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# Big LoopInterplay of Frontend& Safety Server

KOHAF

### **Big Loop** Interplay of Frontend & Safety Server











Modern vehicles are equipped with manifold types of sensors. An example ...







#### Example of Extracted Landmarks

- > The data of these sensors can be utilized to map the direct environments of these vehicles
- > For example, landmarks, such as road / lane geometries, traffic signs, reflector posts, can be extracted from the sensor data
- These local maps can be propagated to the backend-side for collaborative fusion





Example of Sensor Data Preaggregation to Maplets Distinction in Ko-HAF between ...

- 1. Static Sensor Data
  - > Road infrastructure information
  - > Preaggregated to maplets
  - > Normally prioritized upload
- 2. Dynamic Sensor Data
  - > Potential hazard information
  - > Not preaggregated to maplets
  - > Direct and highly prioritized Upload





Example of Sensor Data Preaggregation to Maplets The **preaggregation** of static sensor data to maplets **means that the amount of** required

- > cellular traffic and
- > computational resources at the backend-side

is significantly reduced.





Example of Sensor Data Preaggregation to Maplets

- In Ko-HAF the SENSORIS format has been significantly extended to match the needs of the project
- > The changes are intended to be part of the next format version

#### New Observation: Appending to former Maplet

#### Reobservation: Updating Preaggregation

#### Starting new Maplet

Appending to former maplet ... Appending to former maplet ... Reflector post with ID 1 is already within maplet! Reflector post with ID 2 is already within maplet! Adding reflector post with ID 3 to maplet! Landmark offset to virtual reference point ... Appending to former maplet ... Appending to former maplet ... Current maplet frenet delta 3.13643 Current maplet frenet length 41.1591 Appending to former maplet ... Reflector post with ID 1 is already within maplet! Appending to former maplet ... Appending to former maplet ... Current maplet frenet delta 3.13163 Current maplet frenet length 44.2907 Appending to former maplet ... Reflector post with ID 1 is already within maplet! Appending to former maplet ... Appending to former maplet ... Reflector post with ID 1 is already within maplet! Appending to former maplet ... Current maplet frenet delta 3.12699 Current maplet frenet length 47.4177 Appending to former maplet ... Reflector post with ID 1 is already within maplet! Appending to former maplet ... Reflector post with ID 1 is already within maplet! Appending to former maplet ... Reflector post with ID 1 is already within maplet! Appending to former maplet ... Current maplet frenet delta 3.12227 Current maplet frenet length 50.54 Starting new maplet ... Adding reflector post with ID 1 to maplet! Adding reflector post with ID 2 to maplet!

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#### **Ko-HAF Communication Unit**





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# Safety Server Continuous Update of HD Map

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### Safety Server Initial HD Map



### Safety Server Initial HD Map





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Safety and Comfort of HAD Functions through a Continuous Data Exchange between Vehicle Fleet and Server

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### Safety Server Initial HD Map: Landmarks





### Safety Server Continuous Update of HD Map



# Safety Server HD Map Change Detection





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- > Maps become outdated due to road network changes, such as construction sites, new lanes, lane marking changes, new/removed/ changed traffic signs
- > Modern vehicles are equipped with manifold sensors
- > The data from the vehicle fleet is propagated to the Safety Server and can be utilized for change detection and if required for map updating

# Safety Server HD Map Update Pipeline





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# Safety Server HD Map Update Pipeline Case Study "Dudenhofen Detour"





- > Detour part on the straight (= geometry affected)
- > Same number of lanes (= topology not affected)
- > Lane markings shifted
- > As vehicles continue to drive straight, their data should indicate a change of the road geometry

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### Safety Server HD Map Update Pipeline Key Steps





The pipeline contains a number of preprocessing operations, such as

- > Filtering of fleet and map data
- Transformation of fleet and map data into mathematical models
- > Optimization of the data based on observed features and models
- > Change Detection

### Safety Server HD Map Update Pipeline Key Steps



- > The change detection mainly consists of the association of the initial HD map graph with the graph of the consolidated drives
- > Assumption: At by change affected areas, drives are consistent to each other and inconsistent to the initial HD Map
- > These areas are of special interest as they indicate that the initial HD map is outdated

