Highway Dataset Format

The dataset includes measurement data extracted from one or more recording sites (locations) in the data directory as well as map files per location in the maps directory (if part of the dataset). Data and maps can be associated using a recording's location id. The data for each location is split into multiple continuous recordings.

In total four files are provided for each recording:

- An image of the recorded road section (XX_background.png)
- A csv file describing the recording location (XX_recordingsMeta.csv)
- A csv file containing an overview of recorded vehicle and VRU tracks (XX_tracksMeta.csv)
- A csv file for the tracks' trajectories (XX_tracks.csv)
  These files are created for each recording to ensure easy handling of the data.

In addition the following map data for each recording location are provided:

- Lanelet2 maps (.osm)
- ASAM OpenDrive maps (.xodr)
- 3D scene (.osgb & .fbx)

In the following, the dataset format and especially the meaning of every column is explained in detail.
Please note that we summarize pedestrians, bicyclists and motorcycles to vulnerable road users (VRUs) in the following tables.

Image of the Road Section (XX_background.png)

For each recording a georeferenced image of the road section is added.The image is based on the recording itself by removing all moving vehicles through filtering. Additionally the resolution of the image was
reduced.

Recording Meta Information (XX_recordingMeta.csv)

This file contains metadata for each recording. The metadata provides a general overview, e.g. of the time of recording, the road section considered and the total number of objects tracked.

Name	Description	Unit
recordingId	The id of the recording. Every recording has a unique id.	[-]
locationId	The id of the recording location.	[-]
frameRate	The frame rate which was used to record the video.	[hz]

Name	Description	Unit
speedLimit	The speed limit of the driving lanes. In all recordings, the speed limit is the same for every driving lane.	[m/s]
weekday	The weekday the recording was done.	[-]
startTime	The hour at which the recording was started	[hh]
duration	The duration of the recording.	[s]
numTracks	The number of objects tracked.	[-]
numVehicles	The number of vehicles tracked.	[-]
numVrus	The number of vulnerable road users (VRUs) tracked.	[-]
latLocation	Rough latitude coordinates of recording location. Not to be confused with UTM coordinates!	[deg]
lonLocation	Rough longitude coordinates of recording location. Not to be confused with UTM coordinates!	[deg]
xUtmOrigin	X value of UTM coordinate of origin of the local coordinate system for this recording location. Add this to xCenter to get UTM coordinates.	[m]
yUtmOrigin	Y value of UTM coordinate of origin of the local coordinate system for this recording location. Add this to yCenter to get UTM coordinates.	[m]
orthoPxToMeter	Scale factor from ortho image pixels to UTM meters. This value is needed for visualization.	[m/px]
exportVersion	Version of data format. (may be missing in some datasets)	[-]

Track Meta Information (XX_tracksMeta.csv)

This file contains an overview of all tracks.
The purpose of this file is to allow filtering tracks e.g. by class.

Name	Description	Unit
recordingId	The id of the recording. Every recording has a unique id.	[-]
trackId	The id of the track. The ids are assigned in ascending order for each recording.	[-]
initialFrame	The frame in which the track starts.	[-]
finalFrame	The frame in which the track ends.	[-]
numFrames	The total lifetime in frames.	[-]
width	The width of the tracked object. This property is set to zero for VRUs.	[m]

