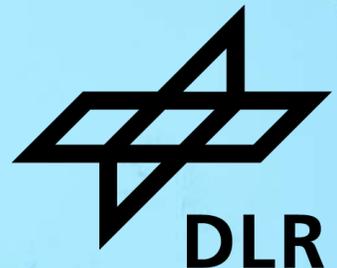


# Improving interoperability between OpenDRIVE HD map data and GIS using GDAL

FOSS4G Europe  
2024-07-05, Tartu  
Michael Scholz



# Institute of Transportation Systems

## Our research infrastructure



STADTBELEUCHTUNG 902945

Source: BS | Energy  
x: 605 168.6 r: 15  
y: 577 306.24 (UTM)

LICHTSIGNALANLAGE 25139

Source: BELLIS  
x: 605 162.71 r: 15  
y: 577 297.43 (UTM)

VORFAHRT 51236

Source: BELLIS  
x: 605 156.88 r: 30  
y: 577 298.07 (UTM)

GELÄNDEMDELL

Source: Geoinformation Braunschweig

# ASAM OpenDRIVE applications

# OpenDRIVE applications

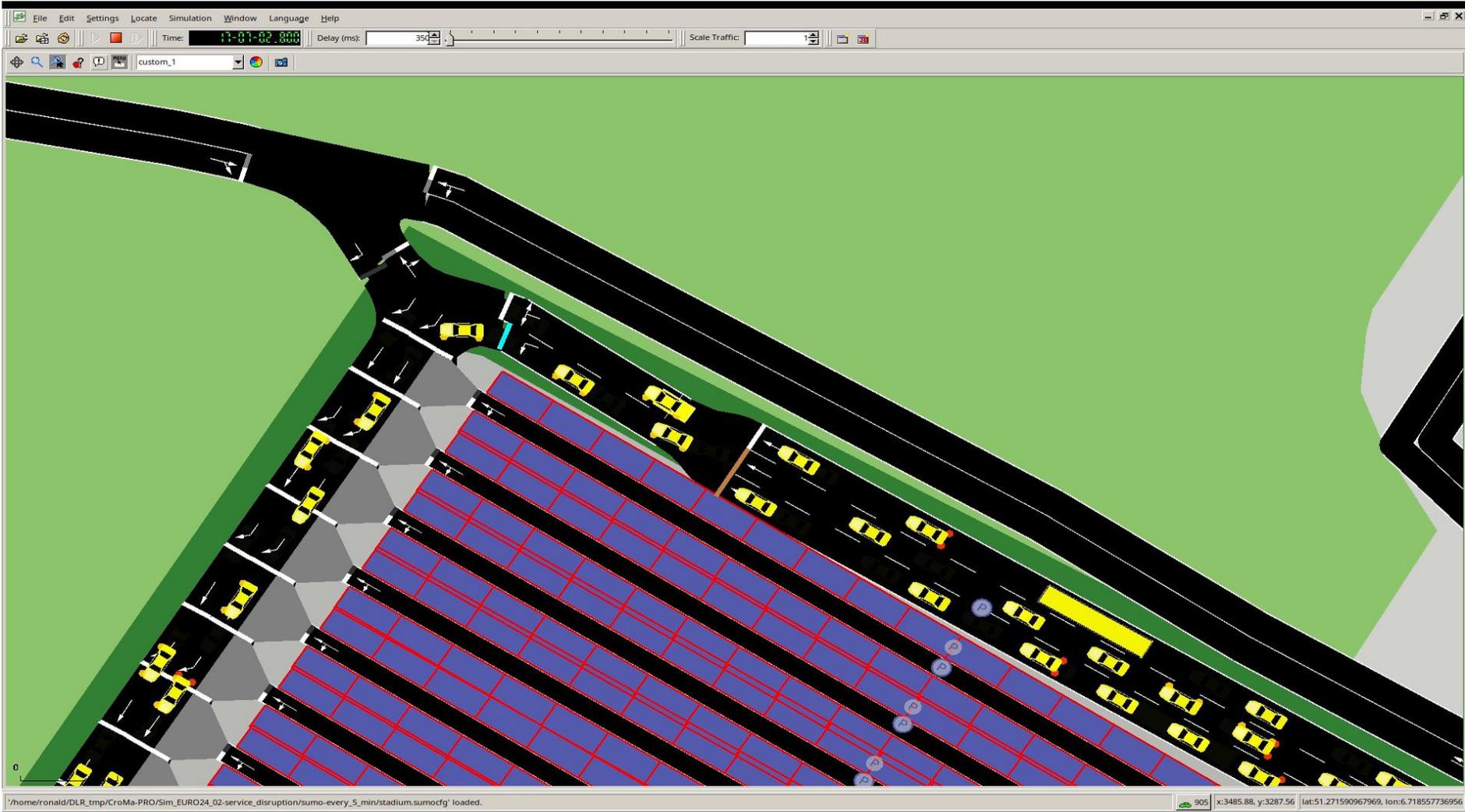
## Urban digital twins for simulation



<https://youtu.be/LDSvDEsvnig>

# OpenDRIVE applications

Microscopic traffic simulation → SUMO



# OpenDRIVE applications

## Automated driving

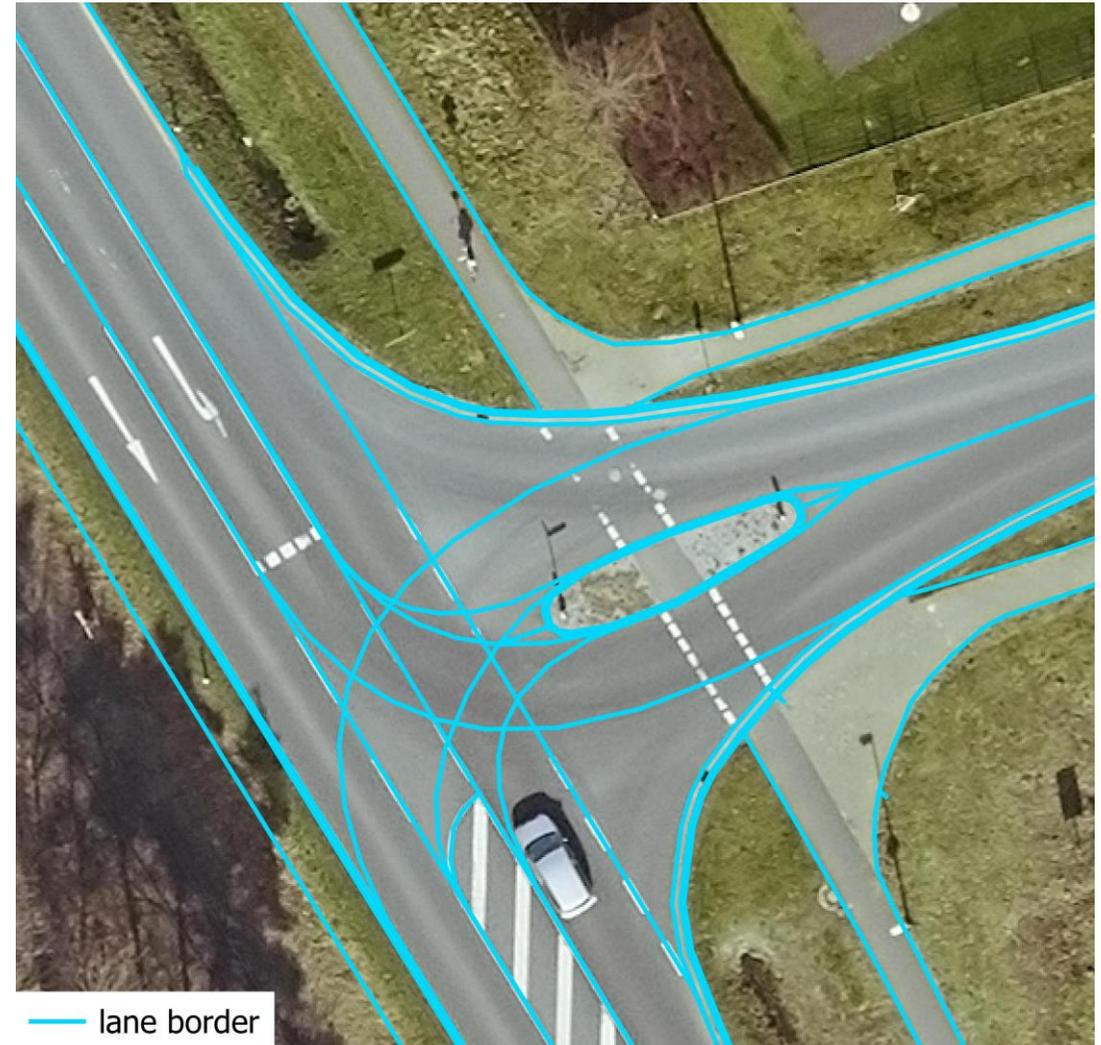


<https://youtu.be/RDXXBqL42W8>