# Safety Server HD Map Update Pipeline Case Study "Dudenhofen Detour"







- > At the HD map update pipeline, consistent parts of the fleet data are consolidated
- For each by change affected area, the consolidated drives are merged into the initial HD map

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# Safety Server HD Map Update Pipeline Case Study "Dudenhofen Detour"







Change types evaluated at Ko-HAF

- Detours (changed geometry, same topology)
- > Lane marking type changes
- Point-object type changes (reflector posts and traffic signs)

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### Safety Server HD Map Update Pipeline Additional Information Layers







- > Additionally to static road network features the vehicles also collect information about the measured cellular network quality
- > The onboard communication module provides all necessary quality parameters
- > Similar to the road network information, this data is also aggregated at the Safety Server
- > The key performance indicators are:
  - > Data Throughput (Upload and Download)
  - > Latency

# Safety Server Frontend Download Interface









- Safety Server stores the HD map tile-based and offers their download to the vehicles on demand
- > Vehicles inform the Safety Server which version of a tile they already have cached
- > Only newer tiles are distributed to the vehicles
- Safety Server allows the vehicles to subscribes for dynamic events
- Vehicles are informed regarding potential hazard information, such as obstacles, broken-down vehicles, or road closures



#### Frontend Sensor Data Download



# Frontend Sensor Data Download

#### Ko-HAF Communication Unit





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### Frontend HD Map Localization



## Frontend HD Map Localization





#### Motivation:

Improving the GNSS-localization by means of HD Map data

#### Input:

GNSS, IMU, Odometry, Landmarks from Sensors, Landmarks from HD Map

#### **Output:**

Improved global and relative position

**GNSS** Localization

HD Map Localization

### Frontend HD Map Localization











+ Additional Sensor Redundancy
+ Increased Sensoric Foresight

Landmarks HD Map

Landmarks Sensors

#### **Foresight-Area**

**Fusion-Area** 

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... distinct partner-individual realizations





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Optimal data association is a hard problem due to its exponential nature ...



Example of JCBB data association ...

Landmarks HD Map

Landmarks Sensors

Associations

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Static environment fusion by means of Bundle-Adjustment based Full-SLAM



#### Input:

Motion Increments **u**, Landmark Observations from Sensors / HD Map **z** plus Associations

#### **Output:**

Landmark Estimates from Sensor Data Fusion I, Global and Relative Vehicle Localization **x** 

Landmarks HD Map

Landmarks Sensors

Landmarks Fusion

sion

#### Landmarks HD Map

Landmarks Sensors

Landmarks Fusion

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Dynamic Ski Case Observation Scenario



- 1. Upload of **lost ski case observation** to the backend-side
- 2. Propagation of the **hazard warning** by the backend-side to the subsequent vehicle
- **3.** Automatic lane change maneuver by the cooperative HAD function
  - $\rightarrow$  Increased safety and comfort

### **Big Loop** Dynamic Events

#### Dynamic Ski Case Observation Scenario



Gefahrenstelle wurde a den Safety-Server gemein

0 km

Autobahnpilot

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# Big Loop Dynamic Events

Dynamic Ski Case Observation Scenario

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# **Big Loop** Related Demonstrations & Talks





Creation and Deployment of HD Map Data Dr. Gunnar Gräfe, 3D Mapping GmbH Tobias Knerr, University Passau – FORWISS Josef Schmid, Technical University of Applied Sciences Amberg-Weiden

#### Continuous Updating of Backend HD Map Data Based on Vehicle Fleet Data

Florian Jomrich, Opel Automobile GmbH Dr. Lukas Klejnowski, Robert Bosch GmbH

Online Localization and Fusion via Vehicle Sensor and Backend HD Map Data Maximilian Harr, Opel Automobile GmbH Dr. Matthias Schreier, Continental Teves AG & Co. oHG

Backend HD Map Data Maximilian Harr, *Opel Automobile GmbH* Dr. Matthias Schreier, *Continental Teves AG & Co. oHG* 

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# Thank you for your attention!

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