Automotive Environment Sensors

Lecture 1.

Introduction (Teaser Trailer)

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Preface

„Autonomous driving is the simplest engineering task*

*On a newly built German highway,
at 12am when the sun shines from above,
in summer at approx. 20 °C and 10% humidity…”
(Unknown sensor-fusion engineer at Robert Bosch)

Course Information

Lecturers: Szilárd Aradi (St106)
Tamás Bécsi (St106)
Olivér Törő (St105)

Credit: 5

2 hrs. lecture/week St321B (here)

2 hrs. lab. /week St121-122 (!!!)

2 midterm exams (Week 7 and 14)

Assessment type: exam

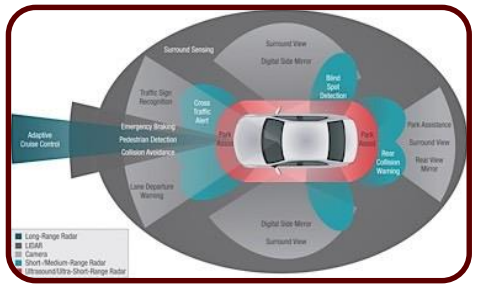
Grade:
$0.25*(\text{midterm}_1+\text{midterm}_2)+0.5*\text{exam}$

Literature: Thrun, Sebastian, Wolfram Burgard, and Dieter Fox. *Probabilistic robotics*. MIT press, 2005.

Connected Courses on AVCE:

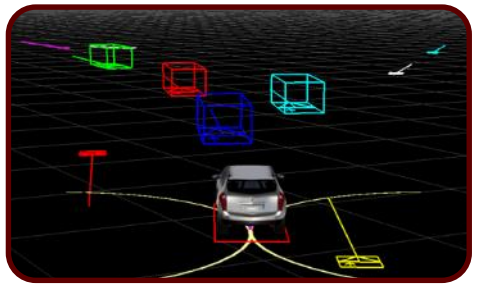
- Control theory and system dynamics
- Vehicle dynamics
- Autonomous robots and vehicles
- Localization and mapping
- Computer Vision Systems
- Machine vision
- etc…

Layered approach for the environment perception framework



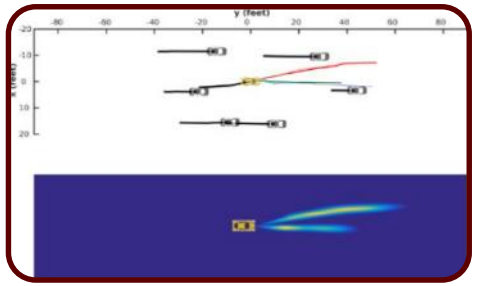
Vehicular Sensors, providing original data

- Vision, Radar, Lidar, Ultrasonic
- Appearance, Motion, Disparity, Distance, Shape etc.



Vehicle and Object Detection (and tracking)

- Sensor Fusion, Data association, Topology and roadside objects etc.
- Vehicle model, dynamics, filtering etc.



Situation understanding

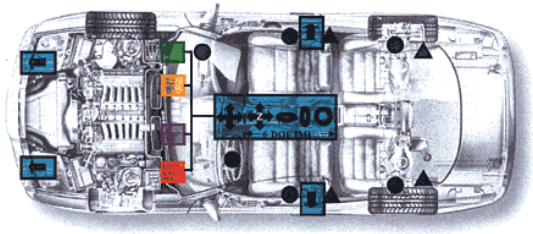
- Behavior models, maneuvers' classification and prediction
- Probabilistic future modeling

(Environment) Sensors

Ultrasonic

GPS and Maps

Chassis



Camera (+infra)

Lidar

Radar

Purpose of environment sensing

- Detecting static and dynamic objects
  - Relative Positions
  - Relative Speed
  - Classification
  - 0,5-250 m range
  - Changing environment(lights, humidity, dust)
  - Multiple types of objects (material, color, shape)
- Challenging

A Slight Remark on ASIL

- ASIL - Automotive Safety Integrity Level
- Safety Integrity Level used in IEC 61508
- ISO 26262 - Functional Safety for Road Vehicles standard
- Risk=f(Severity, Likelyhood, Controllability)

- *More to come in „Safety and Reliability in the Vehicle Industry"*

Severity (S):

S0 No Injuries

…

S3 Life-threatening

Exposure (E):

E0 Incredibly unlikely

…

E4 High probability

Controllability (C):

