HARMAN
A SAMSUNG COMPANY

DATA SCIENCE IM RAHMEN HIGHLY AUTOMATED DRIVING
HD KARTENERSTELLUNG

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AGENDA

1. HARMAN – Who We Are & What We Do
2. Connected Car & SBU Autonomous Driving - Activities
3. HD Map Motivation
4. HD Map Data Science Challenges
5. Summary

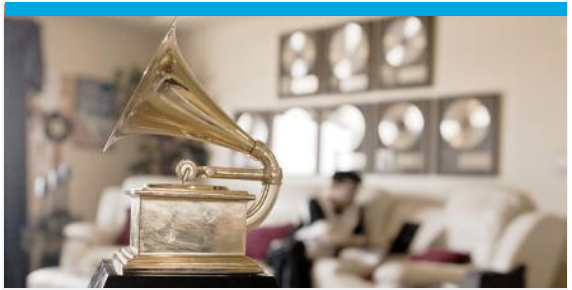
WHO WE ARE & WHAT WE ARE DOING

GLOBAL GROWTH CONTINUES

Innovation breeds quantifiable success

- **30,000** Professionals worldwide
- **15,000** Engineers ~80% Software
- **30+** Countries: Americas, Europe and Asia
- **16+** Legendary brands

GLOBALLY DIVERSE



- **6,529** Patents and patents pending
- **42** Design awards in 2017
- **3** GRAMMY® Awards- AKG, JBL, LEXICON
- **2** Academy Awards

INNOVATION LEADER

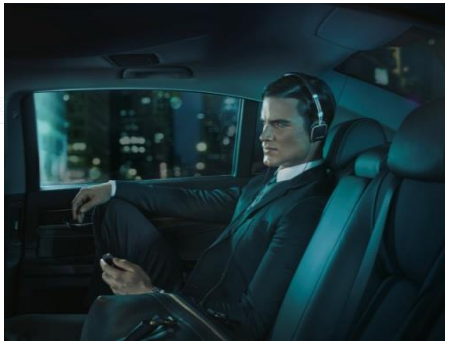
WHO WE ARE & WHAT WE ARE DOING

TECHNOLOGIES FOR A CONNECTED WORLD

CONNECTED CAR

Navigation, Multimedia, Connectivity, Telematics, Safety & Security Solutions

LIFESTYLE AUDIO



Premium Branded Audio Products and Sound Management Software for Car, Home and on the Go

PROFESSIONAL SOLUTIONS

Audio, Lighting, Video Switching and Automation for Enterprise and Entertainment

CONNECTED SERVICES

Cloud, Mobility and Analytics Solutions with OTA Updates for Car, Mobile and Enterprises

