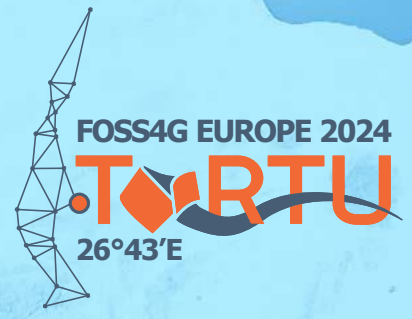
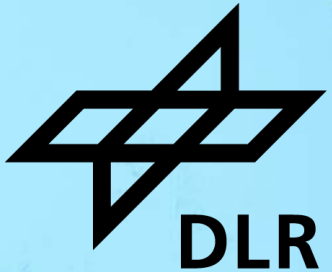
Improving interoperability between OpenDRIVE HD map data and GIS using GDAL

FOSS4G Europe

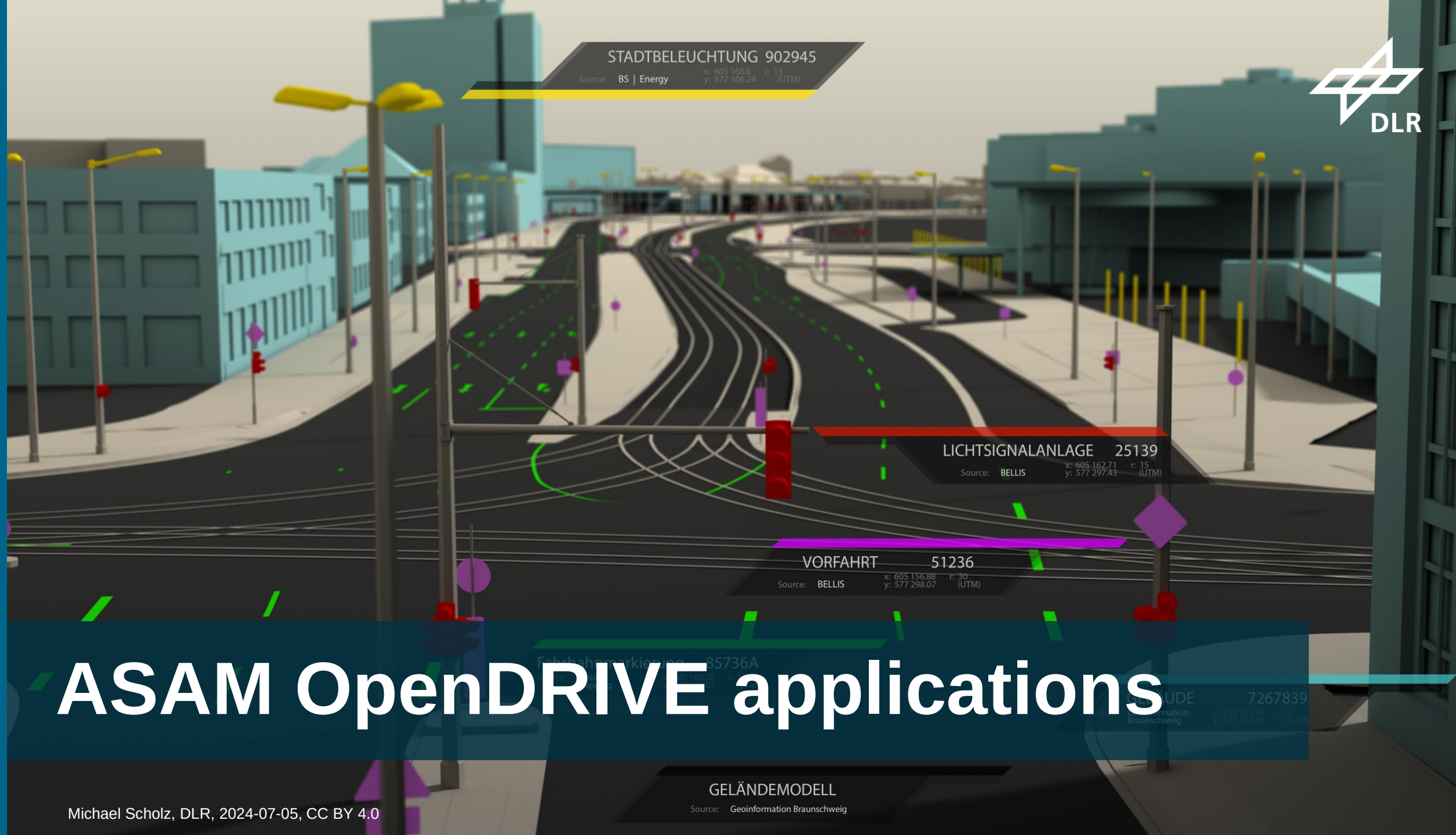
2024-07-05, Tartu

Michael Scholz





Institute of Transportation Systems
Our research infrastructure

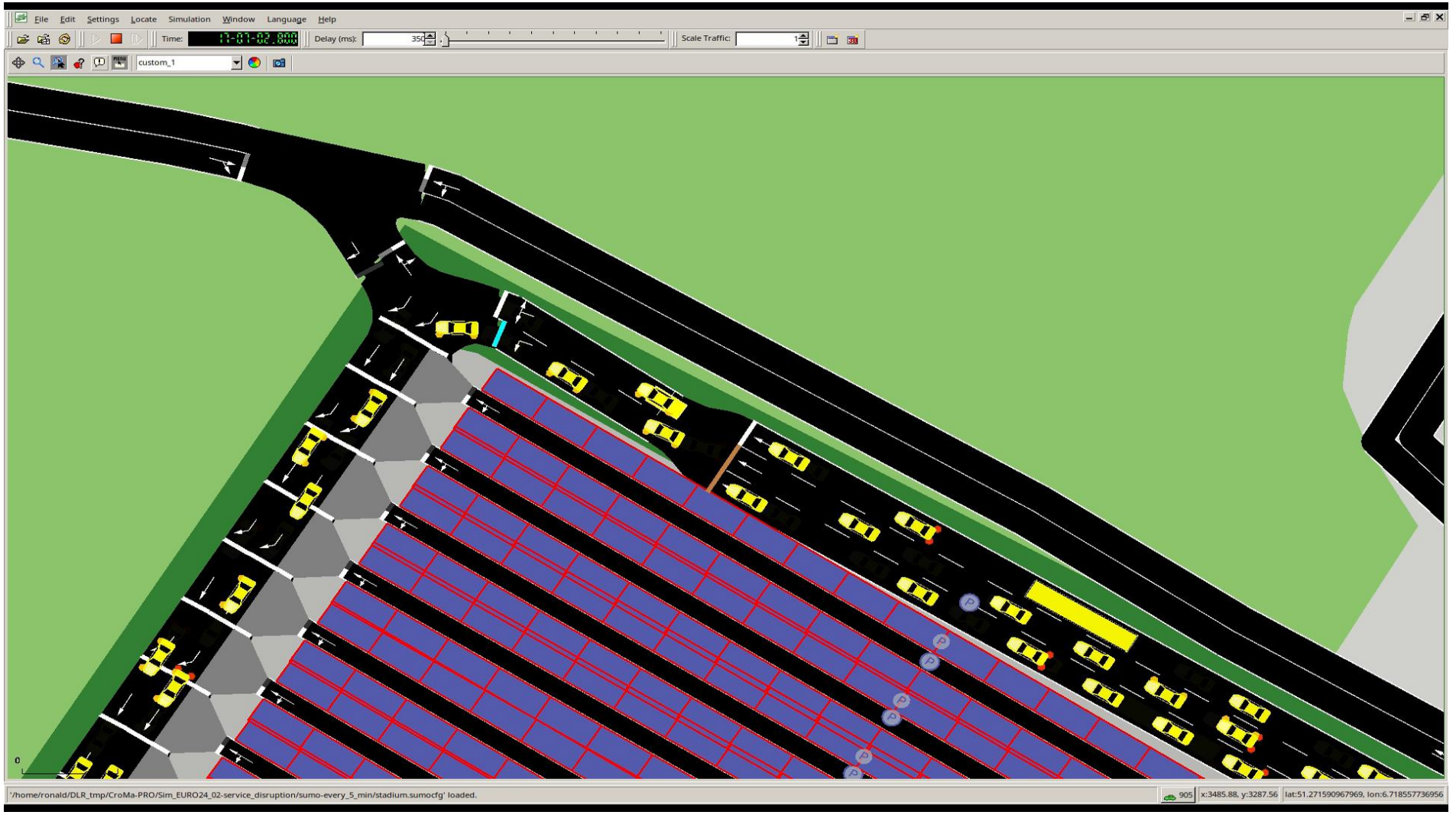


ASAM OpenDRIVE applications

OpenDRIVE applications
