Divide and Conquer: A Systematic Approach for Industrial Scale High-Definition OpenDRIVE Generation from Sparse Point Clouds

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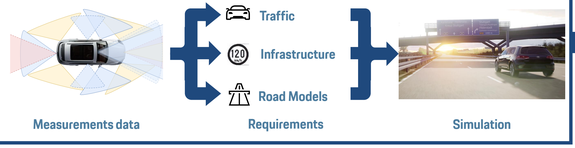
Background

Challenges in Function Validation

- **Increasing complexity of ADAS systems,** due to growing hardware / software
- **Higher requirements for testing and validation**, e.g., in field tests: 6.6 billion kilometres for safe highway pilot
- **Simulation of driving functions necessary**
- **Realistic Content for Simulation derived from reality**

Deriving Simulation from real world



Problem Statement for road models

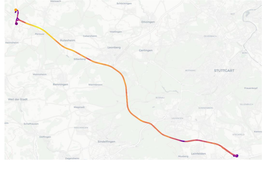
- **Accurate road models needed**, e.g., in driving functions, simulations, HiL / SiL
- **High-definition** (HD) **map** creation: time consuming and expensive
- **Standard-definition** (SD) **data**: inaccurate or not up to date
- **Service Providers:** additional costs and time consuming
- **Existing frameworks:** too specific, limited scalability, missing information, such as entry / exit lanes

Data used in this work

- **One front-mounted Livox LiDAR** and **GeneSys ADMA GNSS inertial system**
- **Data collection** not focused on road generation but on the acquisition of critical driving scenarios as part of the AVEAS research project
- **German interstate highways A8 and A81** around Stuttgart
- **Speed profiles** range from **80 to 140 km/h** in the considered parts

Method Proposal

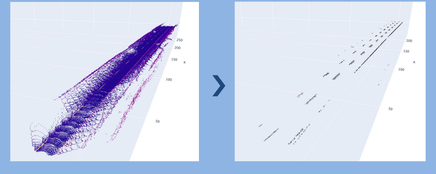
Segment Generation



- **Segment** drive based on **OpenStreetMap (OSM)** data
- **Map Matching** drive data to OSM edges
- **Additional OSM information** is gathered:
  - country of recording
  - type of road, e.g., highway, entry / exit
  - number of lanes
  - existence of shoulder lanes
  - connection to exit or entry lanes

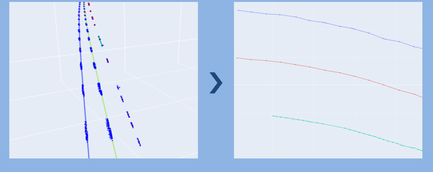
Processing per Segment

Lane marking extraction



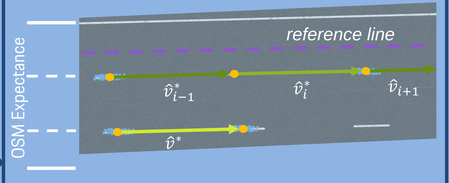
- **Synchronization of LiDAR and GNSS data,** based on the timesteps received from each
- **Cropping point clouds** based on the maximum possible width of the road and the sensor position
- **Filtering ground points** through a RANSAC-based ground plane estimation and using all point beneath
- **Extraction of lane markings** is based on reflectivity, with an iteratively lowering threshold

Generation of lane markings



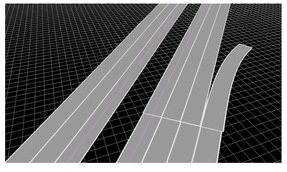
- **Assumption that lane markings are elongated** in the direction of the road is used for dashed and solid lanes
- **DBSCAN clustering** to retrieve the individual lane markings in the point cloud
- **Estimating the directional vector** of each cluster through fitting a 3D line model through a RANSAC-based estimation
- **Building continuous lanes,** through iteratively searching the next lane marking based on the directional vectors

Calculation of Reference Line



- **Lane markings are classified,** based on the size of the marking clusters and the distance between them
- **Expected road marking and sizes are build** from the information gathered from OSM
- **Calculating the offset to reference line**, leveraging the position and classification of the markings
- **Generating reference line points** through the normal vector between markings and the estimated offset

OpenDRIVE Geometry

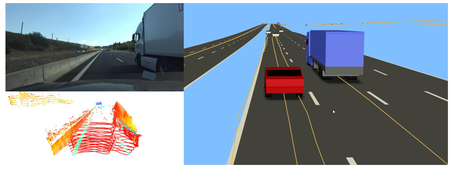


- **Aligning reference line** points between segments
- **Fitting of Parametric cubic curves** through the reference line, where start and end points are higher weighted
- **Combining Segments** into roads, based on OSM *way* IDs
- **Road elevation and super-elevation are added** as additional cubic curves along the fitted reference line
- **Creation of on and off ramps** as spiral geometry, based on information provided by OSM

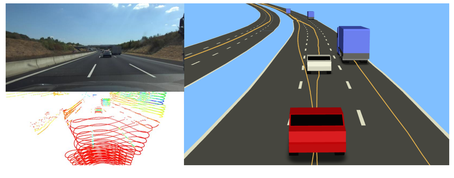
Results

Benefits of the proposed method:

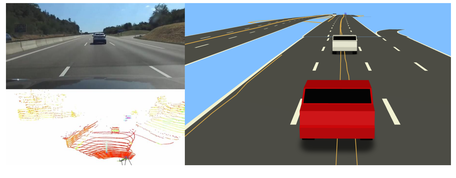
- **Generation directly from real-world test drives**
- **One sparse LiDAR and GNSS** used for reconstruction
- **Achieving HD map quality**
- **Accurate replication into simulation,** as all the traffic participants are placed correctly on each lane and maneuvers are transferred close to reality
- **Scalable** over multiple hundred kilometers
- **Stable against errors,** as these are limited to segments
- **Segments can be modified and corrected** independently
- **Full OpenDRIVE network**, incl. lane wise predecessor and successor, entry and exit lane sections, offramp as junctions



Stability against occlusion:
Despite the LiDAR field of view being occluded to a high degree, our approach can reconstruct a realistic road representation.



Accurate road representation for simulation:
Traffic participants are accurately placed on and within each lane. Observed maneuvers, like cut-in and cut-out, are replicated correctly in the simulation.



Generation from a single drive:
Our proposed methodology enables the generation directly from real-world test drives, without the need for additional recordings for the road generation.

	agst. PEGASUS HD	agst. self (ours)
RMSE	0.337 m	0.274 m
avg. distance	0.243 m	0.213 m
std. deviation	0.201 m	0.166 m
eval. length	44.8 km	30.6 km

High-Definition map quality:
As a reliable accuracy metric, we compare against HD maps from the PEGASUS project. For the evaluation of the reproducibility, we compare four drives on the same road against each other. In both metrics, our approach **achieves HD map quality.**