Driver assistance systems and outlook into automated driving

EAEC-ESFA2015
Bucharest
November 2015

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General presentation of the Bosch Group

- **Some 45,600[1] researchers and developers work at Bosch: at 94[2] locations worldwide, in a unique network.**
- **Each working day, Bosch files 18 patents on average.**
- **This makes Bosch one of the world's leading companies for patent applications.**

[1]As of 01.15 [2]R&D locations with >50 associates, as of 01.15

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Bosch: four business sectors

Bosch Group → 49 billion euros in sales, 360,000 associates

Mobility

Industrial Technology

Energy and Building Technology

Consumer Goods

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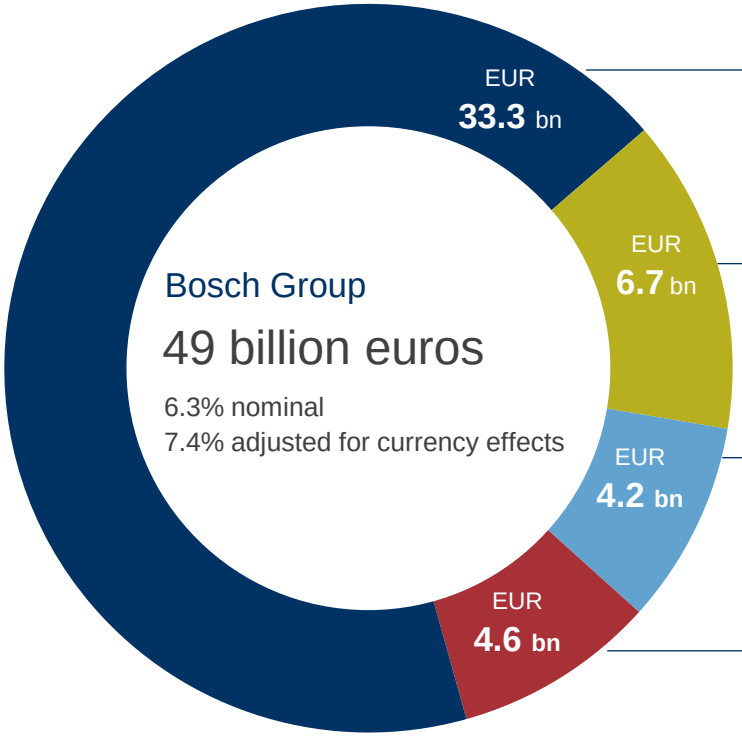
Business year 2014

Sales by business sector



Mobility Solutions

8.9% nominal
9.9% adjusted for exchange-rate effects
68% of total sales

Industrial Technology

-2% nominal
-1% adjusted for exchange-rate effects
14% of total sales

Consumer Goods

5% nominal
7% adjusted for exchange-rate effects
9% of total sales

Energy and Building Technology

1.7% nominal
2.6% adjusted for exchange-rate effects
9% of total sales

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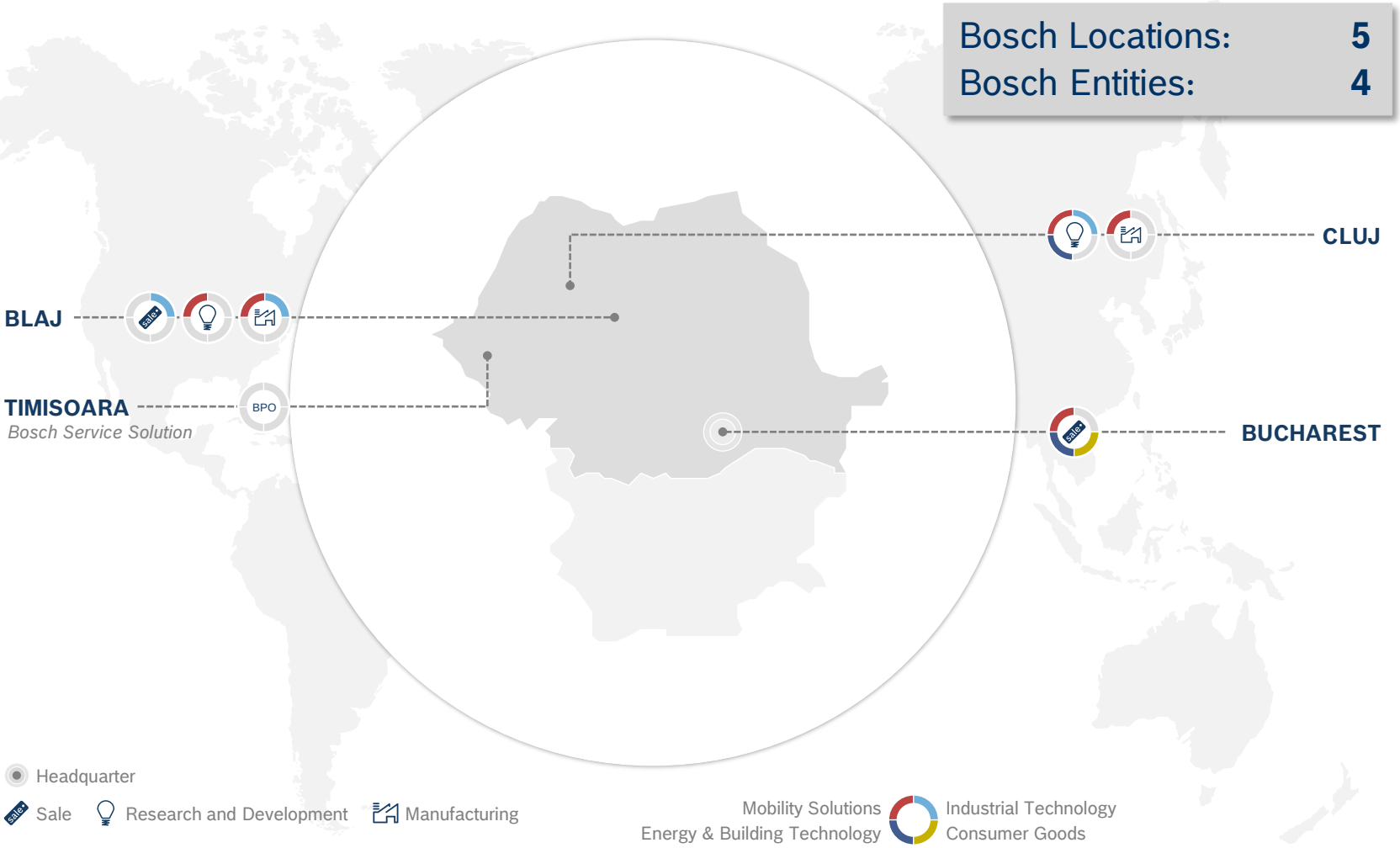
General presentation of the Bosch Group



