or mechanic Systems
- Combination of both

Driver Assistance Systems

- Supporting the driver, help to understand situations easier and quicker
- Support the decision making process

- The driver‘s tasks:
  - Checking the correct way and
  - Observing the environment

Aim/target: **Recognize dangerous situations** for the driver and for other people

and **correct reactions**

- „Tools“: Only the visual perception (eyes)

Fachhochschule Köln
Cologne University of Applied Sciences

Driver Assistance Systems

- Problems with the visual percetion:

1. Limitation of the viewing direction
   Not possible: Watching right and left side at the same time

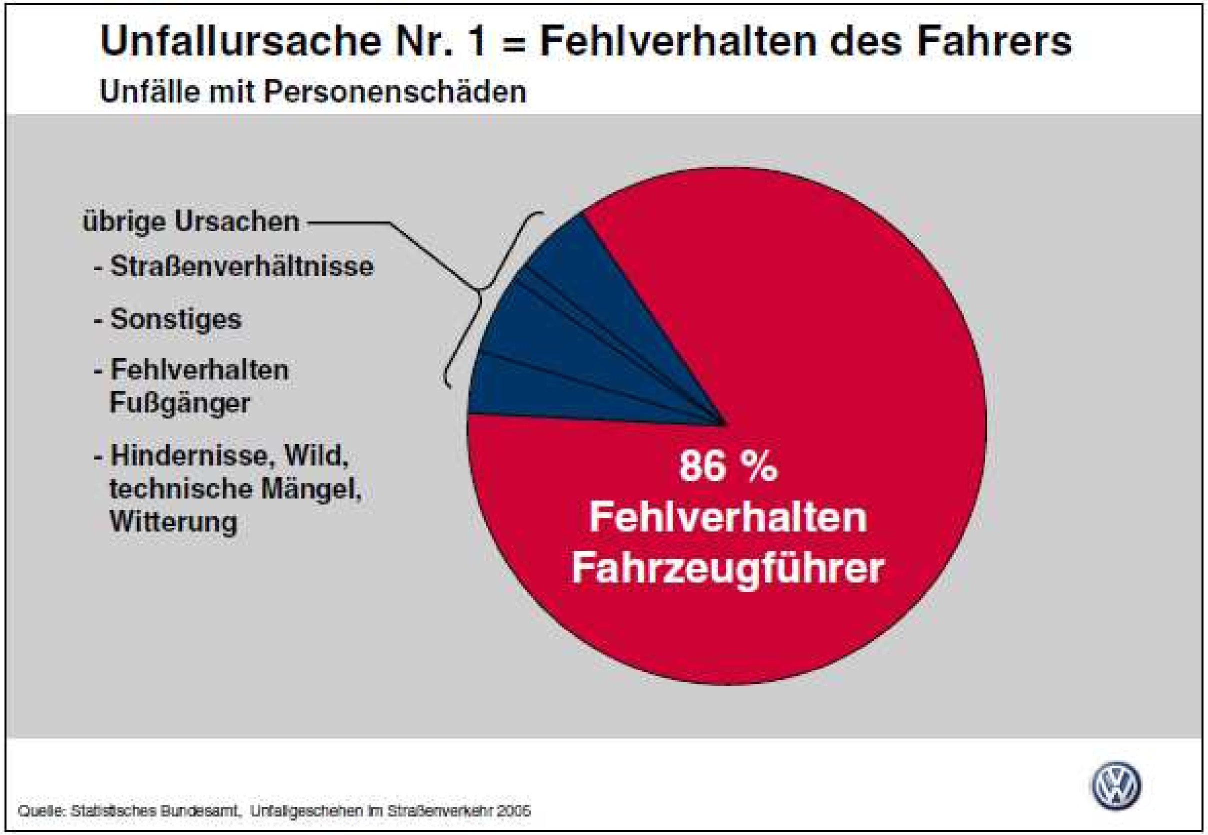
2. Limitation of atmospheric conditions
   Rain, fog, twilight

3. Limitation of other stimuli / overflow
   Stress, aggressions, tiredness

→ Change of priorities and other direction of view (wrong views?)

Driver Assistance Systems

- Cause of accident: Who made the failure?



ü The driver makes wrong decisions in 86% of all cases

Driver Assistance Systems

- What was the reason?

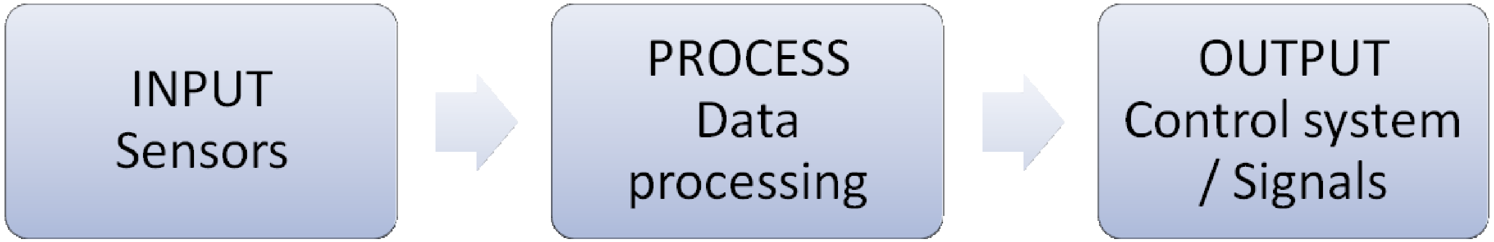
Factors	Number	Percent
Failure to keep in proper lane or running off road	16 551	28.0
Driving too fast for conditions or in excess of posted speed limit or racing	11 803	20.0
Under the influence of alcohol, drugs or medication	7 441	12.6
Failure to yield right or way	4 306	7.3
Innattentive (tallking,eating, etc)	3 415	5.8
Operating vehicle in erratic, reckless, careless or negligent manner	2 712	4.6
Failure to obey traffic signs, signals or officer	2 354	4.0
Overcorrecting/oversteering	2 319	3.9
Swerving or avoiding due to wind, slippery surface, vehicle, object, nonoccupant in roadway, etc...	2 301	3.9
Making improper turn	1 590	2.7
Drowsy, asleep, fatigued, ill or blackout	1 552	2.6
Vision obscured (rain, snow, glare, lights, building, tress, etc)	1 496	2.5
Driving wrong way on one-way trafficway or on wrong side of road	858	1.5
Other factors	9 304	15.7
None reported	21 265	36.0
Unknown	1 187	2.0
Total Drivers	**59 104**	**100.0**

Note: The sum of the numbers and percentages is greater than total drivers as more than one factor may be present for the same driver.