# What does “HD” mean?

## Modelling of road space on lane level

- Driving lanes
- Cycle ways
- Pedestrian ways
- Vegetation strips



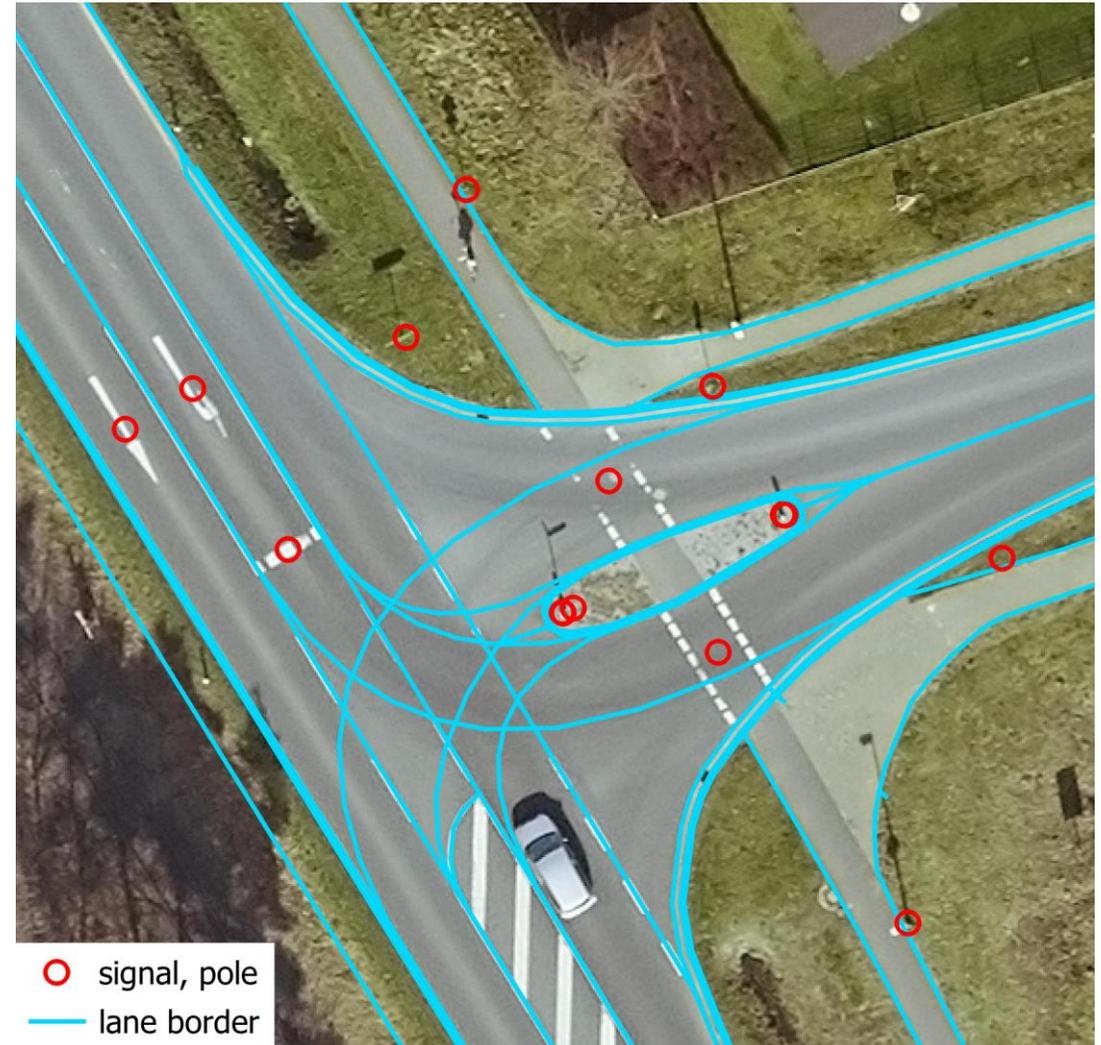
# What does “HD” mean?

## Modelling of road space on lane level

- Driving lanes
- Cycle ways
- Pedestrian ways
- Vegetation strips

## Including traffic infrastructure

- Road markings
- Signals and signs
- Poles, bollards



# What does “HD” mean?



## Mapping accuracy

- Application-dependent 😊
  - Absolute GNSS coordinate error < 20 cm (“trueness”)?
  - Relative coordinate error < 5 cm (“precision”)?

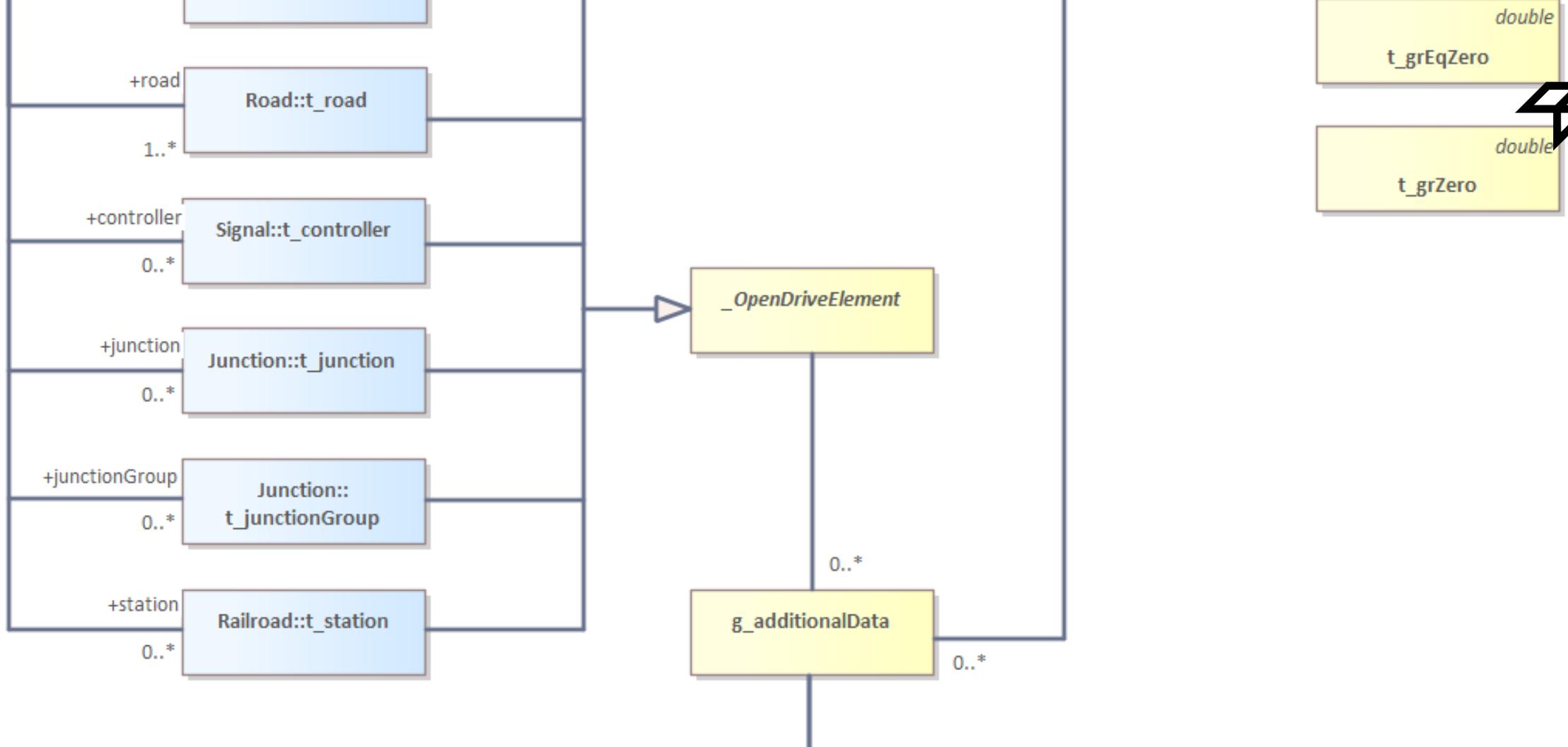
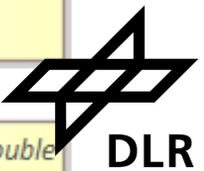
## Data acquisition

- Mobile mapping surveying
- Mainly through manual annotation
  - Expensive
  - Slow

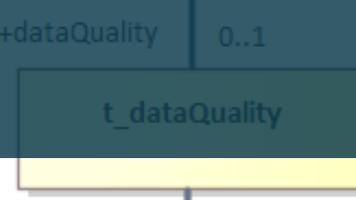
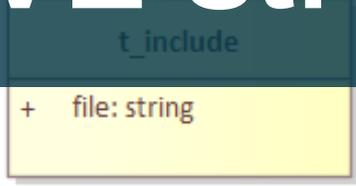
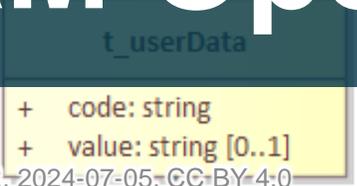
# A “problem” with different perspectives



