GTC 2017

AUTOMATED TRUCK DRIVING AND PLATOONING WITH DRIVE PX 2

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Motivation
Truck related efficiency topics (focus EU)

Energy Efficiency

Source: dieterblasl

Traffic Efficiency

Source: t-online.de

Average Portions of Costs in 2013 (Germany)

Cost Efficiency

Staff
Fuel
Toll
Administration
Other

Source: www.bgl-ev.de

Staff Efficiency

Source: stuttgarter-zeitung.de
Motivation
Truck related safety topics

→ Too small gaps are the main reason for truck accidents in Germany!

Source: remseck.freiewaehler.de

Accident causes in 2014 (Germany)

- Distance: 20%
- Turning/Switching: 17%
- Priority in Traffic: 12%
- Speeding: 10%
- Others: 41%
Introduction of new truck Advanced Driver Assistance Systems (ADAS) only if mandatory or a clear business case for fleet owners available!
Motivation
Truck related driving pleasure topics

„Robot & Us: Self-Driving Trucks Are Coming to Save Lives and Kill Jobs“
Source: Wired, 05th May 2017

Source: express.de

Source: lasiportal.de
Technology transfer passenger vehicle to truck
Examples for challenges

Dimension Variations

Configuration Variations

Large Pitch Angle
Connectivity & automation
Levels of automation and levels of connectivity

- **Robust & secure connectivity**
- **State-of-the-art connectivity**
- **No connectivity**

**Human**
- Level 0: Informed
- Level 1: Assisted
- Level 2: Partly automated
- Level 3: Highly automated
- Level 4: Fully automated
- Level 5: Driverless

**System**
- Highway Chauffeur
- Highway Pilot

**Level of Automation**
- Driver has to be able to take over control within a certain time (e.g. construction zone)
- System can handle highway specific situations. In case of an unknown situation it goes into a secure state.

**Connectivity & Automation**
- ACC
- Platooning
- Robust & secure connectivity
- e.g. traffic information, eCall
- e.g. radio based danger warning

**System in the Loop**
- „Classic Car“
- ACC
- (ACC+LKA)
- autonomous highly automated driving

**Levels of Connectivity**
- Level 0: No connectivity
- Level 1: State-of-the-art connectivity
- Level 2: Robust & secure connectivity

**State-of-the-art connectivity**
- Connectivity & automation
- Connectivity & automation levels

**Driver in the Loop**
- Driver has to be able to take over control within a certain time (e.g. construction zone)
- System can handle highway specific situations. In case of an unknown situation it goes into a secure state.
Connectivity & automation
Levels of automation and levels of connectivity

- **Robust & secure connectivity**
- **state-of-the-art connectivity**
- **no connectivity**

### Levels of Automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Connectivity</th>
<th>Automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no connectivity</td>
<td>informed</td>
</tr>
<tr>
<td>1</td>
<td>state-of-the-art</td>
<td>assisted</td>
</tr>
<tr>
<td>2</td>
<td>robust &amp; secure</td>
<td>partly automated</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>highly automated</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>fully automated</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>driverless</td>
</tr>
</tbody>
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### Platooning
- Often called Platooning
- System only takes over **longitudinal** control
  - Gaps > 15 m

- **Highway Pilot**
  - e.g. traffic information, eCall
  - Radio-based danger warning

- **Highway Chauffeur**
  - Driver has to take over control in certain situations (e.g. construction zone)

### System
- **Google Car**
  - without controls
  - System takes over **longitudinal & lateral** control
    - Gaps < 15 m
    - System is the ultimate fallback level

- **Classic Car**
  - No connectivity
  - System takes over **longitudinal & lateral** control
    - Gaps < 15 m
**Platooning**

**Overview & goals of platooning system**

- **Improve safety** due to longitudinal and lateral guidance
- **Relieve and support** for professional drivers
- **Improved road space**
- **Optimization of traffic flow**
- **Reduction of fuel consumption** due to slipstream driving

Source: [man-truckers-world.de](http://man-truckers-world.de)
**Platooning**

Different types of platooning

<table>
<thead>
<tr>
<th>Longitudinal Control</th>
<th>Lateral &amp; Longitudinal Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Also called “Cooperative ACC”</td>
<td></td>
</tr>
<tr>
<td>▪ Driver in the following truck still has to steer</td>
<td></td>
</tr>
<tr>
<td>▪ Level 1 system</td>
<td></td>
</tr>
<tr>
<td>▪ Following trucks follow first truck automatically</td>
<td></td>
</tr>
<tr>
<td>▪ Following truck driver does not have to steer, brake or accelerate</td>
<td></td>
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</tbody>
</table>

Gap between vehicles

Following trucks follow first truck automatically.
Status quo on automated driving
A highly relevant research topic for many years
Platooning Projects
KONVOI

Goal
Practical usage of truck platoons in road freight transport for verification of prognosticated effects (economy of road space, reduction of fuel consumption, ...)

Project overview
• Duration: 2005 – 2009
• Funded by the German Federal Ministry for Economic Affairs and Energy
• Project Partner: RWTH Aachen University, BAST, MAN, WABCO
Platooning Projects
KONVOI

Functionality of the system

- Electronic coupling of two or more trucks.
- Target distance between vehicles is 10 meters.
- The KONVOI-system includes lateral and longitudinal guidance.
- The leading vehicle will be driven manually.
- The following vehicle will be automatically driven in longitudinal and lateral direction.
- The system is monitored by a truck driver at all times.
- The KONVOI-System can be overruled by the driver at any time.
Platooning Projects
KONVOI

Overview test truck equipment

- GNSS position determination
- Vehicle-to-vehicle communication
- Image processing
- In-Car PCs & microcontroller
- Distance sensors
- Steering torque and angle interface
- Digital map
- dSpace AutoBox
- Brake booster
Platooning Projects
KONVOI

Test runs on public highways in 2009

→ First operation of platoons in real traffic worldwide!
Platooning Projects
European Platooning Challenge 2016
Automated Driving
From Sensing to Trajectory Planning

Automated Driving can typically be divided into

- 1. Perception: Digitalization of environment – object detection, freespace detection, characterization
- 2. Localization: Mapping of objects into local coordinate system
- 3. Motion Planning: Behavior generation and trajectory planning
- 4. Actuation: Trajectory tracking and vehicle dynamics controller
Simplification of the trajectory planning problem

- Find a suitable control function, i.e. a steering and speed profile, which
  - guides the vehicle in a safe and comfortable manner through the environment
  - respecting vehicle’s and environmental constraints, e.g. max steering angle, collision avoidance, vehicle tilting limit, road friction
Cooperation Between NVIDIA and fka
History and Future Plans

History
- First contacts in late 2014
  - Loose conversations and meeting in Santa Clara, CA
- fka presented its motion planner @ELIV 2015, Baden Baden
  - Contact to NVIDIA
- Further exchange on phone, physical meeting @fka
- fka and Nvidia become partners, fka gets full access to Drive PX
- fka is invited to join NVIDIA at its booth @CES 2016

Future plans
- Widen partnership in industrial projects
- Possibly integrate motion planner to DriveWorks software stack
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Neural nets for lane marking recognition (based on AlexNet)
Comparison of three different nets

Complex

Normal

Thin

→ All nets very computational expensive and not executable in real-time on Drive PX 2
→ Using NVIDIA’s LaneNet on Drive PX 2
NVIDIA LaneNet
Running on Drive PX 2 with parameter extraction
Control parameter derived from LaneNet
Control input for lane following control
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