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
## General presentation of the Bosch Group

### Bosch: four business sectors

<table>
<thead>
<tr>
<th>Bosch Group</th>
<th>➤ 49 billion euros in sales, 360,000 associates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mobility</strong></td>
<td><img src="image1" alt="Powertrain systems" /> <img src="image2" alt="Safety systems" /> <img src="image3" alt="Comfort systems" /></td>
</tr>
<tr>
<td><strong>Industrial Technology</strong></td>
<td><img src="image4" alt="Mobile applications" /> <img src="image5" alt="Factory automation &amp; machinery" /> <img src="image6" alt="Renewable energy" /> <img src="image7" alt="Packaging technology" /></td>
</tr>
<tr>
<td><strong>Energy and Building Technology</strong></td>
<td><img src="image8" alt="Heating, ventilation, climate control" /> <img src="image9" alt="Decentralized energy management" /> <img src="image10" alt="Security &amp; safety" /> <img src="image11" alt="Communications" /></td>
</tr>
<tr>
<td><strong>Consumer Goods</strong></td>
<td><img src="image12" alt="Power tools, measuring tools" /> <img src="image13" alt="Garden tools" /> <img src="image14" alt="Household appliances" /> <img src="image15" alt="Sensors &amp; Smart home" /></td>
</tr>
</tbody>
</table>
Business year 2014

Sales by business sector

Bosch Group
49 billion euros
6.3% nominal
7.4% adjusted for currency effects

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
Driver assistance systems and automated driving

Automotive industry trends

➤ Electric - new energy to the powertrain!

➤ Connected – cars active parts in internet!

➤ Automated driving!
We are busy ...
Driver assistance systems and automated driving

We are distracted ...

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Driver assistance systems and automated driving

Some people need assistance ...
Driver assistance systems and automated driving

... and sometimes...
... driving is boring
Driver assistance systems and automated driving

Highly automated driving user experience

https://www.youtube.com/watch?v=CvnuJPlOyHs
Driver assistance systems and automated driving

The automated car will be reality!
Driver assistance systems and automated driving

Automated driving key technologies

<table>
<thead>
<tr>
<th>Surround Sensors</th>
<th>Driver Monitoring</th>
<th>Online Map Data</th>
<th>Functional Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>are highly robust in all use cases</td>
<td>for partly automatic functions</td>
<td>is precise &amp; up to date every moment</td>
<td>guarantees high standard @ reasonable effort</td>
</tr>
</tbody>
</table>

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

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Driver assistance systems and automated driving

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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Driver assistance systems and automated driving

Leading functions of **Advanced Driver Assistance Systems**

- 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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## Driver assistance systems and automated driving

### 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
Driver assistance systems and automated driving

Solutions – roadmap to the automated car

**Degree of automation**

- Single sensor
- Sensor-data fusion
- Sensor-data fusion + map

**Series production**

**ACC/lane keeping support**
- Only longitudinal or lateral control
- Partially automated longitudinal and lateral guidance in driving lane
- Speed range 0-130 kph

**Integrated cruise assist**
- Partly automatic longitudinal and lateral guidance
- Lane change after driver confirmation
- Supervision of surrounding traffic (next lane, ahead, behind)

**Highway assist**
- Highly automated longitudinal and lateral guidance with lane changing
- Reliable environment recognition, including in complex driving situations
- No permanent supervision by driver

**Highway pilot**
- Door-to-door commuting (e.g. to work) in urban traffic
- Strictest safety requirements
- No supervision by driver

**Auto pilot**
- Highly automated longitudinal and lateral guidance with lane changing
- Strictest safety requirements
- No supervision by driver
Driver assistance systems and automated driving

New cars on road for automated driving

- 2013
- 2015

Tests in real traffic conditions accelerate the development of new functions

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Driver assistance systems and automated driving

How to build an automated car!

https://www.youtube.com/watch?v=Op84zlabBAI&feature=youtu.be
Driver assistance systems and automated driving

Stereo vision-based perception

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Driver assistance systems and automated driving

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).
Objects from classification

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

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

Object detection using classification is knowledge and training based
Classification is very much depending on a priori knowledge
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.
Lukas-Kanade optical flow method - 1981

- 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
Driver assistance systems and automated driving

Stereo: Map of depth

Urban scenario with stop at traffic light

Disparity (object distance)
Driver assistance systems and automated driving

Disparity/depth estimation for stereo vision

\[ Z = \frac{f}{d} B \]

- \( Z \): distance
- \( f \): focal length
- \( d \): disparity
- \( B \): base width

Stereo-Video: Measurement principle
3D visualization of point cloud from disparity
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.
Driver assistance systems and automated driving

Stereo: elevated objects detection

Highway scenario with narrow passage

Elevation (object height)
Surround sensing – vehicle sensor concept

- Long-range radar
- Mid-range radar

- 3rd sensor principle
  - Stereo-video

- Long-range radar
  - Mid-range radar

- Near-range cameras
  - Ultrasonic sensors

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
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

**Driver Assistance**
Stereo Image Processing, Embedded Software, Parking & Maneuvering
...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

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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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.

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.

More details: http://www.bosch-career.ro
Thank you for your attention!

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