Karlsruhe Institute of Technology

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Automated Vehicles in Cities – Today and Tomorrow

2016 11th A3PS Conference, Vienna

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

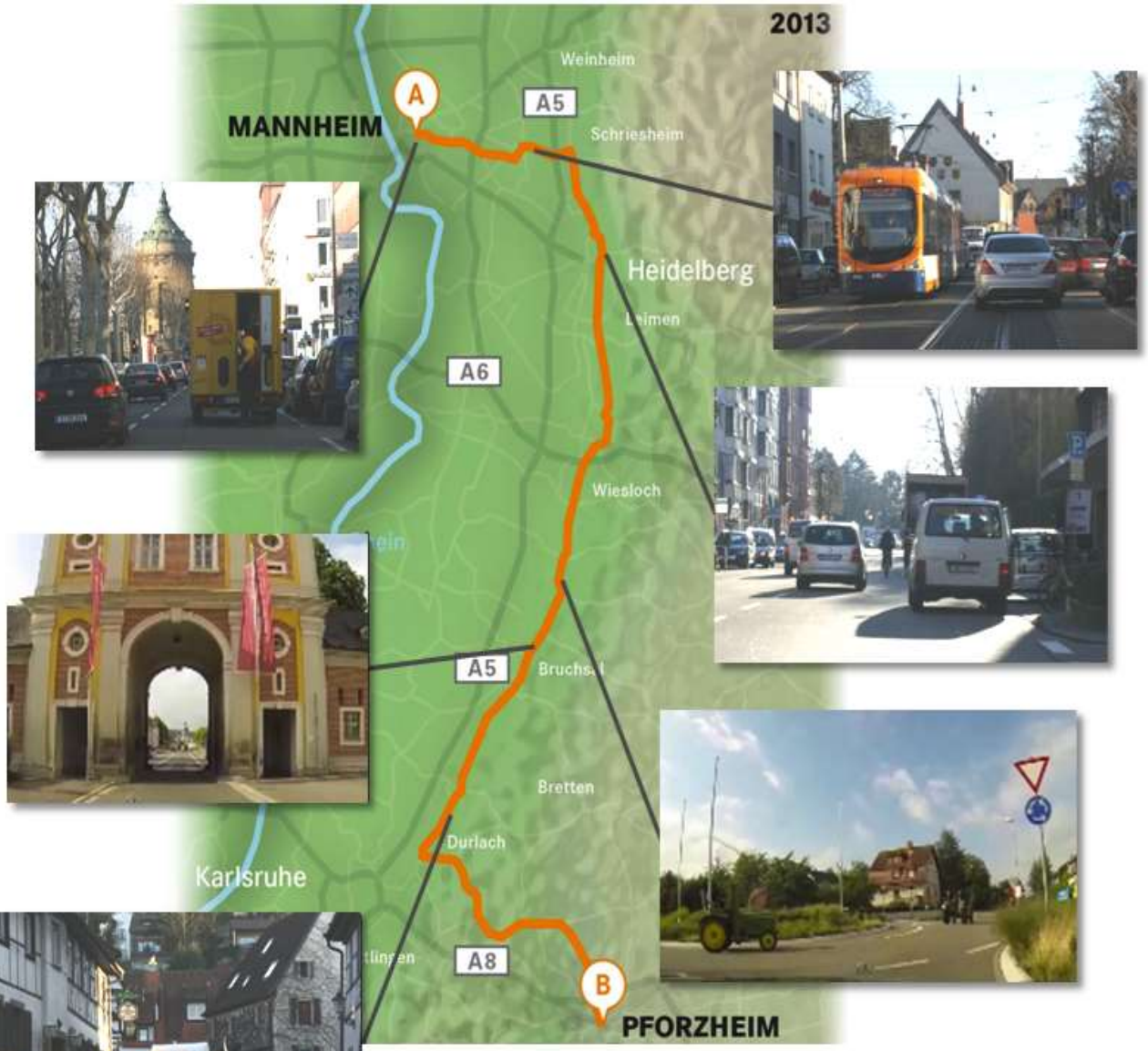
Bertha and Carl Benz ~ 1870

Das Brautpaar Berta Ringer und Karl Benz um 1870

Aus der Sammlung Eugen Benz, Ladenburg

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

What is Missing?

