Radar Based Driver Assistance Systems

Radar Based Driver Assistance Systems
Agenda

- **Driver Assistance Systems**
  - Sensor Data Fusion
  - Basic Terms and Definitions
  - SW Development
  - Radar Basics
- **What can we achieve with a radar sensor?**
  - Adaptive Cruise Control
  - Automatic Emergency Brake

Radar Based Driver Assistance Systems
Use cases addressing end customers needs

Predictive safety

Predictive emergency braking

Evasion assistance

Lane assistance

Predictive pedestrian protection

Turn and crossing assistance

Driver comfort & information

Travel assistance

Driver monitoring

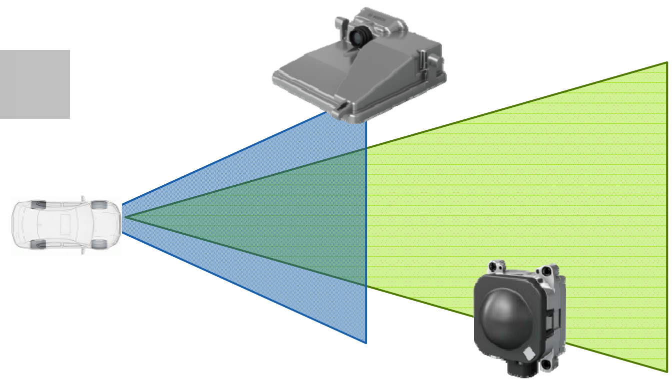
Light and sight assistance

Park and maneuver assistance

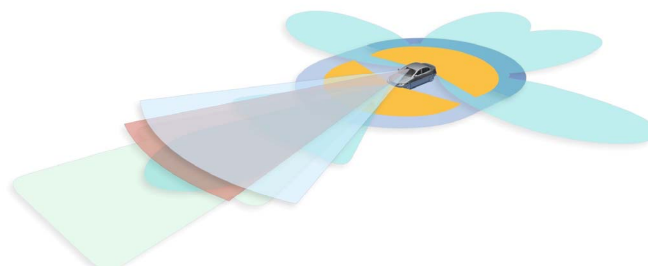
Radar Based Driver Assistance Systems
Driver Assistance Systems (DAS)

Definition

- ➔ Enhanced safety and driving comfort
- ➔ Accident-free driving
- ➔ Supports the driver at the best possible rate, especially in critical situations



- ➔ **Sensors** survey the surroundings and the interior of the vehicle
- ➔ **Control units** monitor and analyze the data of the sensors in real time



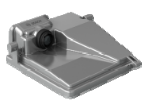
Goal:

- ➔ **reliable support** with validation by fusion of several sensors **to achieve injury**, **accident free** and **comfortable** driving

Radar Based Driver Assistance Systems
Sensor Data Fusion

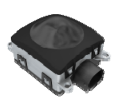
- Sensor Data Fusion consists of 3 elements:
  - Data fusion
  - Environment Model
  - Situation Interpretation
- Video / Radar / Navigation based joint architecture