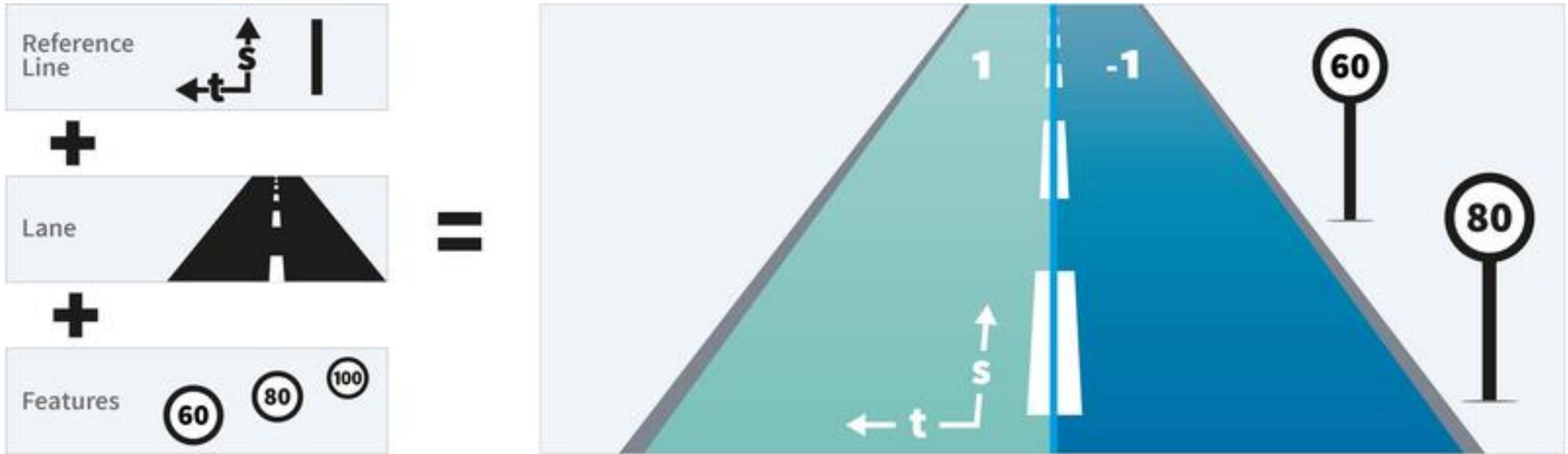
- Public authorities acquire OpenDRIVE data from industrial partners ...
  - ... and cannot use it in common GIS workflows.
- Public authorities want to export cadastral data into OpenDRIVE ...
  - ... and are missing flexible tools.
- Let's extend open-source software to bridge OpenDRIVE with GIS!



# ASAM OpenDRIVE structure

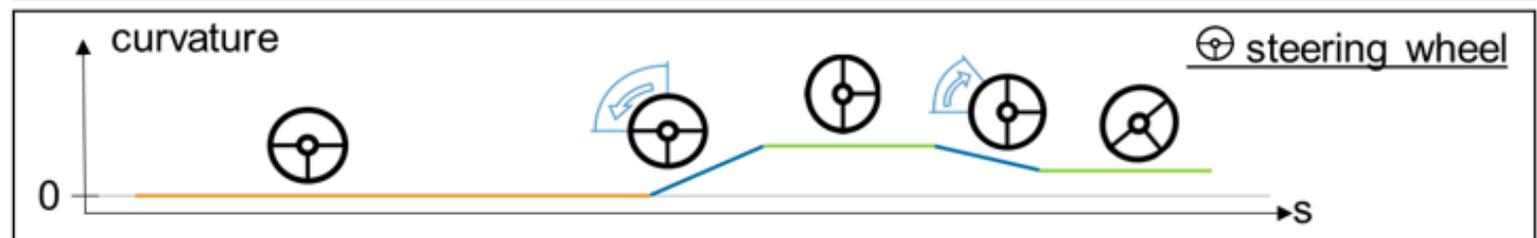
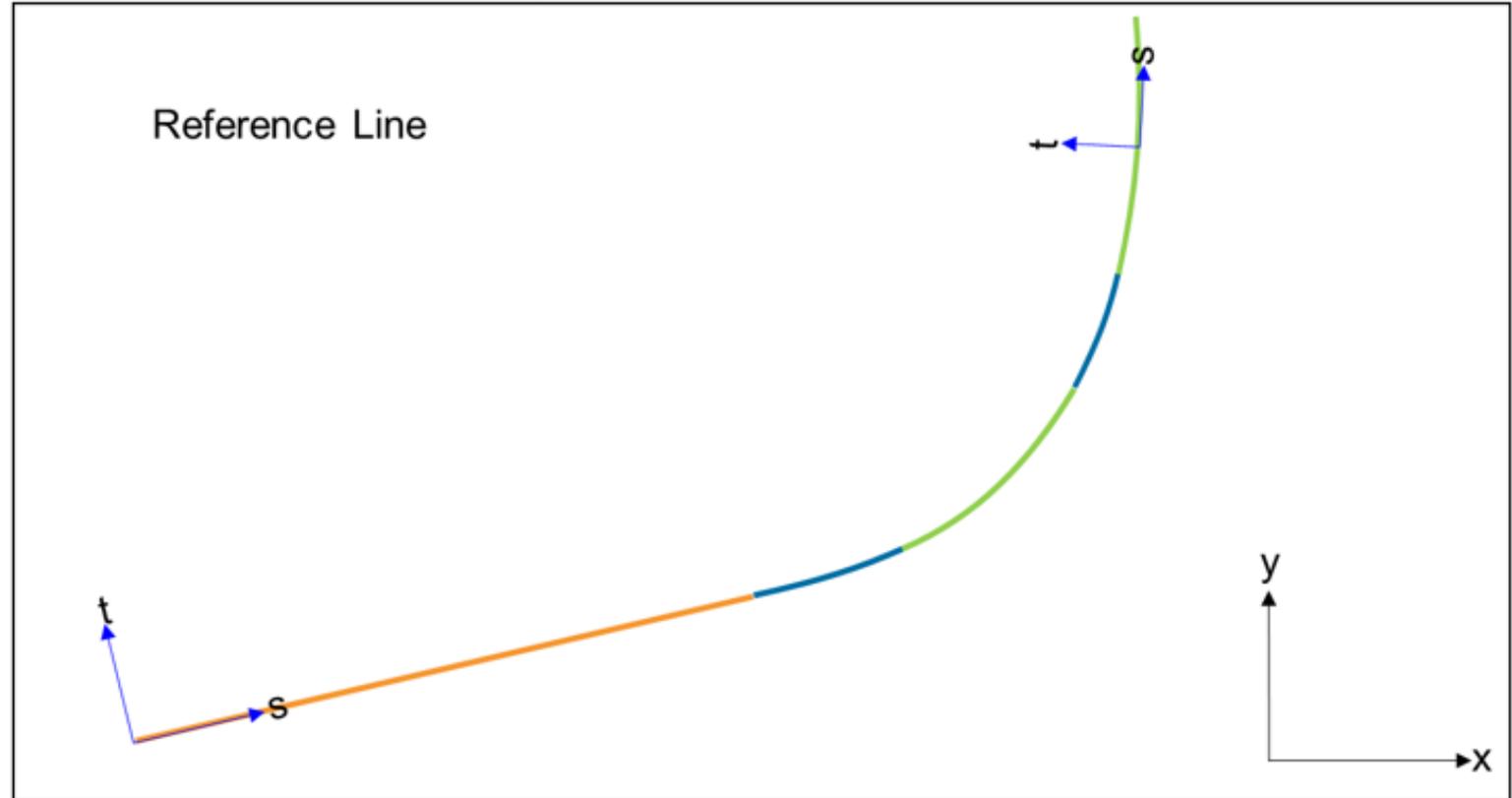
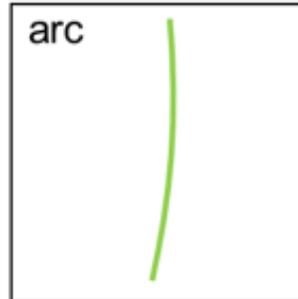
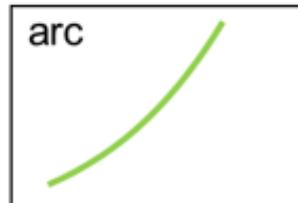
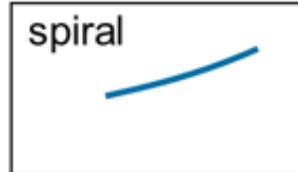
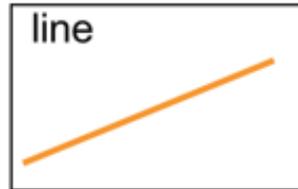


