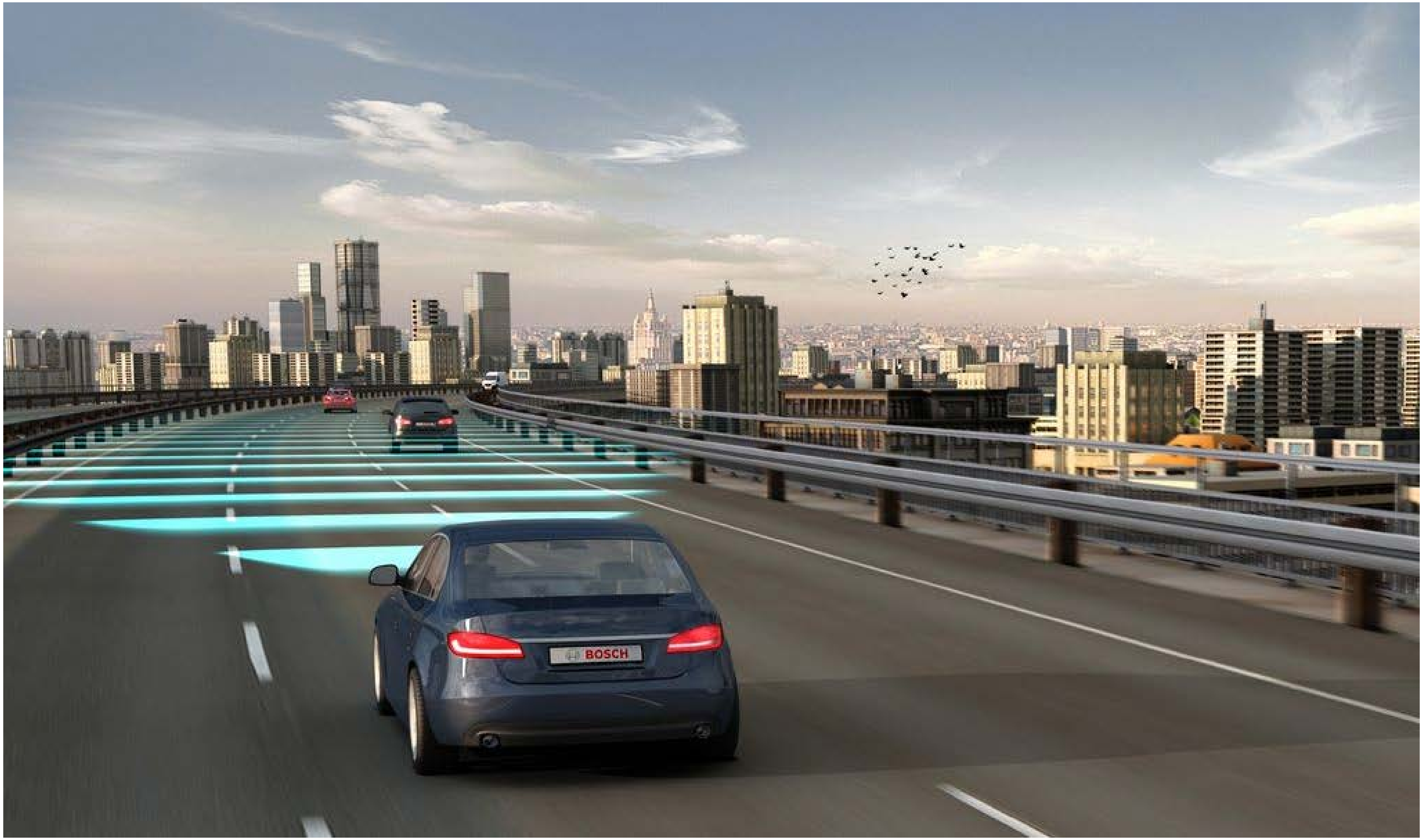
Radar Based Driver Assistance Systems

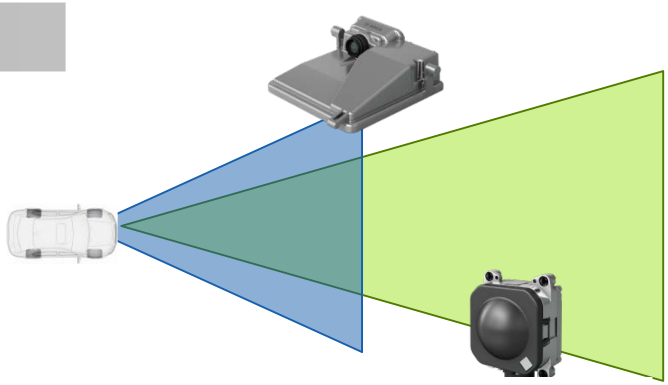


Radar Based Driver Assistance Systems
Agenda

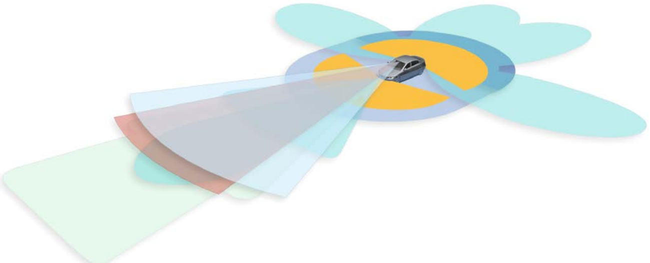
- **Driver Assistance Systems**
  - Basic Terms and Definitions
  - Radar Basics
  - Sensor Data Fusion
  - SW Development
- **What can we achieve mainly with a radar sensor?**
  - Adaptive Cruise Control
  - Automatic Emergency Brake

Radar Based Driver Assistance Systems
Driver Assistance Systems (DAS)

Basic terms



- Enhanced safety and driving comfort (Active safety)