Camera



Lane markings
Objects

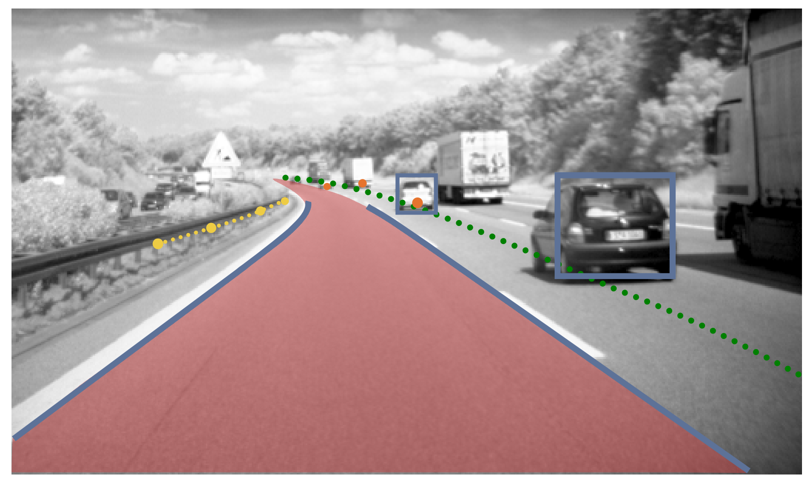
Radar



Moving objects
Stationary objects

Digital Map

Roadway
Attribute

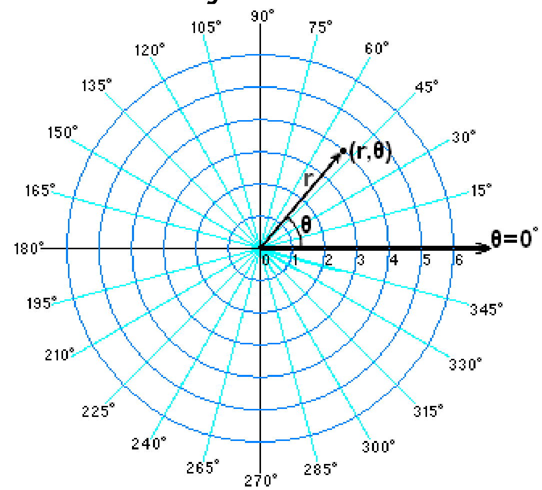


Fusion

Internal | RBRO/ESA2/RADAR | 09/2018

Radar Based Driver Assistance Systems
What do we want to measure?

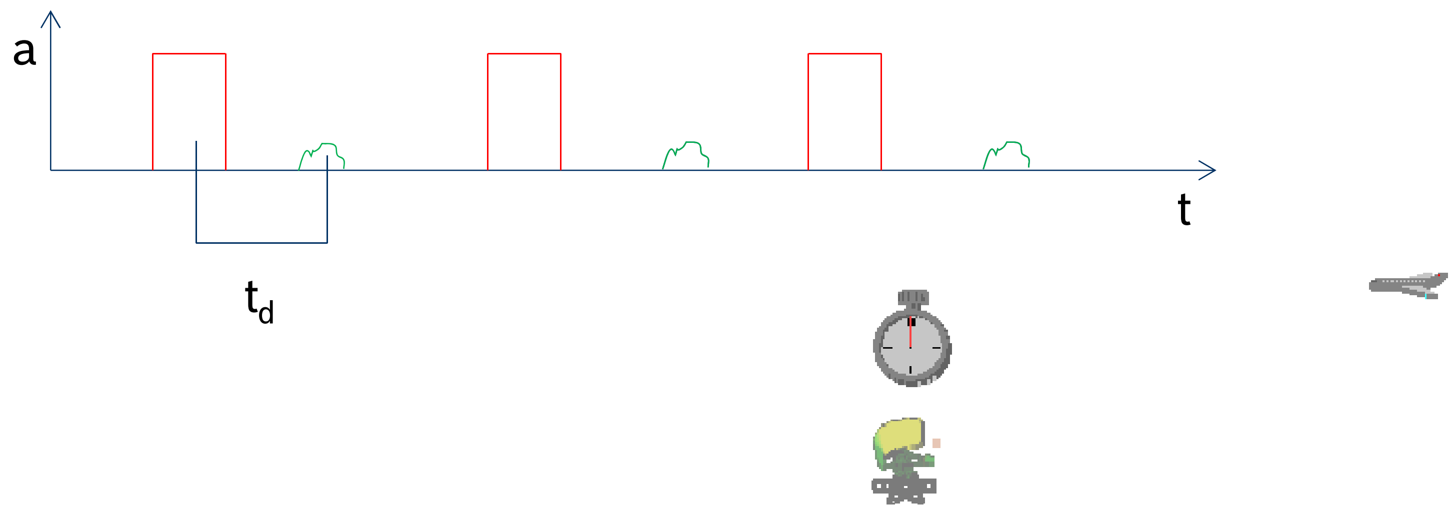
- Azimuth, range, [radial velocity]
- Traditionally the RADAR always uses a polar coordinate system
- Equivalent to a Cartesian coordinate system [r,Θ] <=> [x,y]
- We only measure the radial velocity
  - the two components of the velocity vector in a Cartesian coordinate system can not be reconstructed