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Automotive industry trends

- Electric - new energy to the powertrain!

- Connected – cars active parts in internet !

- **Automated driving!**

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Driver assistance systems and automated driving

We are busy ...

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Driver assistance systems and automated driving

We are distracted ...

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Driver assistance systems and automated driving

Some people need assistance ...

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Driver assistance systems and automated driving

… and sometimes…
… driving is boring

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Highly automated driving user experience

https://www.youtube.com/watch?v=CvnuJPlOyHs

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Driver assistance systems and automated driving

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Automated driving key technologies

Surround Sensors

are highly robust in all use cases

Driver Monitoring

for partly automatic functions

Online Map Data

is precise & up to date every moment

Perception and Localization

leads to unambiguous & comprehensive 360° environment model

Reasoning and Decision Making

allows for correct decisions, even in highly dynamic situations & at incomplete information

Motion Control

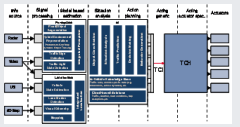
works safe, fast & precise in all dimensions

Functional Safety

guarantees high standard @ reasonable effort

Architecture

supports safety, performance & cost targets.



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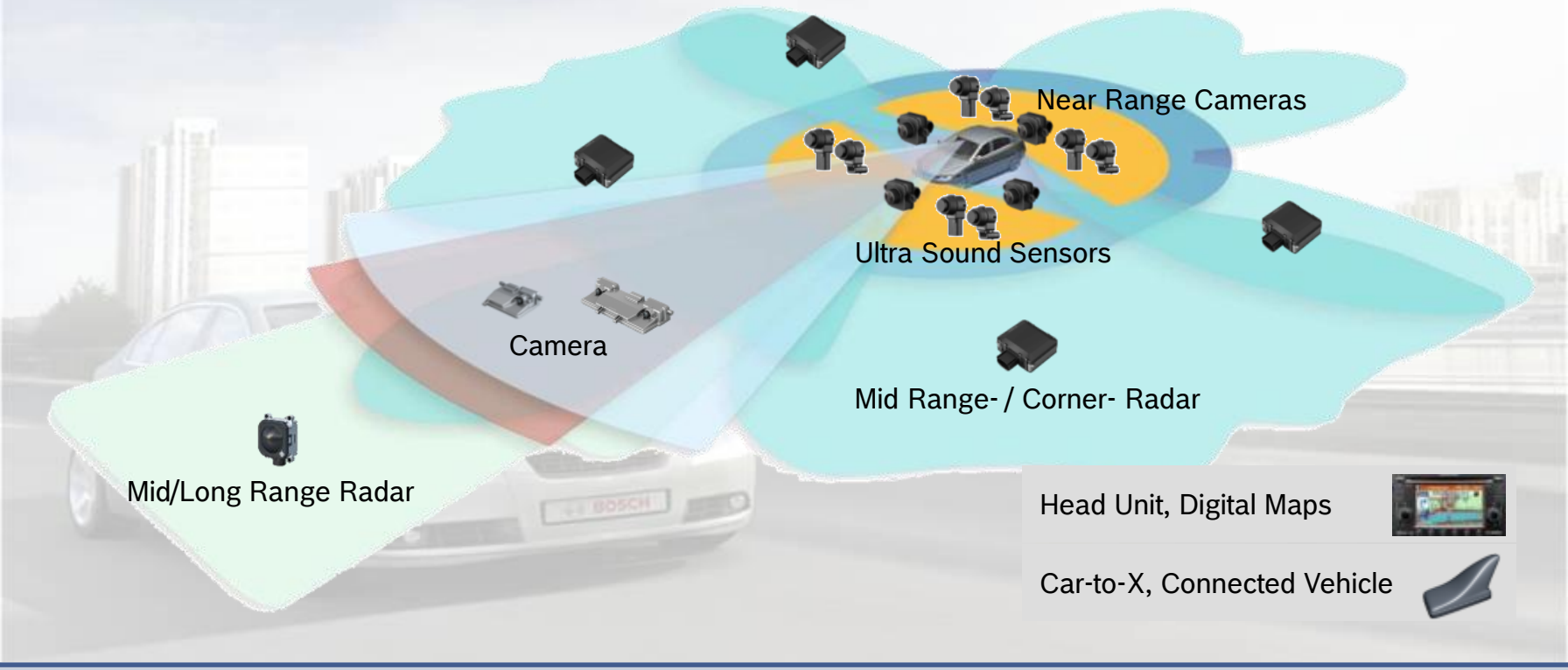
Possible / dominant sensor set up in the market