- 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

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Radar Based Driver Assistance Systems
Use cases addressing end customers needs

Predictive safety

Predictive emergency braking

Evasion assistance

Lane keep assistance

Predictive pedestrian protection

Turn and crossing assistance

Driver comfort & information

Travel assistance

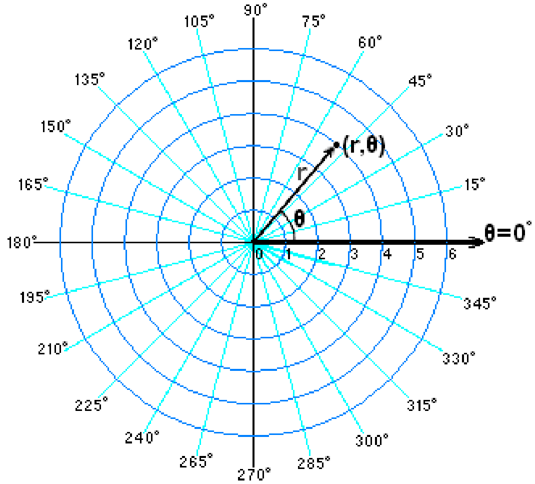
Driver monitoring

Light and sight assistance

Park and maneuver assistance

Radar Based Driver Assistance Systems
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 (measured)