Radar Based Driver Assistance Systems
Distance Measurement Principle

- We measure the time elapsed between the transmitted pulse and the received echo

$$t_d = 2 \times \frac{D}{c} \Leftrightarrow D = t_d \times \frac{c}{2}$$



BOSCH

Radar Based Driver Assistance Systems
Radial Velocity Measurement Principle

$$f_d = \frac{2 v_r f_{tx}}{c}$$

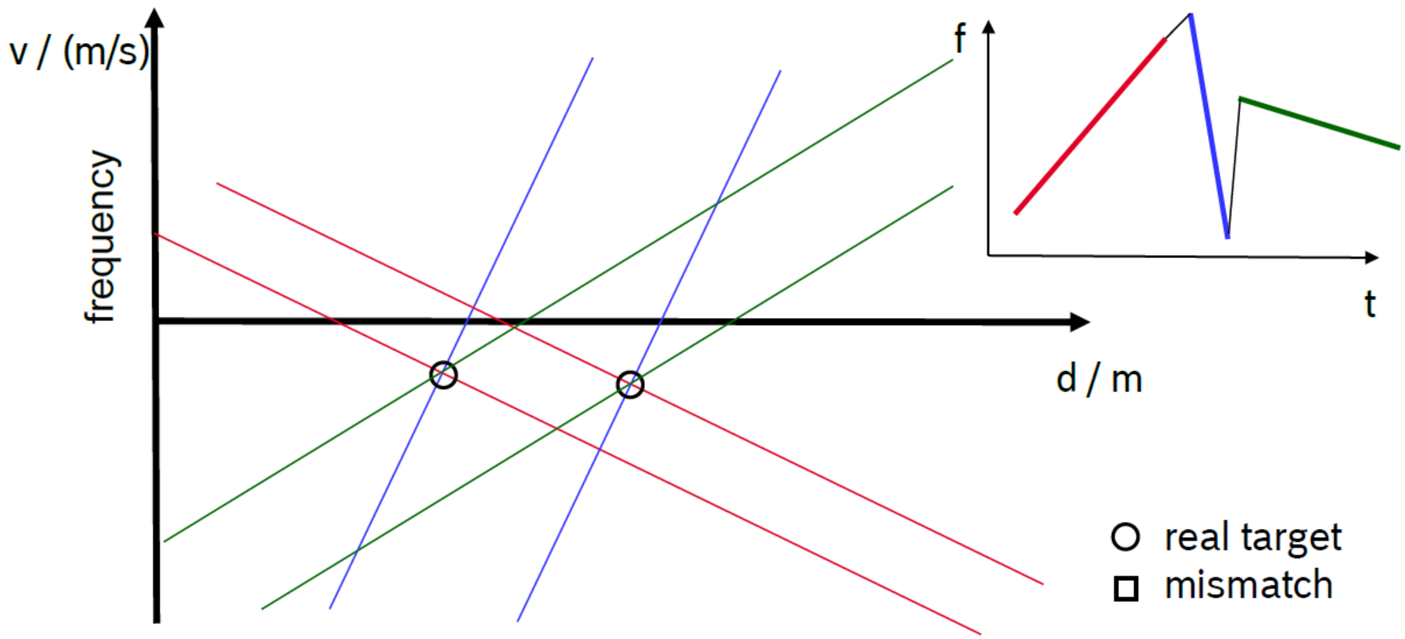
- f_{tx} = is the transmitters frequency
- c = is the speed of the light
- v_r = is the radial speed of the aim

© 2009 Christian Wolff

→ **We know our transmit frequency, and the frequency we received from this we can measure the speed of the target object!**