Urban digital twins for simulation

https://youtu.be/LDSvDEsvnig

OpenDRIVE applications
Microscopic traffic simulation → SUMO



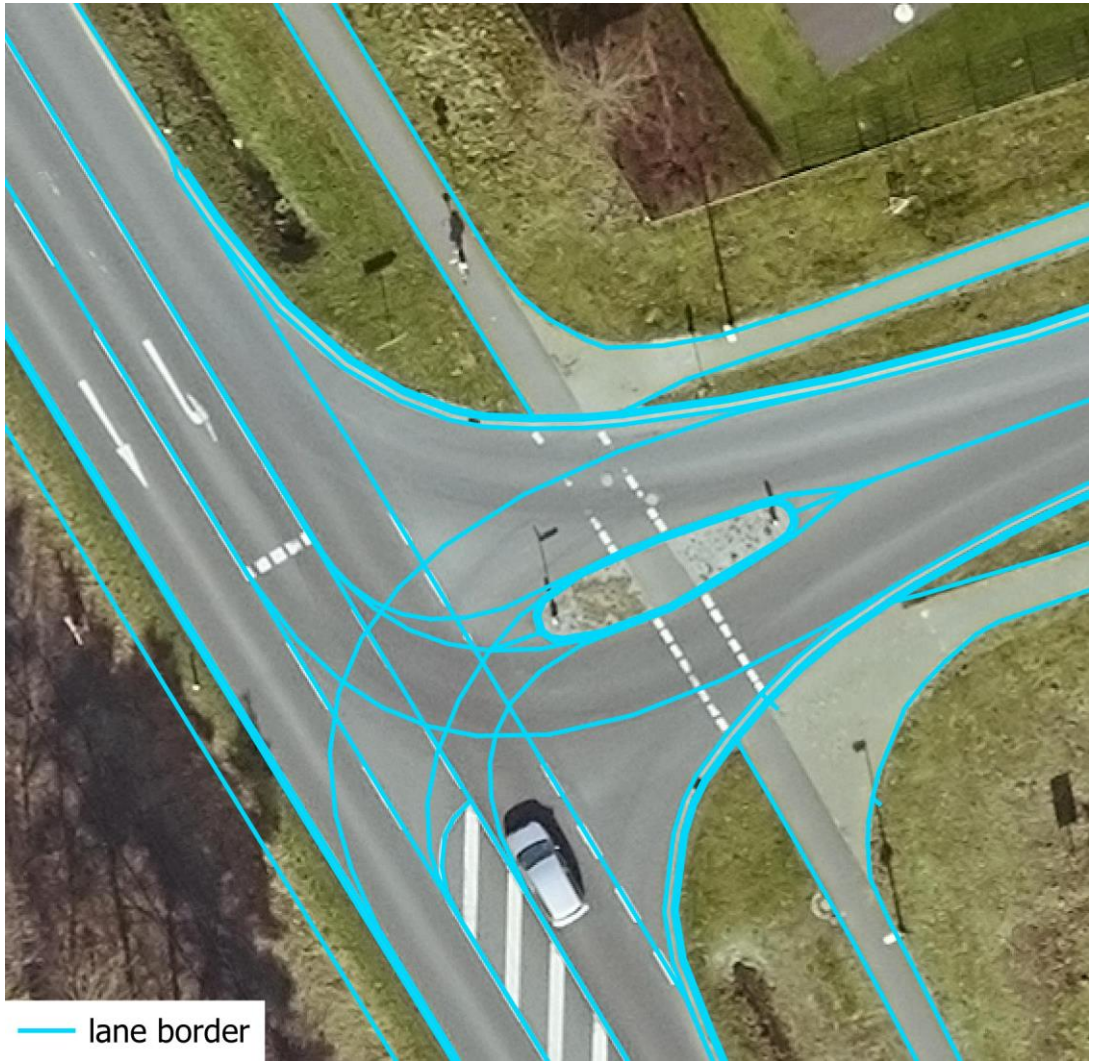
OpenDRIVE applications
Automated driving

https://youtu.be/RDXXBqL42W8

What does “HD” mean?

Modelling of road space on lane level

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



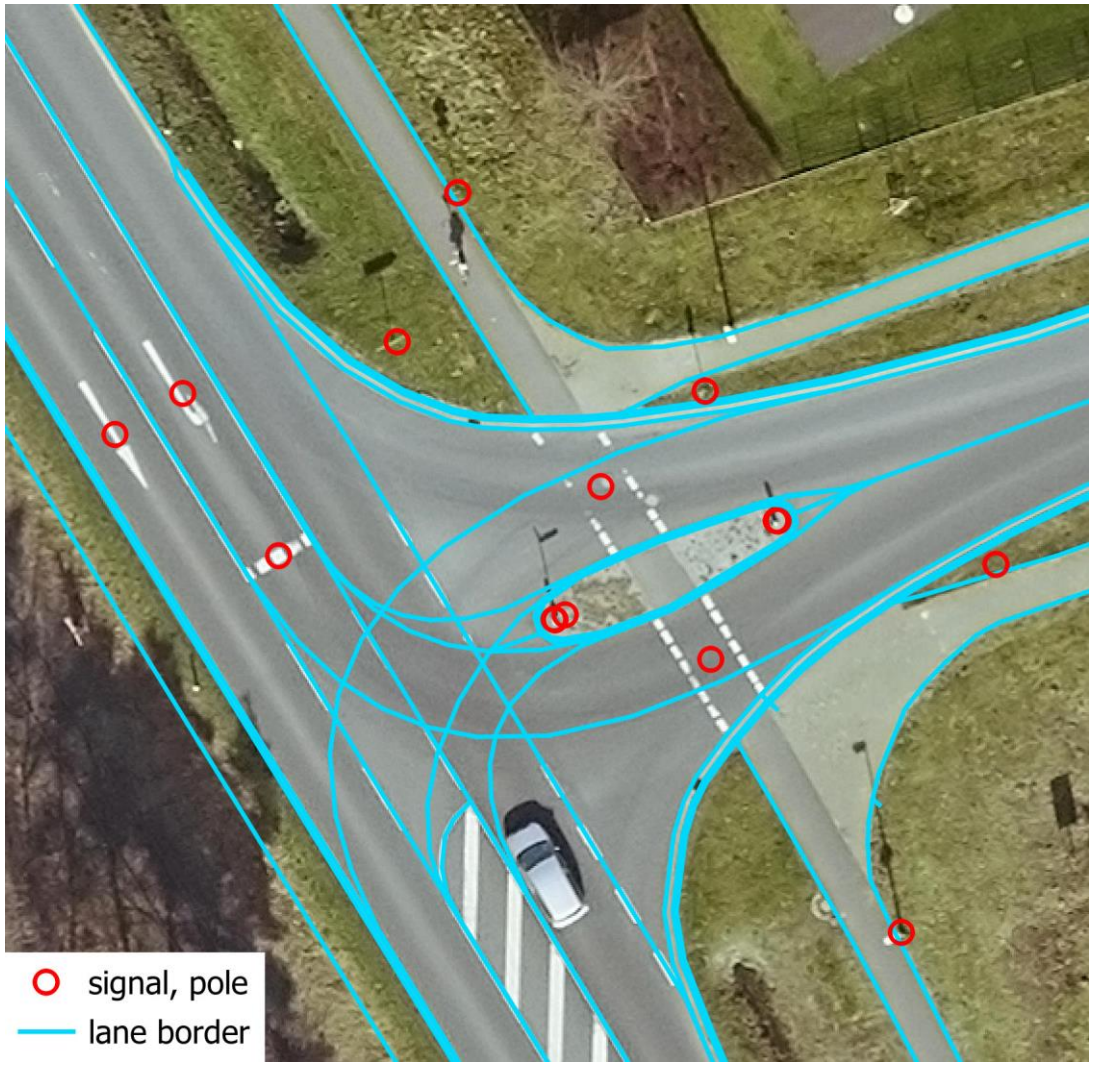
What does “HD” mean?