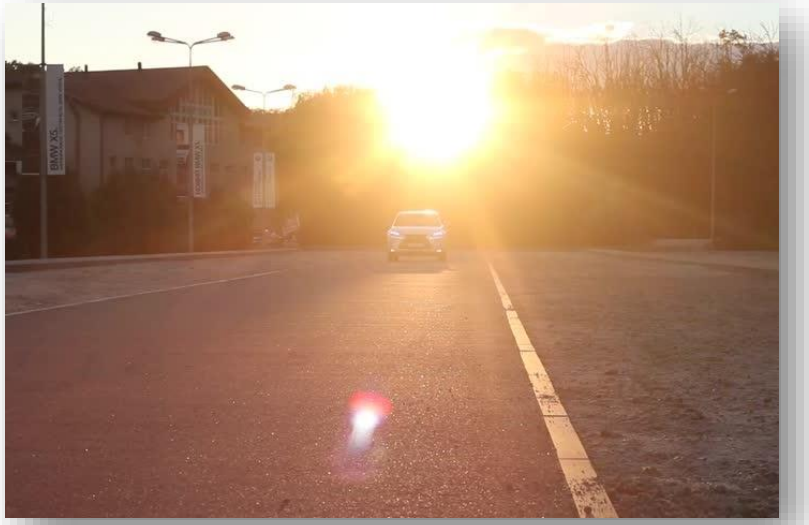
C0 Controllable in general

…

C3 Uncontrollable

Increasing the Level of Automation

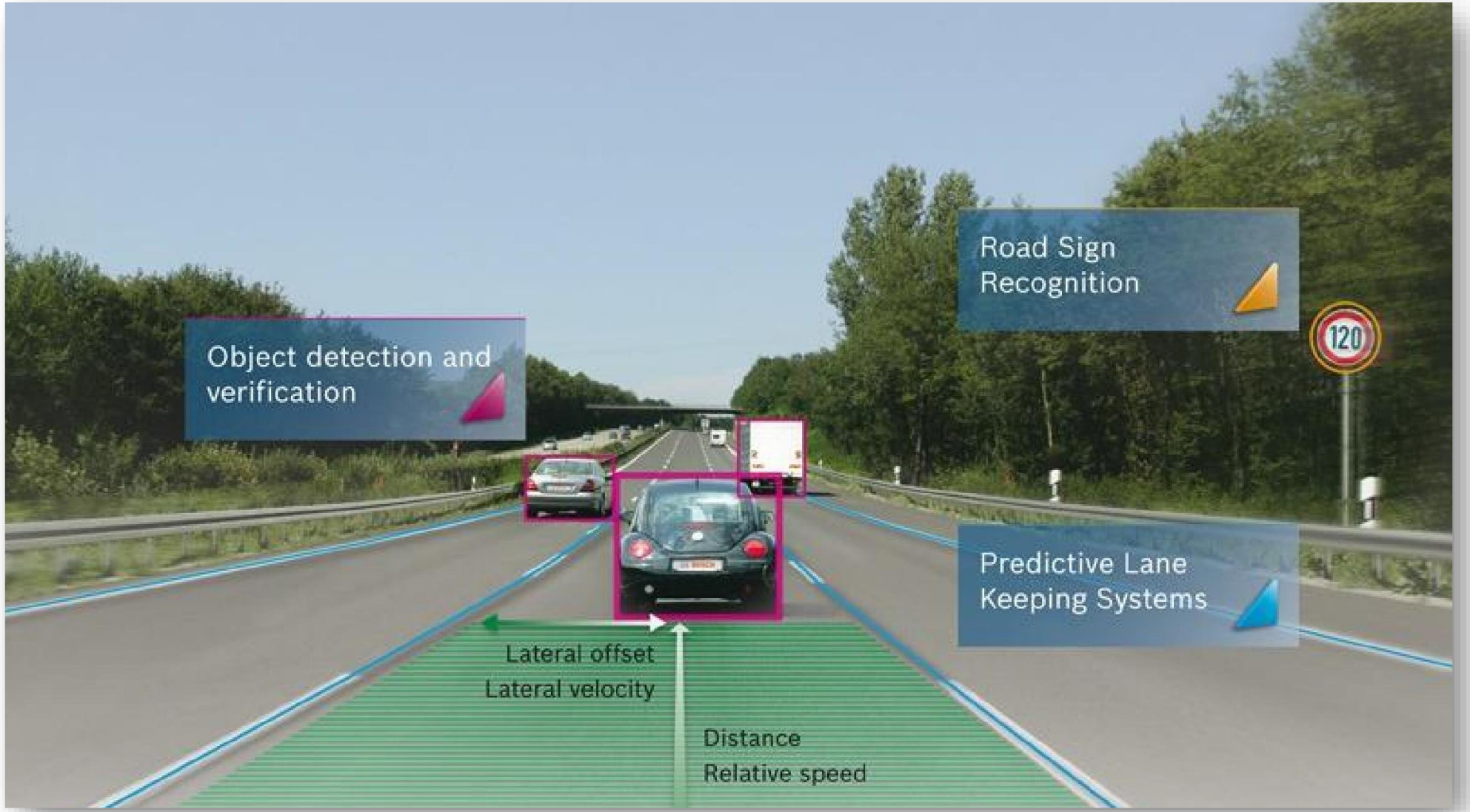
- Solely Camera based systems?
  - Based on human driving, could be feasible
  - Road traffic is the most dangerous form of transportation, most accident is caused by human error.
  - An automated system need to provide higher safety level.
- Improvement: Sensor fusion
  - All parts of the environment are surveilled by multiple sensors.
    - Redundant
    - Confidence
  - Can eliminate the weaknesses of each sensor
  - High and low level fusion



Camera

- Most important sensor of the ADAS systems. (Some say)
- Functions
  - Lane detection
    - Lane departure warning
    - Lane following
    - Lane change
  - Object detection, classification and tracking
    - Adaptive Cruise Control
    - Collision avoidance and warning systems
  - Road sign and traffic light detection
    - Warning systems
    - Cruise control
    - Energy optimization
  - Parking
  - Night vision
- Pros
  - Detailed information on the environment
  - Shape and colour detection
- Cons
  - Sensible to lighting and dust conditions
  - Depth of field detection with mono camera is a challenge
  - High computational needs