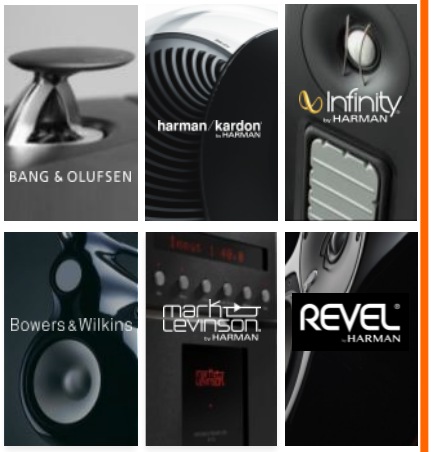
WHO WE ARE & WHAT WE ARE DOING

WE ARE A HOUSE OF BRANDS

CONNECTED CAR

HARMAN

LIFESTYLE AUDIO



PROFESSIONAL SOLUTIONS

CONNECTED SERVICES

HARMAN

WHO WE ARE & WHAT WE ARE DOING

36+ GLOBAL AUTO BRANDS AND GROWING

HARMAN

LONG-TERM CUSTOMERS

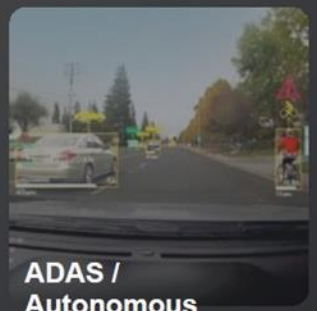


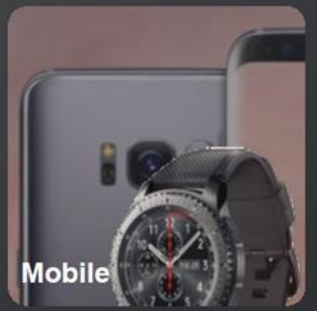
BRIC CUSTOMERS

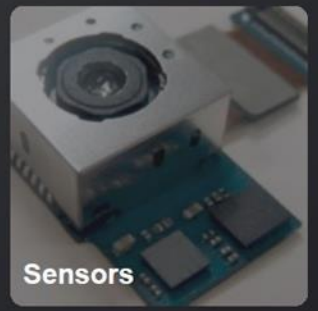
NEW CUSTOMERS

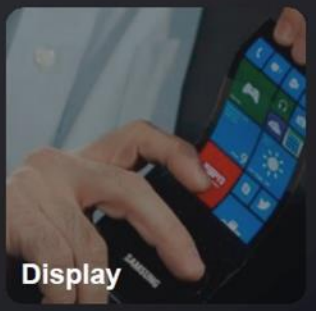
WHO WE ARE & WHAT WE ARE DOING

SAMSUNG AND HARMAN SYNERGIES









CONNECTED CAR & SBU AUTONOMOUS DRIVING - ACTIVITIES
TOMORROWS DIGITAL COCKPITS

Realizing the most advanced infotainment and digital cockpit systems

Features

- Augmented Reality Displays
- Best-in-class Navigation
- Cloud Based Driver Profiles
- Virtual Personal Assistants
- Multi-modal approach to interact with different UI/UX systems (i.e., haptic, gestural, driver monitoring, etc…)

5G always connected

- First automotive grade 5G ready solution

CONNECTED CAR & SBU AUTONOMOUS DRIVING - ACTIVITIES
DS TOPICS TODAY AND TOMORROW

Example Data Science tasks in todays systems

- Map Compilation for Navigation Service
- Processing of Fleet information for up-to-date information layers to onboard navigation systems
- Predicted Traffic Information
- Voice Input
- Destination Input

Data Fusion

Stream Mining

Machine Learning

NLP

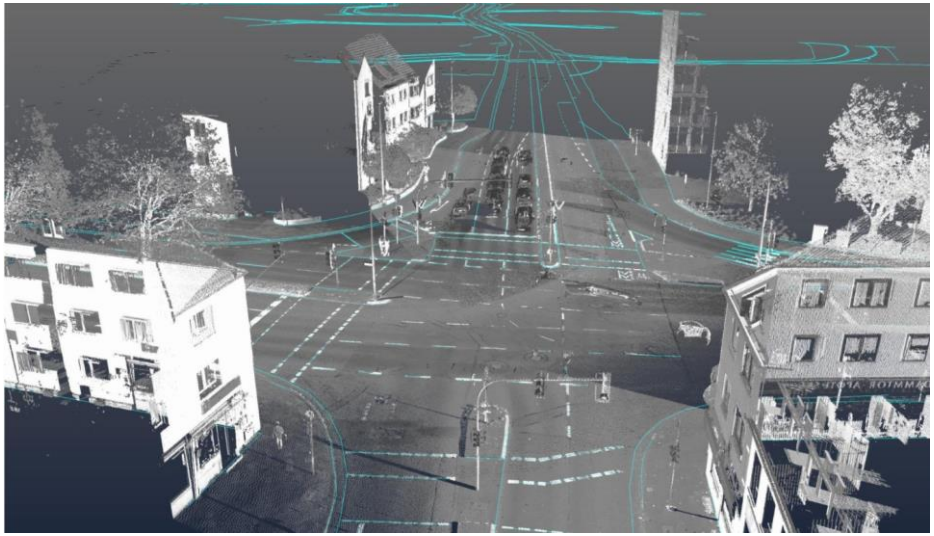
Entity Resolution

HD MAP MOTIVATION

WHAT IS AN HD MAP?

