On the Use of Maps for Automated Driving
What has been Accomplished?
Bertha and Carl Benz ~ 1870
1888 First long distance ride in an automobile by Bertha Benz and her two sons
Bertha Benz Memorial Route

- first automotive long distance journey in 1888
- 104 km
- 3 large cities
- 23 smaller towns
- 18 roundabouts
- > 150 traffic lights
Vision-based autonomous driving
Autonomous Driving in Cities

on behalf of

Mercedes-Benz
What is Missing?
Behavioral Safety

Reliability

- Maps
- Perception
- Situational Awareness
- Motion Planning
- Cooperation
- Testing
Maps & Map-Based Planning

Marc Sons  
Mapping & Localization

Fabian Poggenhans  
Semantic Mapping

Philip Bender  
Behaviour Decision
Map Layers

- **Dynamic layer**
  - dynamic objects
  - new static objects

- **Static planning layer**
  - 3d geometry, lanelets
  - traffic lights/rules
  - tactical information

- **Localization layer**
  - 3d landmarks
  - lane markers
  - 6d camera poses

[Lategahn, Bender, Schreiber, Franke et al. 11-14]
Visual Localization from Point Feature Matches

map features

R, t

image features

[Lategahn et al. 11-14]
start up company Atlatec GmbH
Behavioral Planning Layer
Behavoiral Planning Layer
Planning Layer
From Cognitive to Cooperative Automobiles

- perceive their environment,
- understand it and know the crucial objects and parameters,
- expand their mental map cooperatively when more knowledge becomes available
- know their own skills and capabilities
- plan autonomously safe behaviour reactive to the current situation
- negotiate cooperative behaviour,
- learn

DFG SPP Kooperativ interagierende Automobile 2015 - 2017
International Driving Challenges

- DARPA Challenges
  - 2005 Grand Challenge: Finalist with OSU/KIT Team
  - 2007 Urban Challenge: Finalist with KIT/TUM Team

- Bertha Benz Memorial Route
  - 2013: Mannheim-Pforzheim in collaboration with Daimler

- Grand Cooperative Driving Challenge
  - 2011: 1st Winner KIT Team
  - 2016: 2nd Winner KIT/FZI Team
Grand Cooperative Driving Challenge 2016
Grand Cooperative Driving Challenge 2016
AnnieWAY - Real Driving
Karlsruhe Automated Driving Test Field in Real Traffic

V2X Communication
- Detailed Maps
- Traffic Light Status
- Real-Time Roadside Sensor Information

Zones
- A Dense Coverage
- B Coarse Coverage
- C Longe Distances
Summary & Conclusions

- Automated driving is feasible today!
  - In normal traffic and at normal velocities
  - Safety driver still needed
- Many open issues
  - Behavioral Safety
  - Backend server (maps & co)
  - Cooperative Behavior
  - Benchmarks, validation and test
Swarm-like Traffic

[Ziegler et al., IEEE Intelligent Transportation Systems Magazine, 2014]
[Bender et al., IEEE Intelligent Vehicles Symposium 2014]
[Schreiber et al., IEEE Intelligent Vehicles Symposium 2014]
[Liebner, Klanner, Baumann, Ruhhammer, Stiller, IEEE Intelligent Transportation Systems Magazine, 5 (2), 2013]
[Kitt, Lategahn, IEEE Intelligent Transportation Systems Conf. 2012]
[Lategahn, et al., IEEE Intelligent Vehicles Symposium 2012-2013]
[Geiger, Ziegler, Stiller, IEEE Intelligent Vehicles Symposium 2011]
[Moosmann, Stiller, IEEE Intelligent Vehicles Symposium 2011]
[Ziegler, Stiller, IEEE Intelligent Vehicles Symposium 2010]
[Ziegler, IROS 2011]
[Stiller, Kammel, Lulcheva, Ziegler, Automatisierungstechnik 2008]
[Özgünner, Stiller, Redmill, IEEE Proceedings 2007]