[1]NHTSA Traffic Safety Facts 2005

Driver Assistance Systems

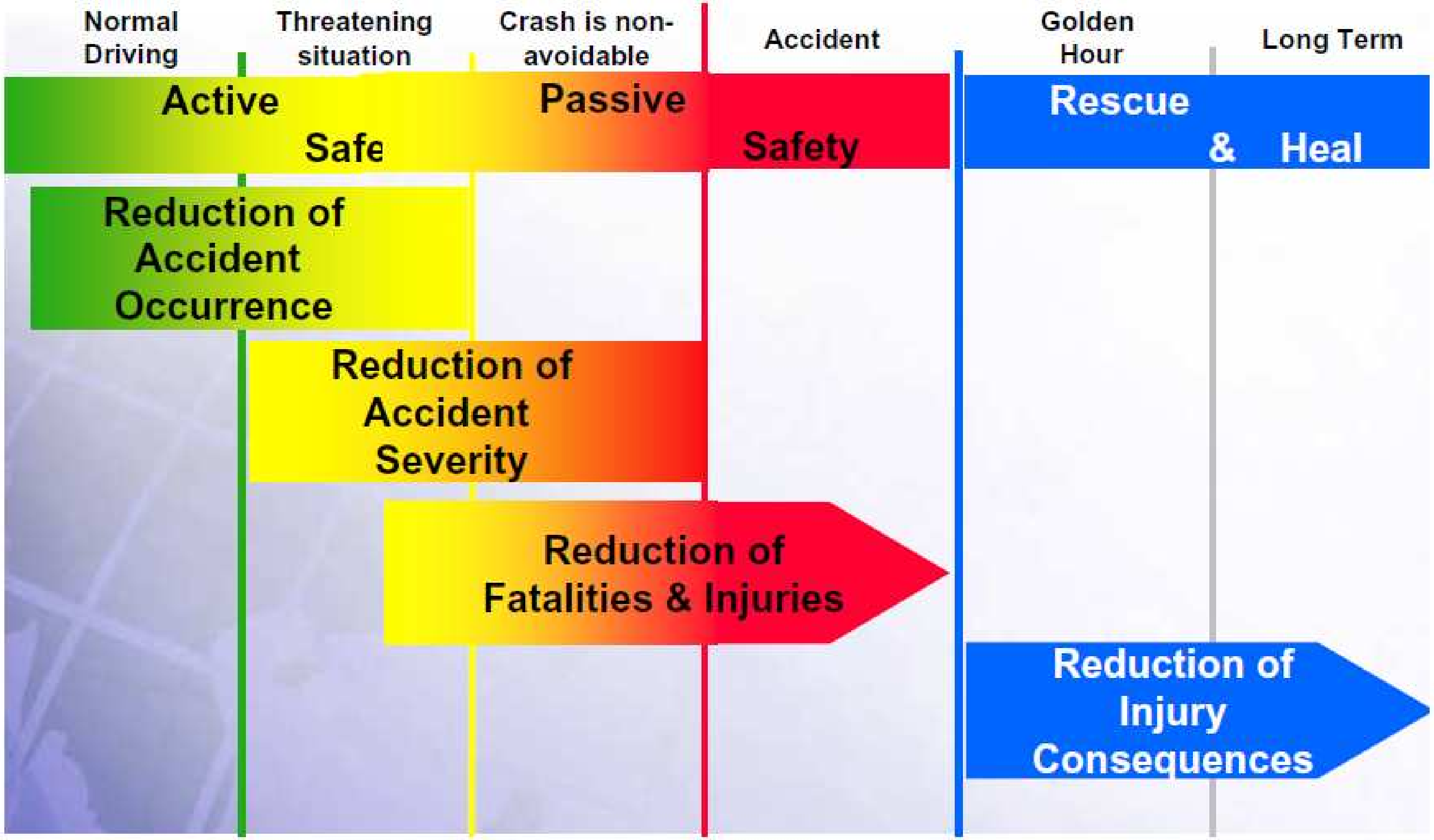
- How does the assistance work? – Components



- **Sensors** are the interface between environment and system.
- **Types of Sensors**: Different technologies that cover a wide area of the environment, including the inside of the car.
- A skilled arrangement and combination of sensors is necessary for getting realistic results.