Typical camera functions

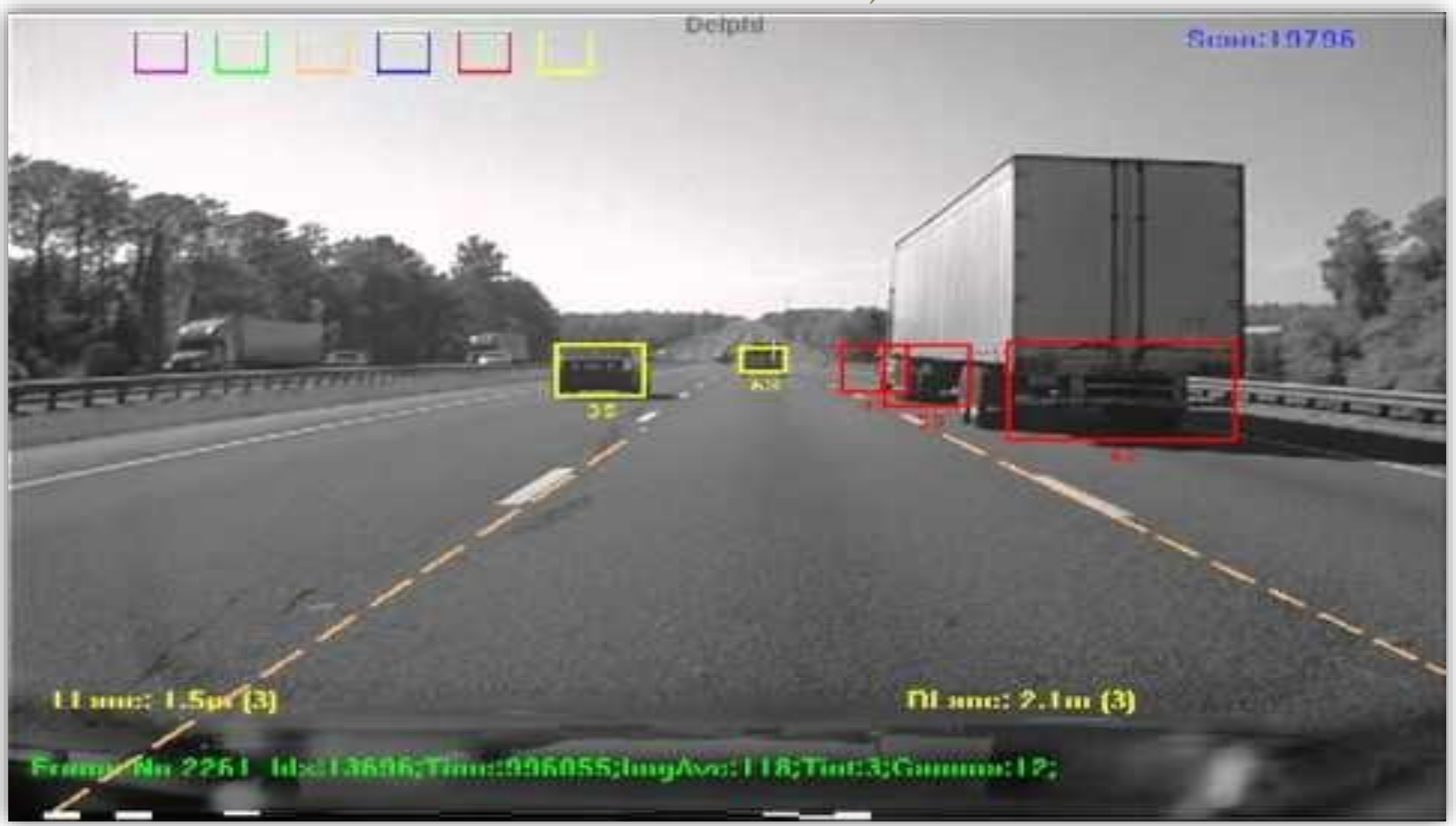


Radar

- Another important sensor for ADAS
- Functions
  - Object detection and classification
    - Adaptive cruise control
    - Collision warning and avoidance
- Pros
  - Low sensibility to weather conditions, not sensible to light
  - For safety critical applications
  - Small size and low price
- Cons
  - Object classification is hard
  - Reflections can cause disturbance

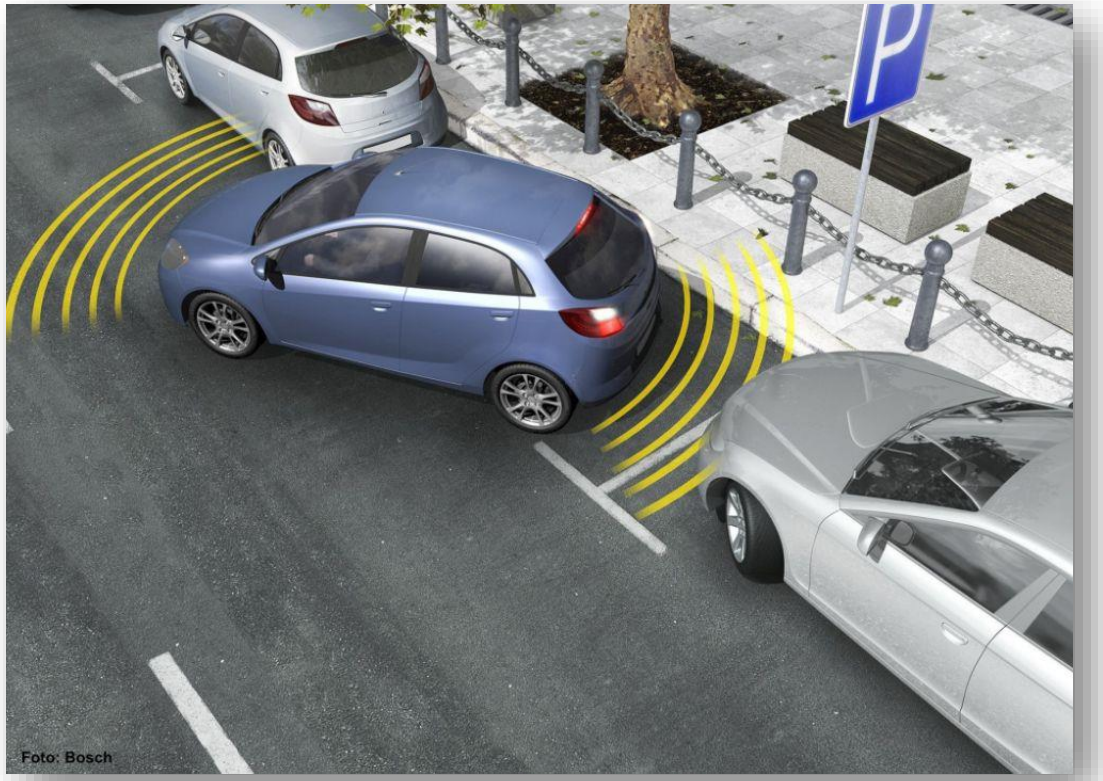
Forrás: Mathworks, Inc.