→ Currently only partly suitable for low car segments due to high cost pressure

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Leading functions of Advanced Driver Assistance Systems

Safety for everyone

Comfort & Assistance

- Blind Spot Detection/ Lane Change Assist/ Cross Traffic Alert
- Pedestrian Protection
- Automatic Emergency Braking
- Lane Departure Warning/ Lane Keeping Support
- Evasion Assist / Construction Zone Assist
- Adaptive Cruise Control
- Road Sign Recognition
- Maneuver Assistance
- Intelligent Headlight Control

➔ Leading functions cover comfort and safety

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Portfolio of current driver assistance functions

Light & sight at night functions

- High Beam Control
- Adaptive Headlight Control
- Masked Continuous High Beam
- Night Vision with Pedestrian Detection

Road Sign functions

- Speed Limits
- Stop Signs
- Give Way Signs
- Additional signs (Pictograms)
- Fusion with digital map
- general signs (triangular, rectangular)

Object / Surface functions

- Adaptive Cruise Control
- Emergency braking on cars
- Emergency braking on pedestrians
- Maneuver Assistance
- Distance information & warning
- Cross Traffic Alert
- Forward Collision Warning
- Speed Bump Assist
- **Adaptive Suspension**

Lane functions

- Lane Departure Warning
- Lane Keeping Assist
- Lane Change Assist / Blind Spot
- **Construction Zone Assist**
- **Narrow Passage Assist**
- Traffic Jam Assist
- Evasion Assist
- Driver Drowsiness Detection

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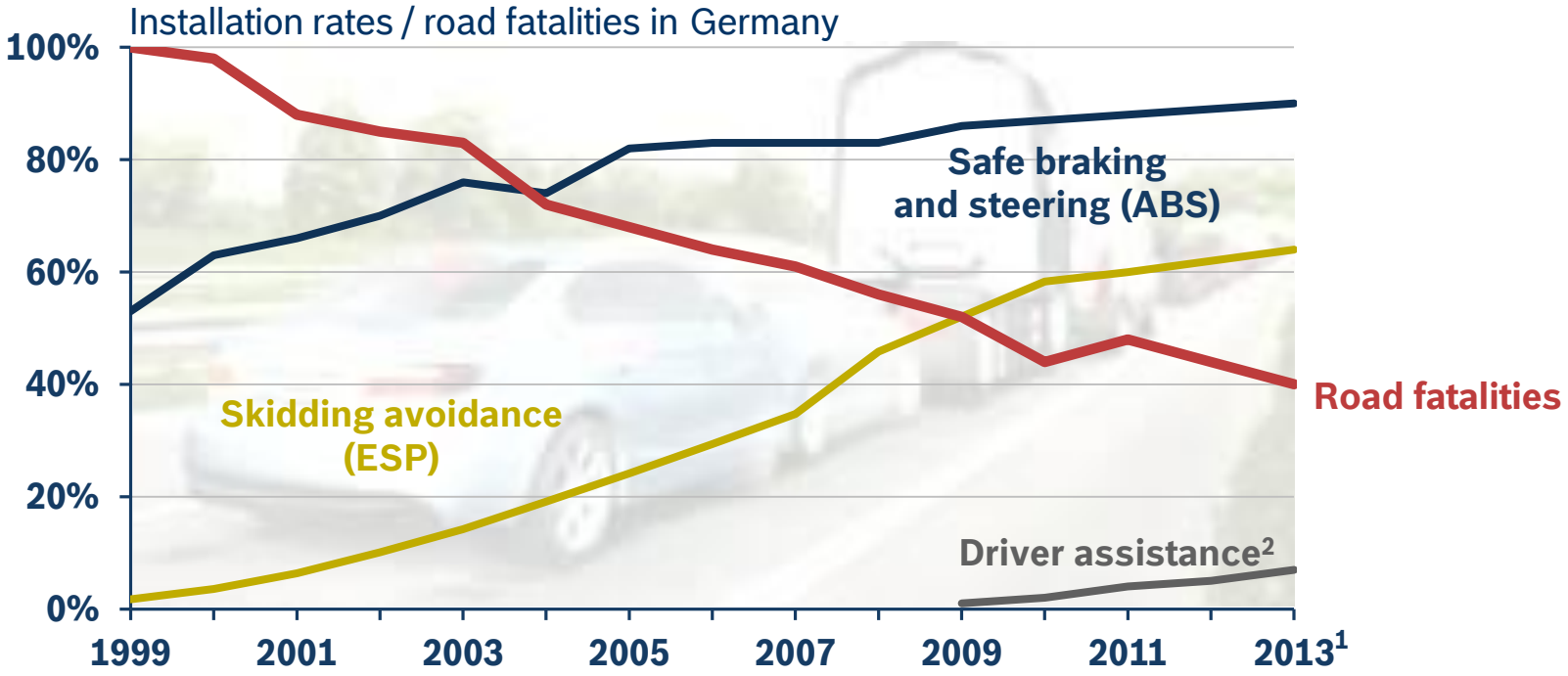
Road safety – influence of driver assistance



Number of road fatalities reduced by 60% within last 14 years

- 90% of all car accidents involving injury are caused by human error
- Introduction of further driver assistance systems will amplify positive trend

Source: Bosch, DAT, BASt. Based on total vehicle fleet. [1] Figures estimated [2] ACC and lane keeping support only

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Solutions – roadmap to the automated car

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New cars on road for automated driving

- 2013

- 2015

->Tests in real traffic conditions accelerate the development of new functions

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How to build an automated car!