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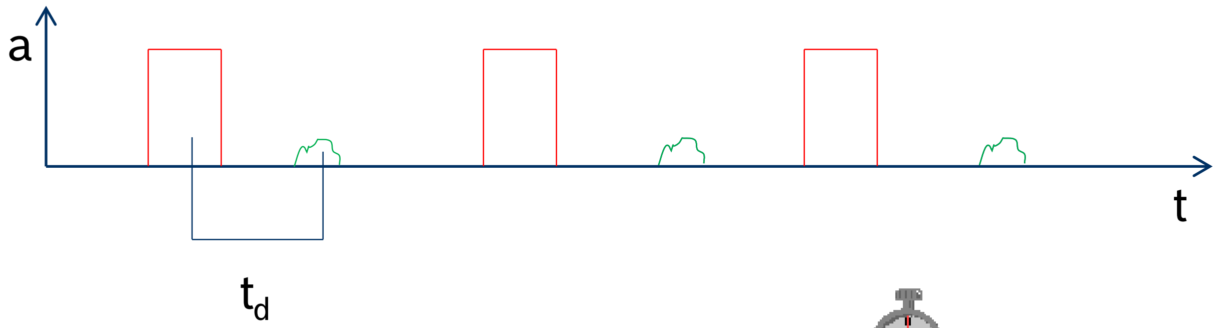
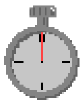
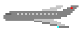
Radar Based Driver Assistance Systems
Distance Measurement Principle

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

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







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

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➔ **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
Radial Velocity Measurement Principle FMCW

$$f = \frac{c}{\lambda}$$

$$f_d = \frac{2D}{c} \cdot \frac{\Delta f}{\Delta t} + \frac{2\, v_r\, f_{tx}}{c} = \frac{2D}{c} \cdot \frac{\Delta f}{\Delta t} + \frac{2 v_r}{\lambda_{tx}}$$

- f_d = frequency difference of the emitted and received signals
- $\Delta f / \Delta t$ = variance of modulation in time
- v_r = is the radial speed of the aim
- λ_{tx} = frequency of emitted signal (77 GHz)

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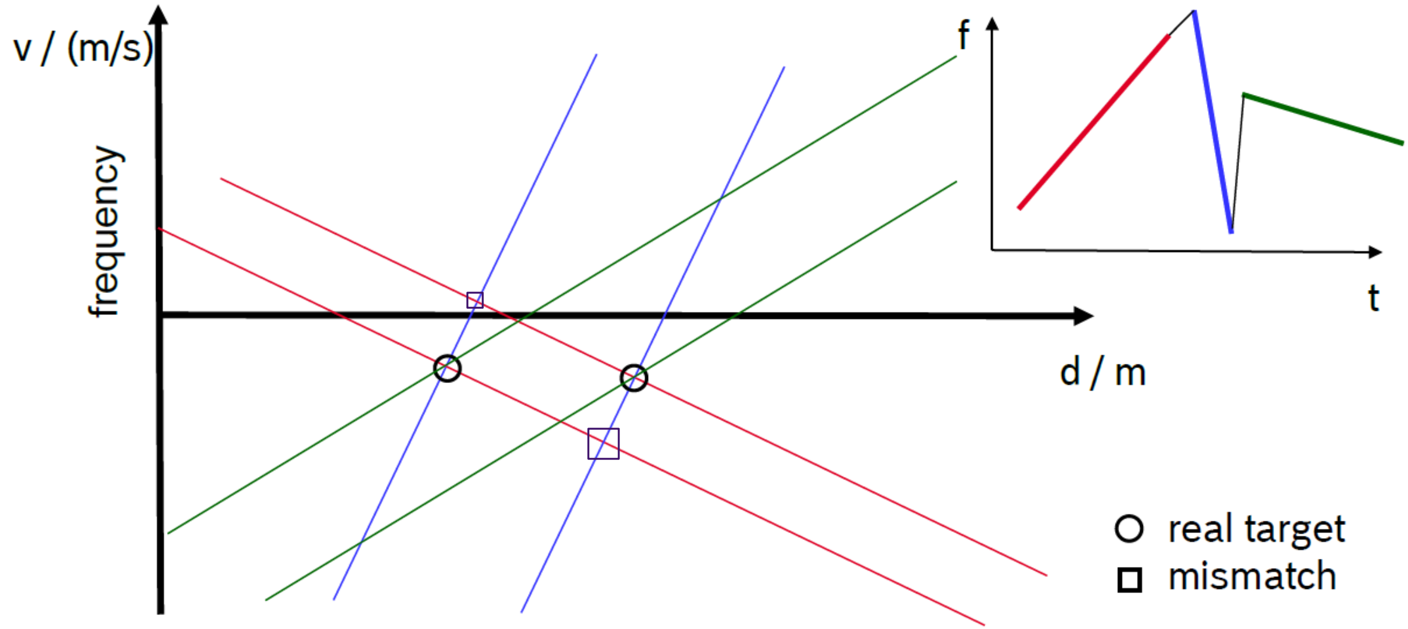
Radar Based Driver Assistance Systems
FMCW Principle