Radar Object Tracking Example

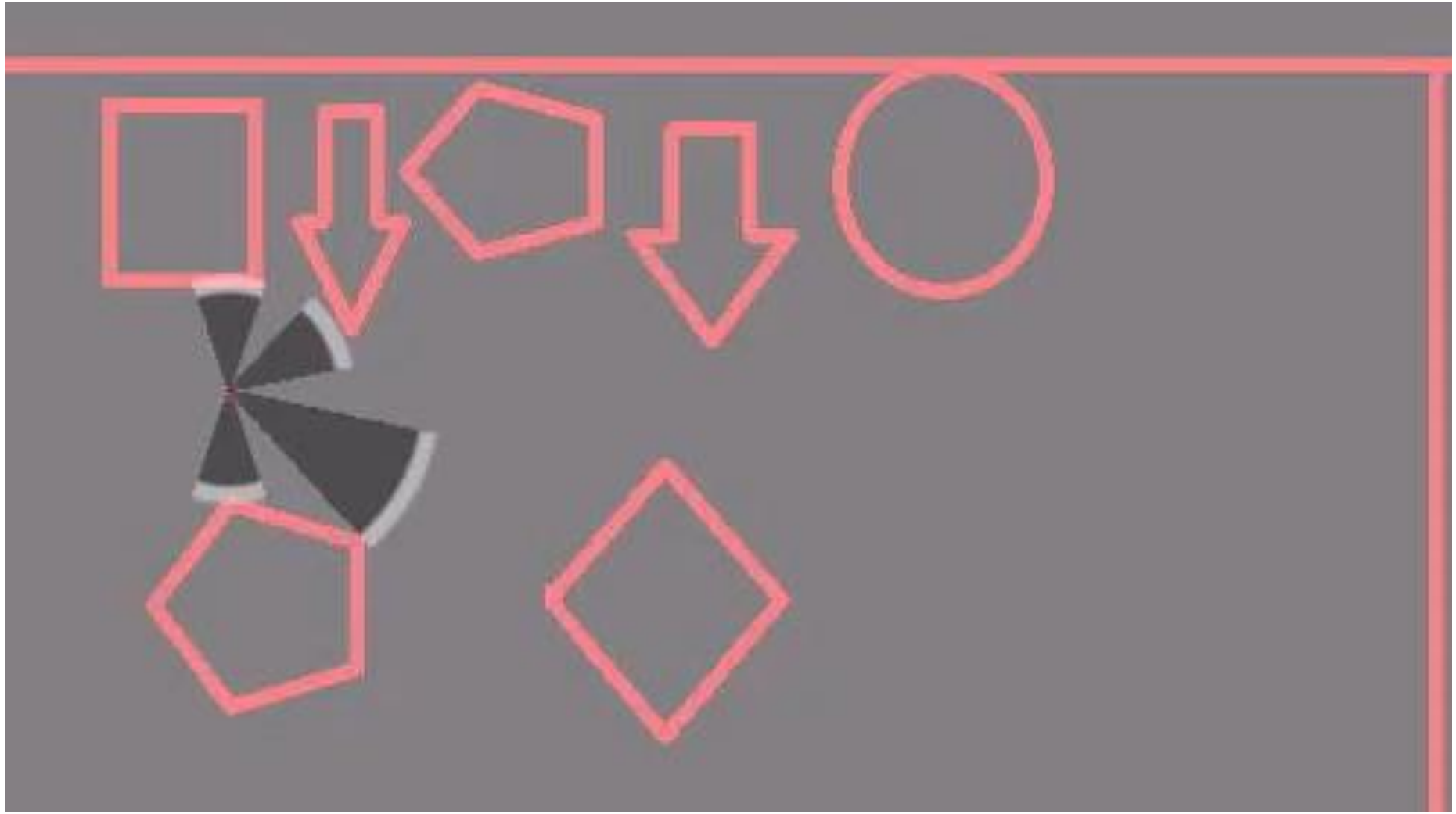


Ultrasonic

- Primarily for comfort functions. New systems are eligible for safety critical functions
- Functions
  - Automated Parking systems
    - Parking spot finder
    - Parking
  - Blind Spot warning*
  - Low speed cruise control
    - Traffic jam assist
- Pros
  - Cheapest
  - Eligible for safety functions
- Cons
  - Low range
  - Sensitive to dust
  - Low speed
  - Accurate localization is a challenge



