On the way to an autonomous Tram

siemens.com/mobility

Driverless operation – Nothing new for rail vehicles, but …

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- Metros and airport shuttles operate in a closed environment, controlled by external, infrastructure based systems
- Means of transport operating in open infrastructure – like trams in a complex urban environment – need different, “intelligent” solutions
- Main tasks are: Permanent surveillance of environment and forward-looking driving to prevent collisions

Similar to the automotive industry

Autonomous driving can only be developed in iterative loops and in several steps

Since 2015 – Step 1 – Assistant systems – Filed test with a Combino in Ulm

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Tram Assistant – Driver Assistant System

- Warning/Braking when potential collision is detected
- New Use Cases currently in implementation status
  - Pedestrian and bicyclists detection
  - Speed supervision

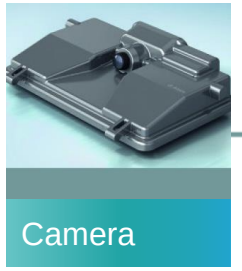
Evaluation KIT – Development Platform

Objective evaluation of field test results

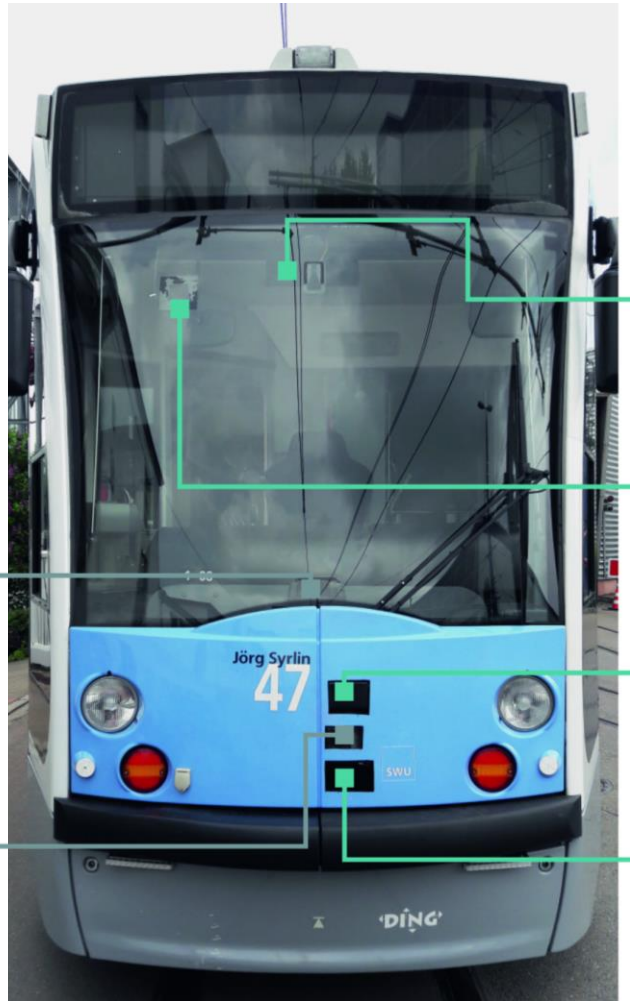
- Optimization of system performance up to serial status for rail application
- Validation of new Use Cases

Tram Assistant


Controller


Camera


Radar



Evaluation Kit

- Automotive Camera
- Camera for event recording
- Automotive Radar
- Laser Scanner (LiDAR)

Siemens Tram Assistant – Automotive components, qualified for the use on trams

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Video sensor

Camera
Behind windshield

- Track detection
- Object detection

Radar sensor

Radar
In front skirt

- Object detection
- Fusion with camera objects
- Object classification
- Determination of objects' criticality depending on their positioning and tram speed

Con-troller

Control unit
In tram interior

- Interface between Siemens Tram Assistant and tram
- Generation of collision warning and braking signal