Maps & Map-Based Planning

Marc Sons

Mapping & Localization

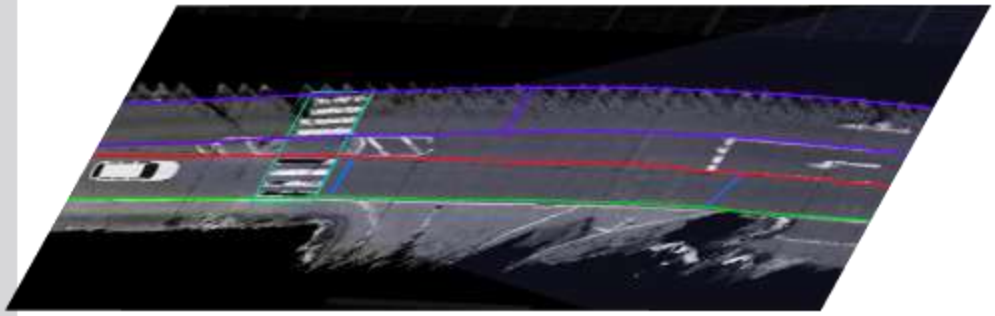
Fabian Poggenhans

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

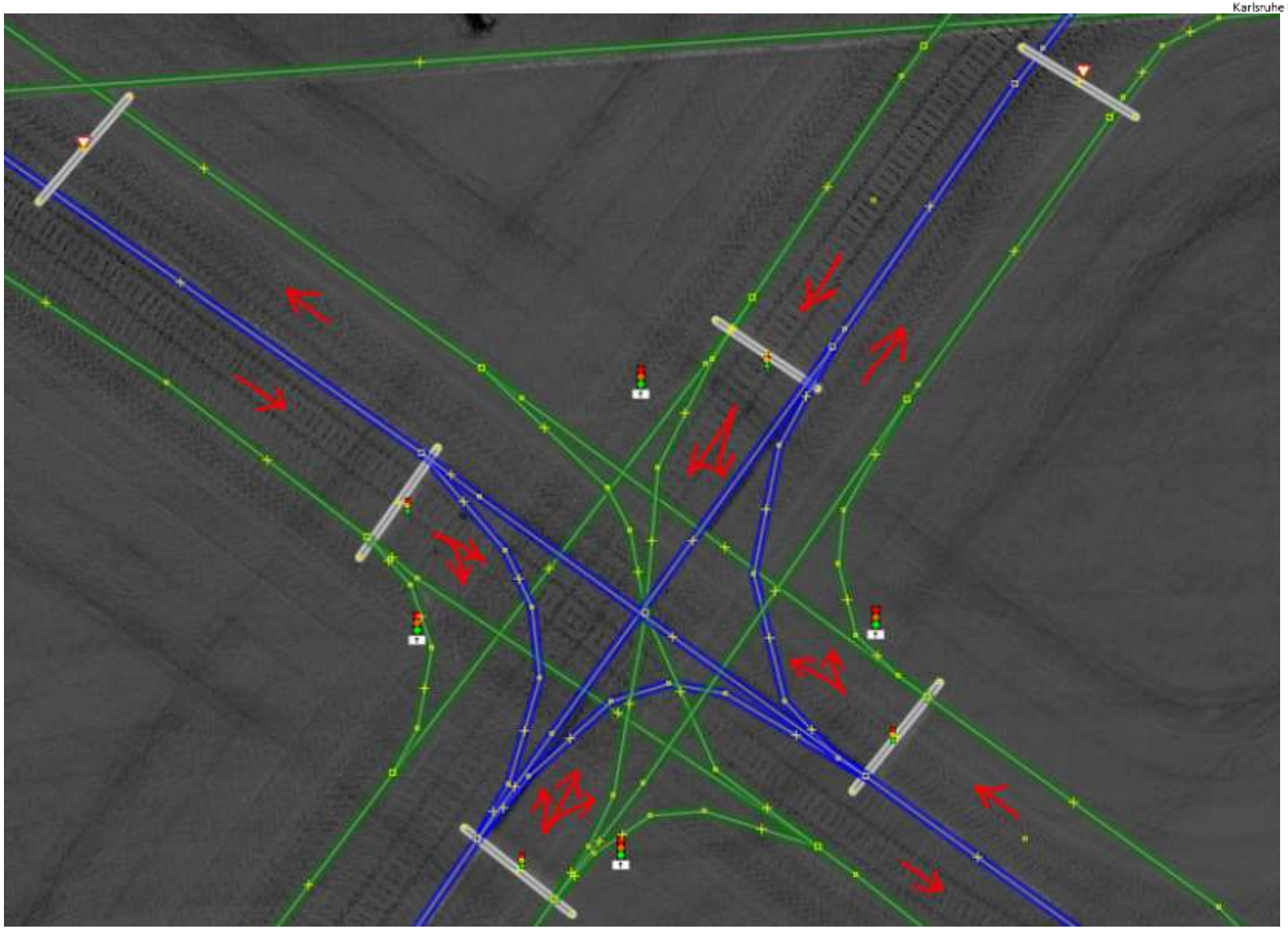
map features

R, t

