Siemens ADAS
Collision avoidance as the first step towards autonomous driving
Advanced Driver Assistance Systems help to avoid collisions and represent the first step towards autonomous driving

- Driver Assistance Systems are state-of-the-art in new cars
- Siemens ADAS transfers this technology to trams:
  - First step: collision avoidance system
  - Long-term target: autonomous driving
- Step-by-step iterations aligned with automotive developments
ADAS Automotive vs. ADAS Rail
At first view automotive products seem to be easily usable

<table>
<thead>
<tr>
<th>The Task</th>
<th>• Sense environment</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>• Assist driver or act autonomously</td>
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<table>
<thead>
<tr>
<th>Used Sensors</th>
<th>• Radar, Camera, …</th>
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<tbody>
<tr>
<td>Detection task</td>
<td>• Detect other vehicles, obstacles, humans, animals etc</td>
</tr>
<tr>
<td></td>
<td>• Consider traffic signs, signals, rules and regulations</td>
</tr>
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<table>
<thead>
<tr>
<th>All the same?</th>
<th>• Youthful optimism : use automotive ADAS on rail …</th>
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<tbody>
<tr>
<td></td>
<td>• Technology is compact, inexpensive, already available, certified</td>
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</table>
ADAS Automotive vs. ADAS Rail
At closer inspection there are significant differences

<table>
<thead>
<tr>
<th>Automotive applications and environments</th>
<th>Rail applications and environments</th>
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<tbody>
<tr>
<td>Protected highway</td>
<td>Complex urban environment incl. operation in pedestrian areas or at crowded stops</td>
</tr>
<tr>
<td>Road vehicles and pedestrians</td>
<td>Additional LRVs and buffer stops</td>
</tr>
<tr>
<td>Detection of road markings (white on black)</td>
<td>Track detection (black on black)</td>
</tr>
<tr>
<td>Road signs and signals</td>
<td>Additional rail signs and signals, differently located</td>
</tr>
<tr>
<td>Concrete/asphalt road</td>
<td>Additional grass and ballasted track Embedded rails and standard rails</td>
</tr>
<tr>
<td></td>
<td>Proximity to fixed installations, e.g. fences, poles</td>
</tr>
<tr>
<td></td>
<td>Trackside rail-specific installations, e.g. stations, switch cabinets</td>
</tr>
<tr>
<td></td>
<td>Far lower brake performance (due to limited friction)</td>
</tr>
<tr>
<td></td>
<td>Non-buckled passengers</td>
</tr>
<tr>
<td></td>
<td>Unwanted “gap filling” by automobiles in dense traffic</td>
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</table>
ADAS Automotive vs. ADAS Rail
The different applications require major adaptations for rail use

To use automotive components in rail applications, adaptations have to be done …

➔ Automotive ADAS sensors are highly specialized
➔ Automotive market is priority (very large quantities and R&D budgets)
➔ Adaptation of automotive components: small Rail market to cover one-time cost
➔ Rail adaptations take time due to priority of automotive sector
➔ Rail roadmap aligned with automotive sector: following market segment

Significant benefit to use automotive baseline developments to leverage synergies
Siemens ADAS system
Few components, straightforward installation, vehicle agnostic
Core components are already proven in automotive and the entire system performance is qualified for the use in rail

<table>
<thead>
<tr>
<th>Multi Purpose Camera</th>
<th>Mid-Range-Radar Sensor</th>
<th>Rail Control Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera mounted in cab</td>
<td>Radar mounted in the front mask</td>
<td>Control Unit mounted inside tram</td>
</tr>
<tr>
<td>• Detects the track</td>
<td>• Detects objects by radar</td>
<td>• Interface between the Siemens Tram Assistant system and tram</td>
</tr>
<tr>
<td>• Detects objects and their location in front of the tram</td>
<td>• Measures object distance and velocity</td>
<td>• Generates collision warning and braking signals</td>
</tr>
<tr>
<td></td>
<td>• Fuses Camera and Radar data</td>
<td>• Cancels signals in case of driver override</td>
</tr>
<tr>
<td></td>
<td>• Determines if an object is a potential collision object</td>
<td>• System diagnostics (error codes)</td>
</tr>
</tbody>
</table>

* Source of pictures: Bosch Engineering
The Siemens Tram Assistant detects and warns of hazardous situations with trams, cars, trucks, busses, buffer stops.

**Use Case 1**
Stationary cars, trucks, busses and trams at rear/front view

**Use Case 2**
Running or stopping cars, trucks, busses and trams at rear/front view

**Use Case 3**
Buffer stops, via attaching a radar reflector

**Use Case 4 – under test**
Completely visible and crossing pedestrians

Scenarios with potential high accident severity (e.g. tram-to-tram collisions) are covered. Other scenarios are under development or evaluation and will be available via software upgrades.
Pattern recognition - trained shapes
Principle of system response of Siemens Tram Assistant

Warning/braking depends on

- Speed of the Tram
- Distance to the object

System calculates

- Stopping distance → Automatic braking
- Warning distance → Warning signal
**Principle of system response : Siemens ADAS**

Camera View including system response strategy:
- Object positioning laterally: Camera
- Object positioning distance: Radar
- Object type classification: Camera

Visualization of Camera View including system response strategy:
- Red: Objects detected by Radar
- Green: Objects detected by Camera
Different levels of system integration for Siemens ADAS

**Integration level Low**
- Hardwired signal to open safety loop

**Integration level Medium**
- “Stand-alone-System” without integration: separate indicator/buzzer

**Integration level High**
- SW Integration into train/brake control
- Hardwired signal to initiate Full Service Brake. Driver can overrule the system reaction.

This system is a driver assistance system: Driver is responsible for driving by sight and should never rely on the system to respond.
Safety and efficiency – the key factors in public transport

Increased **safety** of all passengers and traffic participants

**Lower repair costs** by avoiding or reducing accident damage

**Higher availability of trams** thanks to reduction of accident frequency

- **Safety**
- **Cost efficiency**
- **Availability**
Customer Feedback: Siemens Tram Assistant

Tram drivers show behavioral change

- Awareness of supervision
- Conscious attempt to minimize system interference (incentive ?)
- Higher focus on potential collision situations / geographical areas

Customers embrace new technology

- Ulm and The Hague decided to retrofit their fleets (total 92 vehicles)
- Bremen and Copenhagen ordered vehicles with ADAS (106 vehicles)
- Standard requirement in European Tram tenders
Automotive roadmap towards fully autonomous driving

- Automated valet parking 2018
- Remote park assist 2015
- Evasive steering support 2015
- Automatic emergency braking since 2010
- Assisted driving
  Supports the driver

- Highway assist 2018
- Integrated cruise assist 2017
- Traffic jam assist 2015
- Partially automated driving
  Permanent driver supervision

- Auto pilot >2025
- Highway pilot 2020
- Traffic jam pilot >2016

Source: Bosch AG
Conclusion

• Assisted Driving for Trams is a reality

• Detecting Obstacles is easy : Responding correctly is hard

• Quick win to reduce severity of accidents on shared tracks