Connected Navigation for Highly Automated Driving

Jeffery Ballman
July 27, 2017
Automated Driving – The Vision

Key goals of automated driving

- Increased safety based on the assumption that automated vehicles will cause less accidents than manually operated cars
- Enhanced driving comfort and possibility to work, relax or access entertainment while driving
- New mobility models based on driverless taxis/shuttle services
- Freeing up of city land due to more condensed and/or off-site parking capabilities of future automated cars
- Less traffic jams and improved traffic flow by automated driving
Automated Driving – Piloted Driving Today

- **Mercedes Drive Pilot**
  incl. Active Lane-Change Assistant

- **Tesla Autopilot**
  incl. Auto Lane Change

- **Audi Active Lane Assist**
  and Predictive Efficiency Assistant

- **BMW Active Driving Assistant Plus**

- **Speed Control**
  - Adjust speed according to set maximum speed and traffic ahead
  - Advanced systems additionally adjust speed according to the topography of the route and speed limits

- **Steering Control**
  - Follow current lane and/or car for a certain time
  - Perform lane change manually triggered by driver
Piloted Driving – Closing the Gap

Combining reactive, tactical, and strategical planning for automated driving

**Today**
- Reactive planning on lane/geometry level
  - ~ 10 sec
- Sensor/object data (camera, radar etc.)
  - Computes AD vehicle trajectories based on lane change advice
  - Consideration of surrounding traffic and sensed road characteristic (e.g. lanes)

**Next Generation**
- Tactical AD planning on lane level
  - 10 – 60 sec
- HAD map with detailed lane info
  - Lane accurate positioning
- Generates lane change directives according to currently driven lane and lane situation for upcoming maneuvers along the route

**Future**
- Strategic AD planning on edge level
  - 60 – ∞ sec
- Provides the route to a selected destination for an AD drive
- Suitability of road segments to be considered for route calculation
- Extended Navigation Map

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Piloted Driving Today – Reactive Planning

Characteristics

- Current AD systems relying heavily on locally sensed data
  - Typical sensor set: camera and radar
  - Lane geometries based on camera sensed lane markings for steering control
  - Object detection for velocity control and collision prevention
- Map data only used to certain extent
  - Road class for system activation/deactivation
  - Speed limits and road geometries for speed control
- Lane changes not triggered automatically
  - Driver initiates lane change

Piloted driving uses locally sensed data, driver triggers activities
Piloted Driving Next – Tactical Planning

Lane choice along the route

- **Selection of suitable lanes along the route**
  based on map data with detailed lane information (e.g. lane connectivity, lane marking types)
- **Determination of current lane**
  based on HAD map with detailed lane information (e.g. lane geometry)
- **Planning of required lane changes**
  based on current lane and recommended lane(s)
- **Hand over of lane change advices**
  to active lane-change assistant

Combination of lane accurate map matching and lane accurate maneuver generation based on HAD map data
Piloted Driving Next – Strategical Planning

Selection of a suitable route

- Autonomous Driving is based on routing to a destination
- Route calculation using suitable AD road preferences for entire trip
  - Route selection with smallest possible route segment distances that are not suited for AD
  - Routing needs to consider parameters like road class, lane separation and ADAS accuracy in addition to route length and travel time
- Route might be updated while driving based on dynamic information
  - Traffic situation
  - Local hazard and warnings

Routing technology provided by common navigation systems based on extended navigation map data
Architecture: Reactive - Tactic - Strategic

Strategic planning on edge level, 60 – ∞ sec

Tactical planning on lane level, 10 – 60 sec

Reactive planning on geometry level, ~10 sec

Navigation
- Strategic Guidance
- Strategic Route calc.
- Strategic Entry

Lane Change Planning
- Tactical Guidance
- Tactical Route calc.
- Lane sequence

Active Lane Assist
- Speed Ctrl.
- Steering Ctrl.
- Lane Change
- Lane Keeping

HD-Pos
- Lane Fusion

Lane Keeping

Destination Entry

Route

Camera
Radar
Laser

Auto Drive map

Navigation map

Electronic Horizon

Lane advice

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Map Data for Automated Driving

HAD map data for automated driving

- **AD support for areas with continuous lane markings**
  - Precise lane information is needed for lane accurate positioning and tactical planning of lane changes
  - Required data includes lane geometry, lane markings and lane connectivity

- **Extensions required for areas without continuous lane markings**
  - Geometry of driving path(s) along road segments
  - Geometries of intersection internal lane transitions

- **Incremental Updates**
  - Incremental database updates of lane geometry, lane markings and lane connectivity

HAD map data is a crucial prerequisite for automated driving
Lane Connectivity

- Detailed Lane Topology
- Lane Connectivity
- Inter-connection between lanes
- Up to 1-cm resolution
- Lane direction

Image: Open Lane Model Specification
Lane Transitions across Intersections

- Complex Intersections
- Detailed lane connection for turns and U-turns
- Detailed lane geometries for driving
- Lane markings
Lane Boundaries at Intersections

- Boundary Definitions
- Detailed information about lane widths
- Lane boundaries and curb walls
Standards for Automated Driving

Standardization

- NDS Working Group 3 AutoDrive is working on the definition of maps for automated driving
- NDS Association has publically released the NDS Open Lane Model
- NDS Working Group 2 “Hybrid”: concepts for loadable map data and volatile data
- ADASIS Forum is working on a new version of the ADASIS protocol allowing the distribution of lane accurate AD map data within the vehicle
- Open Auto Drive Forum acts as cross-domain platform driving standardizations in the area of automated driving
- Open Auto Drive Live Map Delivery Chain Taskforce: Coordination of TISA and NDS activities regarding dynamic services for autonomous driving
- TISA TPEG: Introduction of lane level accuracy for traffic information
Dynamic map download of Auto Drive map data

- Increased size of HAD maps caused by increased level of detail
- Need for always up to date map data

Dynamic information with lane accuracy for best-possible usage within HAD services

- Traffic information
- Dynamic opening of hard shoulder, variable speed signs
Get in touch!
sales@elektrobit.com
www.elektrobit.com