https://www.youtube.com/watch?v=Op84zlabBAI&feature=youtu.be

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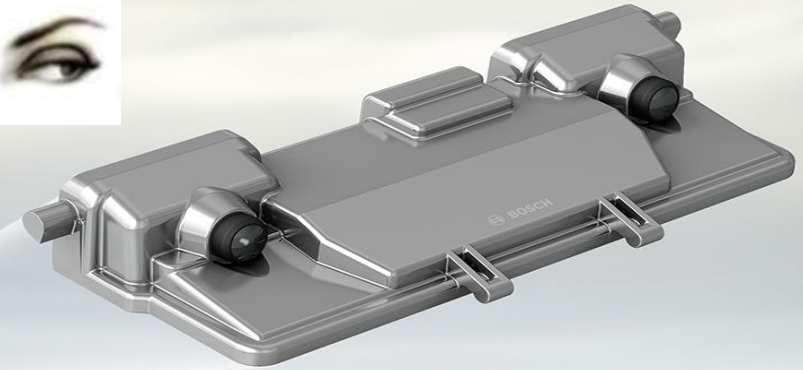
Stereo vision-based perception



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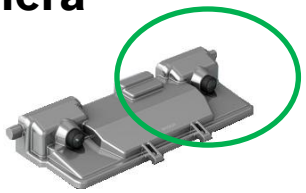
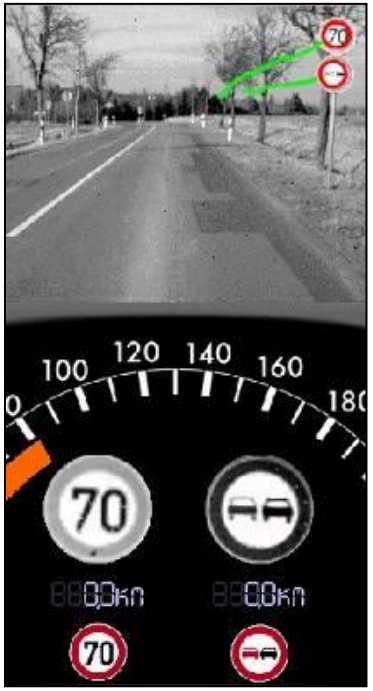
Perception Capabilities of a Mono Video System

- **2D information from the “left” camera**
  - Traffic signs:
    - Speed Limits.
    - Stop Signs.
    - Give Way Signs.
    - Additional signs (Pictograms).
    - General signs (triangular, rectangular).
  - Lane markings.
  - Vehicle lights / traffic lights.
  - Object classification (machine learning).





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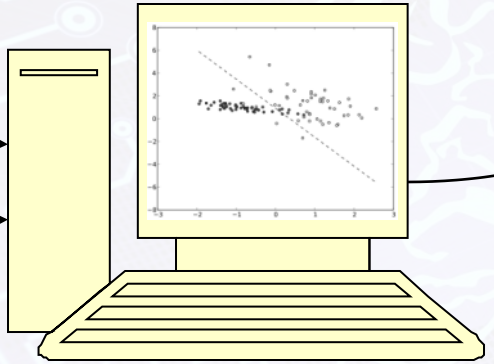
Objects from classification

Positive-Samples

- **Classification methods**: decision trees, neural networks, support vector machines, boosting.

Test

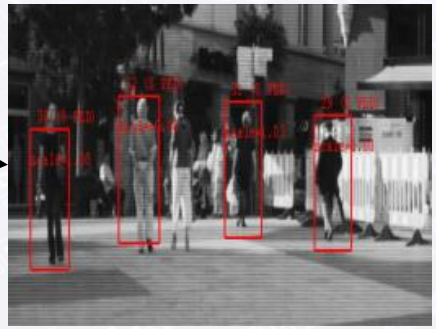
Labeled sequences



Negative-Samples

- **Features**: grayscale values, histogram of oriented gradients, codebook features, Haar –like features

Real World Performance



- Object detection using classification is knowledge and training based
- Classification is very much depending on a priori knowledge