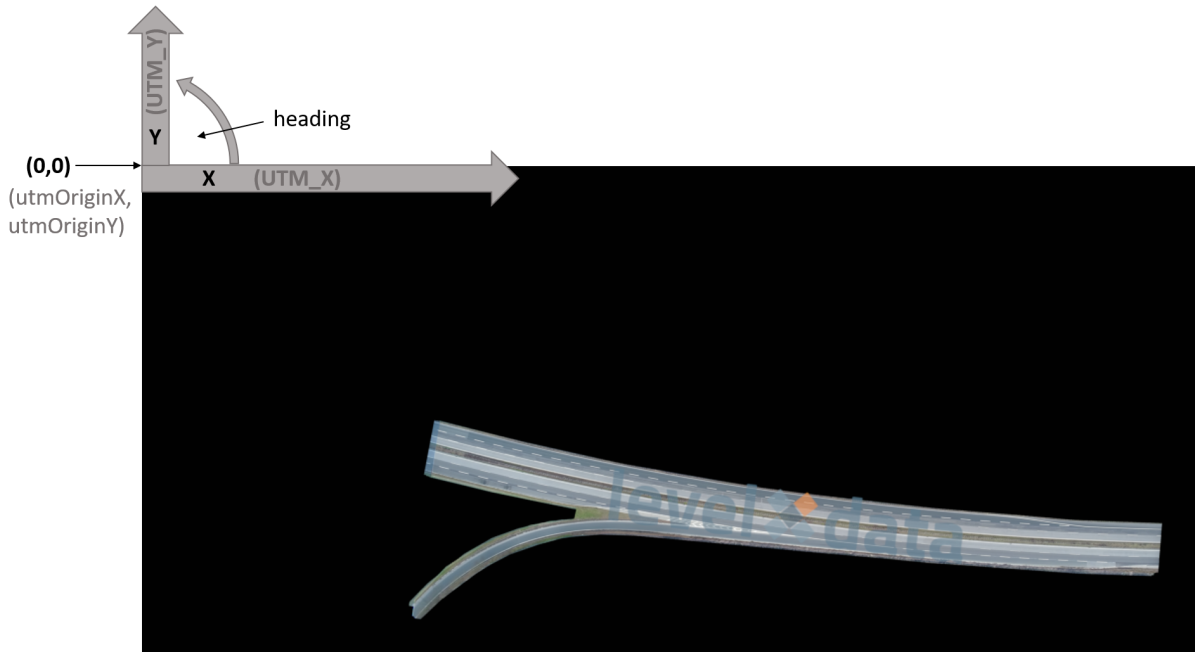
Name	Description	Unit
length	The length of the tracked object. This property is set to zero for VRUs.	[m]
class	The class of the tracked object.	[-]

Tracks (XX_tracks.csv)

This file contains all time dependent values for each track. Information such as current position, velocity and acceleration.

Name	Description	Unit
recordingId	The id of the recording. Every recording has a unique id.	[-]
trackId	The track's id. The ids are assigned in ascending order for each recording.	[-]
frame	The frame for which the information are given.	[-]
trackLifetime	The current age of the track at this frame.	[-]
xCenter	The x position of the object's centroid in the local coordinate system. Add xUtmOrigin to get UTM coordinates.	[m]
yCenter	The y position of the object's centroid in the local coordinate system. Add yUtmOrigin to get UTM coordinates.	[m]
heading	The heading in the local coordinate system.	[deg]
width	The width of the object. This property is set to zero for VRUs.	[m]
length	The height of the object. This property is set to zero for VRUs.	[m]
xVelocity	The velocity in x-axis direction in the local coordinate system.	[m/s]
yVelocity	The velocity in y-axis direction in the local coordinate system.	[m/s]
xAcceleration	The acceleration in x-axis direction in the local coordinate system.	[m/s^2]
yAcceleration	The acceleration in y-axis direction in the local coordinate system.	[m/s^2]
lonVelocity	The longitudinal velocity.	[m/s]
latVelocity	The lateral velocity.	[m/s]
lonAcceleration	The longitudinal acceleration.	[m/s^2]
latAcceleration	The lateral acceleration.	[m/s^2]

Coordinate System



The global coordinate system used is the UTM coordinate system, as we geo-referenced our data.
For easier handling of data of the same intersection in different recordings, we introduced a local UTM-like coordinate system.
The only difference is, that the origin (0, 0) is very close to the recorded road section and the same for all recordings at each location.
To transform positions into the global UTM coordinate system, just add xUtmOrigin and yUtmOrigin to all positions.
The local coordinate system looks as follows: The horizontal axis is the x-axis, which grows to the right.
The vertical axis is the y-axis, which grows upwards.
The heading is calcuated as in the UTM coordinate system.
Finally, we use SI units only.

Map-based Data Enrichment

In addition to trajectories, the map-based data enrichment includes data derived from the maps, such as lane-related values, surrounding vehicle IDs, and criticality metrics.
All map-based data is derived from the lanelet2 maps. The variables are added as additional columns to the XX_tracks.csv files if they are part of the purchased dataset package. If you would like to purchase this data retrospectively, please contact us.