HD Map Characteristics

- Highly detailed + accurate
- Up-to-Date
- Topology
- Geometry
- Geo-Reference Services



© 3D Mapping Solutions

The HD Map…

- extends the car's view
- supports autonomous driving in challenging scenarios
- compensates for sensor/detection errors
- improves localization
- is utilized in simulation environment

HD MAP MOTIVATION

AUTONOMOUS VEHICLES NEED HD MAPS

"Baidu sees Maps for Self-Driving Cars as Bigger Business Than Web Search"

MIT Technology Review, Jan 9th, 2018

Current Maps

- SD Maps (sufficient for navigation)
  - Large coverage
  - Not very accurate (i.e., street – level)
- HD Maps (from survey campaigns)
  - Low coverage
  - Collected with expensive sensors, manual postprocessing

© 3D Mapping Solutions

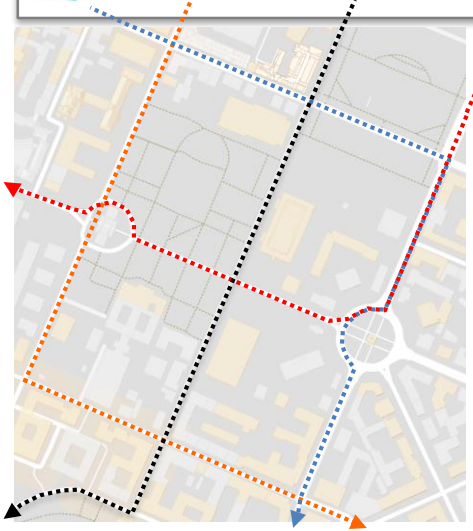
→ HD Map is a key part towards Autonomous Driving and DS is a crucial part of the solution

HD MAP MOTIVATION

CROWDSOURCING INFRASTRUCTURE

HARMAN

Car Fleet / User Devices

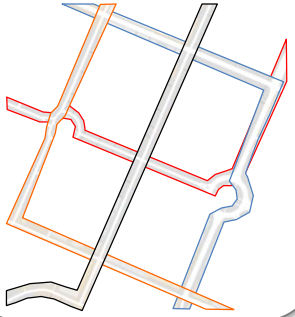


Fleet observations

Map Creation

Map Data
- SD Map
- Survey campaigns

HD Map



Other Inputs
- Road Weather
- Accidents
- Traffic Models
- ...

HD MAP DATA SCIENCE CHALLENGES

GENERAL CHALLENGES

Accuracy

- Lanes, traffic signs, ... should have an accuracy < 10cm
- Positioning and measurement errors sometimes several meters

Up-to-date

- Updates should be visible in global map as fast as possible
- Tradeoff: update speed vs. confidence

Resource constrains

- Bandwidth: accuracy vs. model size
- Computational limitations

Variablity

- Sensor heterogenity
- Data, quality and ecosystem heterogenity

HD MAP DATA SCIENCE CHALLENGES

ON BOARD CHALLENGES

Semantic Feature Detection

Traffic Signs

- Semantic Information + Landmarks
- Object Detection = Region Proposal + Classification
- Detection Speed vs. Accuracy Tradeoff

Traffic Lane

- Positioning perpendicular to driving direction
- Computer Vision vs. Deep Learning

Semantic Segmentation

- Supports traffic sign and lane detection
- Enriches the map content
- Quality assessment of landmarks

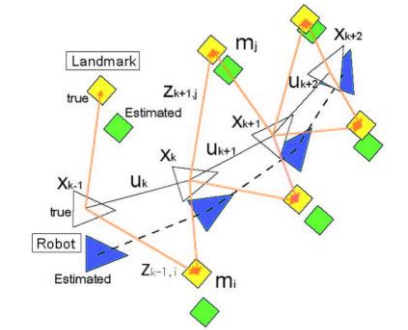
Transformation Gap: Image Space ⇨ Real-World