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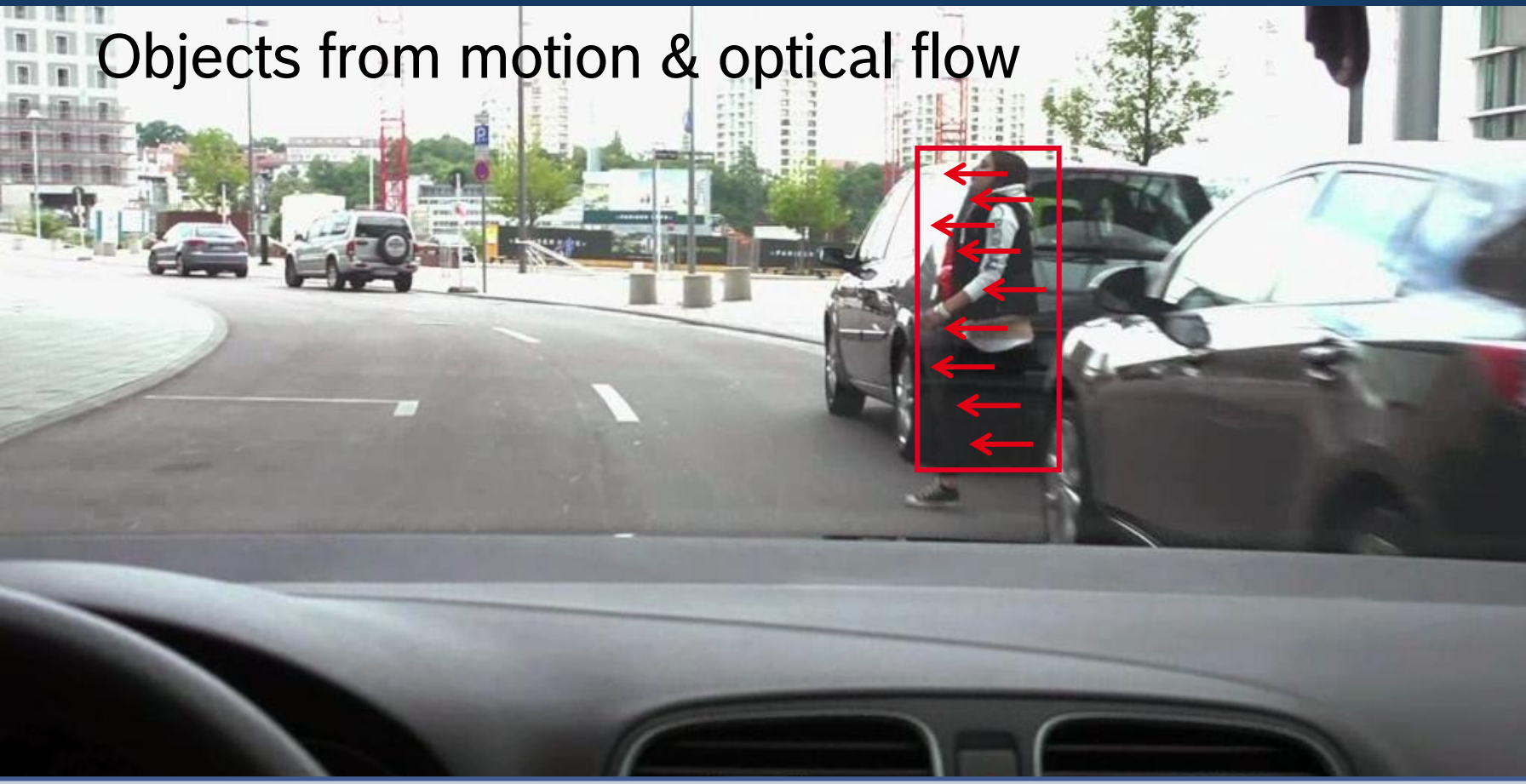
Objects from motion & optical flow



- Object detection from motion (optical flow) is based on existence and clustering of 3D information point cloud depending on motion state of the camera (car).
- No appearance based trained prior knowledge is used for object detection

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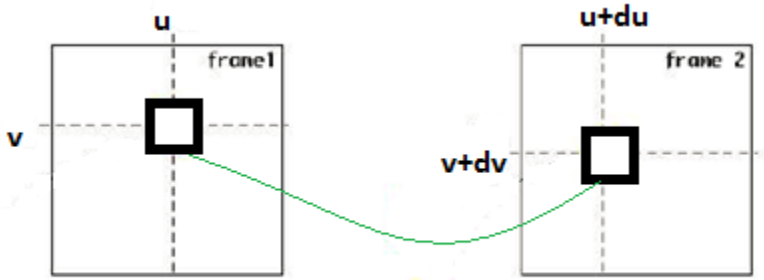
Lukas-Kanade optical flow method - 1981



$$C(du,dv) = \sum_{(u,v)\in window} \left(F(u,v) - F_2(u+du, v+dv)\right)^2 =$$

$$\sum_{(u,v)\in window} \left(F(u,v) - F_2(u,v) - du \cdot \frac{F_2(u,v)}{\partial u} - dv \cdot \frac{F_2(u,v)}{\partial v}\right)^2$$

- Assumption: constant displacement for all the pixels in window.
- Minimization of *C(du,dv)* by doing partial derivatives with respect to *du* and *dv* and setting them equal to 0.

Reference:
An Iterative image Registration Technique with an Application to Stereo Vision, D. Lukas, T. kanade, April 1981
https://www.ri.cmu.edu/pub_files/pub3/lucas_bruce_d_1981_1/lucas_bruce_d_1981_1.pdf