The values include the following elements:

Name	Description	Unit
traveledDistance	The accumulated distance covered by the track up to this point in time.	[m]

Name	Description	Unit
latLaneCenterOffset	Lateral offset of the vehicle's centroid to the closest point on the centerline of the lanelet the vehicle is currently driving in. Semicolon-separated list with values for each lanelet the vehicle is currently in. **(*)**	[m]
laneWidth	Width of the lane at the current centroid position of the vehicle. Semicolon-separated list with values for each lanelet the vehicle is currently in. **(*)**	[m]
laneletId	Semicolon-separated list of the IDs of the lanelets the vehicle is currently driving in according to the Lanelet2 map. Determined by the vehicle's centroid position. **(*)**	[-]
laneChange	Whether the lane was changed in lateral direction. First frame, in which the centroid is in the new lane.	[m]
lonLaneletPos	Length of the segments of the centerline from the start of the lanelet to the closest point on the centerline from the vehicle's centroid. Semicolon-separated list with values for each lanelet the vehicle is currently in. **(*)**	[m]
laneletLength	Length of the complete centerline of the lanelet the vehicle is currently driving in. Semicolon-separated list with values for each lanelet the vehicle is currently in. **(*)**	[m]
leadDHW	Distance Headway from the front bumper of the current vehicle to the rear bumper of its lead vehicle (default value: -1).	[m]
leadDV	Relative velocity between the current vehicle and its lead vehicle. Positive if the current vehicle is faster than lead (default value: -1000).	[m/s]
leadTHW	Time Headway from the front bumper of the current vehicle to the rear bumper of its lead vehicle (default value: -1).	[s]
leadTTC	Time-to-Collision from the front bumper of the current vehicle to the rear bumper of its lead vehicle (default value: -1).	[s]
leadId	The ID of the lead vehicle in the same lane (default value: -1). **(**)** This and the following surrounding vehicle IDs are best visualized using the drone-dataset-tools.	[-]
rearId	The ID of the rear vehicle in the same lane (default value: -1). **(**)**	[-]
leftLeadId	The ID of the lead vehicle in the left adjacent lane in travel direction or in one of its further left adjacent lanes (default value: -1). **(**)**	[-]

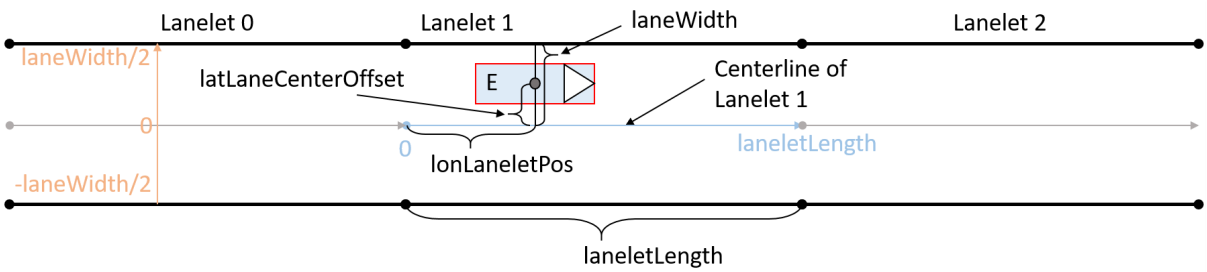
Name	Description	Unit
leftRearId	The ID of the rear vehicle in the left adjacent lane in travel direction or in one of its further left adjacent lanes (default value: -1). **(**)**	[-]
leftAlongsideId	Semicolon-separated list of the IDs of the alongside vehicles (with longitudinal overlap) to the left of the vehicle in travel direction or in one of its further left adjacent lanes (default value: empty). **(**)**	[-]
rightLeadId	The ID of the lead vehicle in the right adjacent lane in travel direction or in one of its further right adjacent lanes (default value: -1). **(**)**	[-]
rightRearId	The ID of the rear vehicle in the right adjacent lane in travel direction or in on of its further right adjacent lanes (default value: -1). **(**)**	[-]
rightAlongsideId	Semicolon-separated list of the IDs of the alongside vehicles (with longitudinal overlap) to the right of the vehicle in travel direction or in one of its further left adjacent lanes (default value: empty). **(**)**	[-]

(*) For more details on how these values are calculated, check the separate section below.