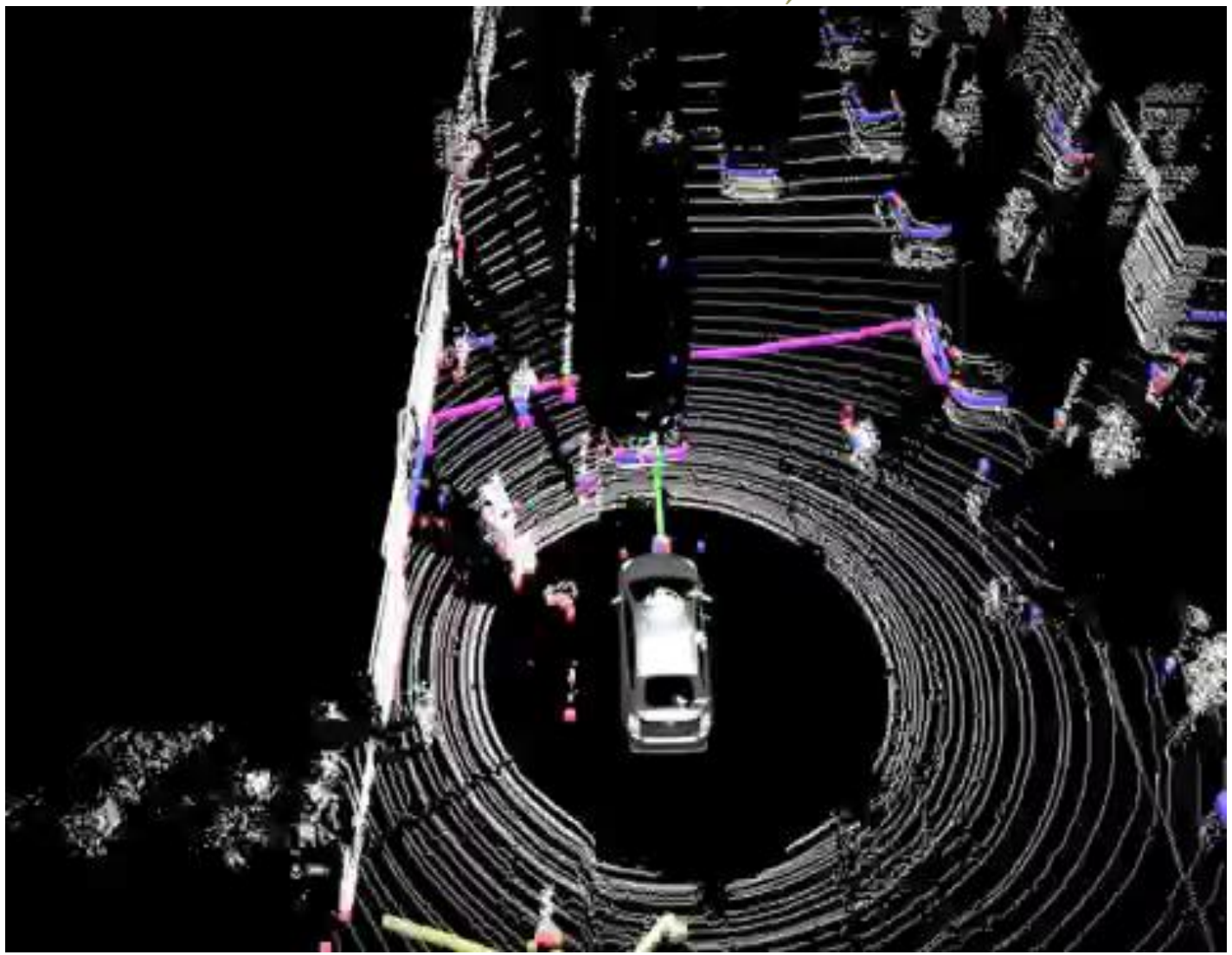
UltraSonic Mapping



LIDAR

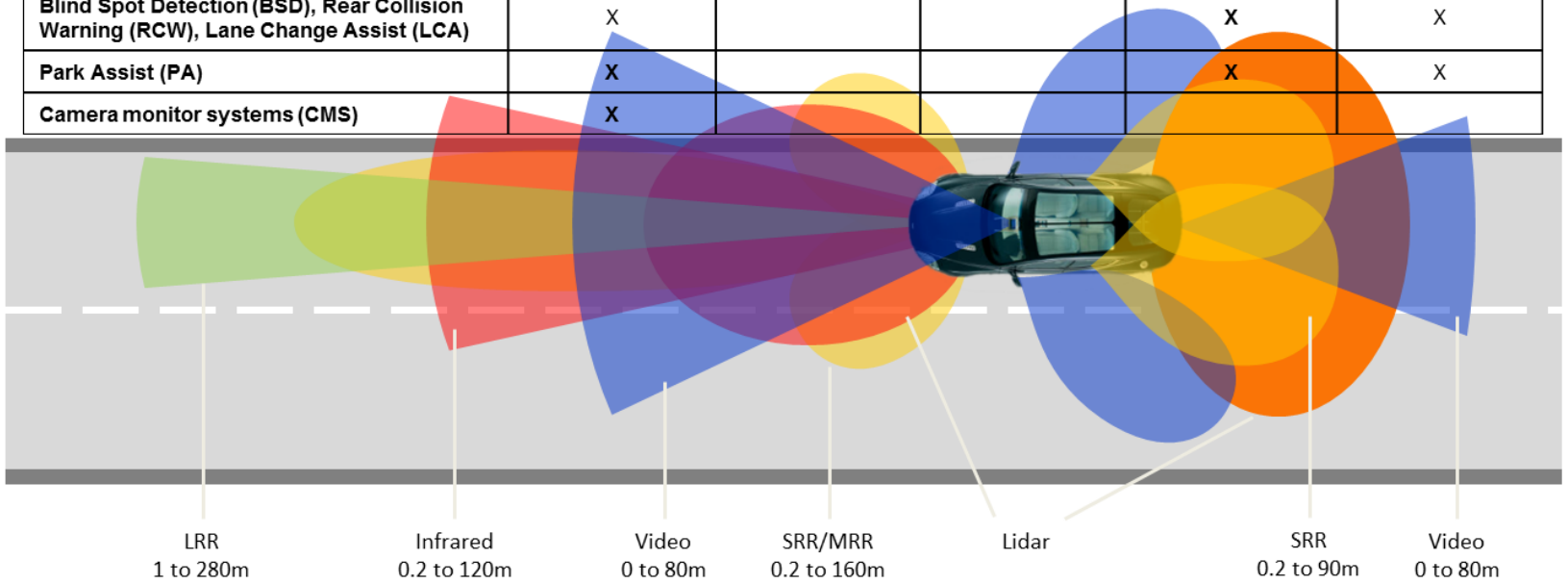
- Laser scanning for distance, 2D or 3D point cloud.
- Functions
  - Reference measurements
  - Object detection and classification
  - Lane detection
  - Road state
- Pros
  - Accurate high resolution measurement
  - Low sensibility to weather
- Cons
  - Expensive
  - Light absorbing materials cause problem
  - Mirrors cause problem

LIDAR Object Detection Example



Commercial solutions

Sensor Type / Application	Vision	Infrared / Thermal	Long Range Radar 76..81MHz	Short / Mid Range Radar 24..26 / 76..81 GHz	Lidar
Adaptive Front Lighting (AFL), Traffic Sign Recognition (TSR)	**X**				
Night vision (NV)	X	**X**			
Adaptive Cruise Control (ACC)	X		**X**	**X**	X
Lane Departure Warning (LDW)	**X**				
Low-Speed ACC, Emergency Brake Assist (EBA), Lane Keep Support (LKS)	X			**X**	**X**
Pedestrian detection	**X**	X		**X**	
Blind Spot Detection (BSD), Rear Collision Warning (RCW), Lane Change Assist (LCA)	X			**X**	X
Park Assist (PA)	**X**			**X**	X
Camera monitor systems (CMS)	**X**				