# Linearly referenced geometries



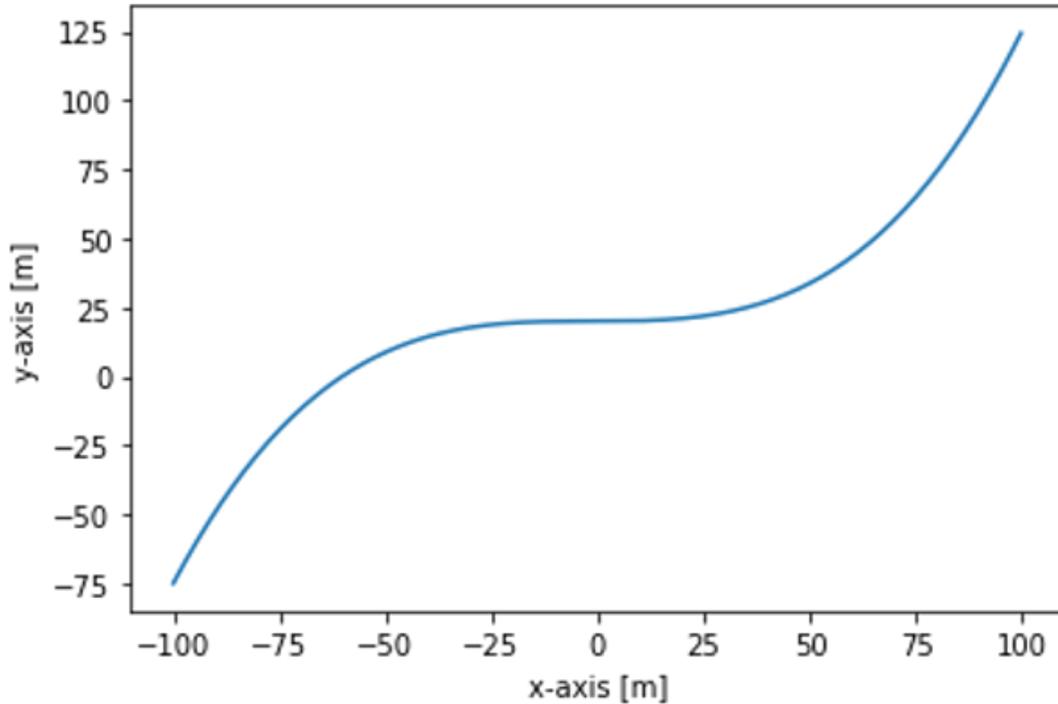
© ASAM e. V.

# Parametric geometries



# Parametric geometries

## Cubic polynomials



© ASAM e. V.

```
<geometry
```

```
s="0.000000000000e+00"
```

```
x="6.804539427645e+05"
```

```
y="5.422483642942e+06"
```

```
hdg="5.287405485081e+00"
```

```
length="6.565893957370e+01">
```

```
<paramPoly3
```

```
aU="0.000000000000e+00"
```

```
bU="1.000000000000e+00"
```

```
cU="-4.666602734948e-09"
```

```
dU="-2.629787927644e-08"
```

```
aV="0.000000000000e+00"
```

```
bV="1.665334536938e-16"
```

```
cV="-1.987729787588e-04"
```

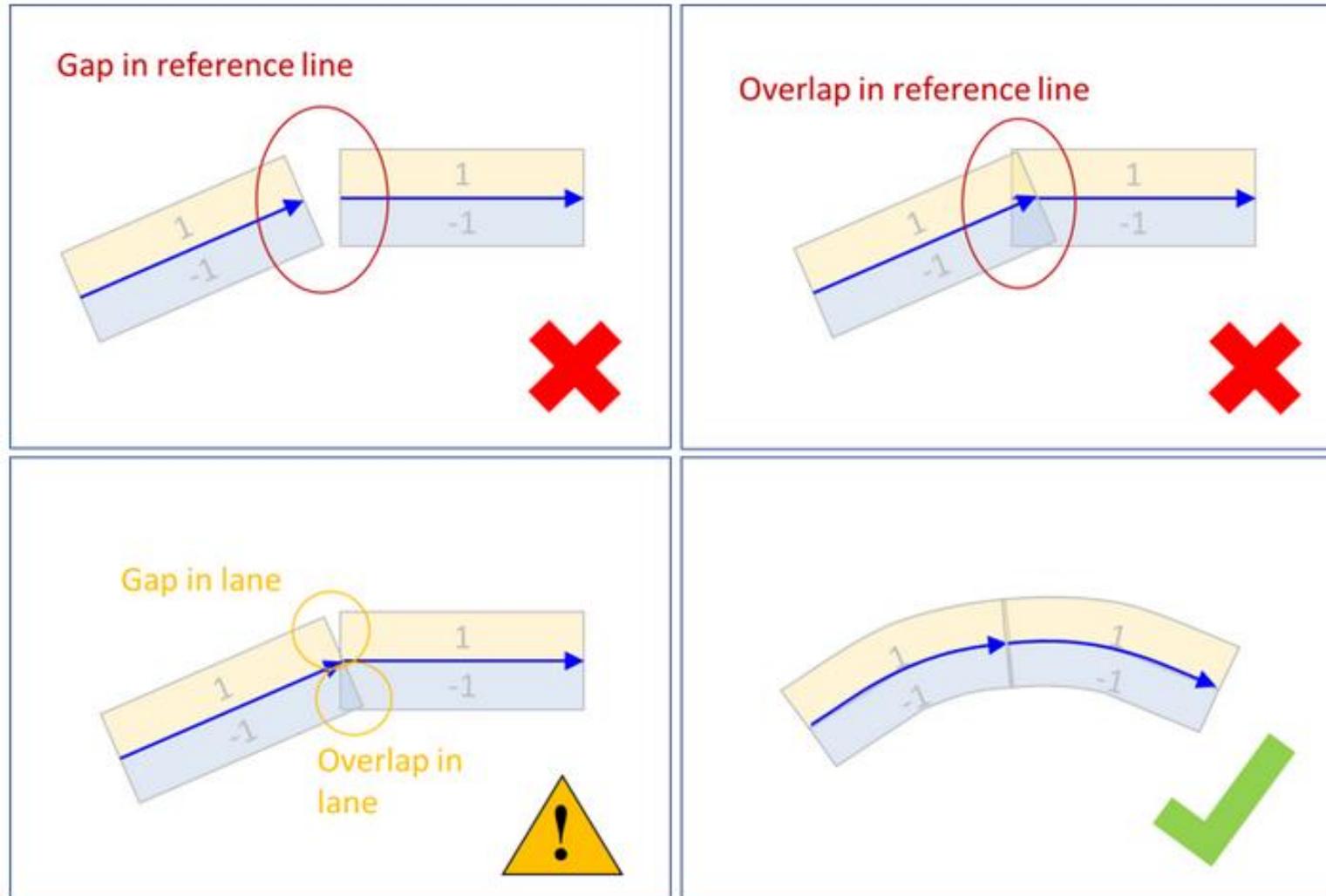
```
dV="-1.317158625579e-09"
```

```
pRange="arcLength">
```

```
</paramPoly3>
```

```
</geometry>
```

# Modelling constraints



# Hierarchical data model



```
<road length="1000.0" id="0">
  <link>
    <successor elementType="road"
      elementId="1" contactPoint="start"/>
  </link>
  <type s="0.0" type="motorway"/>
  <planView>
    <geometry x="0.0" y="0.0" hdg="0.0"
      length="1000.0">
      <arc curvature="0.004"/>
    </geometry>
  </planView>
  <elevationProfile>
  </elevationProfile>
  <lateralProfile/>
  <lanes>
    <laneSection>
      <left>
        <lane id="7" type="border">
        </lane>
        <lane id="6" type="shoulder">
        </lane>
        <lane id="5" type="stop">
        </lane>
        <lane id="4" type="driving">
          <link>
            <successor id="4"/>
          </link>
          <width a="3.75"/>
          <roadMark type="solid" weight="bold"
            color="white" width="0.3">
            <type>
              <line length="1.0" space="0.0"
                width="0.3"/>
            </type>
          </roadMark>
        </lane>
      </left>
    </laneSection>
  </lanes>
</road>
```

# Hierarchical data model

## With many cross-references



```
<road name="Boulevard of Rock" length="66.6"  
  <link>  
    <predecessor elementType="junction" e  
    <successor elementType="junction" ele  
  </link>
```

```
<signal s="0" t="0" id="1337"  
  country="LV-426" subtype="-1"  
  <laneValidity fromLane="1"  
</signal>
```

```
<lanes>  
  <laneSection s="0">  
    <left>  
      <lane id="3" type="border"  
        <link>  
          <successor id="3"/>  
        </link>
```

```
<junction name="ne Kreuzung halt" id="1234">  
  <connection id="0" incomingRoad="1" connectingRoad="2"  
    <laneLink from="-7" to="-7"/>  
    <laneLink from="-6" to="-6"/>  
    <laneLink from="-5" to="-5"/>  
    <laneLink from="-4" to="-4"/>
```