(**) For more details on how the surrounding vehicle IDs are calculated, check the separate section below.

Lane-related Values

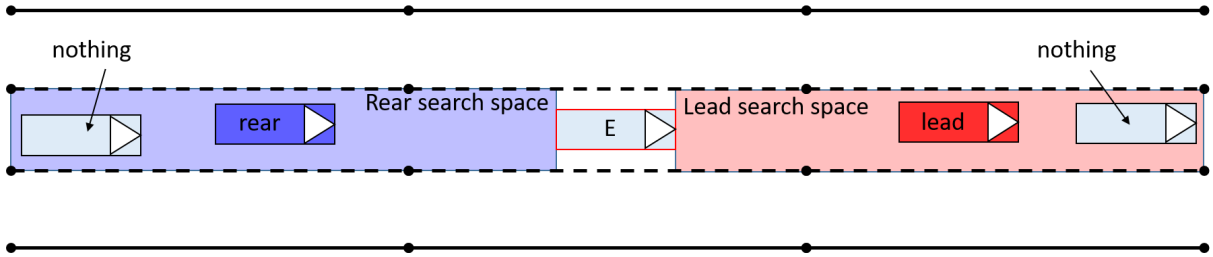
The lane-related values are calculated using the Lanelet2 maps. The values are calculated for the bounding box centroid of each vehicle. The following picture visualizes the different values. In constrast to the map in the picture, the width of a lanelet (and especially of following lanelets) is **not** necessarily constant over the complete lanenet. Therefore, the lane width-related values (laneWidth, latLaneCenterOffset) are calculated for each vehicle position individually:



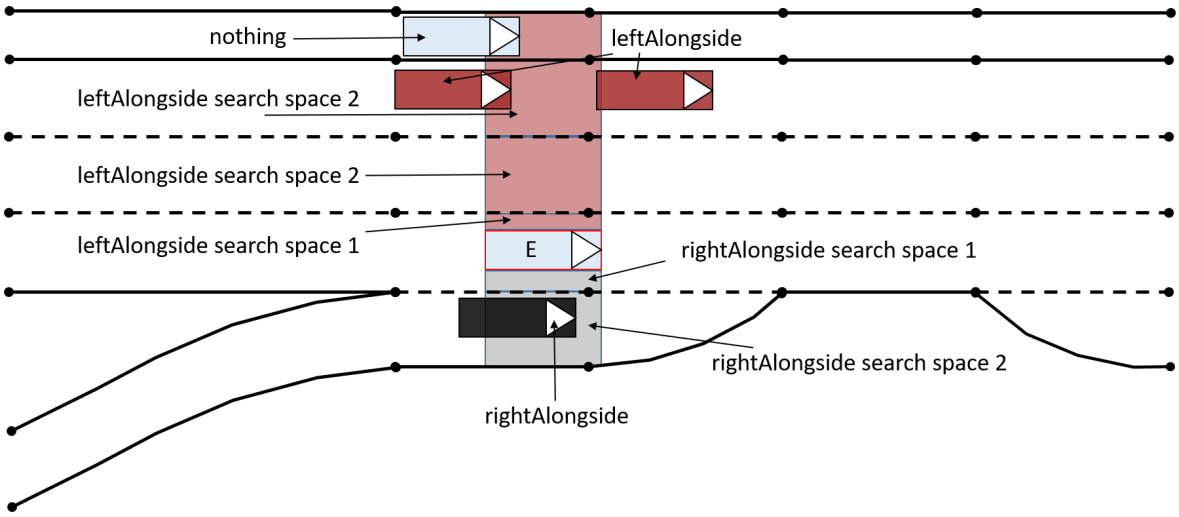
Surrounding Vehicle IDs

The surrounding vehicles are calculated using the Lanelet2 maps. The bounding box centroid of each vehicle is used to determine, in which lanelet it is currently driving. Lanelets with an *lxd_virtual* tag are ignored. The following images present the concepts of the search algorithms for the surrouding vehicle IDs of an ego vehicle (E). The surrounding vehicle IDs can also be visualized using the drone-dataset-tools.