HD MAP DATA SCIENCE CHALLENGES

ON BOARD CHALLENGES

Simultaneous Localization and Mapping

Perfect map ⇨ localization is „easy“
Perfect localization ⇨ mapping is „easy“

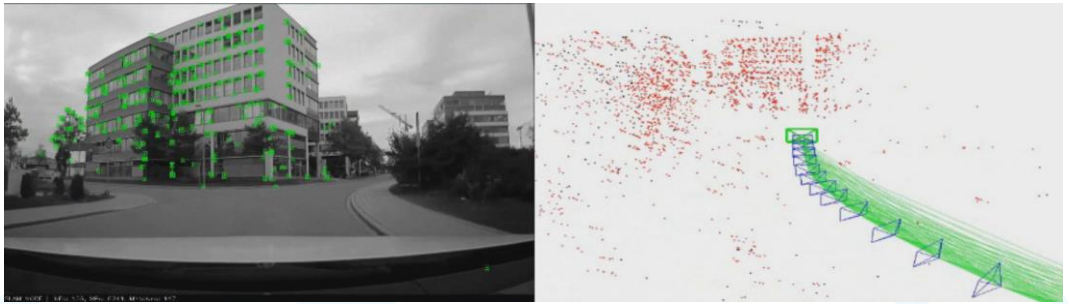


SLAM

- Identification of landmarks that are visible from different positions
- Measurement of position change
- Construct Triangles (= Posegraph)
- Adjustment of measurement errors

Visual SLAM

- Landmarks = Image Keypoints
- Position Change = Bundle Adjustment
- Byproduct: image to world correspondence

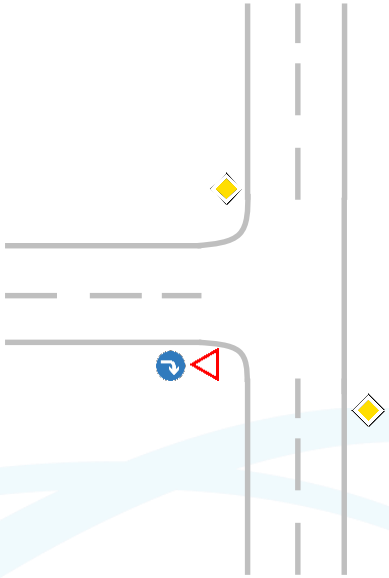



INITIALIZE

HD MAP DATA SCIENCE CHALLENGES

OFF BOARD CHALLENGES

Building the global map

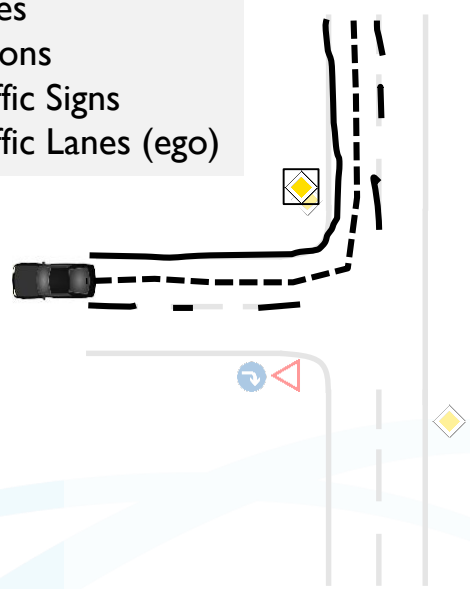


HD MAP DATA SCIENCE CHALLENGES

OFF BOARD CHALLENGES

Building the global map

Vehicle Data (simplified)
- Trajectories
- Observations
  - Traffic Signs
  - Traffic Lanes (ego)