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

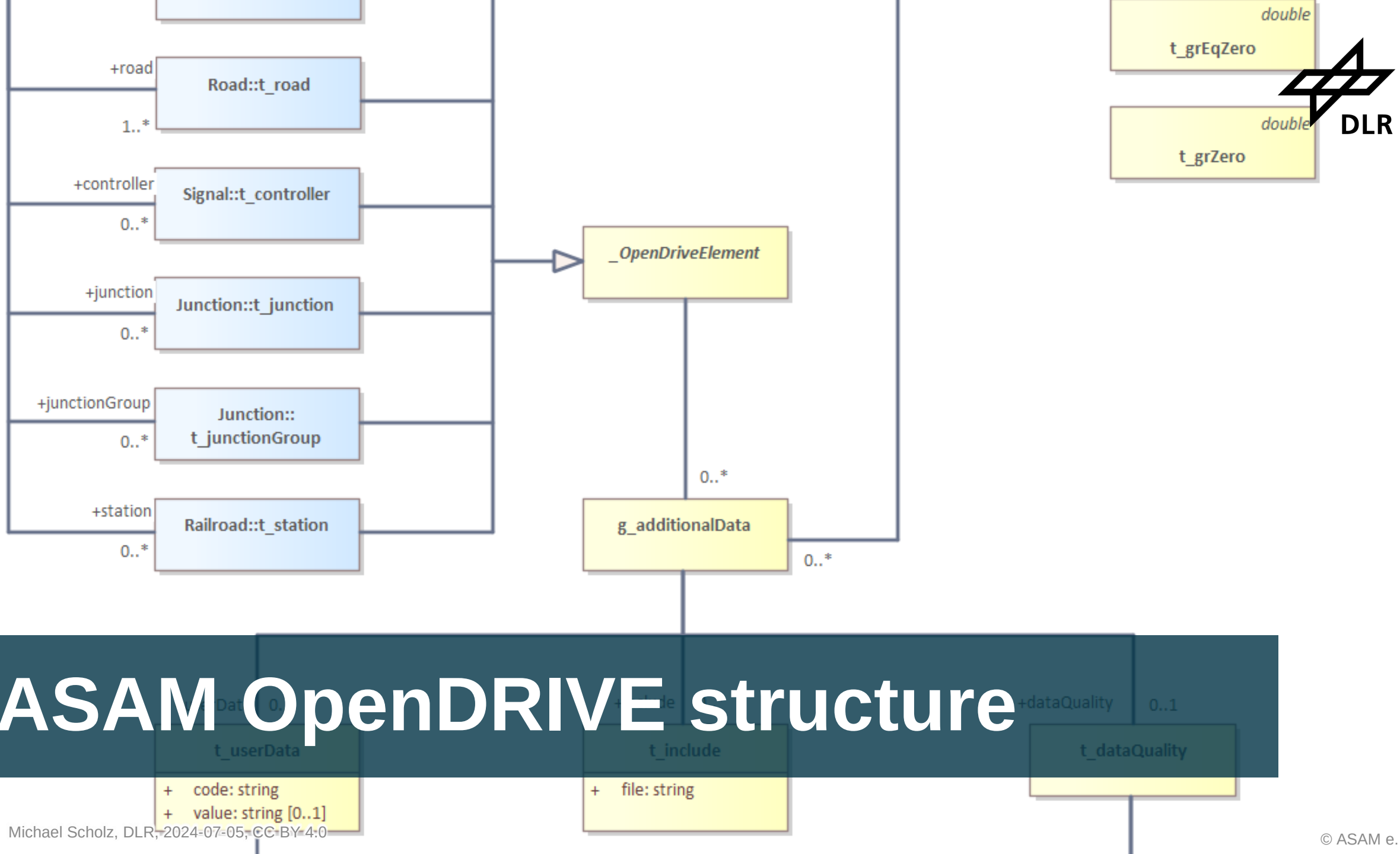
- Application-dependent 😛
  - Absolute GNSS coordinate error < 20 cm (“trueness”)?
  - Relative coordinate error < 5 cm (“precision”)?

Data acquisition

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

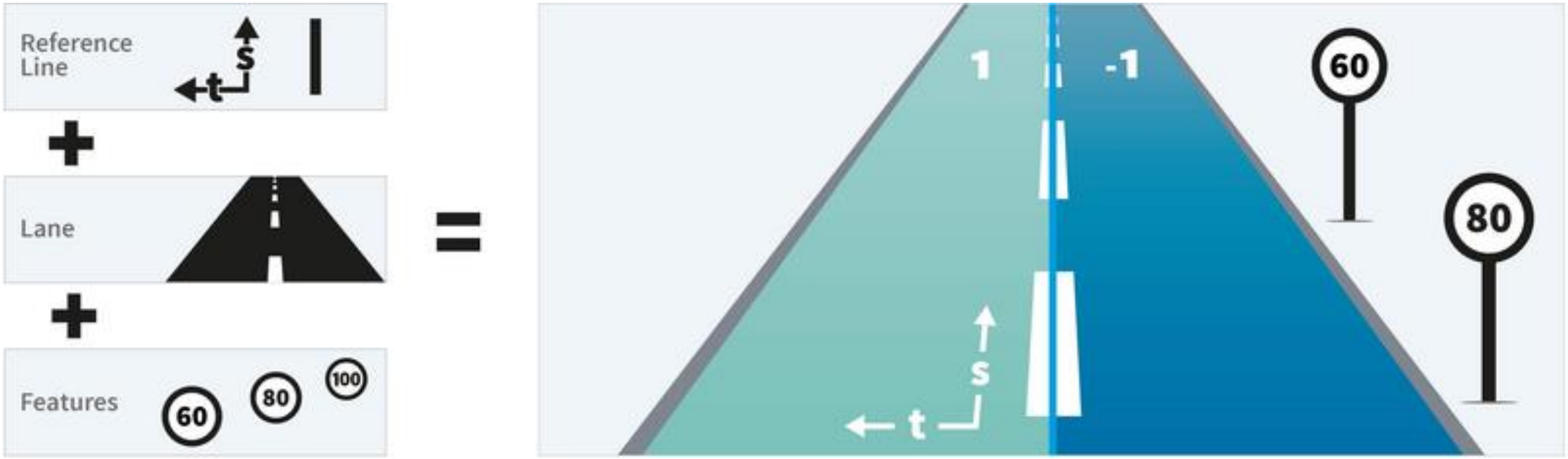
A “problem” with different perspectives

- 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!