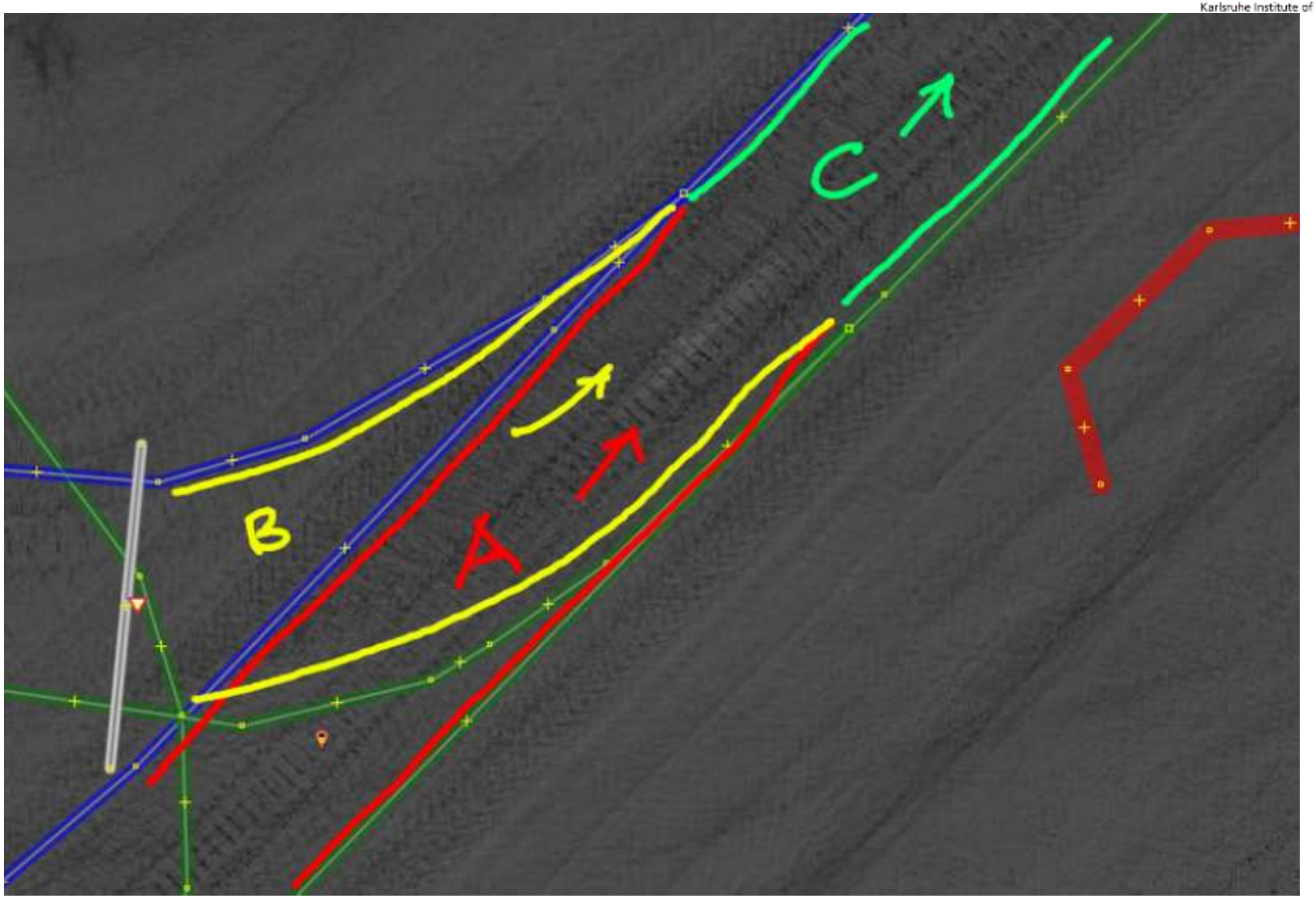
image features

[Lategahn et al. 11-14]
start up company Atlatec UG

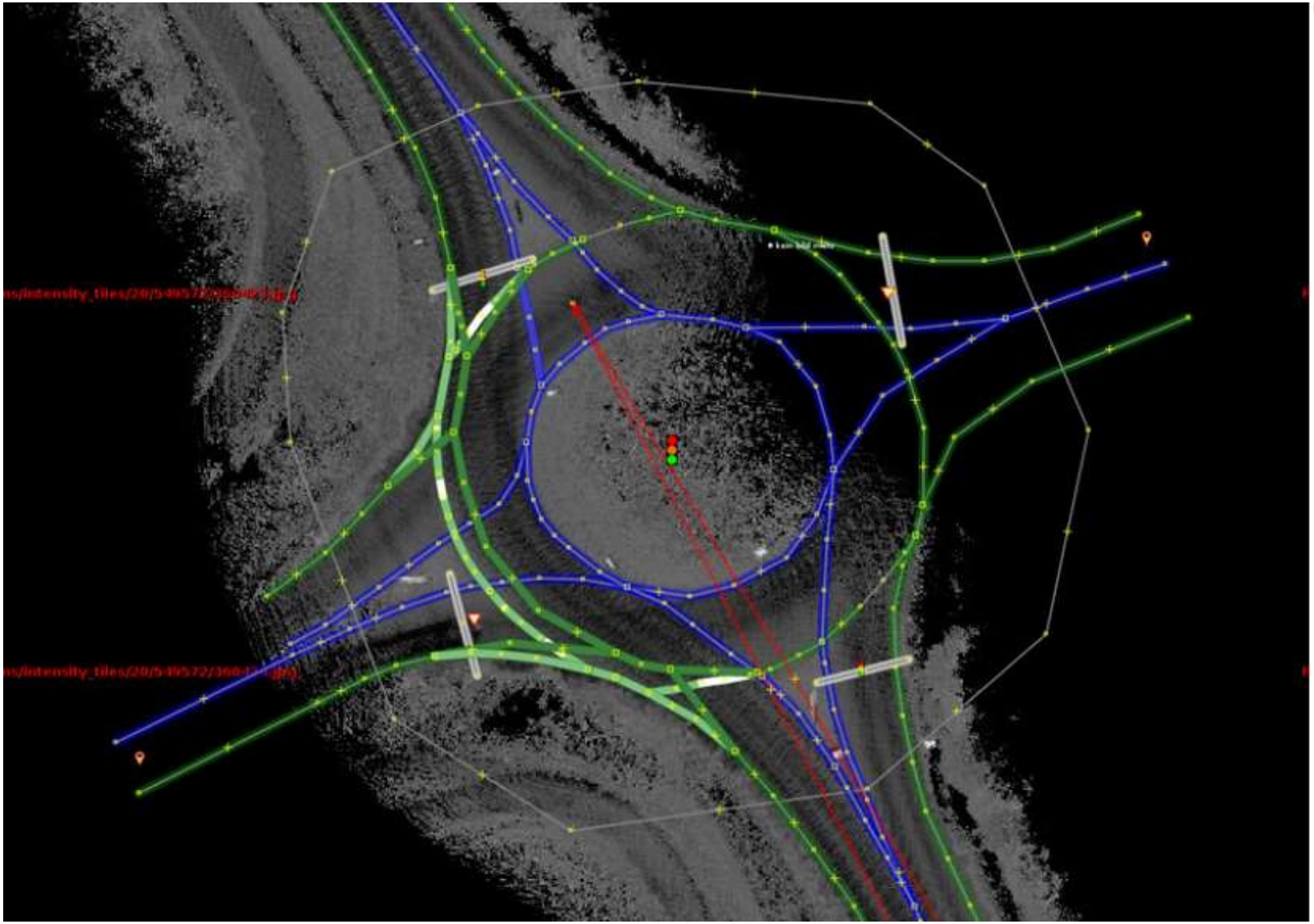