HD MAP DATA SCIENCE CHALLENGES

OFF BOARD CHALLENGES

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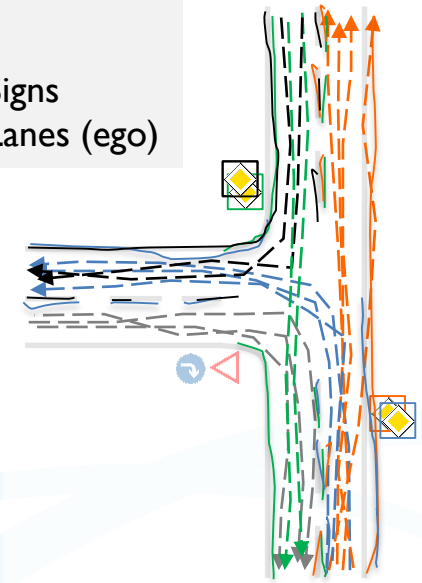

OFF BOARD CHALLENGES

Building the global map

Topology

- Challenges:
  - GPS Quality/Errors/Outliers/Resolution
  - Scalability
  - Automatic Adaptataion
  - Border Effects

Vehicle Data (simplified)
- Trajectories
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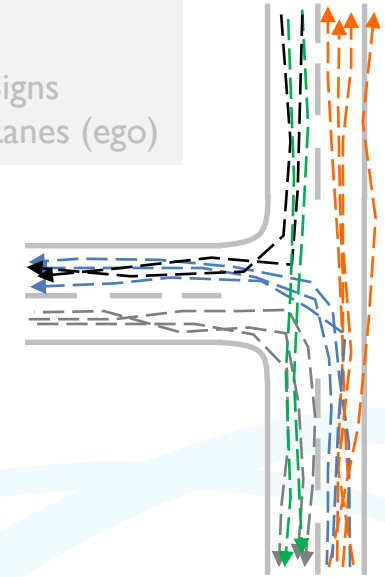

HD MAP DATA SCIENCE CHALLENGES

OFF BOARD CHALLENGES

Building the global map

Topology

- Challenges:
  - GPS Quality/Errors/Outliers/Resolution
  - Scalability
  - Automatic Adaptataion
  - Border Effects

- Methods:
  - Trajectory Clustering
  - Map Construction Algorithms
  - Self-Organizing Maps
  - ...

Vehicle Data (simplified)
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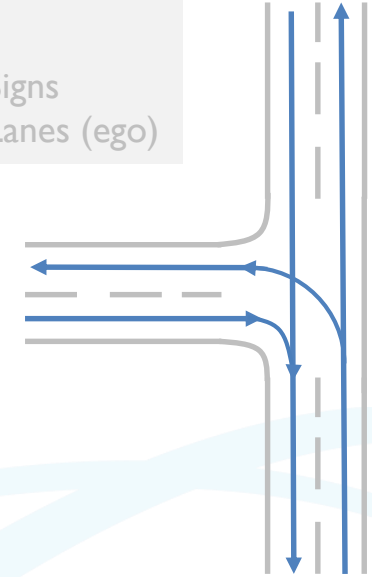

HD MAP DATA SCIENCE CHALLENGES

OFF BOARD CHALLENGES

Building the global map

Geometry

- Challenges:
  - Outliers/Quality/Misdetections
  - Border Effects
  - Scalability
  - Association

Local Maps (simplified)
- Trajectories
- Observations
  - Traffic Signs
  - Traffic Lanes (ego)

OFF BOARD CHALLENGES

Building the global map
Geometry

- Challenges:
  - Outliers/Quality/Misdetections
  - Border Effects
  - Scalability
  - Association

- Methods:
  - Assignment Algorithms
  - Clustering
  - Probabilistic Models
  - Graph Optimization
  - …

Local Maps (simplified)
- Trajectories
- Observations
  - Traffic Signs
  - Traffic Lanes (ego)

SUMMARY

DATA SCIENCE TO CREATE HD MAPS

HD Map is a key part towards Autonomous Driving and Data Science is a crucial part of the solution!

On Board

- Neural Networks, Computer Vision, Pattern Recognition, Probabilistic Filters, SLAM, NLP, …

Off Board

- Graph Optimization, Clustering, Big Data, Machine Learning, Entity Matching, Genetic Algorithms, Data Integration, Uncertain Data Processing, Spatial Modeling, Assignment Algorithms, Outlier Detection,…


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