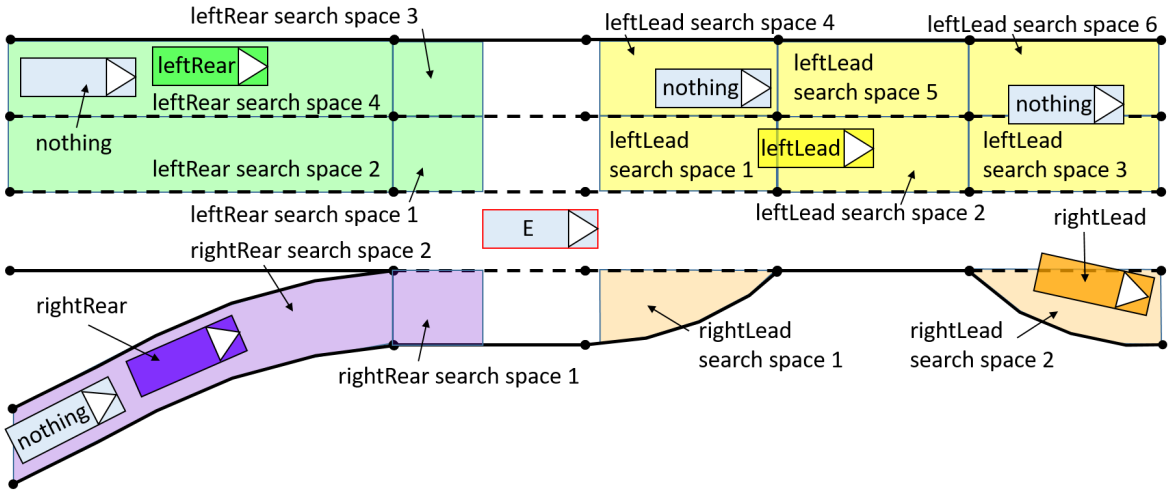
The lead and rear IDs are calculated as depicted below:



The leftAlongside and rightAlongside IDs are calculated as depicted below:



The leftRear, leftLead, rightRear and rightLead IDs are calculated as depicted below:



Maps

ASAM OpenDRIVE maps

For all locations, a digital map in OpenDRIVE® v1.4 format is provided. For more information about OpenDrive refere to the ASAM website. ASAM OpenDRIVE is supperted by several simulation tools such as esmini, Carla, etc. The information in the map is based on the georeferenced drone images and speed limit information from OpenStreetMap.

The maps contain the following map object types:

- Road network, Road and Lane connections, predeces-sors / successors
- Road shape and width
- Lane number, width, and type (including sidewalks & bicycle lanes)
- Markings (type, color)
- Speed Limits
- Flat terrain
- Generalized curb stone heights
- Traffic islands
- Parking areas
- Road stencil markings (text, arrows, etc.)
- Important Traffic Signs (Stop, Yield, Turn,...)
- Roundabouts
- Guardrail, concrete divider, noise protection wall
- Further markings
    - Crosswalks (including zebra markings)
    - Restricted area markings

Lanelet2 maps

For all locations, a digital map according to the core format described in the Lanelet2 library is provided to the customer. The information in the map is based on the georeferenced drone

images and speed limit information from OpenStreetMap.

The maps contain the folllowing information:

- Road network, Road and lane connections, predecessors/successors
- Road shape and width
- Lane number, and type (including sidewalks & bicycle lanes)
- Lane markings
- Traffic islands
- Parking areas
- Surroundings (buildings/parks/vegetation)
- Generalized curb stone heights
- Intersections areas
- (Virtual) connection lanes on intersections
    - For drivable lanes and bicycle lanes
- Roundabouts
- Regulatory elements
    - Traffic Lights (focus on vehicle lights)
    - Right of way (including traffic signs and stop/wait lines, if available)
- Further markings
    - Crosswalks (including zebra markings)
    - Restricted area markings

Custom lanelet tags

The maps also contain additional tags for lanelets which are not explicitly specified in the original documentation.

Name	Description
speed_limit	All lanelets which have the type "road" or a variation of it are tagged with a speed_limit tag which denotes the speed limit of the lanelet. The value of the tag contains the speed limit and its unit (either km/h or mph).
onramp	Marks the lanelet as part of an onramp leading to a highway. Value is always "yes".
offramp	Marks the lanelet as part of an offramp leading away from a highway. Value is always "yes".