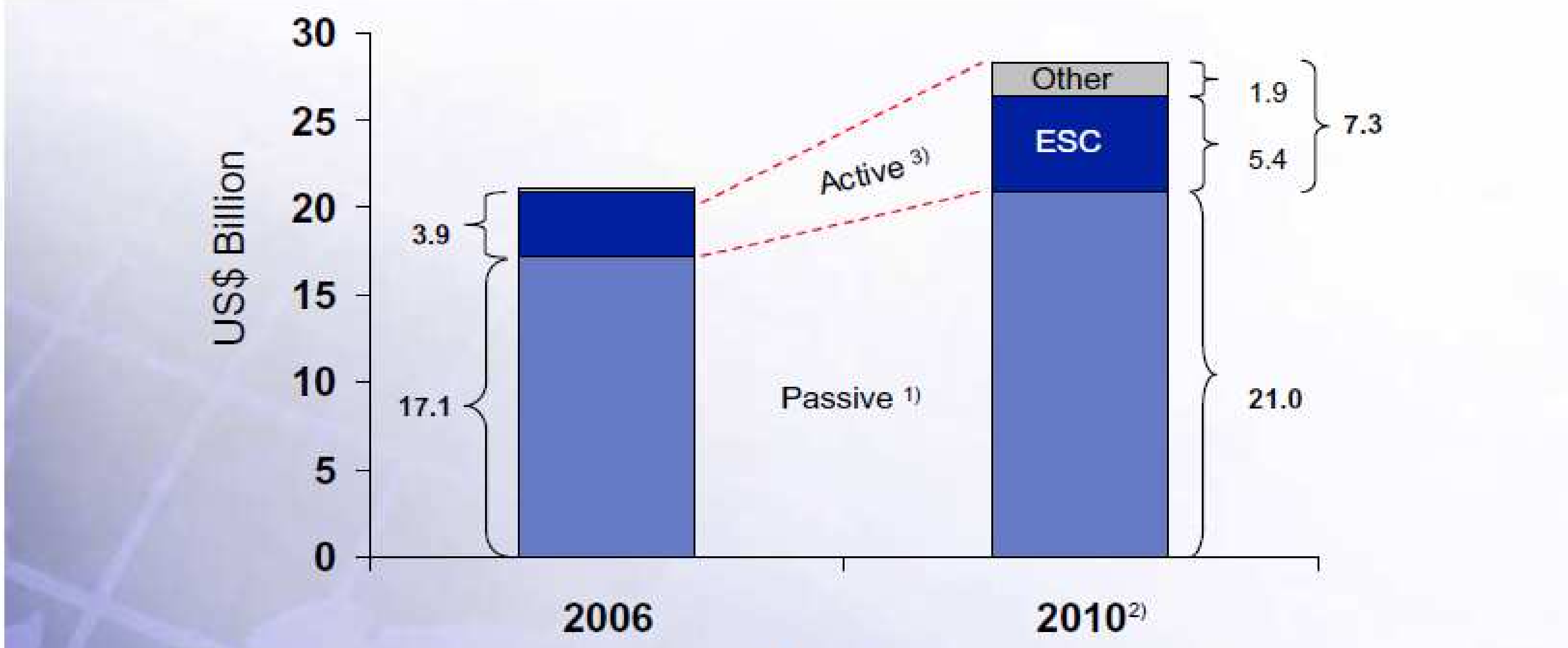
Driver Assistance Systems

- Where do the assistance systems work?



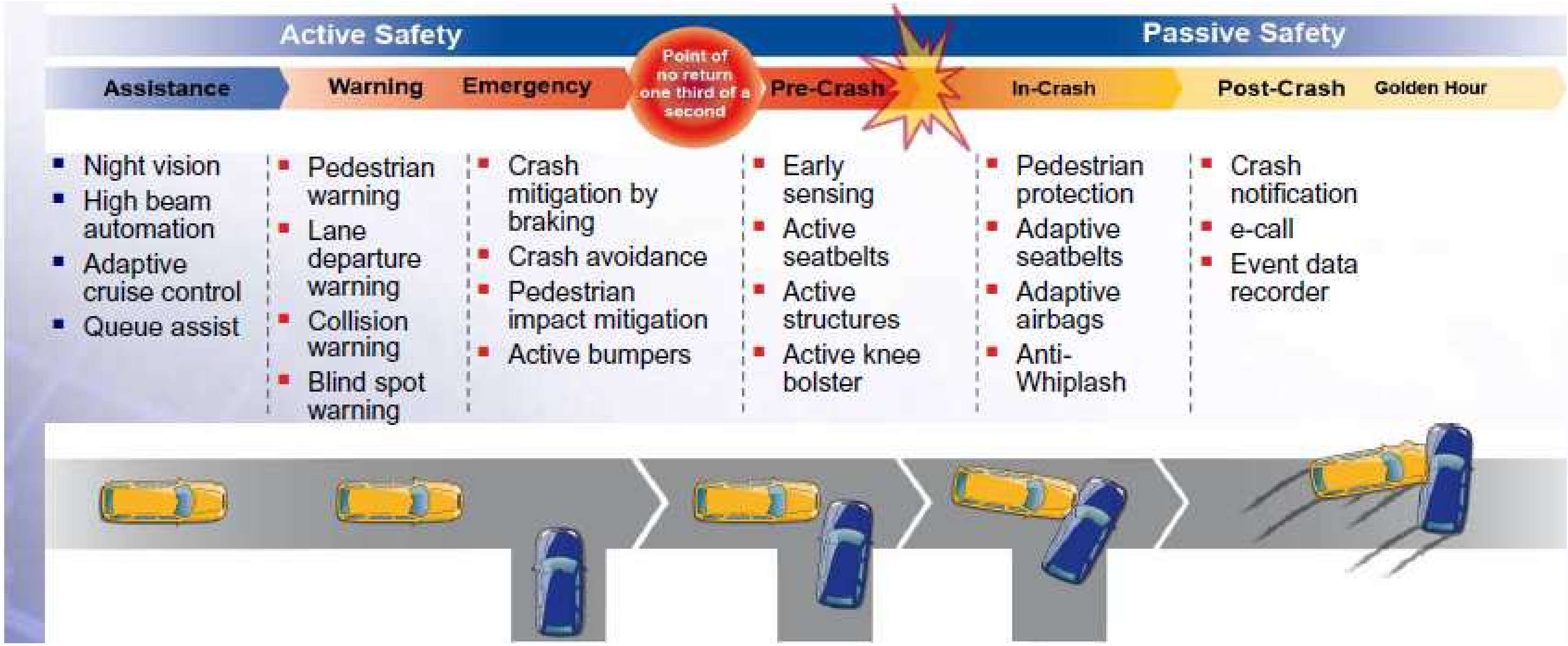
Driver Assistance Systems

- A growing market



1) Includes airbags, seatbelts and related electronics.
2) Based on light Vehicle Production forecasts from CSM and J.D.Power.
3) Includes Electronic Stability Control (ESC) and Radar/Vision (Drive Assistance).

Driver Assistance Systems



ØSensors are needed in <u>every</u> single system to gather necessary information

Systems: ***Lateral/Side Sensing and Control Systems***
Longitudinal Sensing and Control Systems
Integrated Lateral and Longitudinal Control and Sensing Systems

Lateral/Side Sensing and Control Systems

- Road as a base for gathering information
- Lane recognition uses the measurement of lane markings
- Side sensing uses imagebased methods and distance sensoring

Ø Examples:

- Lane Departure Warning
- Road Departure Warning
- Curve over-speed countermeasures
- Lane Keeping Assist
- Parallel parking assist
- Blind spot monitoring
- Lane change assist
- Rollover collision avoidance

Longitudinal Sensing and Control Systems

- Events in front and backwards of the vehicle are interesting
- Provides help for avoiding collisions (barriers, traffic density, …)
- Advanced systems analyse and identify objects (children, pedestrians) which are not in the perception area of the driver