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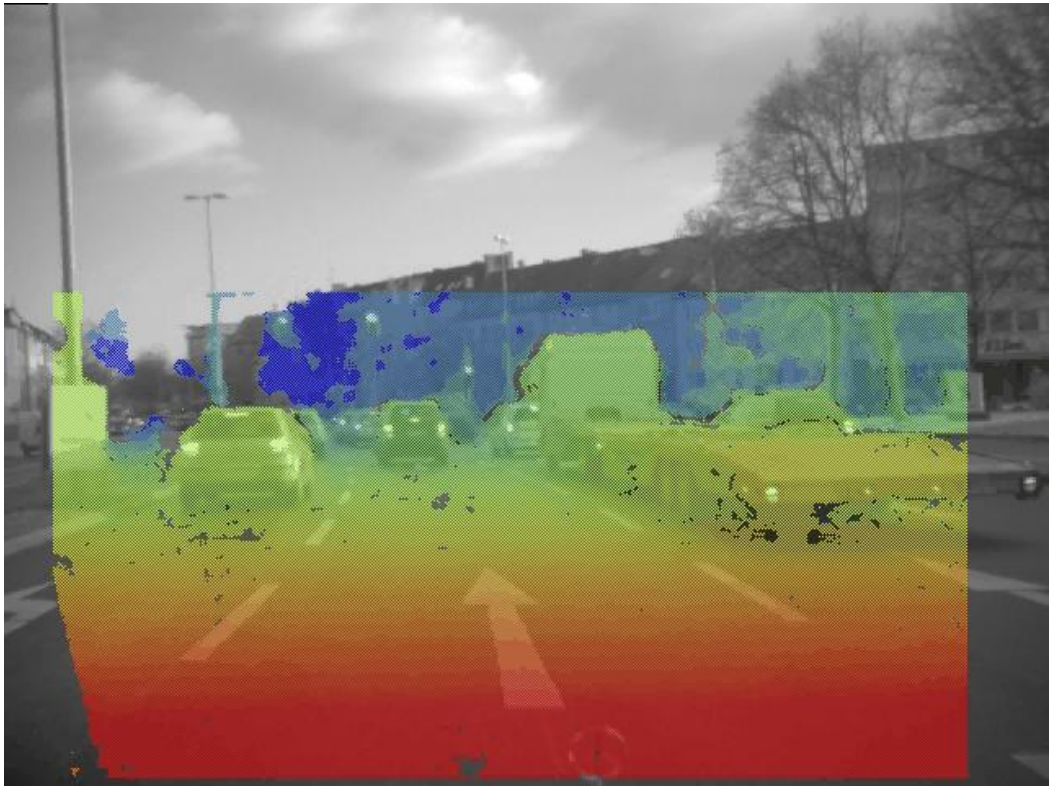
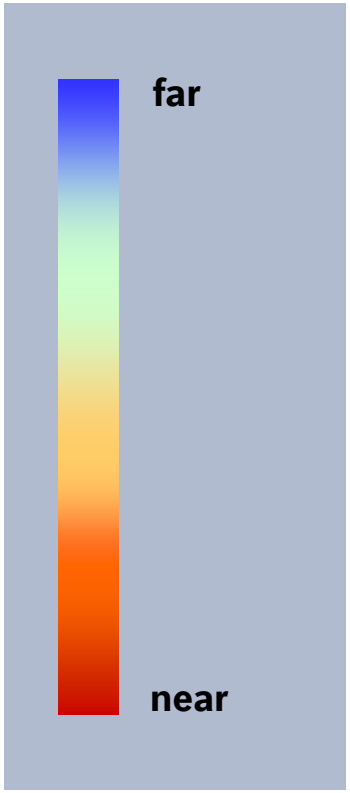
Stereo: Map of depth





Urban scenario with stop at traffic light

Disparity
(object distance)

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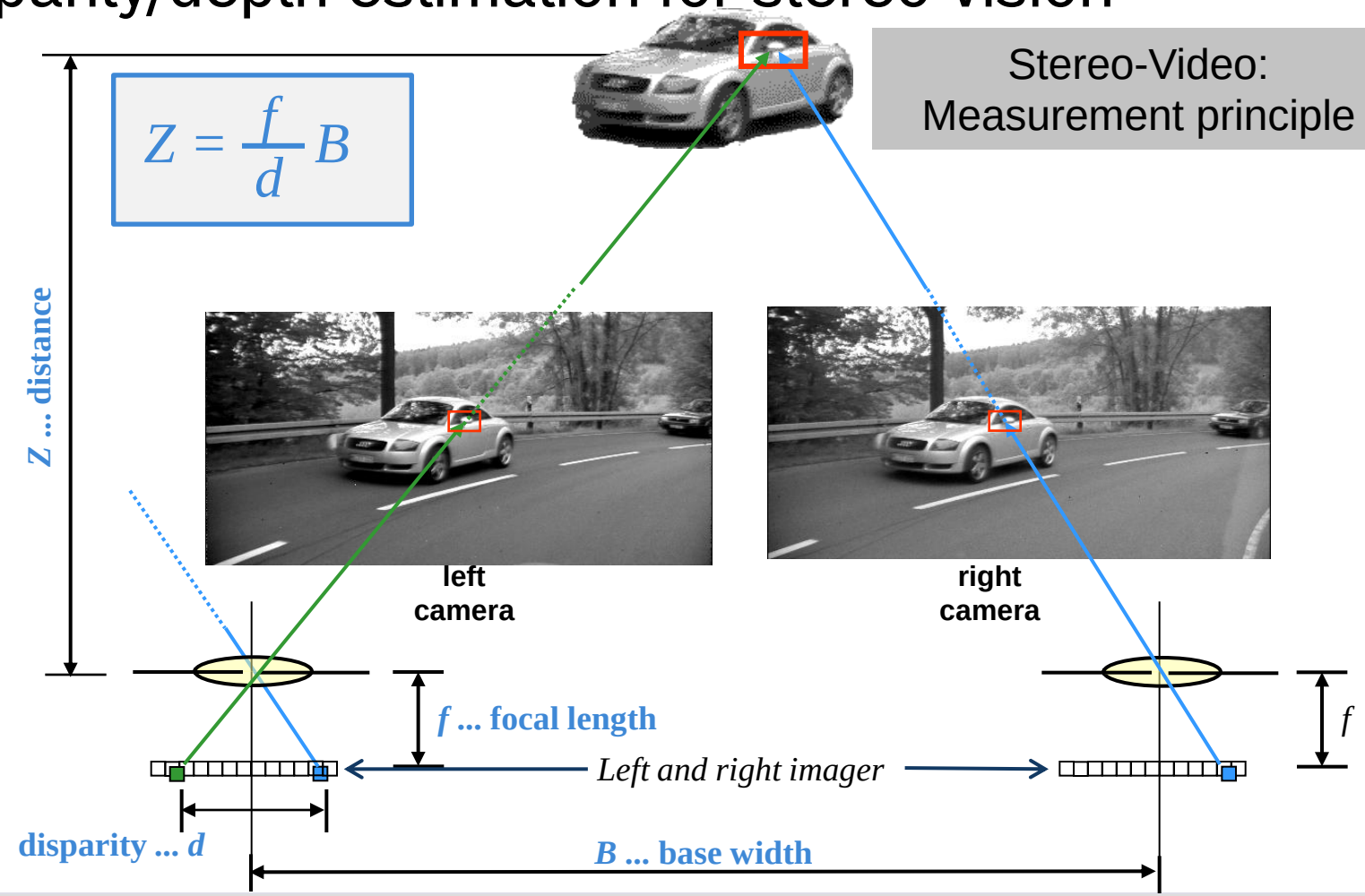
Disparity/depth estimation for stereo vision