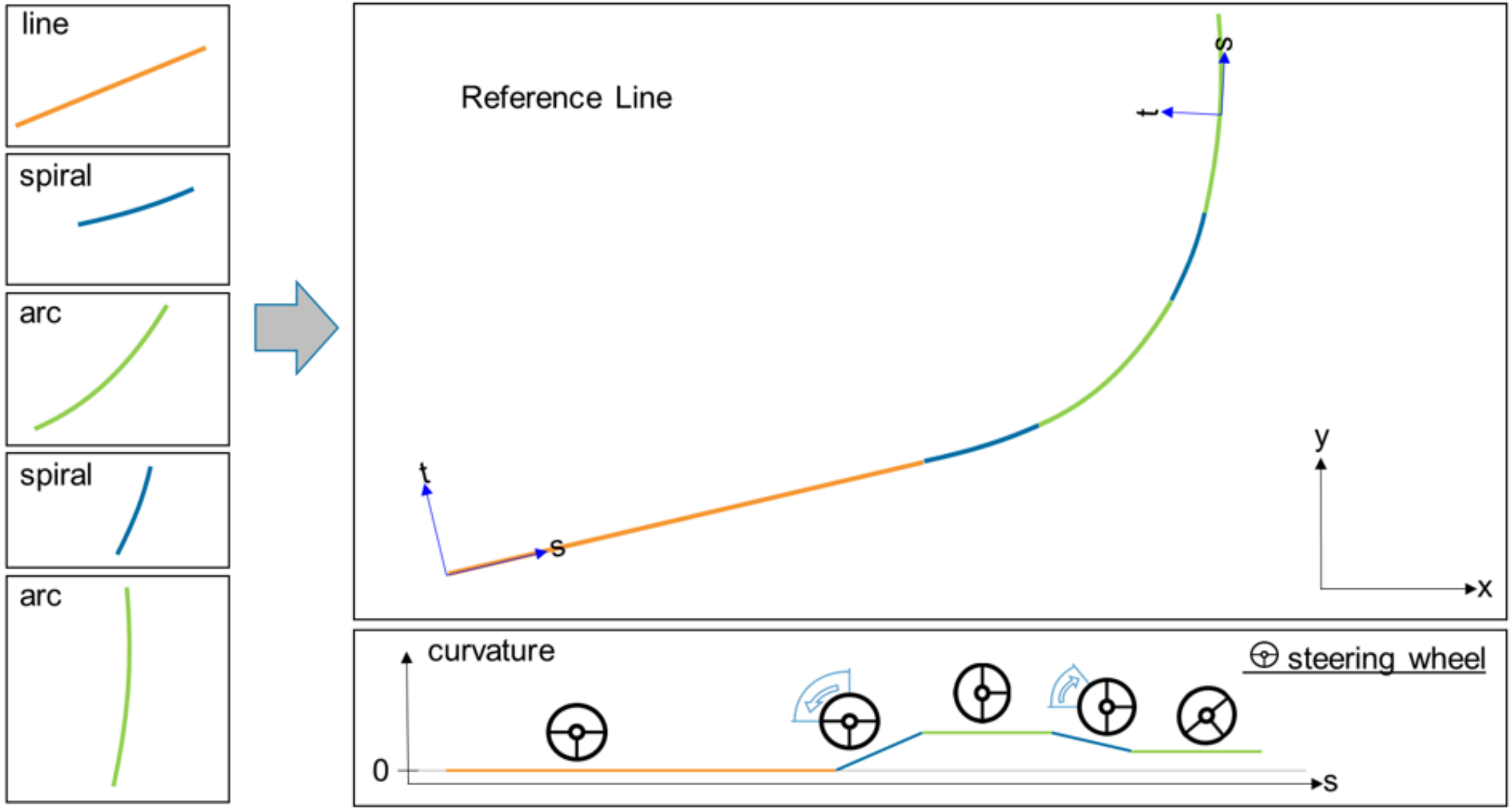


ASAM OpenDRIVE structure

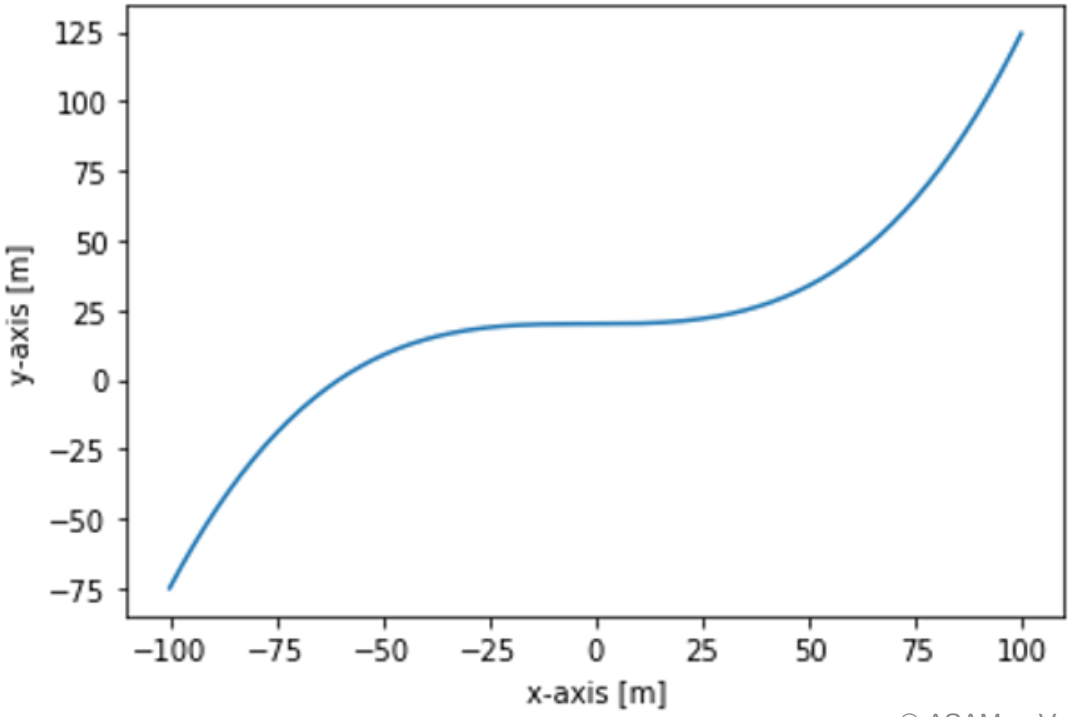
Linearly referenced geometries



Parametric geometries



Parametric geometries
Cubic polynomials




```
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        x="6.804539427645e+05"
        y="5.422483642942e+06"
        hdg="5.287405485081e+00"
        length="6.565893957370e+01">
        <paramPoly3
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                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>
```
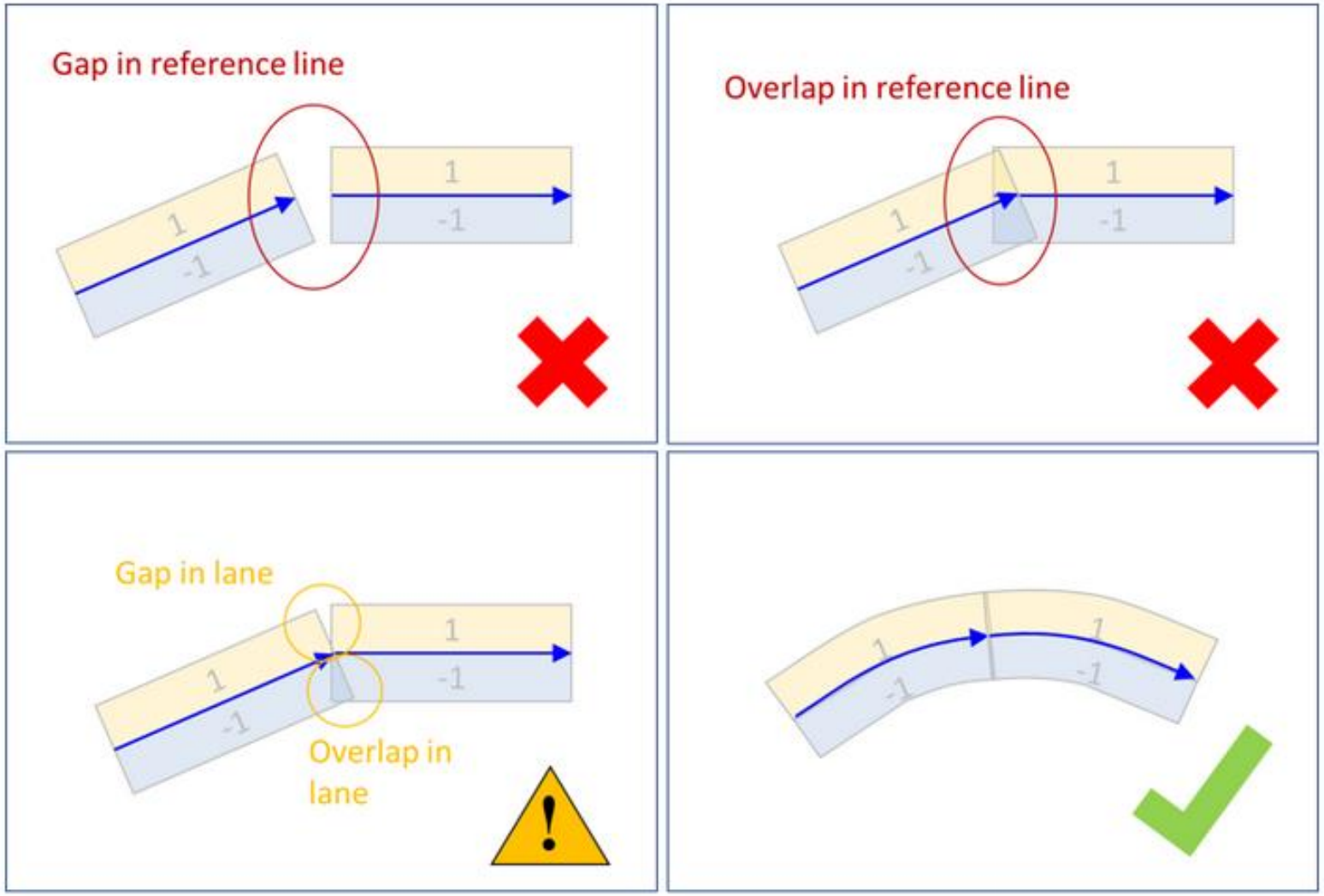