Frequency-Matching: 2 targets, 3 ramps

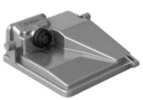


→Using three ramps, the method is capable of multi-target scenarios
→Using four ramps, ghost targets can be efficiently suppressed

Radar Based Driver Assistance Systems
Sensor Data Fusion

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

Camera



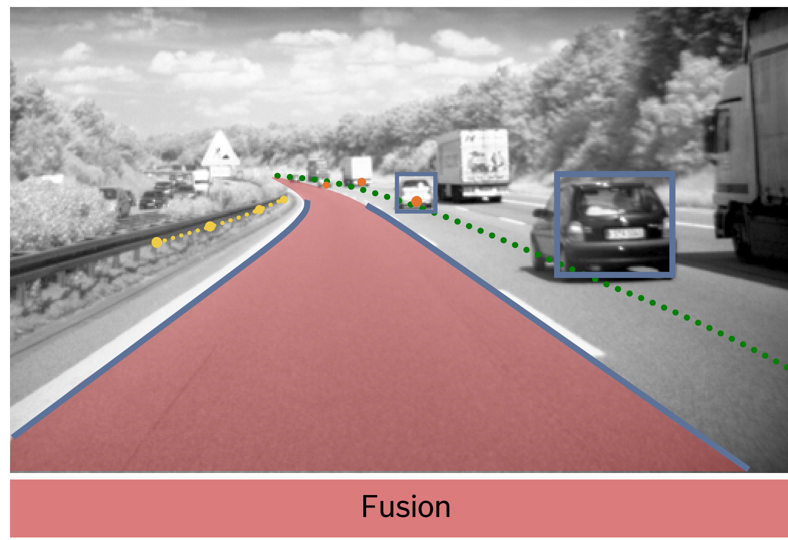
Lane markings
Objects

Radar

Moving objects
Stationary objects

Digital Map

Roadway
Attribute



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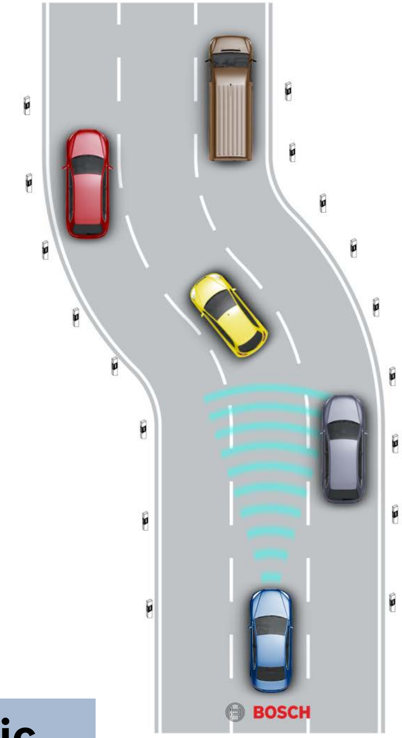
Radar Based Driver Assistance Systems
ACC

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 within secure limits.