Stereo-Video:
Measurement principle



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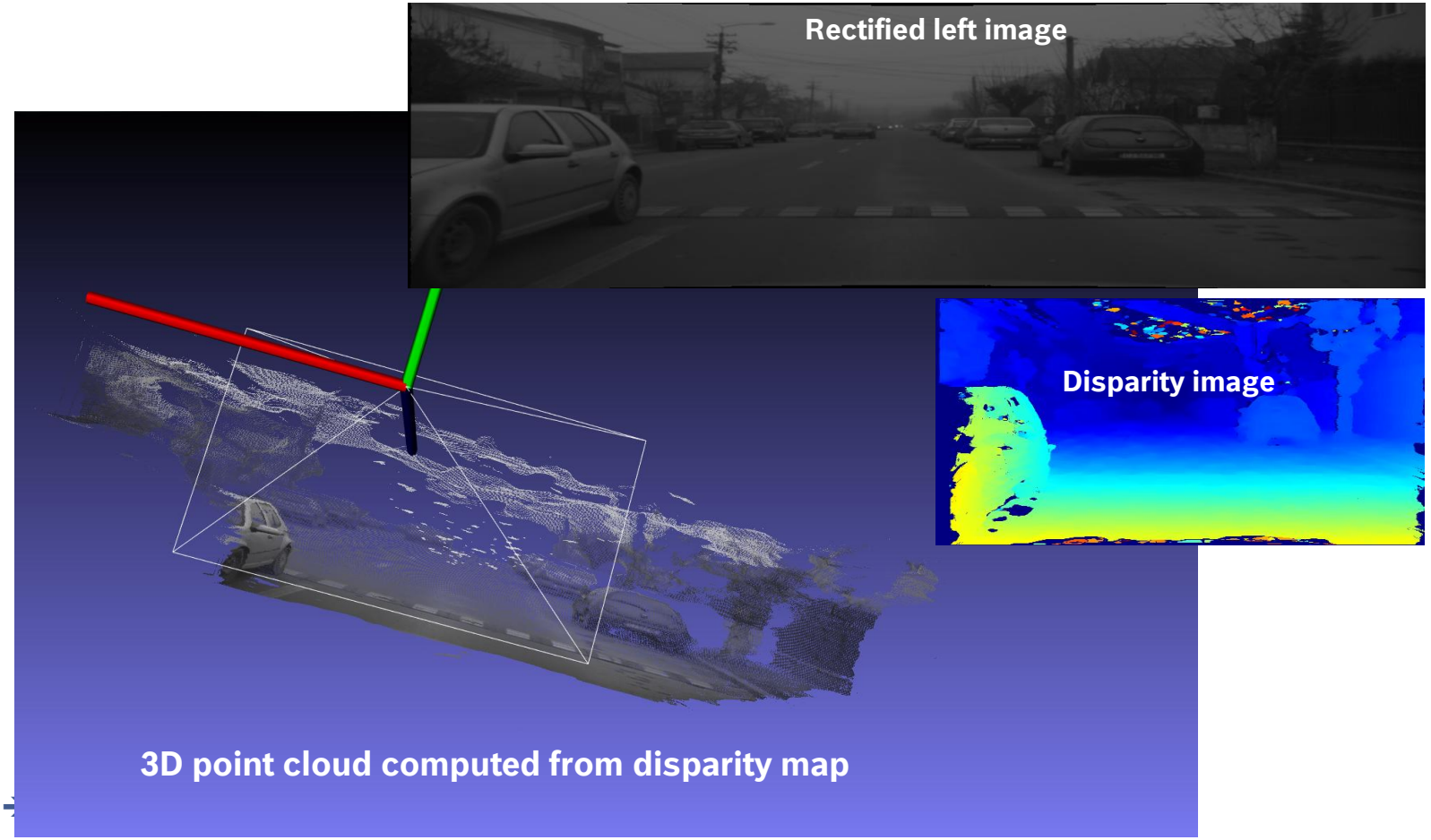
3D visualization of point cloud from disparity



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Perception Capabilities of a Stereo Video System

- complete **3D environment information**
  - path topography (slopes, bumps, potholes, lane grooves)
  - height obstructions (bridges, trees)
  - path width (narrow passages, parking)
- complete **3D object information**
  - cars, trucks, cycles, pedestrians, ...
  - guard rails, poles, walls, trees, animals,...

Stereo Camera is the only sensor which is able to provide comprehensive 2D/3D information

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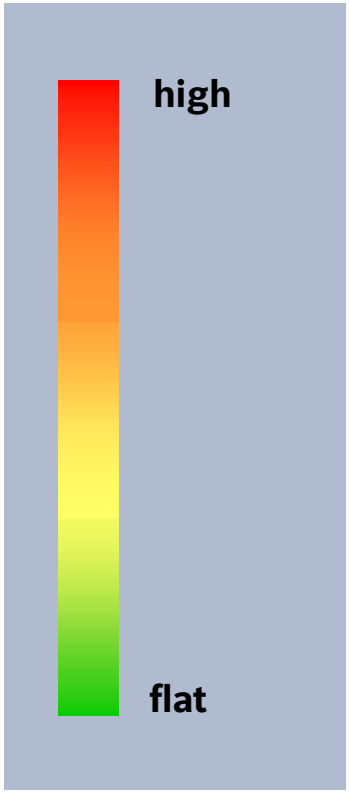
Stereo: elevated objects detection