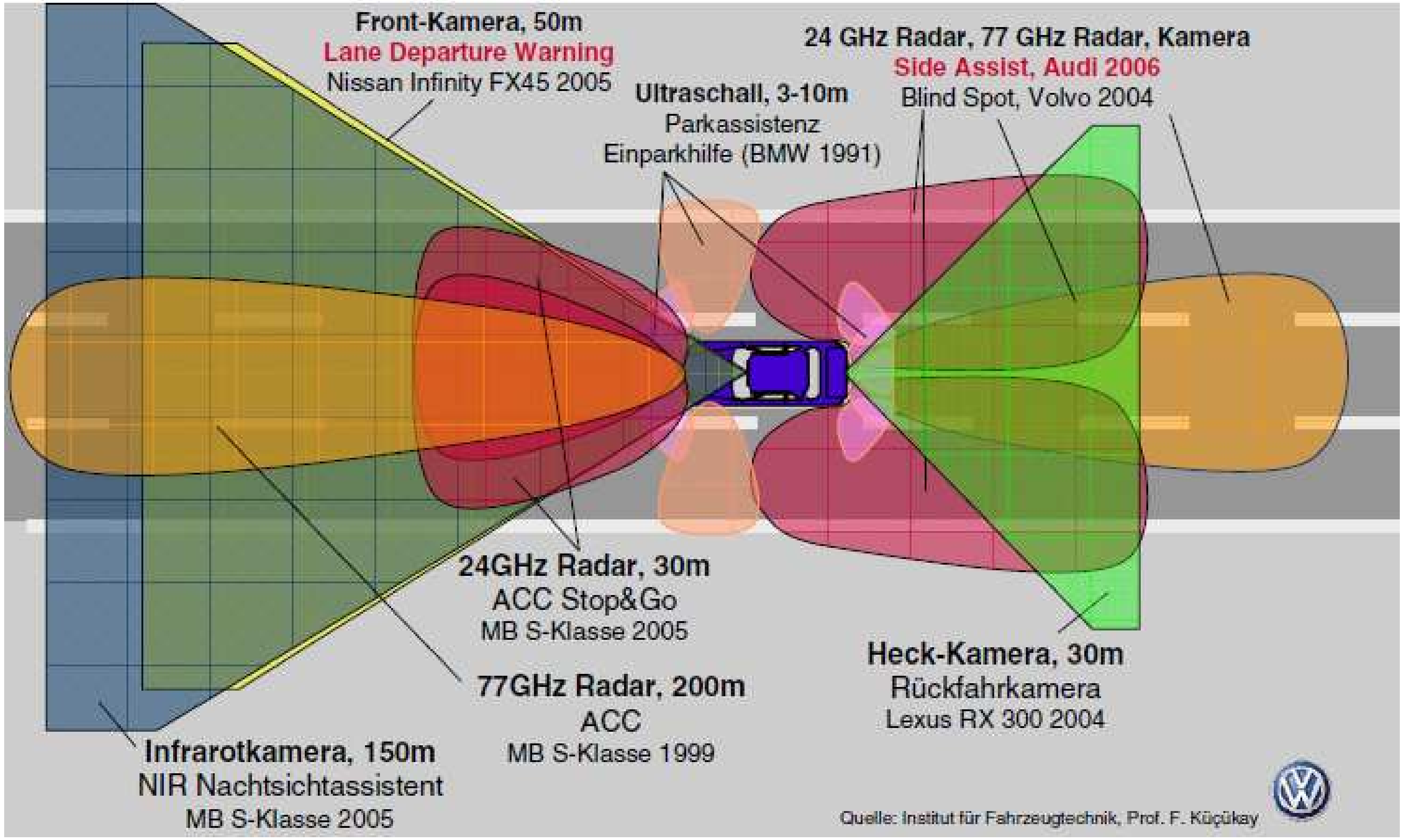
Ø Examples

- Backup / parking assist
- Night Vision
- Adaptive front lightning
- Adaptive Cruise Control
- Forward collision warning
- Safe gap advisory
- Rear impact contermeasures
- Breaking assist (precrash)
- Forward collision mitigation/avoidance
- Pedestrian detection and warning

Future of sensing and control systems

	State of the art	Near Future: + 5…10 years	Future
Enhanced Vision	Sensitive Guidance Night Vision I	Traffic Sign Assist Night Vision II	
Longitudinal Control	ACC Basic Full-Speed ACC	PreCrash Assist	Collision Avoidance Automated Drive
Lateral Control	Lane Departure Warn Blind Spot	Lane Keeping	
Driver Monitoring	Driver Identification	Driver Awareness	Eye-Tracking
HMI Improvement	e.g.: Head-Up-Display	Map matched HUD	Oriented HUD

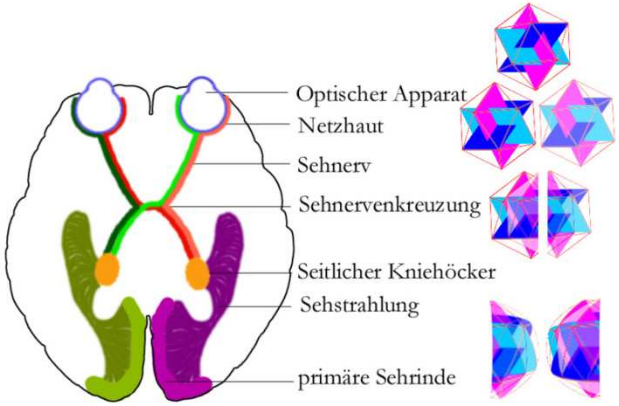
Sensors



- Different types of sensors for measuring the environment

Wave

- Different characteristics of sensors
- Various physical principles are used



Waves

ü Waves in the form of light are detected by the human eye

ü The eyes are the visual interfaces between environment and brain

ü The principles of driver assistent systems are similar to the eyes

ü Passive detection of waves and active detection possible

ü Transport of energy without emitating mass

ü Types: electromagetic waves (no mass needed), acoustic and water waves (air or water as mass needed)

Wave

- Wave equation is a differential equation of the 2nd order for the fuction:

$$\mathbf{A}\left(\mathbf{r}, t\right)$$

A: Deflection of the osciallation

r: Position; t: Time

- Respecitve equation:

$$\frac{1}{c^2}\frac{\partial^2 u}{\partial t^2} - \sum_{i=1}^{n}\left(\frac{\partial^2 u}{\partial x_i^2}\right) = 0$$

c: Phase velocity (air: 330m/s)

- Common solution: Covered waves with identic speed of propagation in different directions
- Result: Always different types of waves that can be simplyfied in three base waves (plan waves, cylindric waves and ball waves)

Physical fundamentals

Navier-Stokes-equation

Navier-Stokes describes the flow in Newton liquids and gases

Navier-Stokes is a typical system of not linear partial differential equations of second order:

$$\rho \frac{\partial \mathbf{v}}{\partial t} + \rho(\mathbf{v} \cdot \nabla)\mathbf{v} = -\nabla p + \eta \Delta \mathbf{v} + (\lambda + \eta)\nabla(\nabla \cdot \mathbf{v}) + \mathbf{f}.$$

Solving this equation-system

Finite differences, finite element, relaxations methods

Solution is possible in a convex/concave n-dimensional solution space (Hilbert-space)

Physical fundamentals

Bernoulli-equation

$$\frac{1}{2}\rho v^2 + \rho g h + p = \text{const.}$$

Continuity equation

$$\overrightarrow{A_1} \cdot \overrightarrow{v_1} = \overrightarrow{A_2} \cdot \overrightarrow{v_2}$$