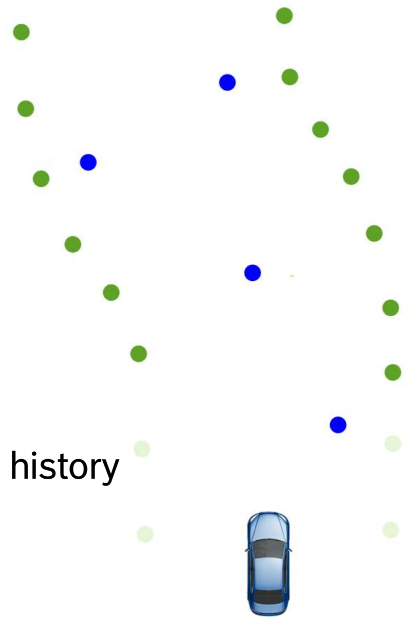


→ **Achieve comfortable driving through automatic longitudinal control**

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(+ ego)
    - Creating lanes based on the object and ego movement history



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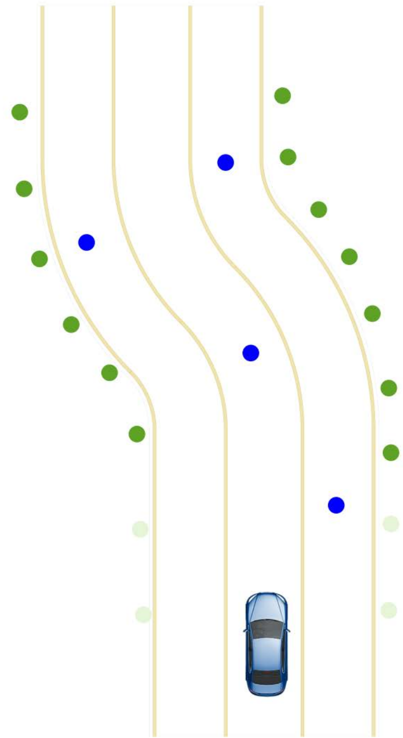
Radar Based Driver Assistance Systems
Radar-Video Fusion

- Road estimation in the case of video fusion
  - Use of road markings (lines) from video based driver assistance systems
  - Object classification by video



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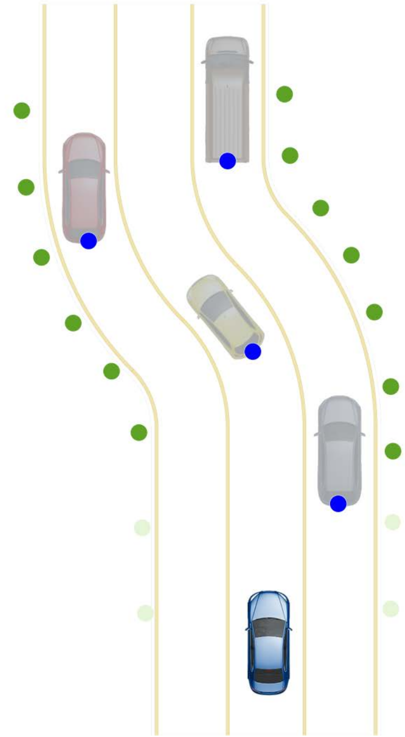
Radar Based Driver Assistance Systems
Object classification

- 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



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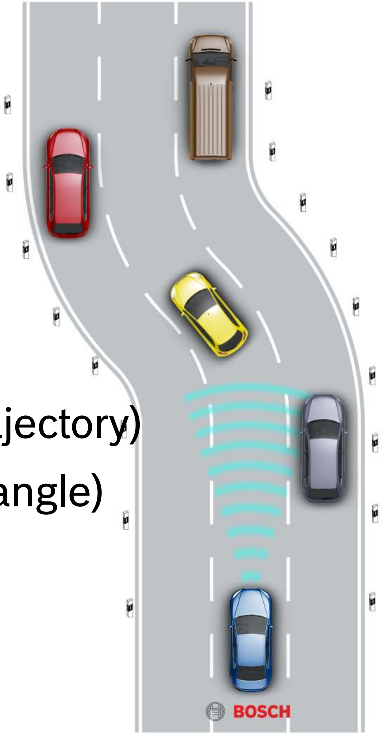
Radar Based Driver Assistance Systems
Parallel lanes

- 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
  - the target object position, direction and trajectory