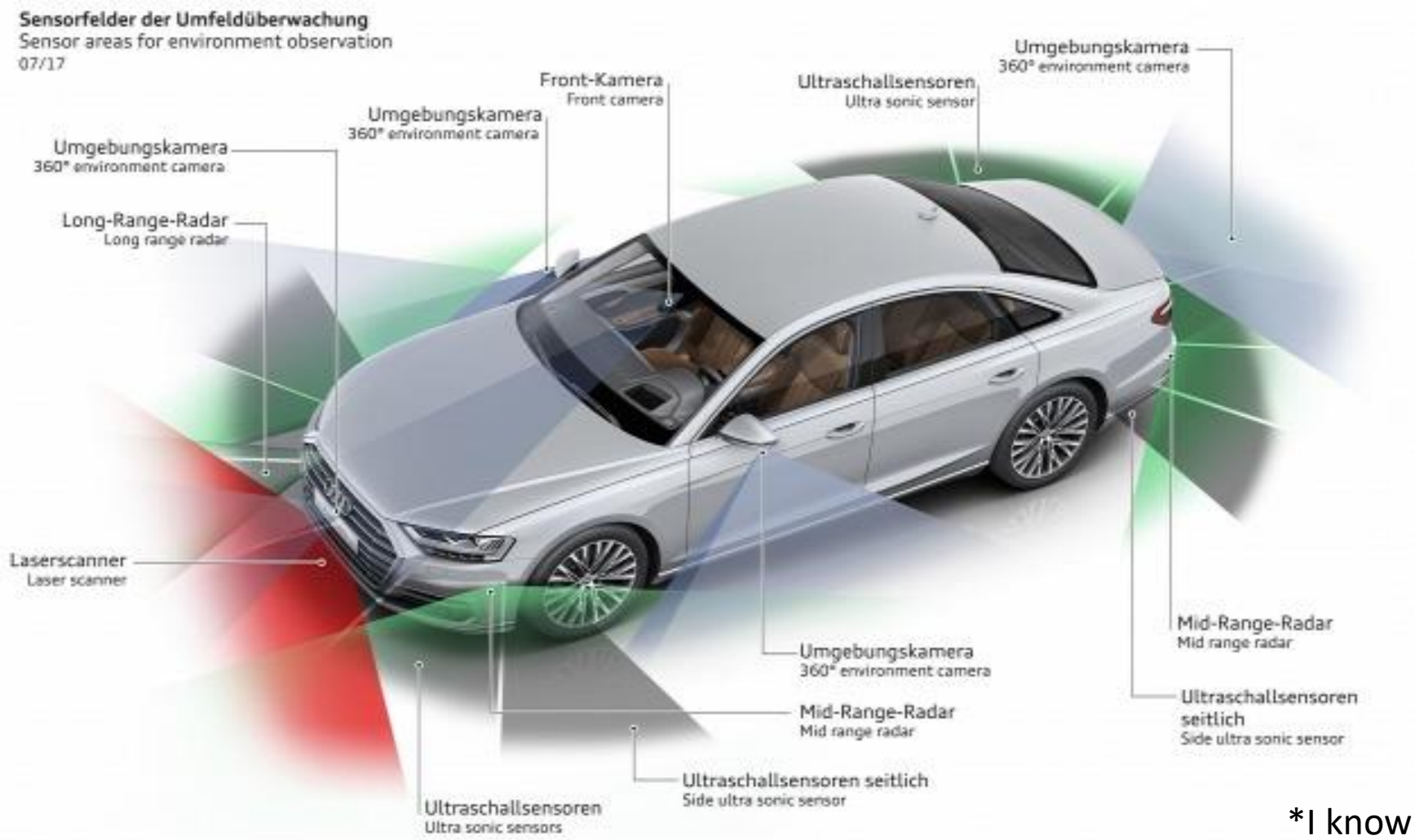


Forrás: Texas Instruments Inc.

Trends

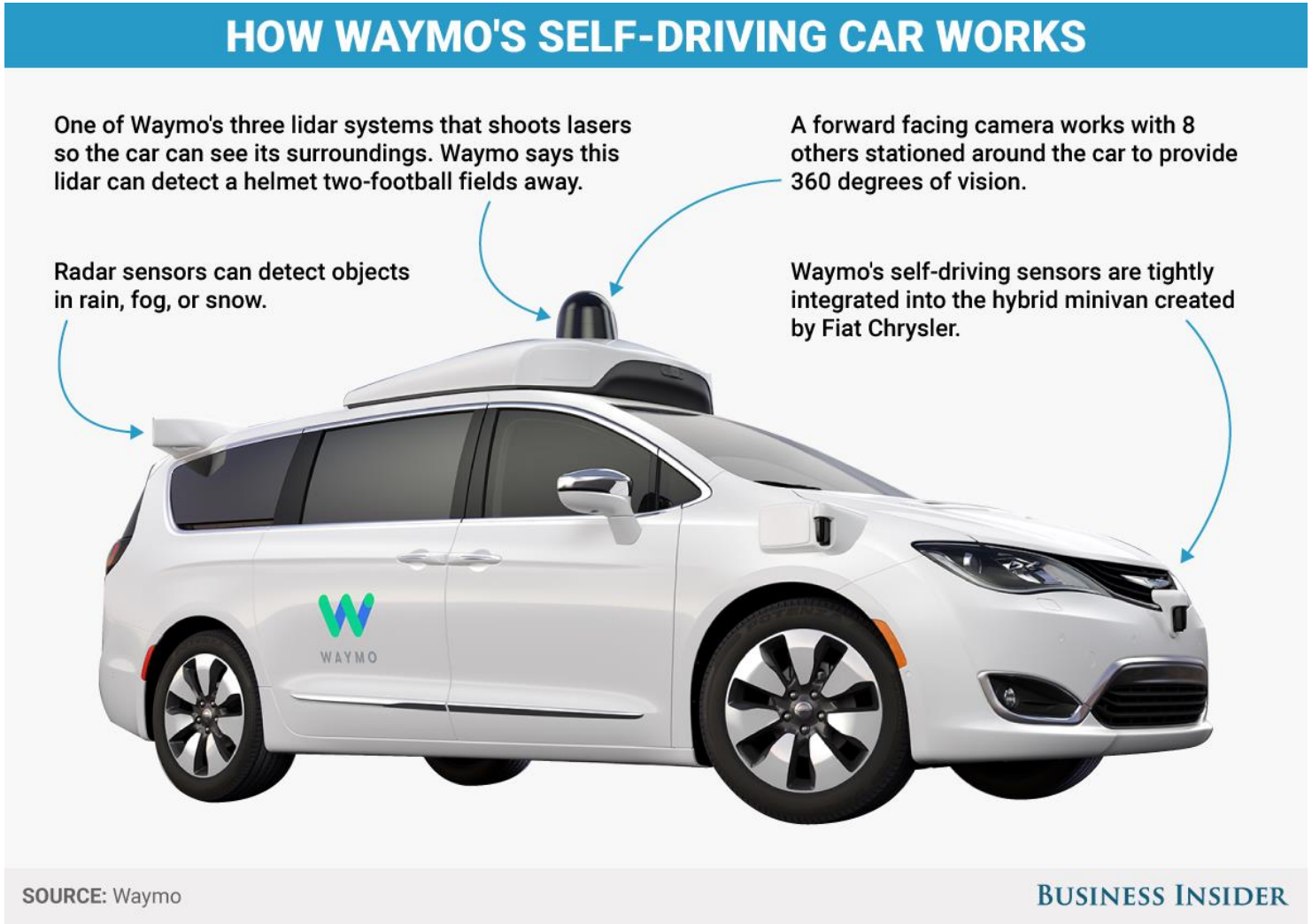
- All sensor type will give 360 degree info
  - Different radar ranges
  - different view angle cameras
- 3D Lidars instead of 2D
  - Still expensive (1000s USD)
  - 100 USD is a desired price