Modelling constraints



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"/>
  <elevationProfile>
  <lateralProfile/>
  <lanes>
    <laneSection>
      <left>
        <lane id="7" type="border">
        <lane id="6" type="shoulder">
        <lane id="5" type="stop">
        <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>
```

Hierarchical data model
With many cross-references

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

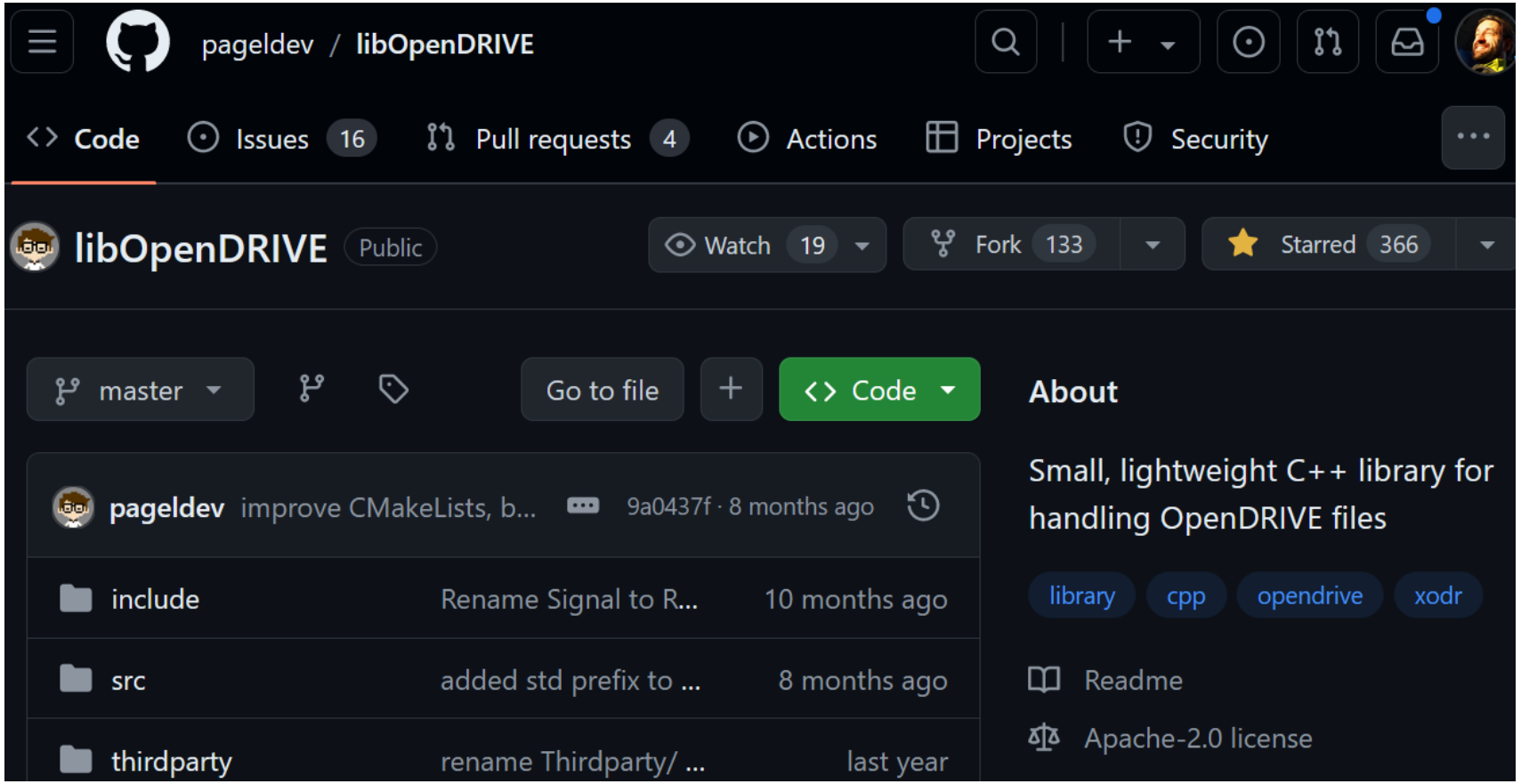
GDAL driver implementation

Geospatial Data Abstraction Library (GDAL)

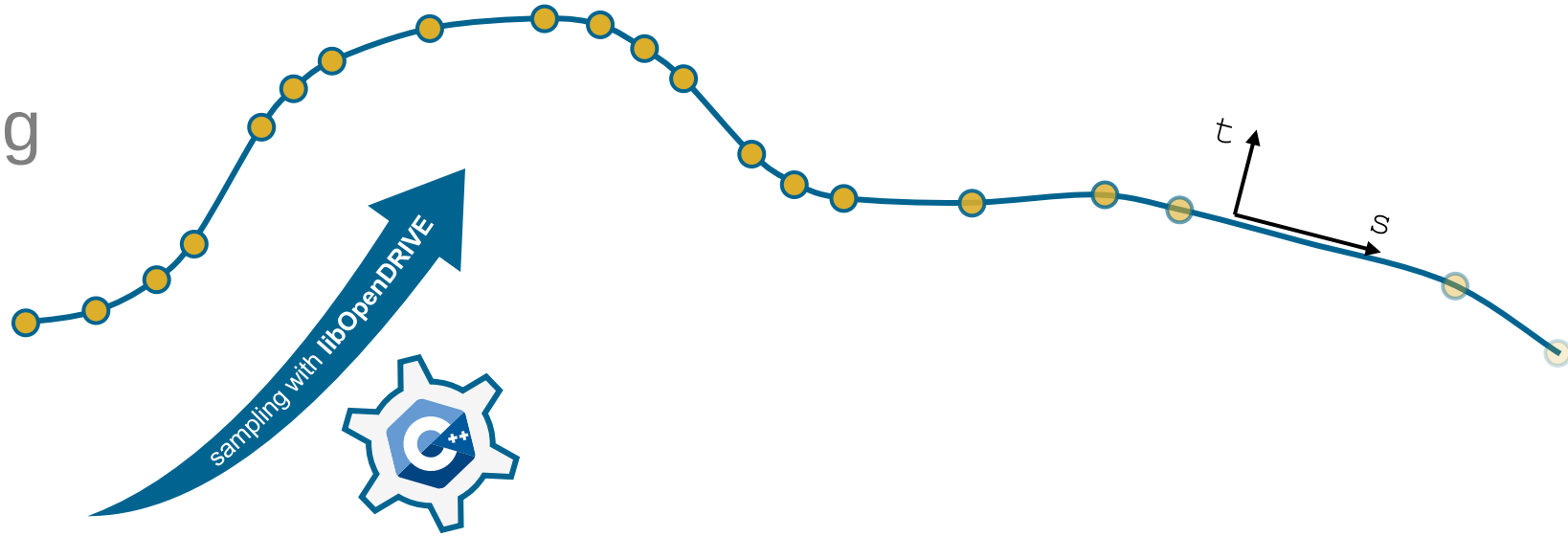
- Wikipedia:
  - “GDAL/OGR provides at least partial support for 154 raster and **93 vector geospatial data formats**”
- Many open and proprietary GIS tools depend on GDAL
- GDAL implements OGC Simple Features as vector data model

Make OpenDRIVE geometries GISable
Sampling with libOpenDRIVE

github.com/pageldev/libOpenDRIVE DOI 10.5281/zenodo.7771708



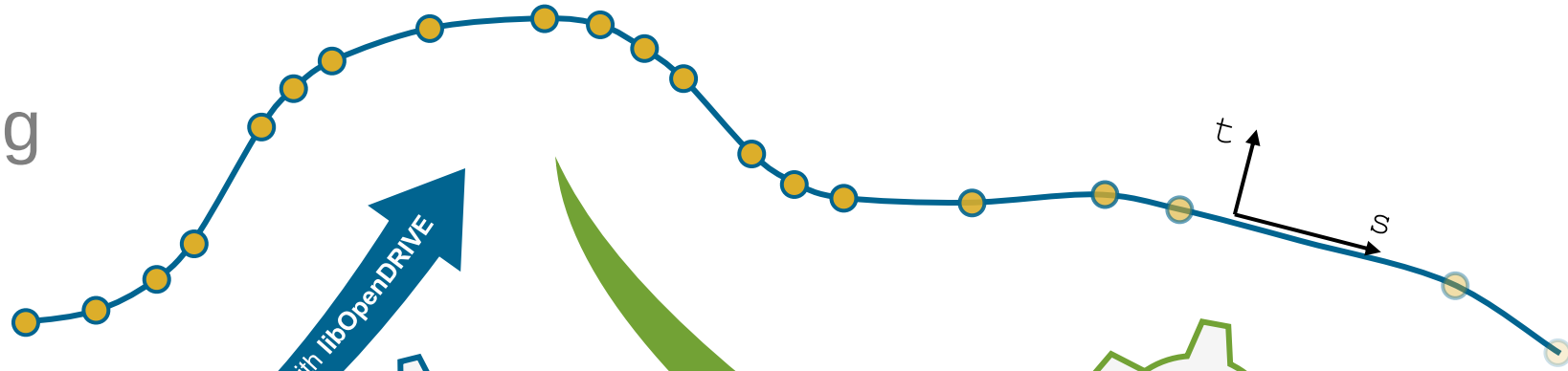
Sampling