# GDAL driver implementation

# Geospatial Data Abstraction Library (GDAL)



- Wikipedia:
  - “GDAL/OGR provides at least partial support for 154 raster and **93 vector geospatial data formats**”
- Many open and proprietary GIS tools depend on GDAL
- GDAL implements OGC Simple Features as vector data model

# Make OpenDRIVE geometries GISable

## Sampling with libOpenDRIVE



[github.com/pageldev/libOpenDRIVE](https://github.com/pageldev/libOpenDRIVE)

DOI 10.5281/zenodo.7771708

pageldev / libOpenDRIVE

Code Issues 16 Pull requests 4 Actions Projects Security

libOpenDRIVE Public Watch 19 Fork 133 Starred 366

master Go to file Code

pageldev improve CMakeLists, b... 9a0437f · 8 months ago

include	Rename Signal to R...	10 months ago
src	added std prefix to ...	8 months ago
thirdparty	rename Thirdparty/ ...	last year

About

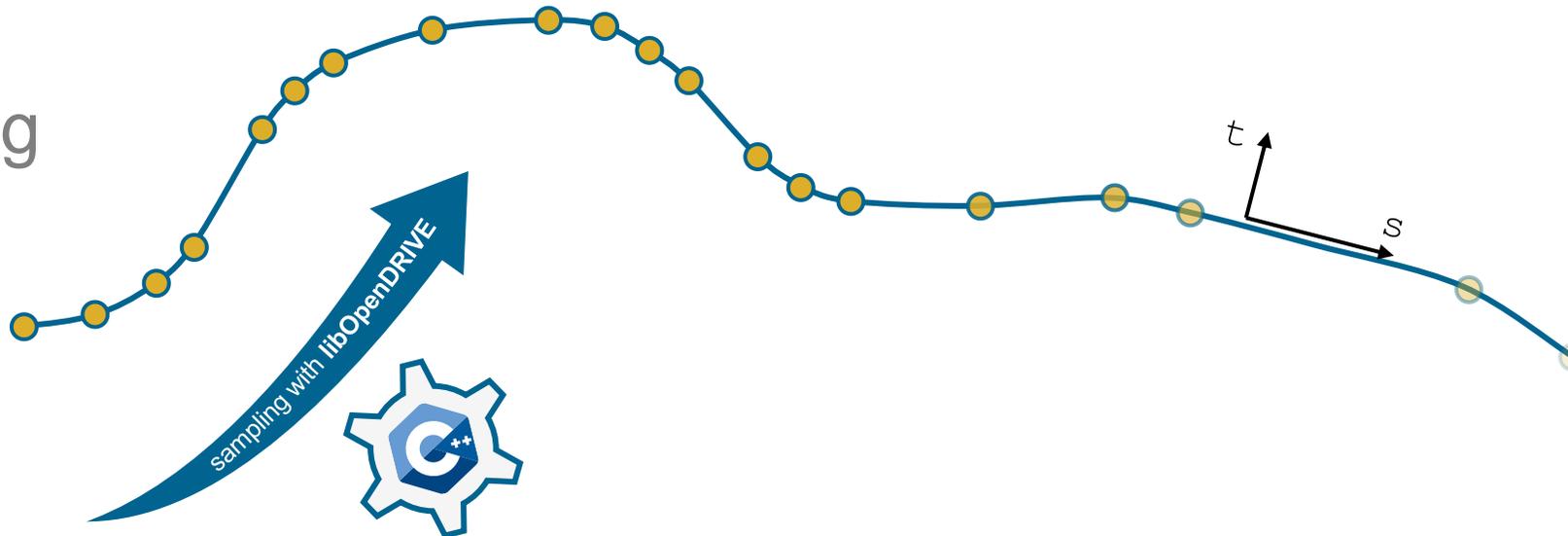
Small, lightweight C++ library for handling OpenDRIVE files

library cpp opendrive xodr

Readme

Apache-2.0 license

# Sampling



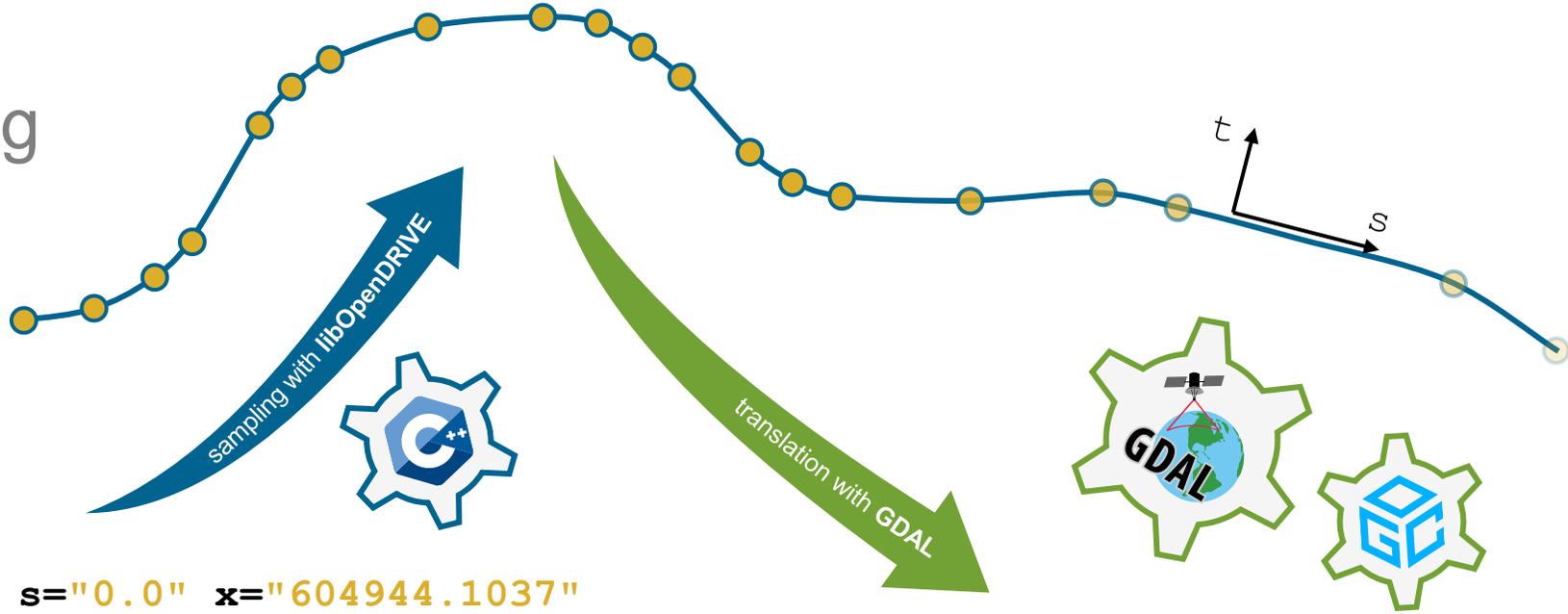
```

<planView>
  <geometry s="0.0" x="604944.1037"
    y="5792860.1272"
    hdg="3.5148"
    length="9.7589">
    <arc curvature="9.0884E-4"/>
  </geometry>
  <geometry s="9.7589" x="604935.03"
    y="5792856.5285"
    hdg="3.5237"
    length="12.0">
    <line/>
  </geometry>
</planView>

```

OpenDRIVE Model

# Sampling



```

<planView>
  <geometry s="0.0" x="604944.1037"
    y="5792860.1272"
    hdg="3.5148"
    length="9.7589">
    <arc curvature="9.0884E-4"/>
  </geometry>
  <geometry s="9.7589" x="604935.03"
    y="5792856.5285"
    hdg="3.5237"
    length="12.0">
  </geometry>
</planView>
  
```

OpenDRIVE Model

```

LineString(
  604944.1037 5792860.1272,
  604752.81 5792819.10, ...)
  
```

```

LineString(
  604935.03 5792856.5285,
  604754.39 5792810.73, ...)
  