Result: **ground speed of the vehicle**

not the absolut vehicle velocity

Physical fundamentals

Maxwell equations

$$\operatorname{div} \boldsymbol{D} = \rho$$

or

$$\boldsymbol{\nabla} \cdot \boldsymbol{D} = \rho \quad \Leftrightarrow \quad \oint_{\partial V} \boldsymbol{D} \cdot \mathrm{d}\boldsymbol{A} = \int_V \rho \, \mathrm{d}V$$

$$\operatorname{div} \boldsymbol{B} = 0$$

or

$$\boldsymbol{\nabla} \cdot \boldsymbol{B} = 0 \quad \Leftrightarrow \quad \oint_{\partial V} \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{A} = 0$$

$$\operatorname{rot} \boldsymbol{E} + \frac{\partial \boldsymbol{B}}{\partial t} = 0 \quad \Leftrightarrow \quad \oint_{\partial A} \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{s} + \frac{\mathrm{d}}{\mathrm{d}t}\left(\int_A \boldsymbol{B} \cdot \mathrm{d}A\right) = 0$$

or

$$\boldsymbol{\nabla} \times \boldsymbol{E} + \frac{\partial \boldsymbol{B}}{\partial t} = 0$$

Physical fundamentals

Maxwell equations

$$\operatorname{rot} \boldsymbol{H} = \boldsymbol{j}_l + \frac{\partial \boldsymbol{D}}{\partial t}$$

or

$$\boldsymbol{\nabla} \times \boldsymbol{H} = \boldsymbol{j}_l + \frac{\partial \boldsymbol{D}}{\partial t} \Leftrightarrow \oint_{\partial A} \boldsymbol{H} \cdot \mathrm{d}\boldsymbol{s} = \int_A \boldsymbol{j}_l \cdot \mathrm{d}\boldsymbol{A} + \frac{\mathrm{d}}{\mathrm{d}t}\left(\int_A \boldsymbol{D} \cdot \mathrm{d}\boldsymbol{A}\right)$$

The application of the third Maxwell law leads to following sensor

Mathematics

Solving the equation systems

1. Applying the differential equation system
2. Applying sophisticated solution systems as the method of the steepest descent
3. Observing the „n dimension hyper space“ with respect of discontinuity, convexity etc (Hilbert space, maximum principle of Pontryagin etc)
4. Evaluation of the results by aid of test data sets

Questions/problems as

-why better solving the differential system

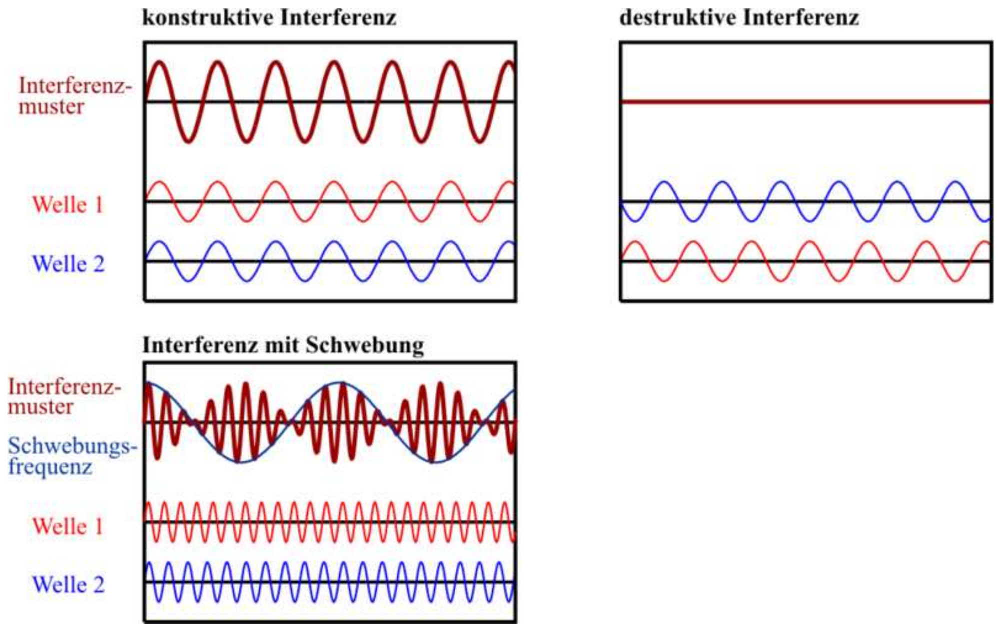
-What is about continuity in the Hilbert space ....

Wave

- **Wave classes:**

1. Medium/Mass attatched waves:
   - Longitudinal waves: parallel to the propagation direction
   - Transversal waves: orthographic to the propagation direction

2. Waves that don‘t need a medium:
   - Light
   - Radio waves
   - X-radiation
   - …



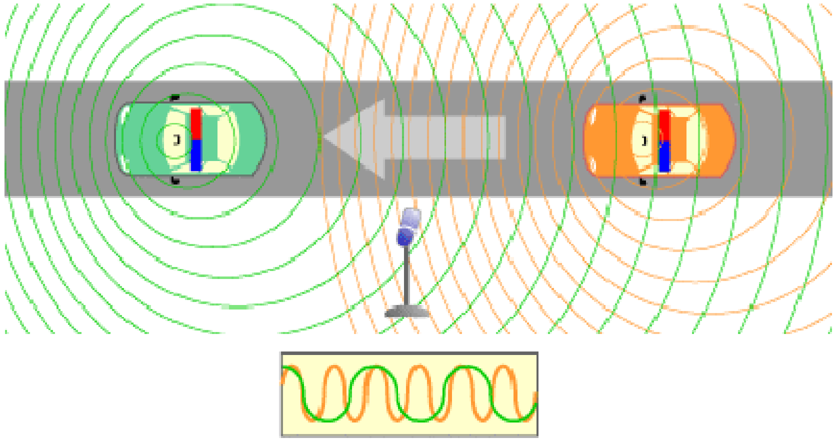
- **Covering of waves:**

Spectrum of waves of different frequencies (ex. Sunlight)

Wave

- **Doppler-effect**

ü Change of the recogniced frequency with a relative movement of sender (policecar) and receiver (microphone)