Radar Based Driver Assistance Systems
FMCW Principle

Frequency-Matching: 2 targets, 3 ramps



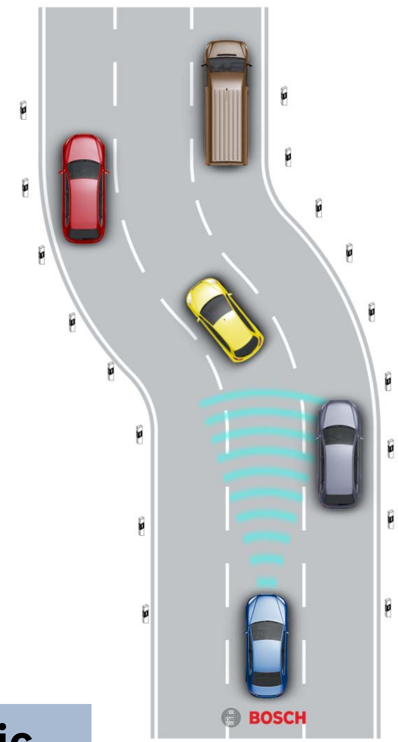
→Using three ramps, the method is capable of multi-target scenarios
→Using four ramps, ghost targets can be efficiently suppressed

Radar Based Driver Assistance Systems
ACC Stop and Go

BOSCH

Radar Based Driver Assistance Systems
Adaptive Cruise Control

- **Goal**
  - Blue vehicle should always keep a secure distance to the yellow vehicle while keeping the set speed, or the speed of the yellow vehicle
- **Inputs**
  - Radar data
  - Additional video data
  - Ego car data
- **Reaction**
  - Acceleration or deceleration

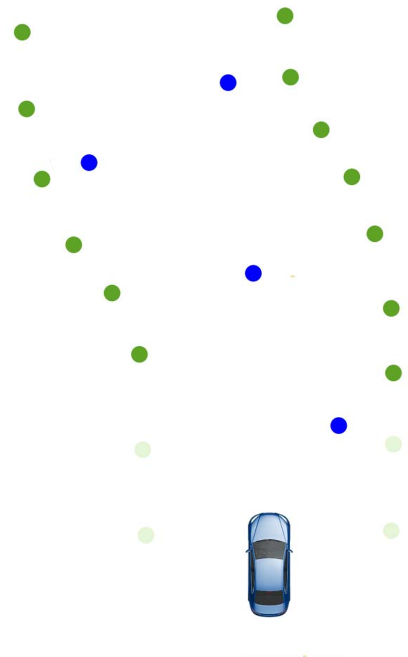


➔ **Achieve comfortable driving through automatic longitudinal control**

BOSCH

Radar Based Driver Assistance Systems
Radar points

- **Object types**
  - Stationary objects
  - Dynamic objects



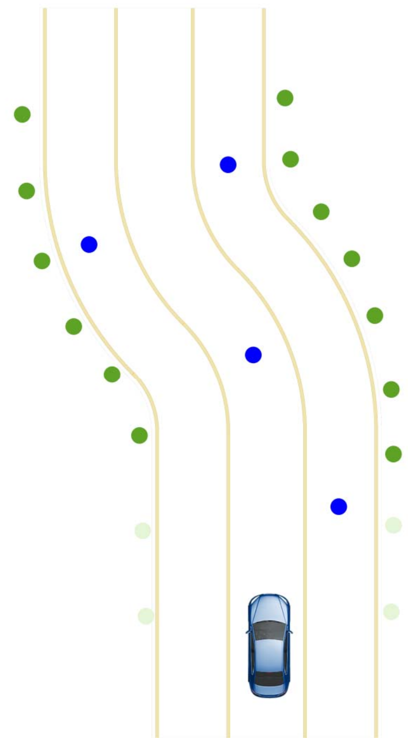
- **Road estimation is based on**
  - the connection of stationary objects
  - the tracking of moving objects