Example: Audi A8 2018*



*I know It's 2019…

Google Waymo

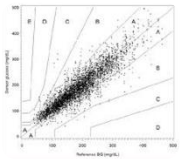


System Uncertainty Trade-off

Environment

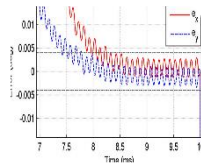
Not always ideal
Hidden things
Unpredictable/Not working

Sensors

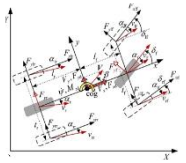


Range
Resolution
Noise

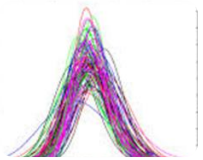
Actuators



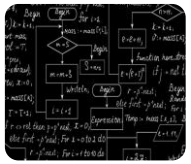
Control Noise
Wear and tear



Models

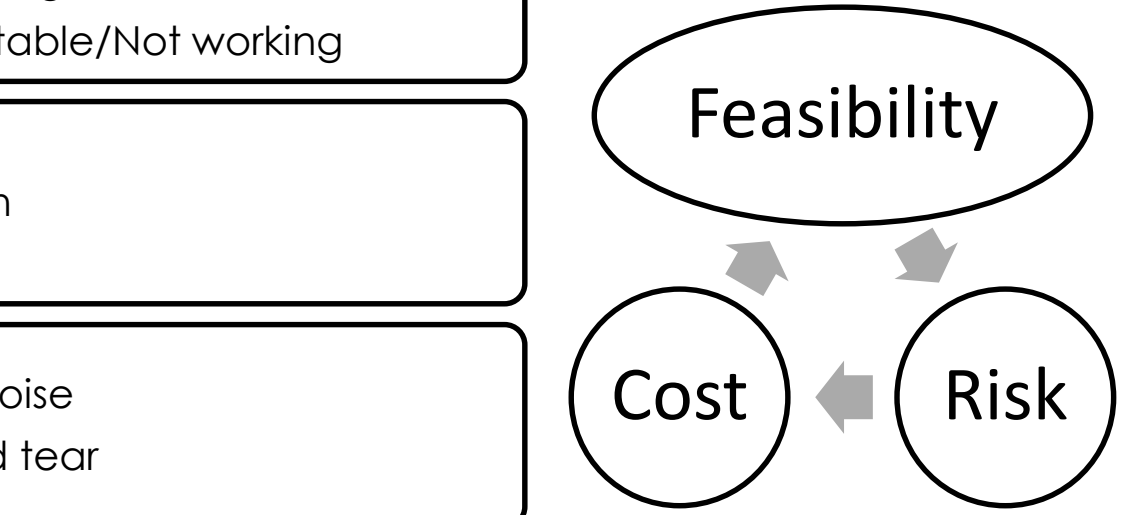


Abstraction/Modeling Level
Parameter uncertainty

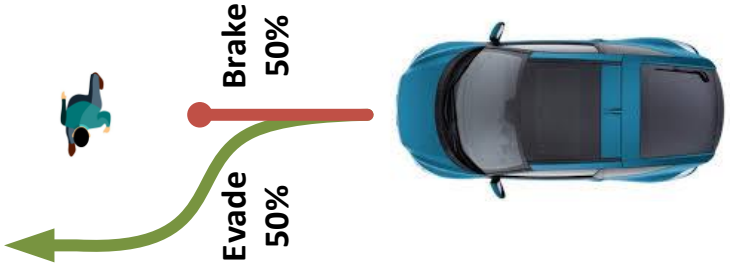


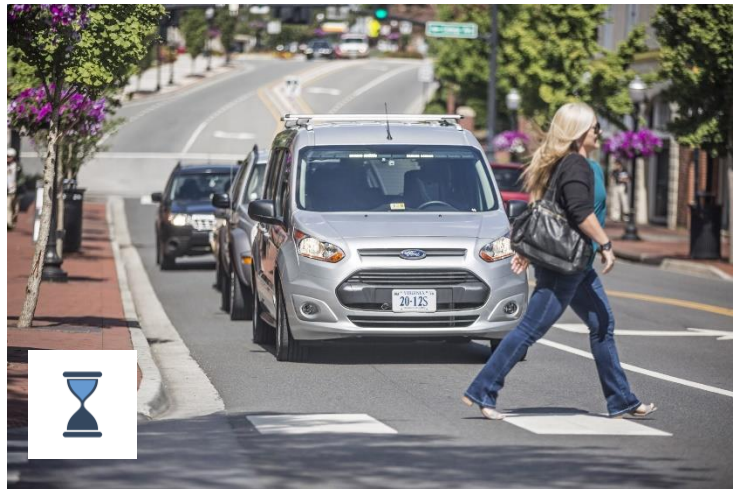
Solvers, Algorithms

NP hard problems
Computational complexity



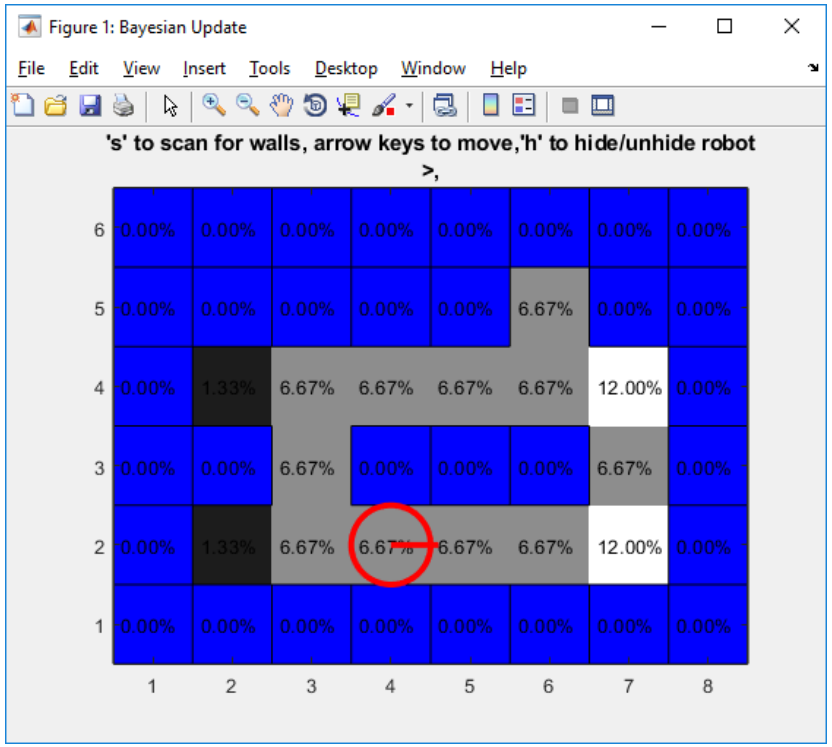
Numerical complexity



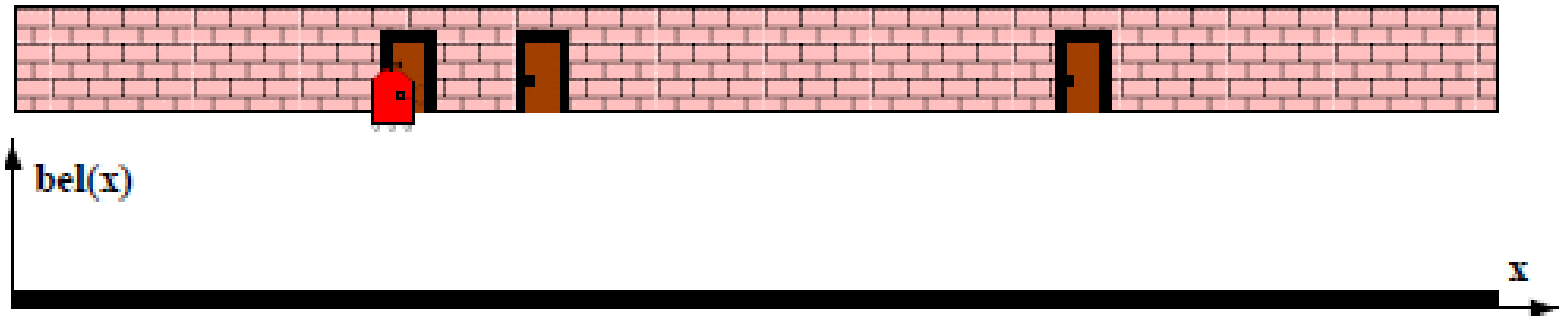


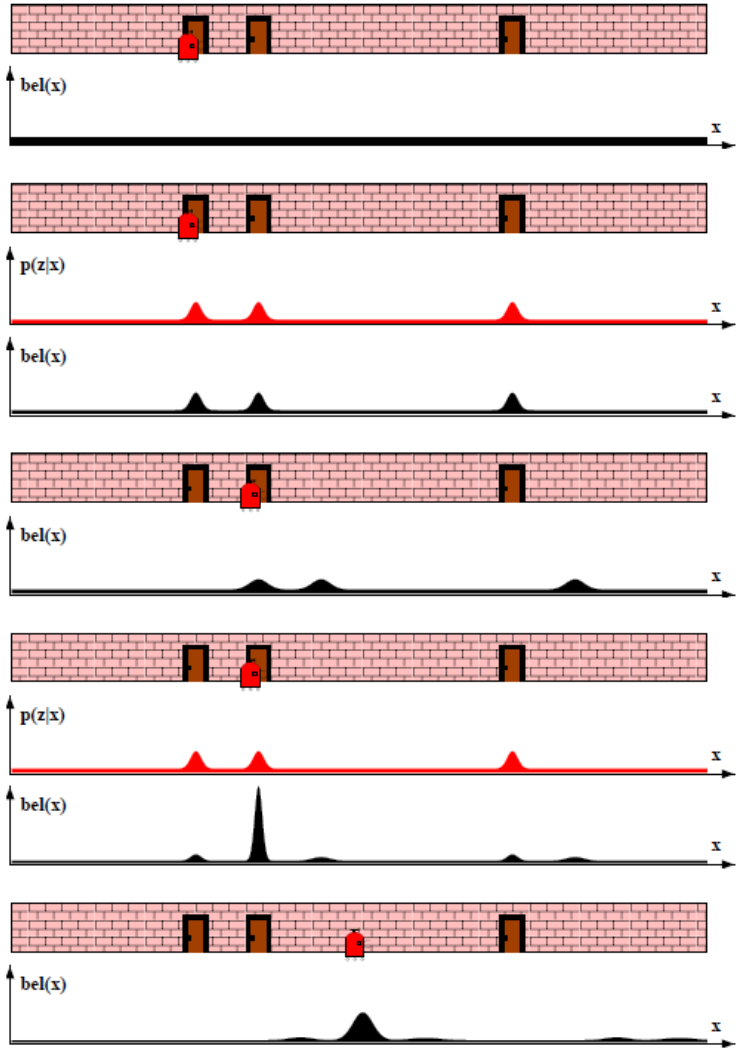
Simple Robot (with Bayes rule) Example

- **Localization**
- **Unit-size robot in**
- **A grid world**
- **Five actions: {left,up,right,down,scan}**
- **The robot actuators are inaccurate**
  - *probStraight* = 0.8; % Probability of going in the desired direction
  - *profOffby90Deg* = 0.1; % Probability of going in an other direction