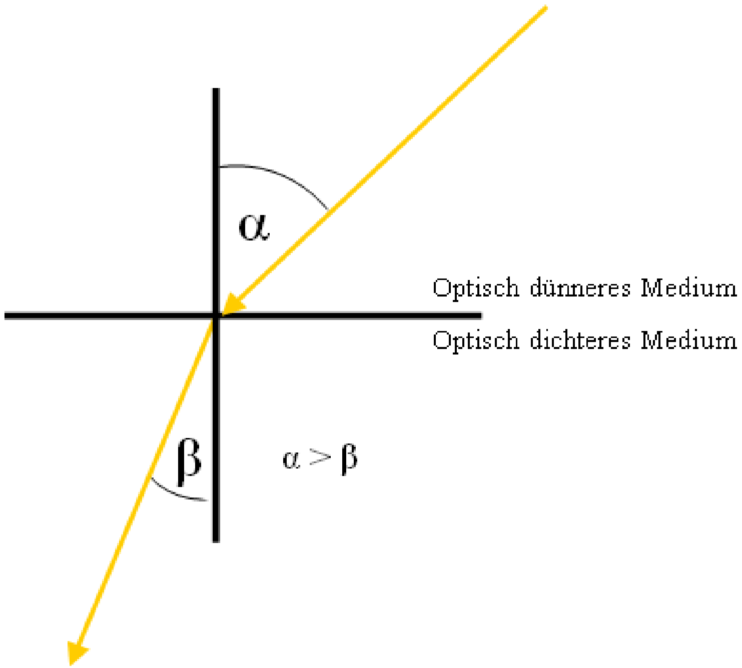
ü Decreasing frequency: Car is leaving

ü Increasing frequency: Car is arriving

Wave

- **Refraction**

Change of propagation direction between two mediums



Responding formula:

$$\frac{\sin \varepsilon}{\sin \varepsilon'} = \frac{c_1}{c_2}$$

E: Incoming angel

E‘: Refraction angel

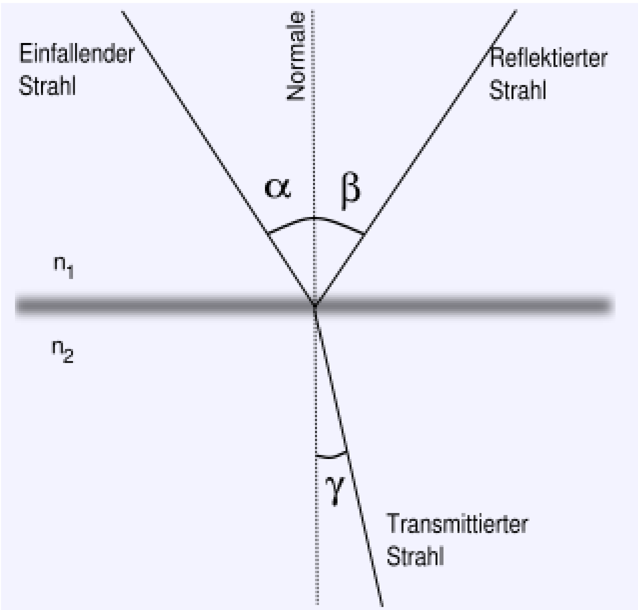
c1; c2: Wave velocity

Wave

- **Reflection**

Effect that occurs when rays or waves carom on a surface

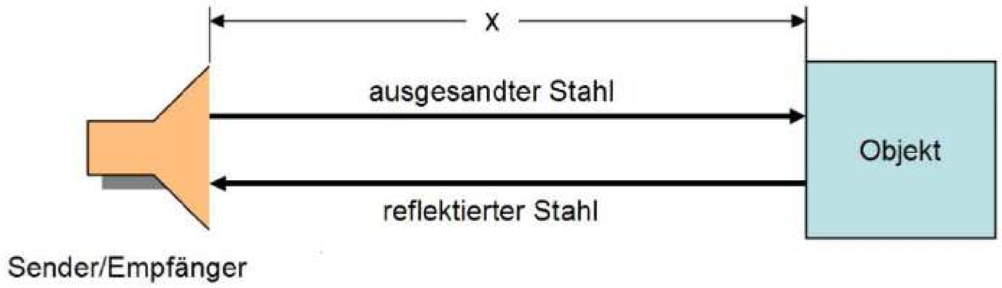
- Incoming angle equals outgoing angle
- Reflected wave is in the level of incoming wave and perpendicular