Internal | RBRO/ESA2/RADAR | 09/2018

BOSCH

Radar Based Driver Assistance Systems
Radar-Video Fusion

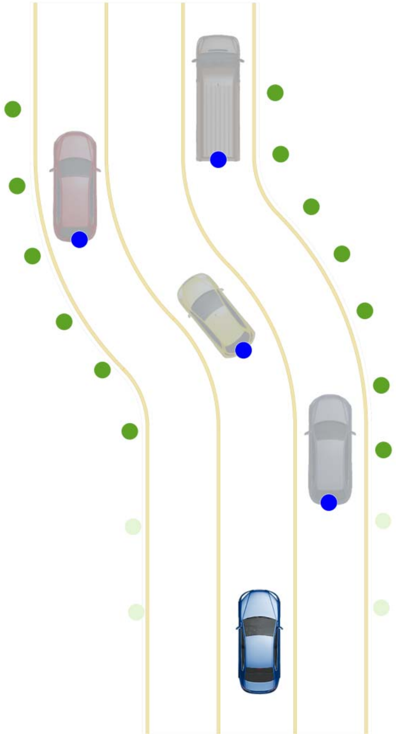
- Use of road markings (lines) from video based driver assistance systems



BOSCH

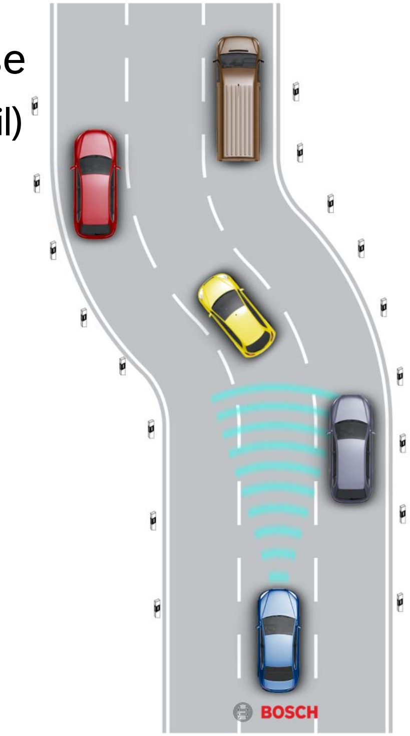
Radar Based Driver Assistance Systems
Object classification

- Classification of objects in both sensors:
  - Radar classification based on the behavior of the objects
  - Video classification based image features
- Fusion of video based information and radar based information in one system in order to get reliable data



Radar Based Driver Assistance Systems
Parallel lanes

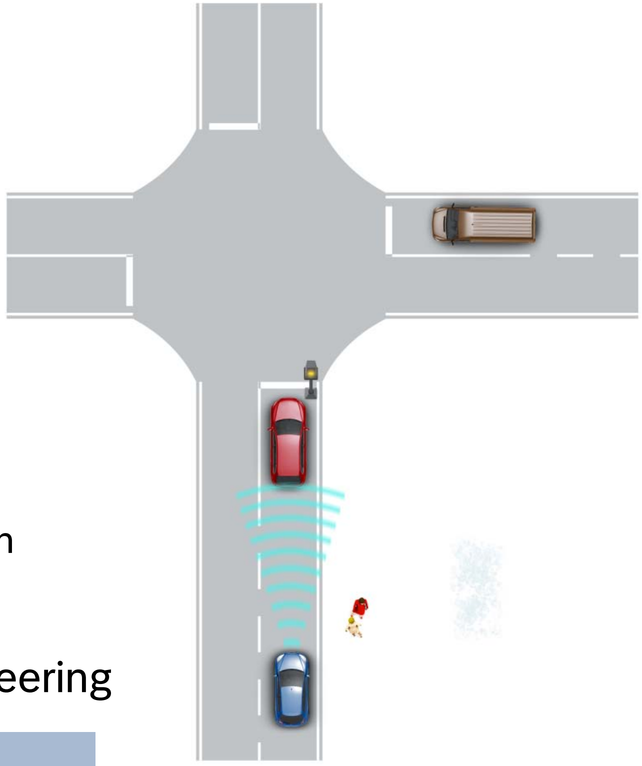
- Yellow vehicle remains the ACC target object because
  - Connection of stationary objects (reflector posts, guardrail)
  - Video line detection and lane recognition
  - Tracking of red and brown vehicle
- indicates how the road ahead looks like