Planning Layer



Planning Layer



Planning Layer

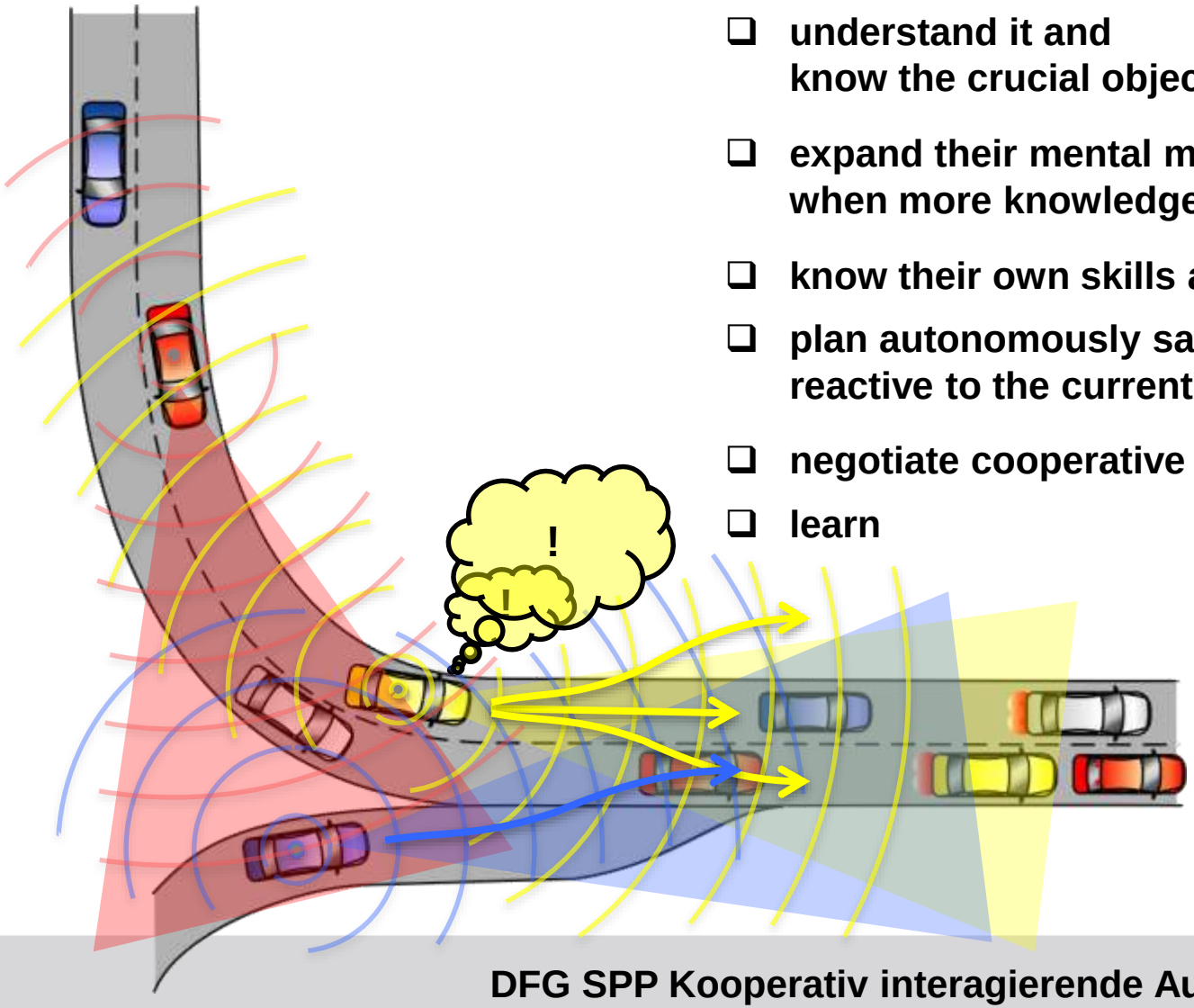


Behavioral Safety