- Transmitted ray: see „refraction“

Principles of measurement

- **Running-time measurement / propagation-delay measurement**



Object, sender/receiver, sent/reflected ray
x: distance

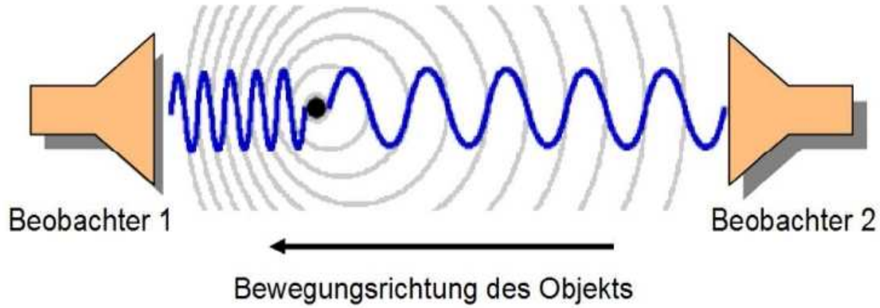
$$x = v\frac{\Delta t}{2}$$

v: velocity

- **Doppler-effect**

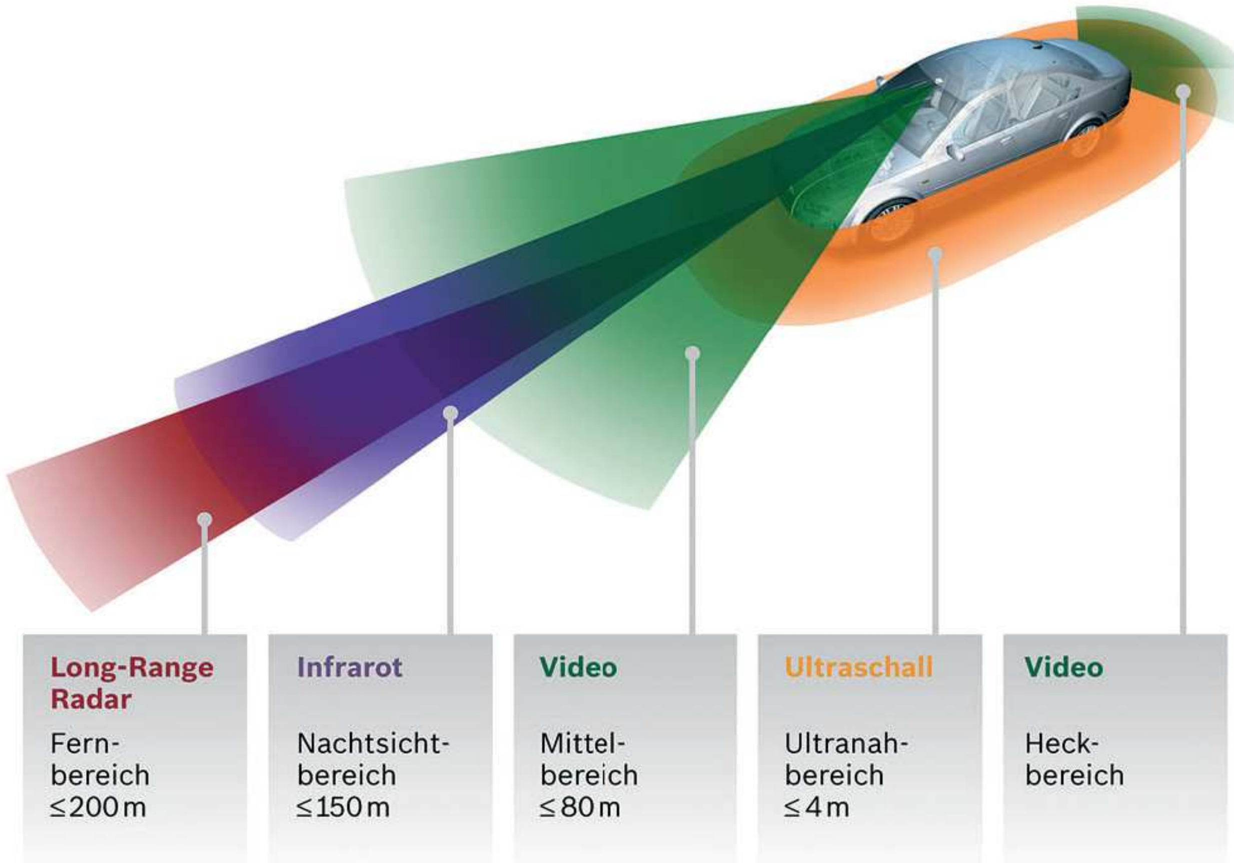
$$v_{rel} = \frac{1}{2}\left(\frac{f_R}{f_S} - 1\right) \times c$$

fS/fR: sent/received frequency
vrel: relative velocity



Concrete systems

- RADAR, LIDAR, Ultrasonic-, Infrared-, Videosystems

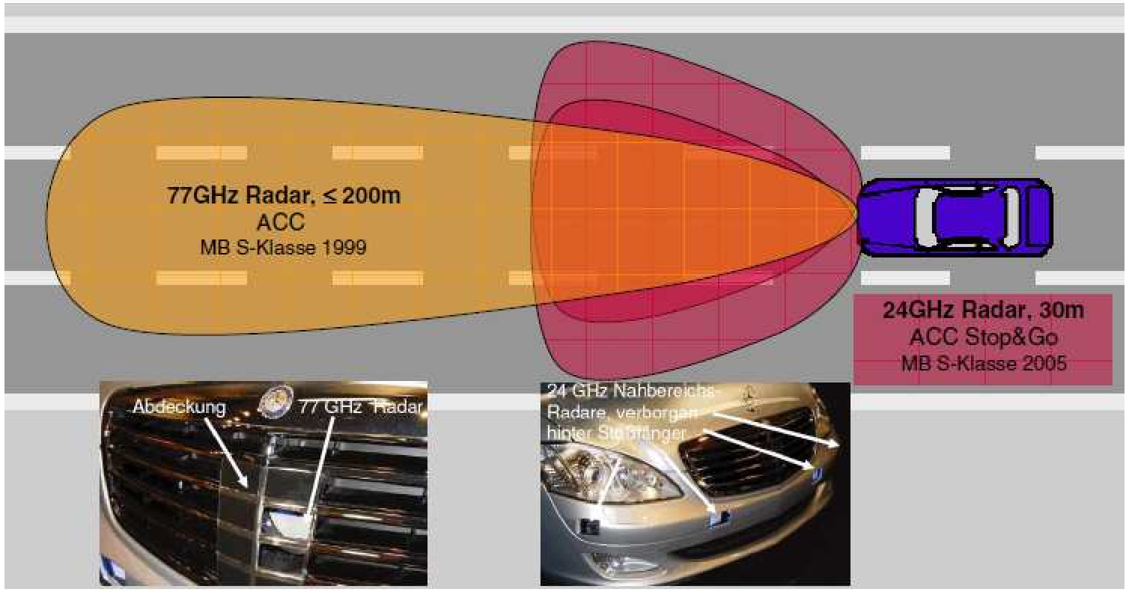


Concrete systems - RADAR

- **RA**dio **D**etection **A**nd **R**anging
- Longrange-RADAR and shortrange-RADAR
- Measurement principles:
  - Doppler-effect for measureing the relative velocity and
  - Running-time measurement for detecting the distance of objects
- Objects occur as moveing points in a reflection center
- Advantages of RADAR sensors:
  - Independence of weather conditions
  - Direct measurement of distance and rel. velocity possible
- Disadvantage:
  - Objects occur as points (no realistic measures)

Concrete systems - RADAR

- **Longrange-RADAR**
- Range: 2 – 120m
- Angle: +/-4°

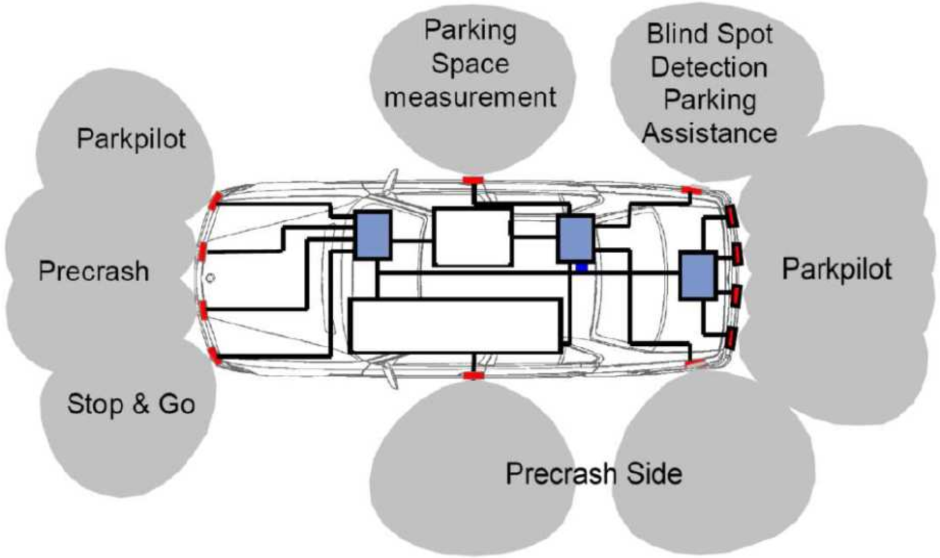


Quelle: Institut für Fahrzeugtechnik, Prof. F. Küçükay

- Since 2001 in mass production by Daimler, BMW, Audi, VW
- Minimum speed: 30 km/h
- Very unadaquate shortrange sensing