```
<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



sampling with **libOpenDRIVE**

translation with **GDAL**

straight into **GIS**

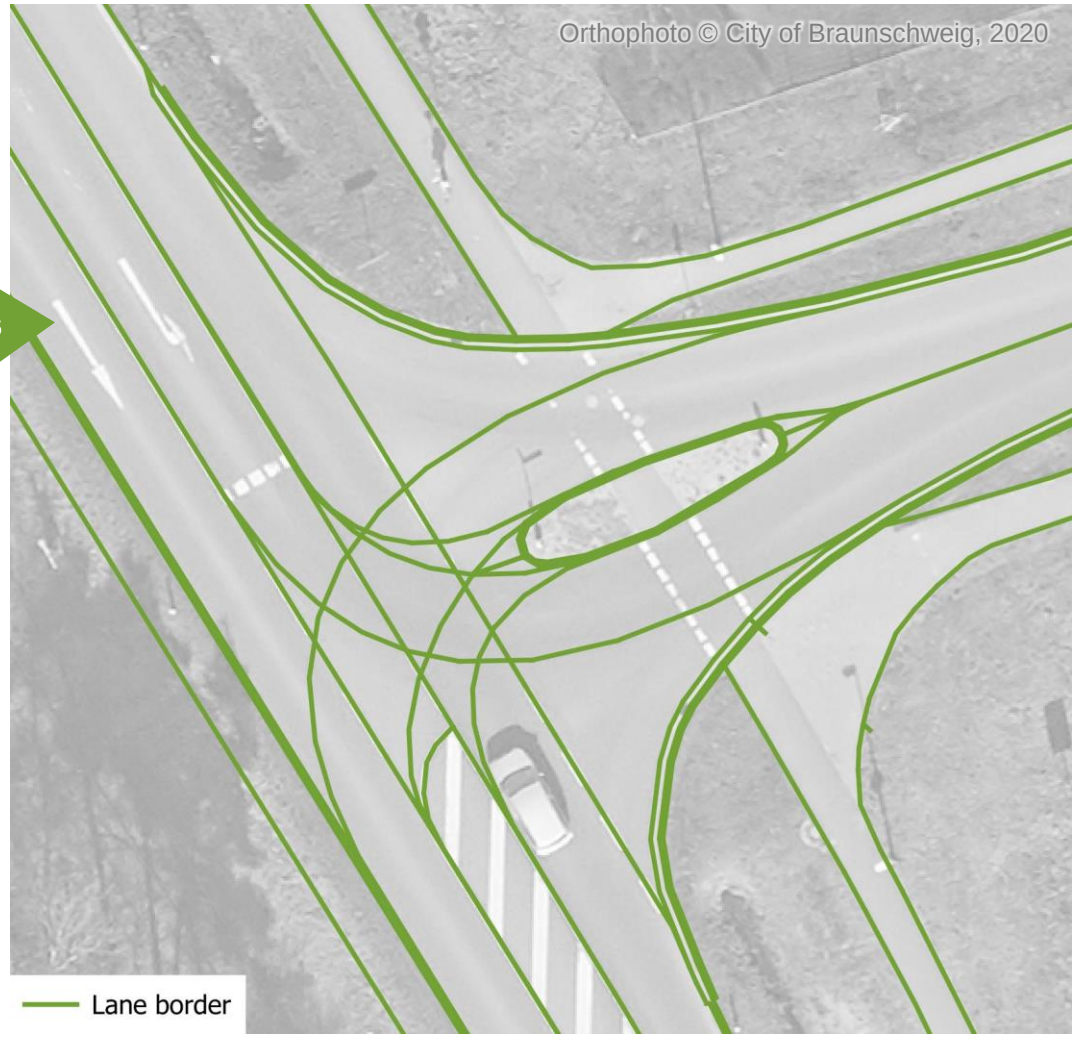
```
<planView>
  <geometry s="0.0" x="604944.1037"
            y="5792860.1272"
            hdg="3.5148"
            length="9.7589">
    <arc curvature="9.0884E-4"/>
  </geometry>
  <geometry s="9.7589" x="604935.03"
            y="5792856.5285"
            hdg="3.5237"
            length="12.0">
 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

OpenDRIVE Model

```
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
`Point`	`signal`
`LineString`	`referenceLine` `laneBorder`