- **Robot Sensors are also inaccurate**
  - *sTruePositive* = 0.8; % probability scanner detects wall if there is a wall
  - *sTrueNegative* = 0.6; % probability scanner detects no wall if no wall



Markov Localization (Continuous Space)





- Known Map
- Unknown Position
- Motion Model
- Measurement Model
- Probabilistic belief

Course Roadmap

Week		Lecture	Lab (Matlab exercises)
2019.02.06	1	Introduction	A humble engineers guide to computational complexity (and also the answer to whe the World will end)
2019.02.13	2	Introduction to probabilistics	Particle Filter Localization
2019.02.20	3	Localization and Bayes Filtering	Bayes-KF estimation
2019.02.27	4	State Estimation, Kalman Filters, EKF	Various KF/EKF object tracking/state estimation examples
2019.03.06	5	SLAM	EKF SLAM problem
2019.03.13	6	Behavior	TBD
2019.03.20		Spring Break	
2019.03.27	7	Exam week	
2019.04.03	8	Sensors Basics	TBD
2019.04.10	9	 Faculty profession day	
2019.04.17	10	Radar	FMCW example
2019.04.24	11	Ultrasonic/Lidar	Probabilistic Grid Mapping
2019.05.01	12	 International Labor Day	
2019.05.08	13	AI applications – connection to other topics	Scan matching
2019.05.15	14	Exam week	