Source of pictures: Bosch Engineering

Siemens Tram Assistant –
Improved safety and efficiency in public transport

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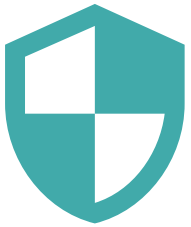
Lower repair costs
by avoiding or reducing accident damage

Higher
Availability



Improved
Safety

Enabler for
autonomous driving

Siemens Tram Assistant (The Hague, Ulm, Bremen, Copenhagen)
Siemens Mainline Assistant (under qualification)

Since 2017 – Step 2 – The autonomous tram – Idea and Motivation of Siemens Mobility

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- Collision warning systems contribute to tram safety and cost reduction already today
- Development of autonomous driving must be done in the field environment – the complex situations can only be “learned” in real-life traffic
- Other than autonomous driving cars and busses, an autonomous tram has never been demonstrated or tested
- That was how the idea to present a demonstrator at Innotrans 2018 was born in summer 2017
- Plan is to use the test vehicle as a prototype on the long way to the fully autonomous driving tram
- Gathered experiences are used also for the further development of driver assistant systems

Sources of pictures: Google, Daimler AG, navya

The autonomous tram –
How the autonomous trams works

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1 Continuous scan of environment

2 Intelligent assessment of traffic situation

3 Adequate reaction

Lidar

Radar

Cameras

The autonomous tram –
The test vehicle masters all relevant driving tasks

Extension by

7km

after **Innotrans**

Approaching a signal

Approaching a station

Crossing pedestrians

Crossing cars

The autonomous tram – What did we learn and what are the next steps?

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- Autonomous driving of trams is technically feasible!
- The technologies which are available today form a good basis
- But: Adaptation to the tram specific operation scenarios is a big challenge. We need to build the necessary know-how by ourselves
- For that purpose the tests in Potsdam are continued and expanded
  - Validation of sensor perception at reduced sight (rain, snow, darkness) and deriving fields of actions
  - Expansion to other line sections for testing additional traffic scenarios, e.g. following another car
  - Realization of autonomous operation in the depot area and preparation of industrialization of this solution
- Clarification of homologation requirements

The autonomous tram – Evaluation of depot automation

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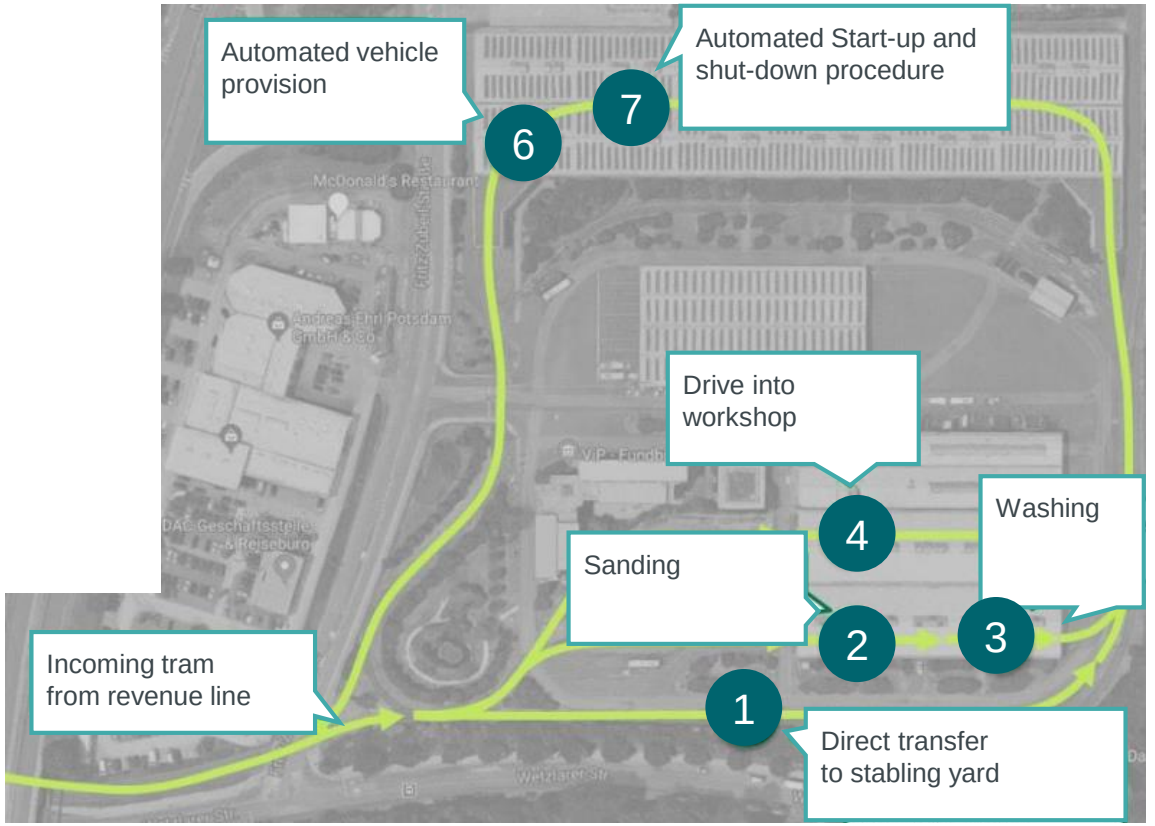
- Depot automation is a key element on the way to autonomous driving
- Protected, semi-closed environment – ideal test field, homologation expected to easier
- Target 1: Reduction of labor effort for regular shunting operations within depot (sanding, washing, maintenance)
- Target 2: Shortening of tram start-up and shut-down procedures, as well as walking times of drivers to and from stabling yard