```

Simple Features Model

# Make OpenDRIVE geometries GISable

## Voilà



Simple Feature type	OpenDRIVE element
<b>Point</b>	signal
<b>LineString</b>	referenceLine laneBorder
<b>Polygon</b>	lane roadMark roadObject

# Make OpenDRIVE geometries GISable

## Writing the GDAL driver



```
user@machine:/dev/gdal$ ogrinfo --formats
```

# Make OpenDRIVE geometries GISable

## Writing the GDAL driver



```
user@machine:/dev/gdal$ ogrinfo --formats
```

```
Supported Formats:
```

```
PCIDSK -raster,vector- (rw+v): PCIDSK Database File
CSV -vector- (rw+v): Comma Separated Value (.csv)
GML -vector- (rw+v): Geography Markup Language (GML)
KML -vector- (rw+v): Keyhole Markup Language (KML)
GeoJSON -vector- (rw+v): GeoJSON
... many more ...
MBTiles -raster,vector- (rw+v): MBTiles
OGCAPI -raster,vector- (rov): OGCAPI
ESRI Shapefile -vector- (rw+v): ESRI Shapefile
SQLite -vector- (rw+v): SQLite / Spatialite
TIGER -vector- (rov): U.S. Census TIGER/Line
```

# Make OpenDRIVE geometries GISable

## Writing the GDAL driver



```
user@machine:/dev/gdal$ ogrinfo --formats
```

Supported Formats:

```
PCIDSK -raster,vector- (rw+v): PCIDSK Database File
```

```
CSV -vector- (rw+v): Comma Separated Value (.csv)
```

```
GML -vector- (rw+v): Geography Markup Language (GML)
```

```
KML -vector- (rw+v): Keyhole Markup Language (KML)
```

```
GeoJSON -vector- (rw+v): GeoJSON
```

```
... many more ...
```

```
MBTiles -raster,vector- (rw+v): MBTiles
```

```
OGCAPI -raster,vector- (rov): OGCAPI
```

```
ESRI Shapefile -vector- (rw+v): ESRI Shapefile
```

```
SQLite -vector- (rw+v): SQLite / Spatialite
```

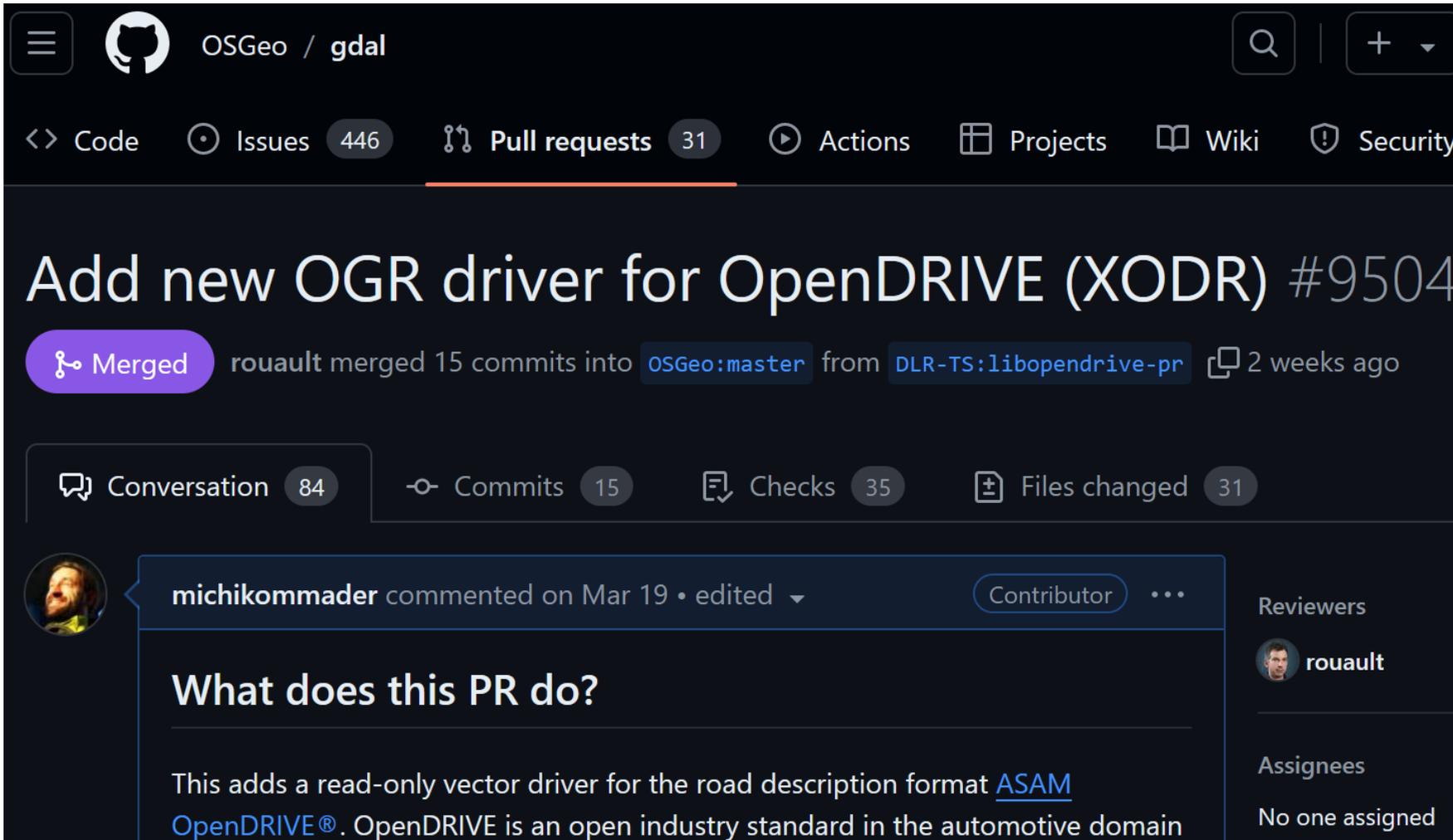
```
TIGER -vector- (rov): U.S. Census TIGER/Line
```

```
XODR -vector- (rov): OpenDRIVE - Open Dynamic Road Information for Vehicle Environment
```

**Yay!**

# Make OpenDRIVE geometries GISable

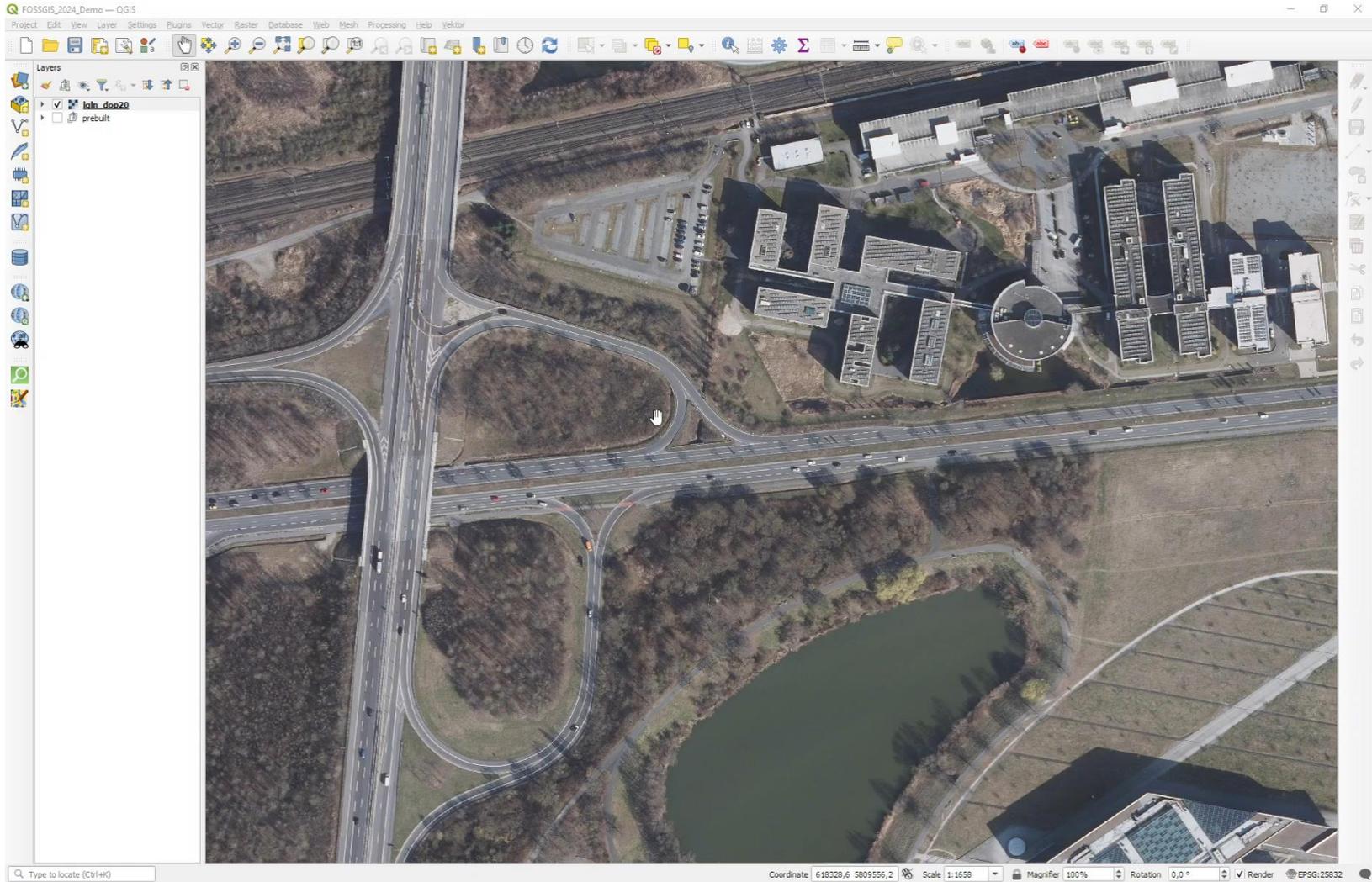
## Available in GDAL 3.10, try it out!