- The information coming from target object(position, trajectory)
- The information from the ego vehicle(yaw angle, s.w. angle)
- Road topology

  ->Indicates how the road ahead looks like



Radar Based Driver Assistance Systems

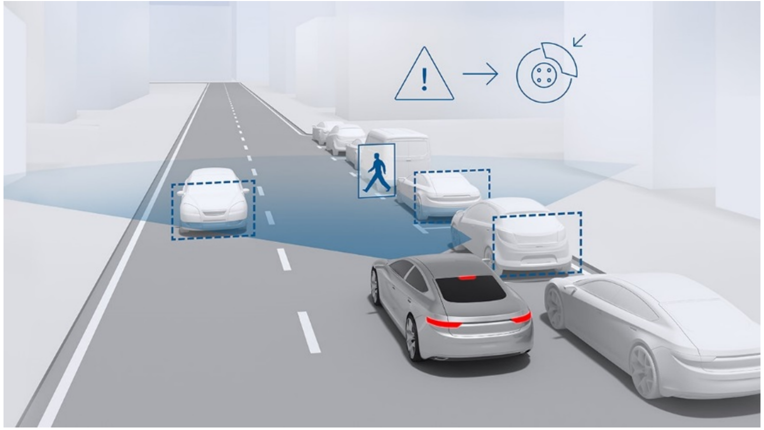
Radar Based Driver Assistance Systems
Automatic Emergency Breaking

- **Goal**
  - Fast reaction to avoid collision (or mitigate a collision)
- **Input**
  - Ego Motion
  - Object type classification(ped., cyclist, etc.)
  - Motion model for various object types
  - Calculate time to collision
  - Additional information from the driver
    - Driver monitoring to estimate the level of attention:
      - intention to brake, intention to evade
- **Reaction**
  - Collision avoidance/mitigation with braking/steering

→ Achieve safer driving through automatic braking

Radar Based Driver Assistance Systems
Pedestrian Protection

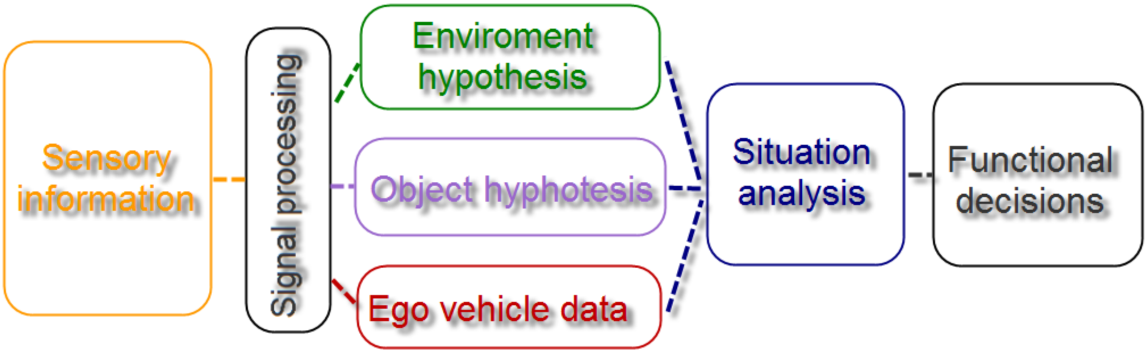
- **Goal**
  - Fast reaction to avoid collision
- **Input**
  - Ego Motion
  - Object type classification
  - Micro Doppler information
  - Calculate time to collision
  - Trajectory overlap
- **Reaction**
  - Collision avoidance/mitigation with braking/steering



→ **Achieve safe driving through automatic braking**

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**
  - Warning, Partial Braking, Brake Support, Full Emergency Braking




Predictive Pedestrian Protection
www.bosch.com
This movie shows proprietary Bosch technology.
The vehicle shown was chosen soley as a carrier for demonstration purposes.

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Radar Based Driver Assistance Systems

Thank you for your attention!