Successive acquaintance with and achievement of acceptance of autonomous systems

The autonomous tram – The way to autonomous driving

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Use Case	Description	Benefits
Depot operation 	Autonomous operation on semi-protected track areas with low speed	• Reduction of personnel and of accident potentials (no personnel in dangerous areas) • Optimization of vehicle transfer (less waiting times)
Automated vehicle stabling and provision 	Transfer to stabling yard after revenue operation and vehicle provision for start of revenue operation at higher speed, in partially public areas	• Reduction of non-productive time-consuming vehicle transfers • Faster provision of additional vehicles in case of demand peaks
Fully automated operation on specific sections 	System takes over complete driving responsibility in suitable areas, e.g. fully segregated line sections	• Reduction of monotonous supervision tasks • Idle times for the drivers • Improved safety for all road-users
Fully autonomous operation 	Unattended operation on entire lines	• No more driver necessary • Omission of driver's cabins, more space for passengers • New operating models possible, e.g. demand oriented instead of fixed schedules

The autonomous tram – Transfer of experiences to other solutions

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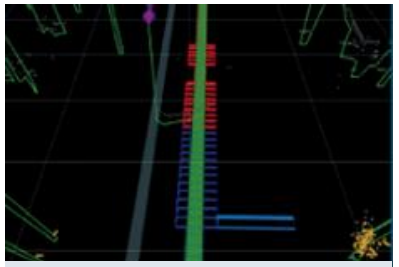
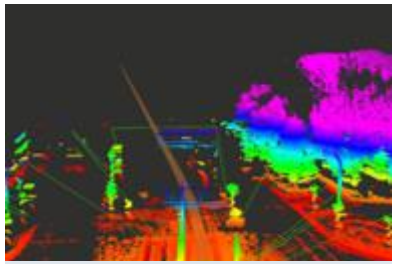
Collision avoidance for Mainline

Siemens Mainline Assistant for obstacle detection (up to 40km/h) to avoid collisions e.g. with buffer stops, trains, wagons, people and other obstacles

Sensorsetup Tram



Train Position Determination Tram



Free Space Detection Tram

Further Use Cases

Driverless depot operations and stabling, driverless operation on suitable segments

Core for all vehicle types

Siemens Mainline Assistant | Qualification in cooperation with Deutsche Bahn/Advanced Trainlab