Reliability

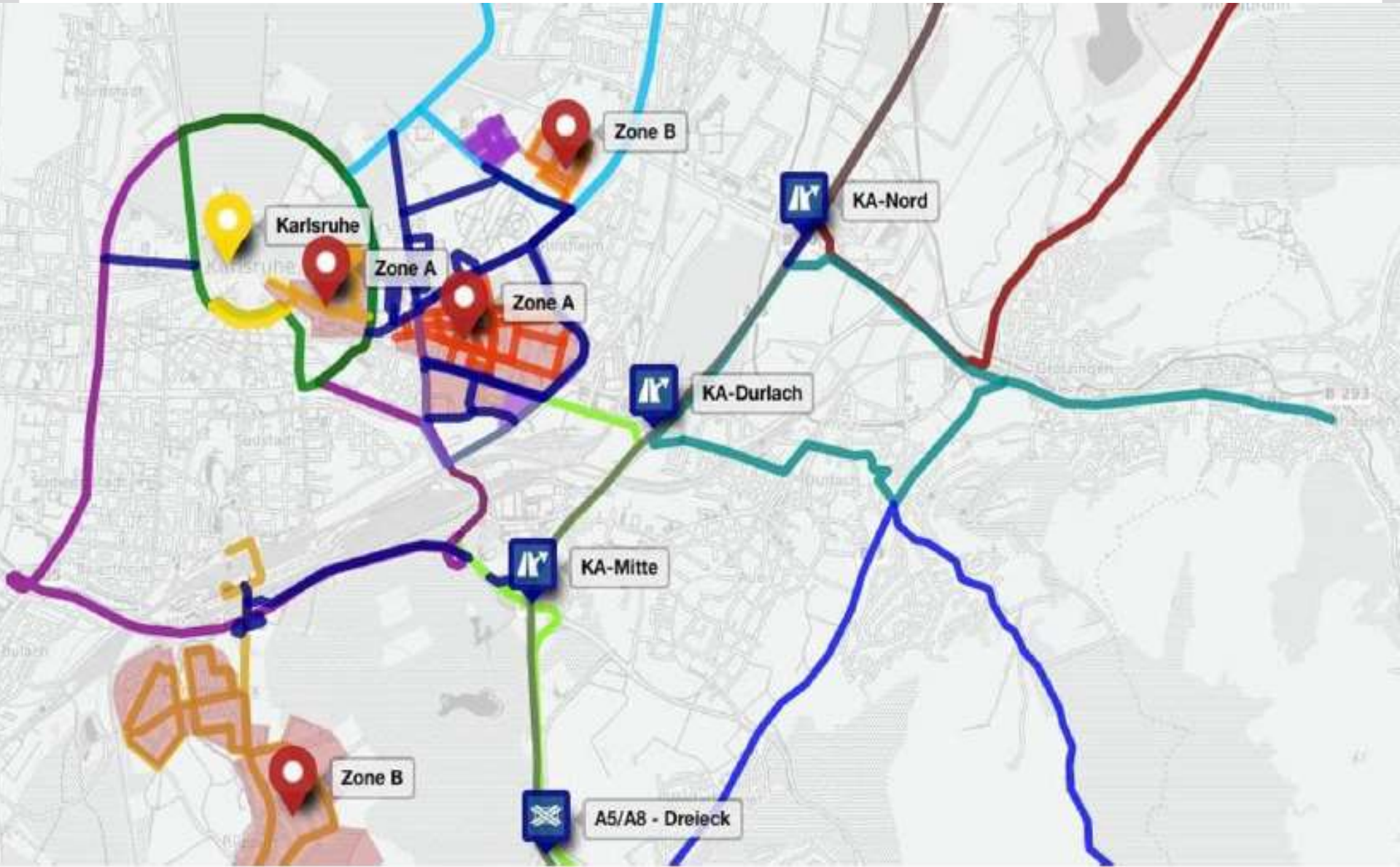
- Maps
- Perception
- Situational Awareness
- Motion Planning