Radar Based Driver Assistance Systems

Radar Based Driver Assistance Systems
Automatic Emergency Breaking

- **Goal**
  - Fast reaction to avoid collision
- **Input**
  - Ego Motion
  - Object type classification
  - Motion model for various object types
  - Calculate time to collision
  - Additional information from the driver
    - Driver monitoring to estimate the level of attention
- **Reaction**
  - Collision avoidance/mitigation with braking/steering

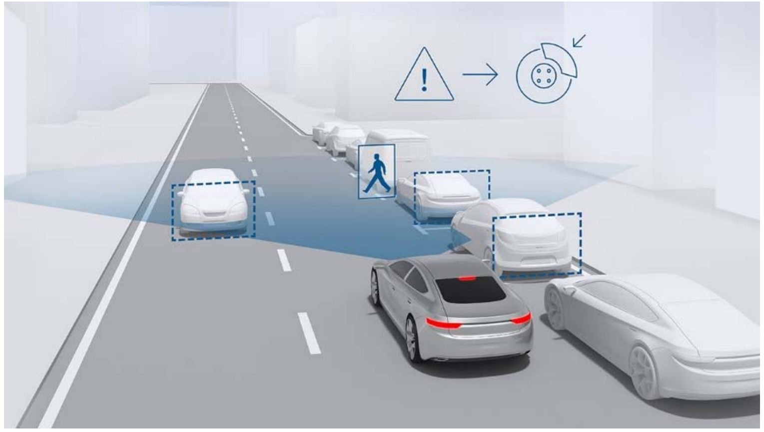


→ **Achieve safe driving through automatic braking**

BOSCH

Radar Based Driver Assistance Systems
Pedestrian Protection

- **Goal**
  - Fast reaction to avoid collision
- **Input**
  - Ego Motion
  - Object type classification
  - Micro Doppler information
  - Calculate time to collision
  - Trajectory overlap
- **Reaction**
  - Collision avoidance/mitigation with braking/steering

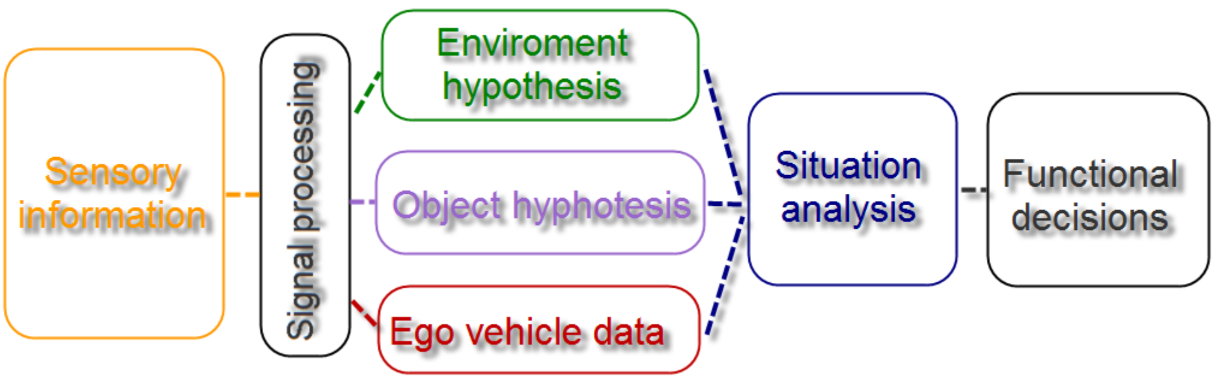


➔ **Achieve safe driving through automatic braking**

BOSCH

Radar Based Driver Assistance Systems
System Approach

- **Data Fusion from different sources (e.g. Radar, Video, Ultrasonic)**
  - Objects, line, lane, road signs etc.
- **Environmental Hypothesis**
  - E.g.: Parallel Lanes, Object-Lane association
- **Situation Analysis**
  - Criticality of the situation, Driver Activity
- **Decision**
  - Warr




Predictive Pedestrian Protection

Radar Based Driver Assistance Systems

Thank you for your attention!

BOSCH