A screenshot of a GitHub pull request page. The repository is 'OSGeo / gdal'. The pull request title is 'Add new OGR driver for OpenDRIVE (XODR) #9504'. It shows that 'rouault' merged 15 commits into 'OSGeo:master' from 'DLR-TS:libopendrive-pr' two weeks ago. The pull request is marked as 'Merged'. Below the merge information, there are statistics: 84 conversations, 15 commits, 35 checks, and 31 files changed. A comment from 'michikommader' dated Mar 19 asks 'What does this PR do?'. The comment text reads: 'This adds a read-only vector driver for the road description format [ASAM OpenDRIVE®](#). OpenDRIVE is an open industry standard in the automotive domain'. On the right side, the 'Reviewers' section shows 'rouault' and the 'Assignees' section shows 'No one assigned'.

[dlr-ts.github.io/gdal-opendrive-how-to](https://dlr-ts.github.io/gdal-opendrive-how-to)

# Make OpenDRIVE geometries GISable

## QGIS demo



noch automatisiert

# More tools for ASAM OpenDRIVE

**Open***DRIVE*

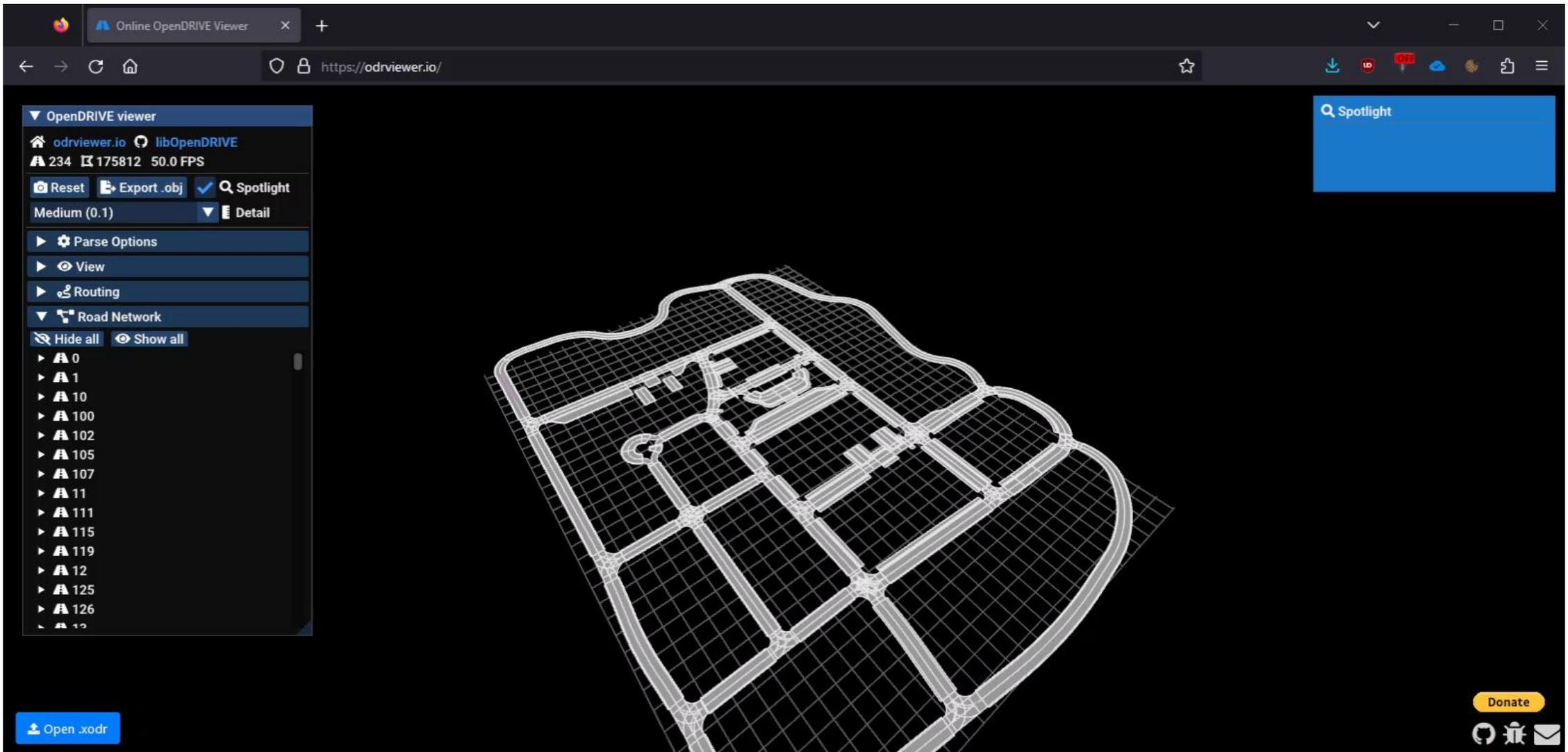
# Tools for OpenDRIVE



- Proprietary software exists → expensive and/or with little GIS interoperability
- Growing community: [github.com/beneschwab/awesome-openx](https://github.com/beneschwab/awesome-openx) 