Concrete systems - RADAR

- **Shortrange-RADAR**
- Range: 25cm – 20m
- Accuracy: +/- 20cm
- Angle: +/- 45° (hor.)
  +/- 15° (vert.)
- Eff. Power: 1mW, low



- Legal and used in the USA since 2002
- Frequence authorization missing in Europe

Concrete systems - LIDAR

- **LI**ght-**D**etection-**A**nd-**R**anging
- Example: „ALASCA“ by IBEO
- Class 1 Laser (safe for eyes)
- Wavelength: 1000nm, infrared rays, not visible for the eyes
- Angel resolution: 0.25°
- Range: 100m
- Accuracy: +/- 3cm
- Horizontal range: 270° (wide range!) at 10 – 40Hz
- Vertical range: 3.2° (four levels, see page 30)
- Principle: Light-running-time measurement with 14.4kHz lightpulsing

Concrete systems - LIDAR

LIDAR-Scanner

- Advantages:
  - High resulotion
  - Direct measureing of distance and real object measures (no points!)

- Disadvantages:
  - Weather
  - Unreal refections

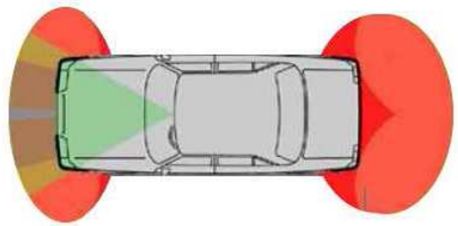
Concrete systems - LIDAR

- **Hard- and Software support**
- Processing of the gathered information necessary

- Classes:

Klasse	Länge[m]	Breite[m]	Geschw.[km/h]
LKW	5,5 - 20	2,1 - 2,9	<120
PKW	2,7 - 5,5	1,0 - 2,1	<250
Motor-/Fahrrad	<2,1	<1,5	<250
Fußgänger	<1,5	<1,0	2-40
Unbekannt kein	<1,5	<1,0	<2
Unbekannt groß	>20	>2,9	Ohne Betrachtung

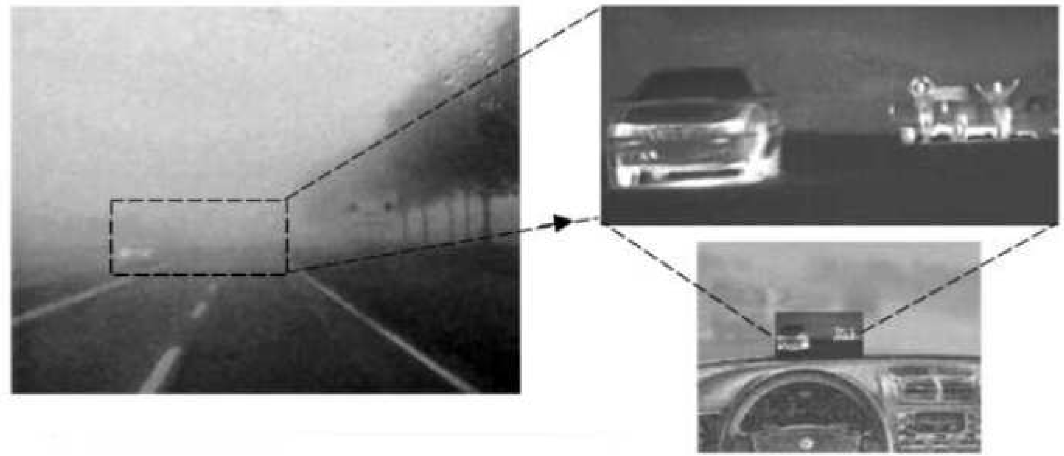
Concrete systems – Ultrasonic



- Only for the near environment (20cm – 1.5m)
- Wavespeed: 330m/s (slow)
- Frequency: 50kHz
- Direct measureing of distance with piezo ceramics (transceiving)
- Advantages: cheap, easy integration
- Disadvantages: covers short distance, low frequency (only usable up to 20km/h)
- Most used of all types of sensors!

Concrete systems – Infrared camera

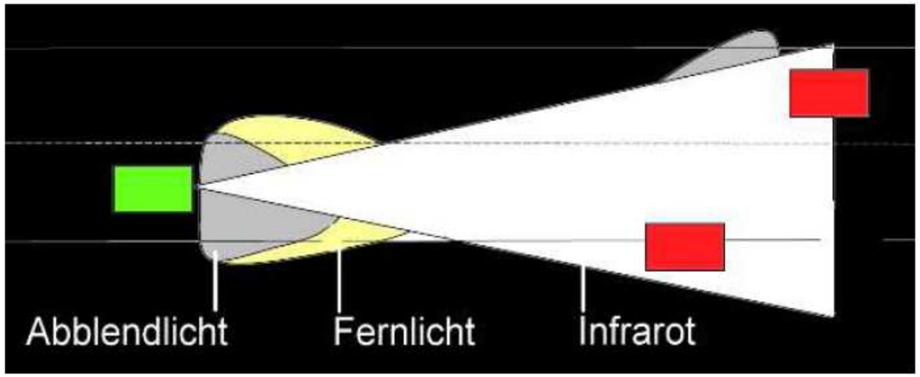
- Often used by the militaries
- Detection of warm/cold objects/environment as a source for generating a picture/film that can be watched regularly



- Infraredray-wavelength: 0,8 bis 1000micrometer
- Advantages: weather independent, night-use possible, HUD usable

Concrete systems – Infrared camera

- **FIR** (**F**ar-**I**nfrared-**R**adiation)
- Wavelength: 7000 bis 12000nm
- Range: 0 bis 200m
- No light source necessary
- Not used in cars (Problem: cooling, -200°C)
- But new optics with germanium and tex-glass make FIR attractive for cars
- Quality: 320x240 QVGA
- Can be ordered in Cadillac cars (USA)



Concrete systems – Infrared camera

- **NIR**: Near-Infrared-Radiation
- Wavelength: 800 bis 1100nm
- Active light source necessary (front halogenlamps, 380 to 2000nm)
- Range: 0 – 80m
- Silicium-sensors
- Quality: VGA (640x480 pixels)

Break

Lecture I

Next following

Lecture II

Videosystems