From Cognitive to Cooperative Automobiles

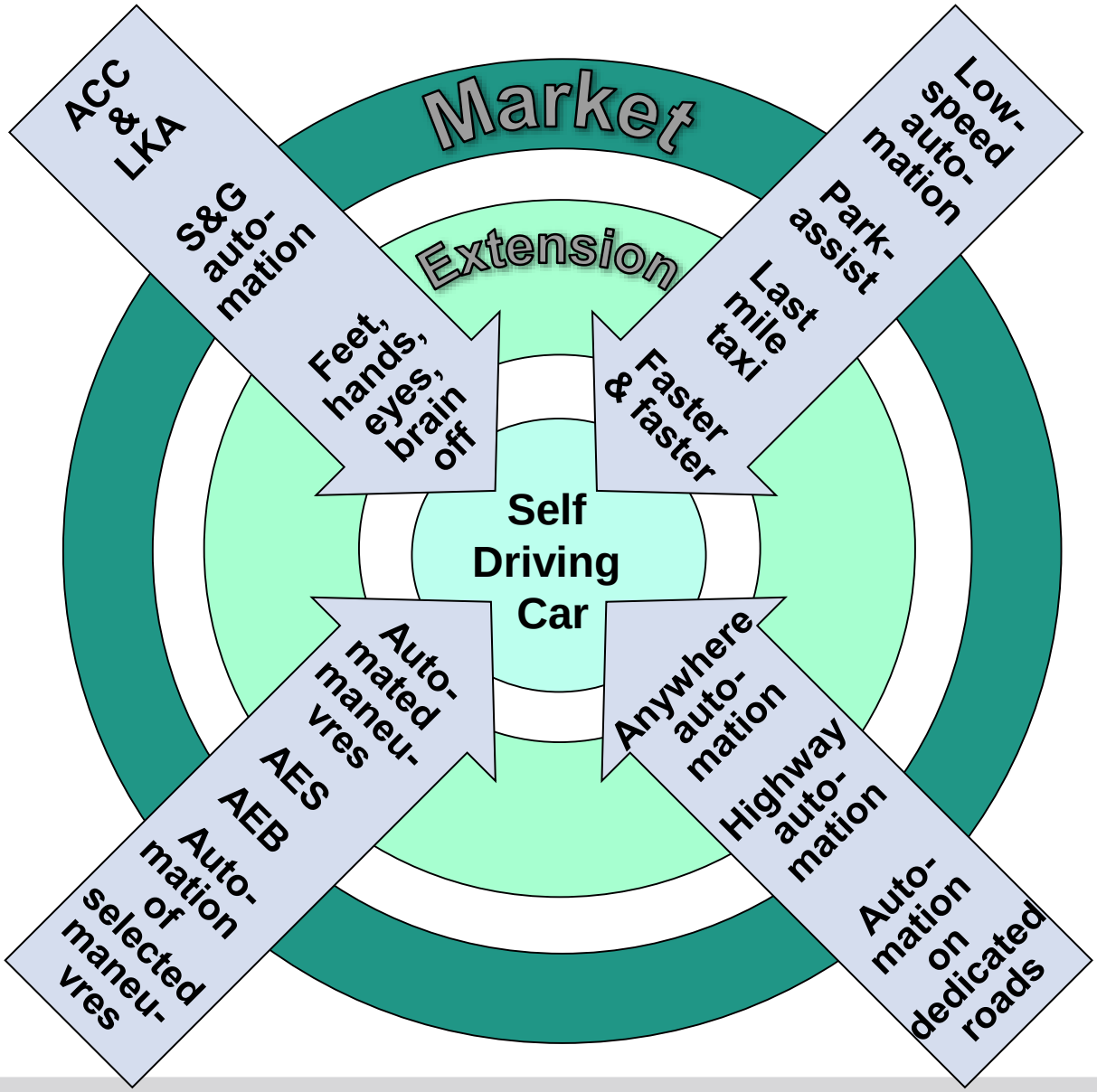


- perceive their environment,
- understand it and
  know the crucial objects and parameters,
- expand their mental map cooperatively
  when more knowledge becomes available
- know their own skills and capabilities
- plan autonomously safe behaviour
  reactive to the current situation
- negotiate cooperative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

Karlsruhe Test Field for Automated Driving



Functional Evolution or Disruptive Change?



Summary & Conclusions

- Automated driving is feasible today!
  - In normal traffic and at normal velocities
  - Safety driver still needed

- Many open issues
  - Safety assessment
  - Backend server (maps & co)
  - Handling of rare situations
  - Cooperation
  - Benchmarks, validation and test

- Evolutionary or disruptive market introduction?

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]
[Geiger, et al., International Journal of Robotics Research 32, 2013]
[Liebner, Klanner, Baumann, Ruhhammer, Stiller, IEEE Intelligent Transportation Systems Magazine, 5 (2), 2013]
[Geiger, et al.IEEE Trans. Intelligent Transportation Systems, 13 (3),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]
[Özgüner, Stiller, Redmill, IEEE Proceedings 2007]