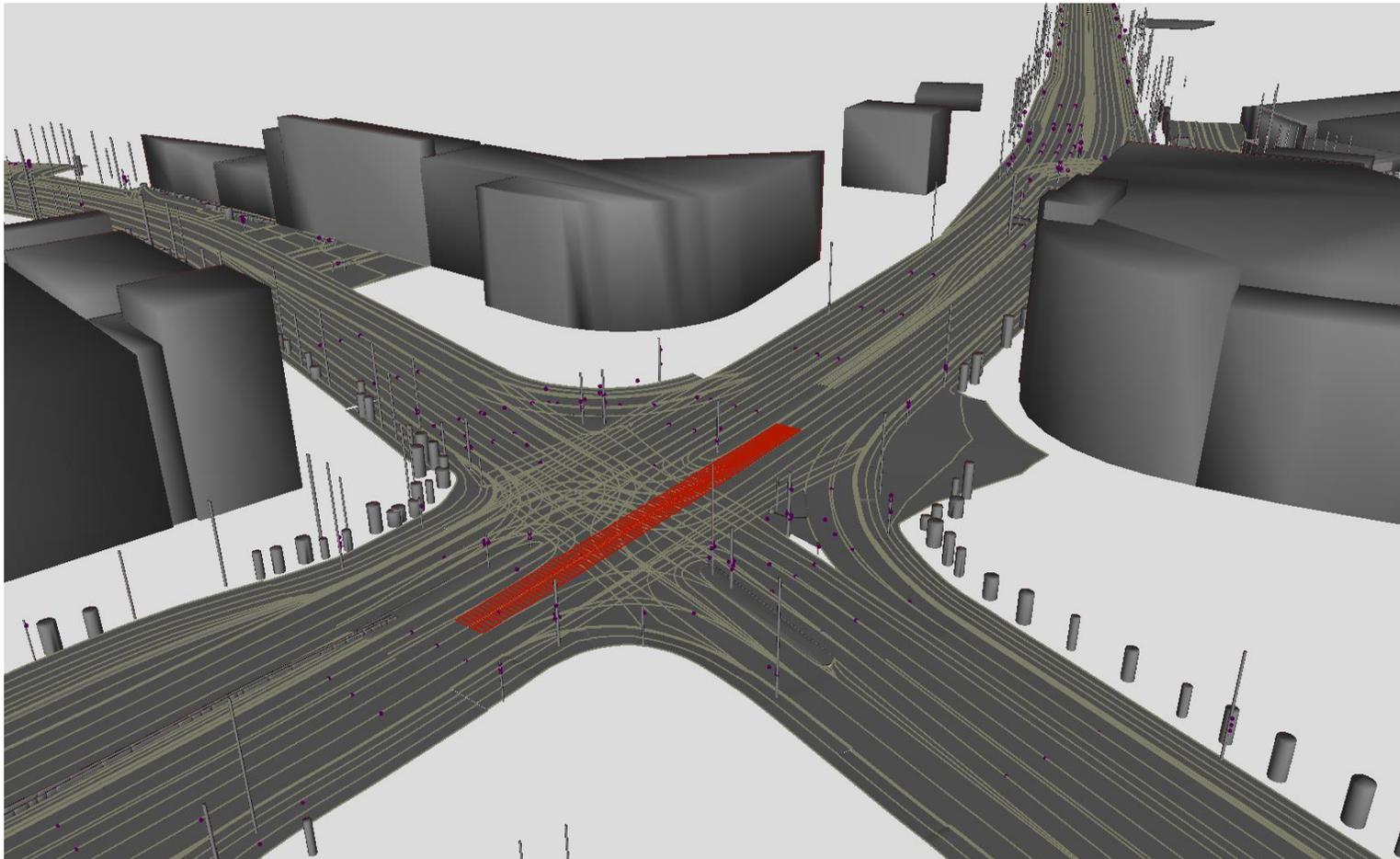
# Tools for OpenDRIVE

## odrviewer.io, also using libOpenDRIVE



# Tools for OpenDRIVE

r:trân (rtron.io), conversion to OGC CityGML 3.0



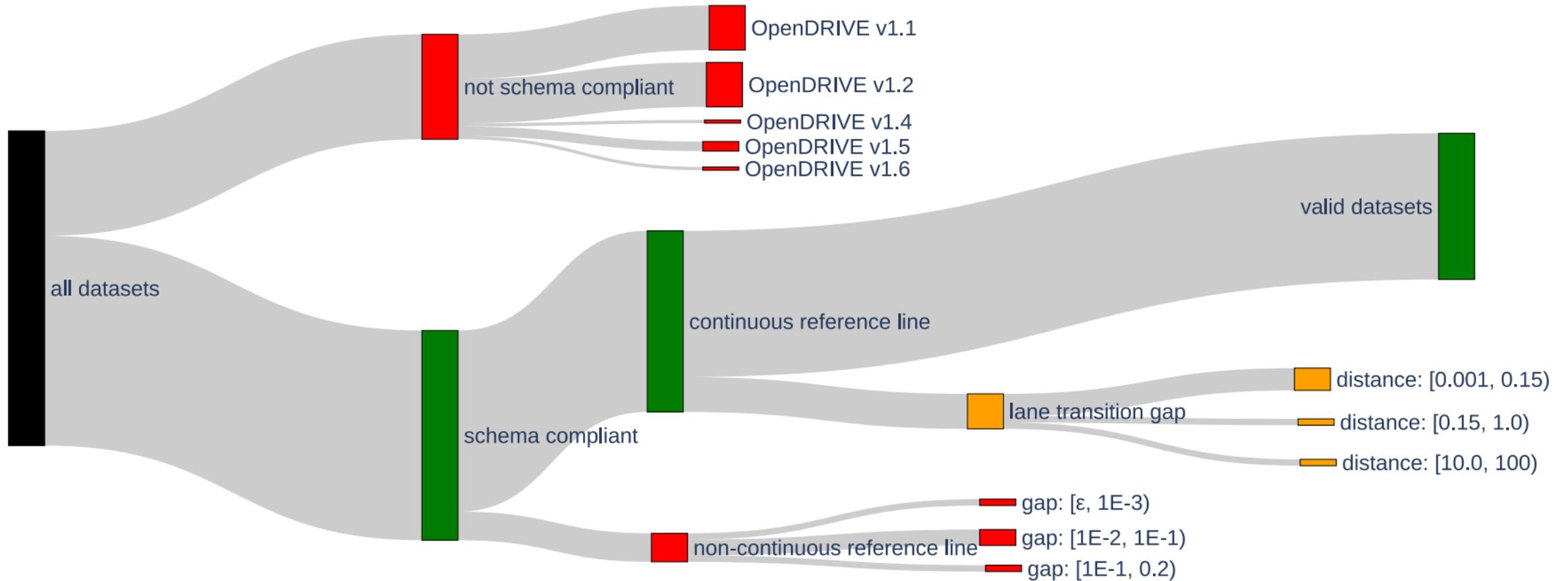
Property	Value
Feature Type	Road
Coordinate System	<a href="#">EPSG:32632</a>
Dimension	3D
Number of Vertices	768
Min Extents	678819.6072548759, 5405772.029156608, 418.7514057725761
Max Extents	678866.4587420645, 5405787.700486677, 418.97760792542...
▼ <b>Attributes (60)</b>	
citygml_feature_role (encoded: UTF-16LE)	cityObjectMember
citygml_level_of_detail(0) (encoded: UTF-16LE)	2
citygml_target_uri (encoded: UTF-16LE)	<a href="http://www.opengis.net/citygml/transportation/2.0">http://www.opengis.net/citygml/transportation/2.0</a>
fme_aggregate (string)	fme_aggregate
fme_type (string)	fme_surface
gml_id (encoded: UTF-16LE)	UUID_065ce01e-2791-4eb6-8cb0-63f208c85e16
gml_name (encoded: UTF-16LE)	LaneSurface
gml_parent_id (encoded: UTF-16LE)	fme-gen-1527720d-ec1a-409c-8b71-8184256fcoa4
opendrive_identifier_laneId (encoded: UTF-16LE)	-1
opendrive_identifier_laneSectionId (encoded: UTF-16LE)	3
opendrive_identifier_modelDate (encoded: UTF-16LE)	13-06-18
opendrive_identifier_modelName (encoded: UTF-16LE)	SAVE_Ingolstadt
opendrive_identifier_modelVendor (encoded: UTF-16LE)	3D Mapping Solutions
opendrive_identifier_roadId (encoded: UTF-16LE)	3124021
opendrive_identifier_sourceFileHashSha256 (encoded: UTF-16LE)	75f5186976d879be2bb8e9dc8b3c4c9d1384cc55ac51547e01...
opendrive_identifier_sourceFileName (encoded: UTF-16LE)	2019-01-25_SAVE_Ingolstadt_Prio1
opendrive_lane_level (encoded: UTF-16LE)	false
opendrive_lane_material_curvePositionStart_0 (encoded: UTF-16LE)	0.0
opendrive_lane_material_friction_0 (encoded: UTF-16LE)	1.0
opendrive_lane_material_roughness_0 (encoded: UTF-16LE)	0.0
opendrive_lane_material_surface_0 (encoded: UTF-16LE)	asphalt
opendrive_lane_roadMark_color_0 (encoded: UTF-16LE)	STANDARD
opendrive_lane_roadMark_color_1 (encoded: UTF-16LE)	STANDARD
opendrive_lane_roadMark_color_2 (encoded: UTF-16LE)	STANDARD
opendrive_lane_roadMark_color_3 (encoded: UTF-16LE)	STANDARD
opendrive_lane_roadMark_color_4 (encoded: UTF-16LE)	STANDARD
opendrive_lane_roadMark_color_5 (encoded: UTF-16LE)	STANDARD
opendrive_lane_roadMark_curvePositionStart_0 (encoded: UTF-16LE)	0.0
opendrive_lane_roadMark_curvePositionStart_1 (encoded: UTF-16LE)	6.9048
opendrive_lane_roadMark_curvePositionStart_2 (encoded: UTF-16LE)	9.952
opendrive_lane_roadMark_curvePositionStart_3 (encoded: UTF-16LE)	15.8268
opendrive_lane_roadMark_curvePositionStart_4 (encoded: UTF-16LE)	24.9801
opendrive_lane_roadMark_curvePositionStart_5 (encoded: UTF-16LE)	34.0587
opendrive_lane_roadMark_material_0 (encoded: UTF-16LE)	standard
opendrive_lane_roadMark_material_1 (encoded: UTF-16LE)	standard
opendrive_lane_roadMark_material_2 (encoded: UTF-16LE)	standard
opendrive_lane_roadMark_material_3 (encoded: UTF-16LE)	standard
opendrive_lane_roadMark_material_4 (encoded: UTF-16LE)	standard
opendrive_lane_roadMark_material_5 (encoded: UTF-16LE)	standard
opendrive_lane_roadMark_type_0 (encoded: UTF-16LE)	NONE
opendrive_lane_roadMark_type_1 (encoded: UTF-16LE)	BROKEN
opendrive_lane_roadMark_type_2 (encoded: UTF-16LE)	NONE
opendrive_lane_roadMark_type_3 (encoded: UTF-16LE)	BROKEN
opendrive_lane_roadMark_type_4 (encoded: UTF-16LE)	NONE
opendrive_lane_roadMark_type_5 (encoded: UTF-16LE)	BROKEN
opendrive_lane_roadMark_weight_0 (encoded: UTF-16LE)	STANDARD

Features Selected: 1 of 1

DOI 10.5281/zenodo.7702313

# Tools for OpenDRIVE

r:trân (rtron.io), with comprehensive validation



Schwab, B. and Kolbe, T. H.: VALIDATION OF PARAMETRIC OPENDRIVE ROAD SPACE MODELS, ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., X-4/W2-2022, 257–264, <https://doi.org/10.5194/isprs-annals-X-4-W2-2022-257-2022>, 2022.

# What's next?



- Adding features to libOpenDRIVE and bundling binary releases
- Stronger coupling of ASAM OpenDRIVE with OGC CityGML 3.0  
→ [Transportation area concept ideation workshop](#) on 24<sup>th</sup> July
- Subject in new OGC “Transportation and Mobility Domain Working Group“?
- Similar GDAL driver for [railML](#) and other transport-domain-specific models?

# Questions?



What: Improving interoperability between OpenDRIVE HD map data and GIS using GDAL

Where: FOSS4G Europe, Tartu

When: 2024-07-05

Who: michael.scholz@dlr.de

How: Content CC BY 4.0 DLR, unless stated otherwise  
Conference logo CC BY-ND 4.0 Raivo Aunap