Highway scenario with narrow passage



Elevation
(object height)

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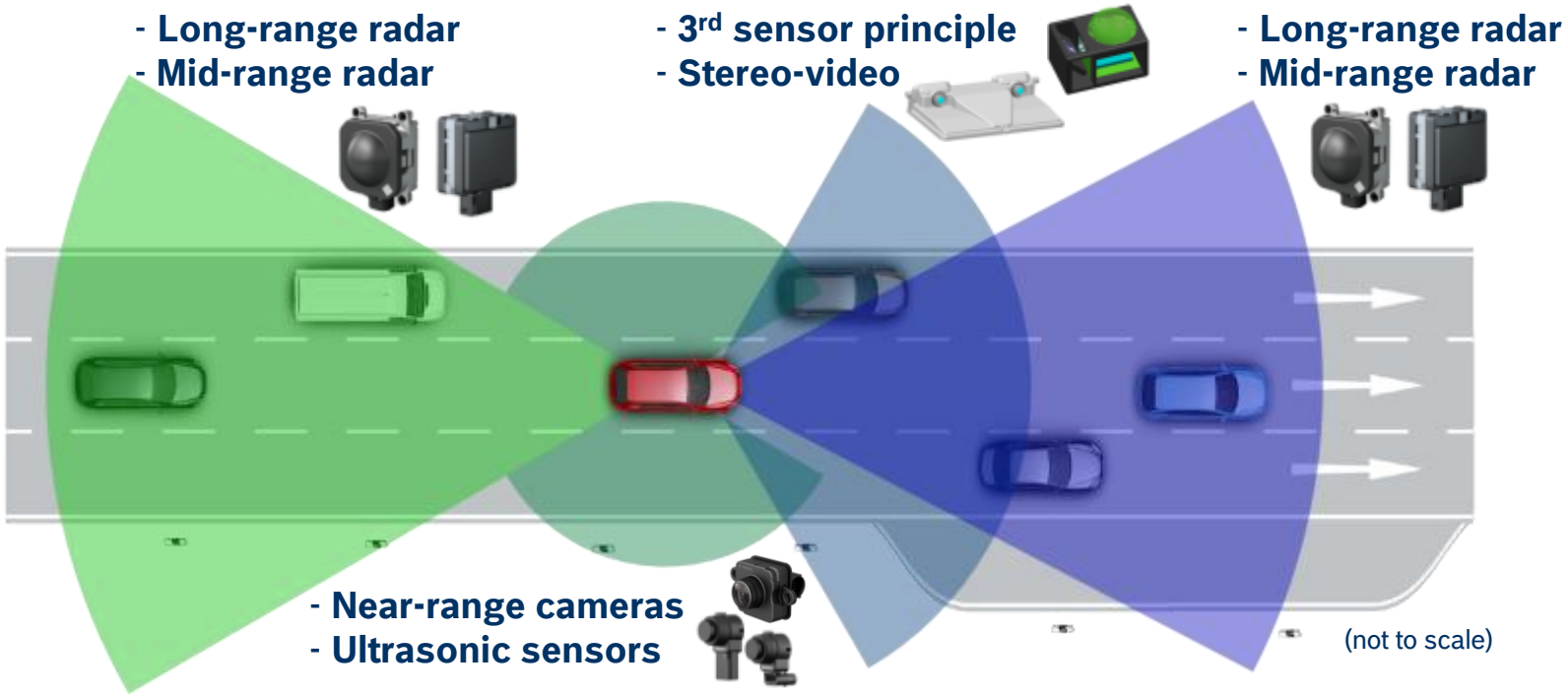
Surround sensing – vehicle sensor concept



360° surround sensing by combination of different sensors

- Long- and mid-range radar prerequisite for driving at higher speed
- Satisfy reliability requirements by using multiple sensors for each area

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Research and Development in Cluj

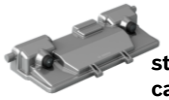
Current projects

Photovoltaic inverters
Embedded Software, Development and Testing,
Power Management, Online control & monitoring

...automotive technology for green energy solutions

Electric Power Steering
Embedded Software development for
electronic steering control unit

...comfort system fulfilling highest safety requirements



stereo camera

Driver Assistance
Stereo Image Processing
Embedded Software
Parking & Maneuvering

ultrasonic sensors

...on the way to autonomous driving

Reliability Engineering
Testing and Analysis of
electronic devices

...durable and reliable products

Engineering Service Center Cluj
to internal and external customers
PCB layout, mechanical design, ...

...competitive services for Bosch and non-Bosch customers

Analytic Service Center
Data analysis, algorithm & sensor development incl. support
for AE/PJ-I4.0

...virtual world becomes the leading system

i4.0 CONNECTED INDUSTRY

Competences

- Project Management
- System & Application
- Algorithms Development
- Embedded Software
- System Testing
- 2nd & 3rd Level Support
- Mechanical Design
- PCB Layout
- Hardware

Outlook

- Research & Development Services
- Cluj plant - Electronics Manufacturing Services
- Local Romanian customers

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Collaboration possibilities

Open positions available in the R&D Cluj team.

Working students/Master/Diploma @ Bosch:

Develop state of the art algorithmic methods in collaboration with Bosch R&D engineers.

PhD @ Bosch:

Research and innovation in the areas of driver assistance systems.
Perception for highly automated driving.
Develop new ideas related to driver assistance, autonomous vehicles and related product.
Next generation video-based driver assistance systems.
Example topics: precise localization, surface modeling, situation interpretation & path planning.

➔ More details: http://www.bosch-career.ro

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