`Polygon`	`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

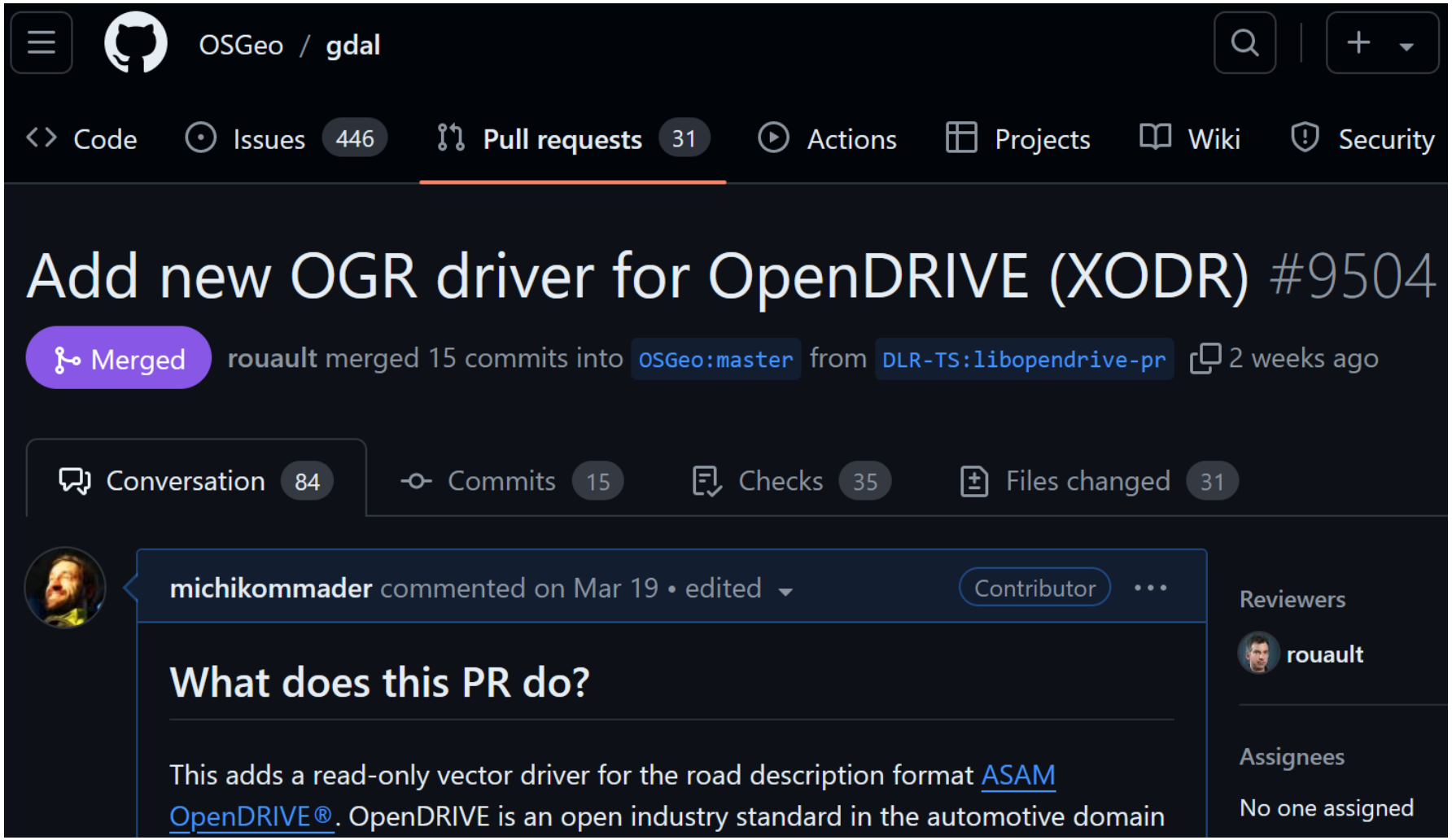
```
user@machine:/dev/gdal$ ogrinfo --formats
Supported Formats:
  PCIDSK -raster,vector- (rw+v): PCIDSK Database File
  CSV -vector- (rw+v): Comma Separated Value (.csv)
  GML -vector- (rw+v): Geography Markup Language (GML)
  KML -vector- (rw+v): Keyhole Markup Language (KML)
  GeoJSON -vector- (rw+v): 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
```

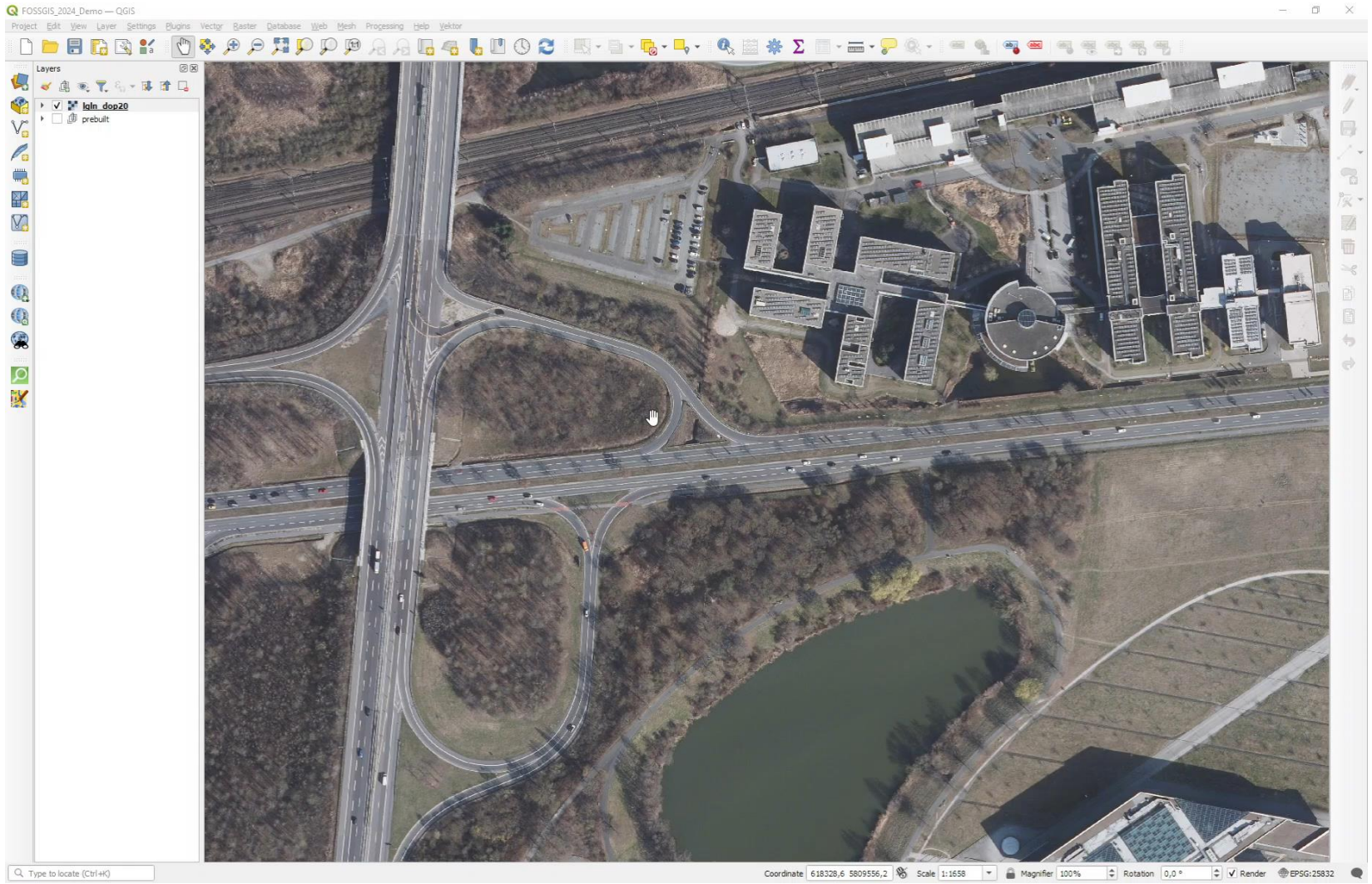
Yay!

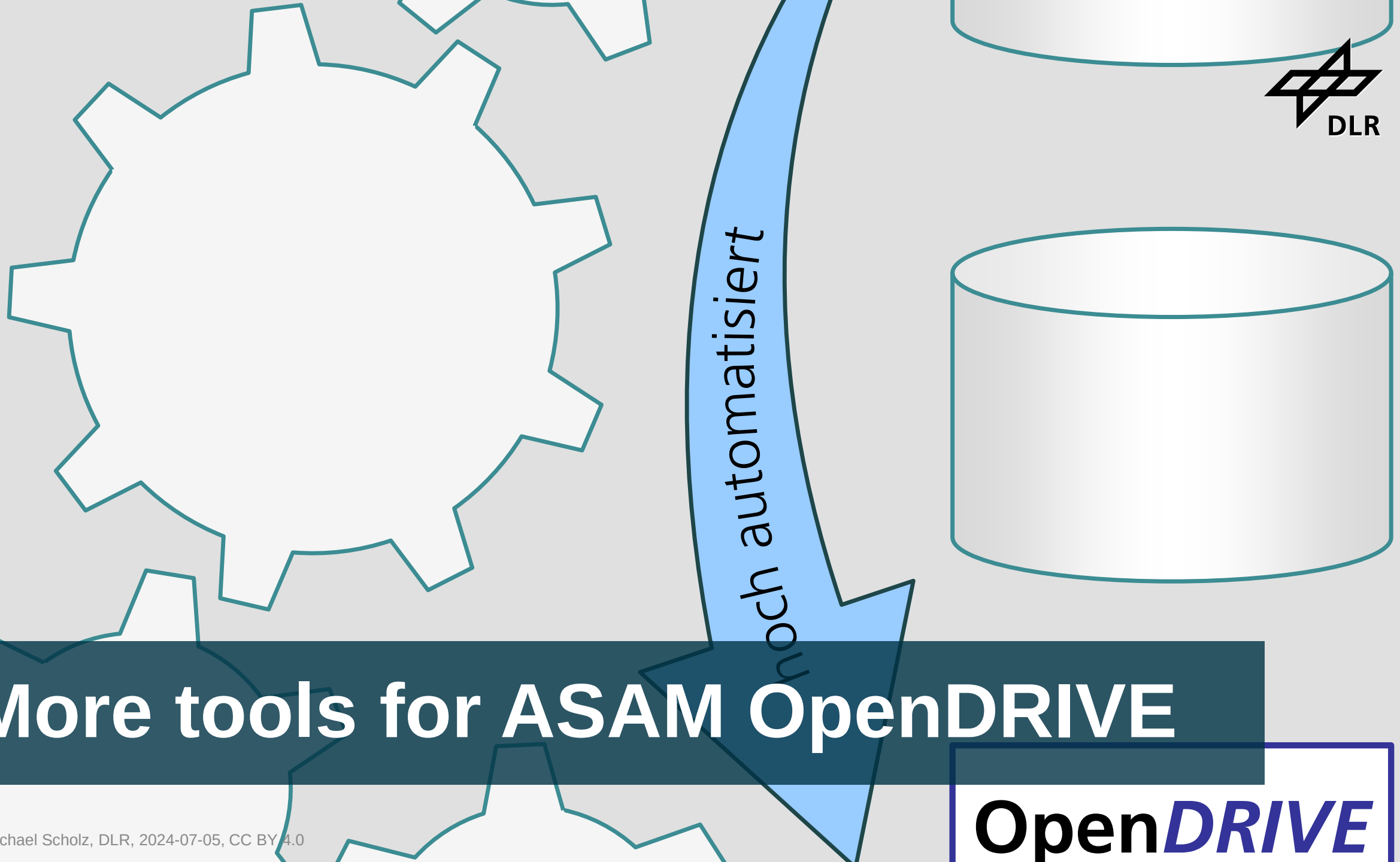
Make OpenDRIVE geometries GISable
Available in GDAL 3.10, try it out!



dlr-ts.github.io/gdal-opendrive-how-to

Make OpenDRIVE geometries GISable
QGIS demo





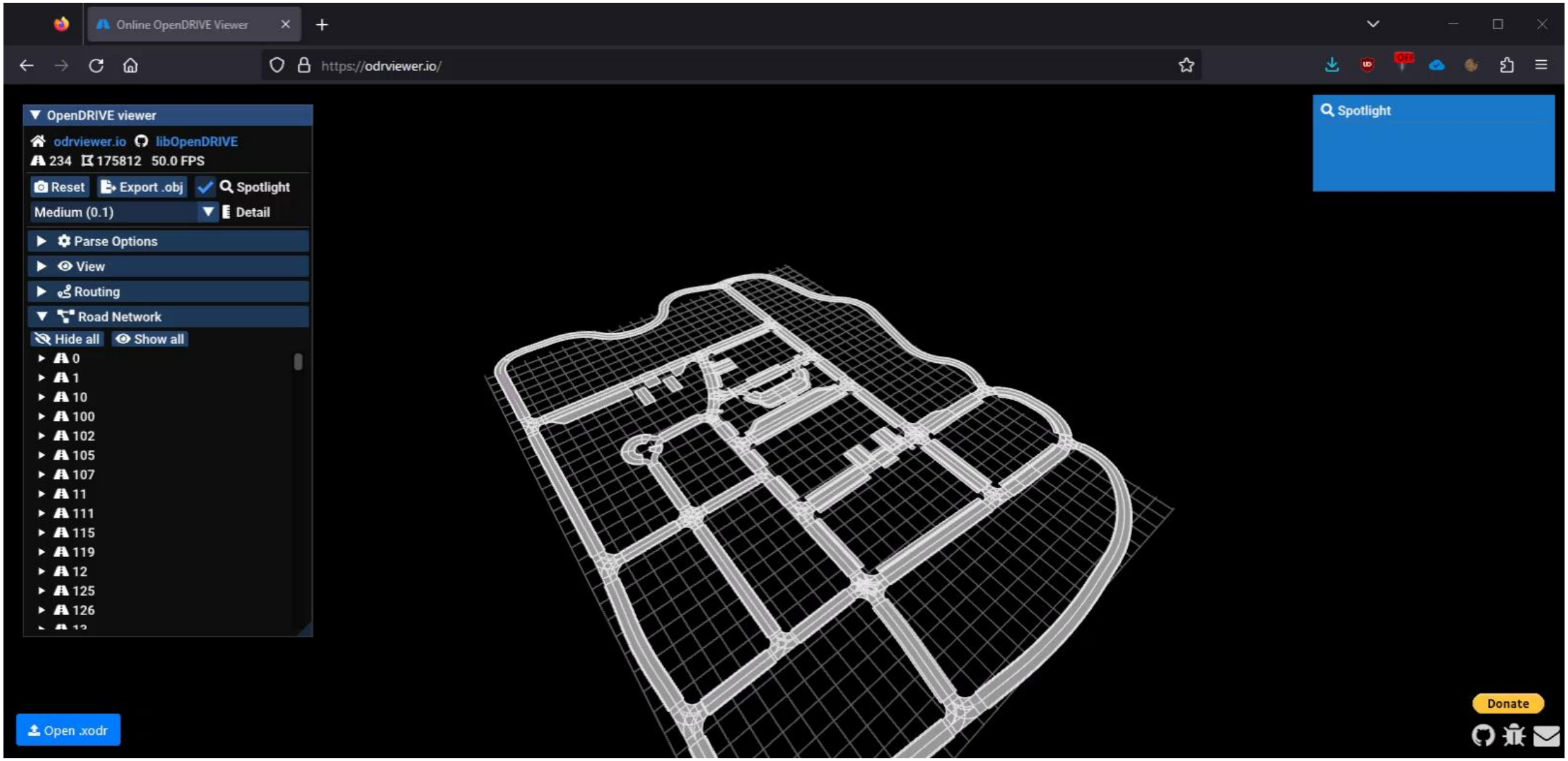
More tools for ASAM OpenDRIVE

OpenDRIVE

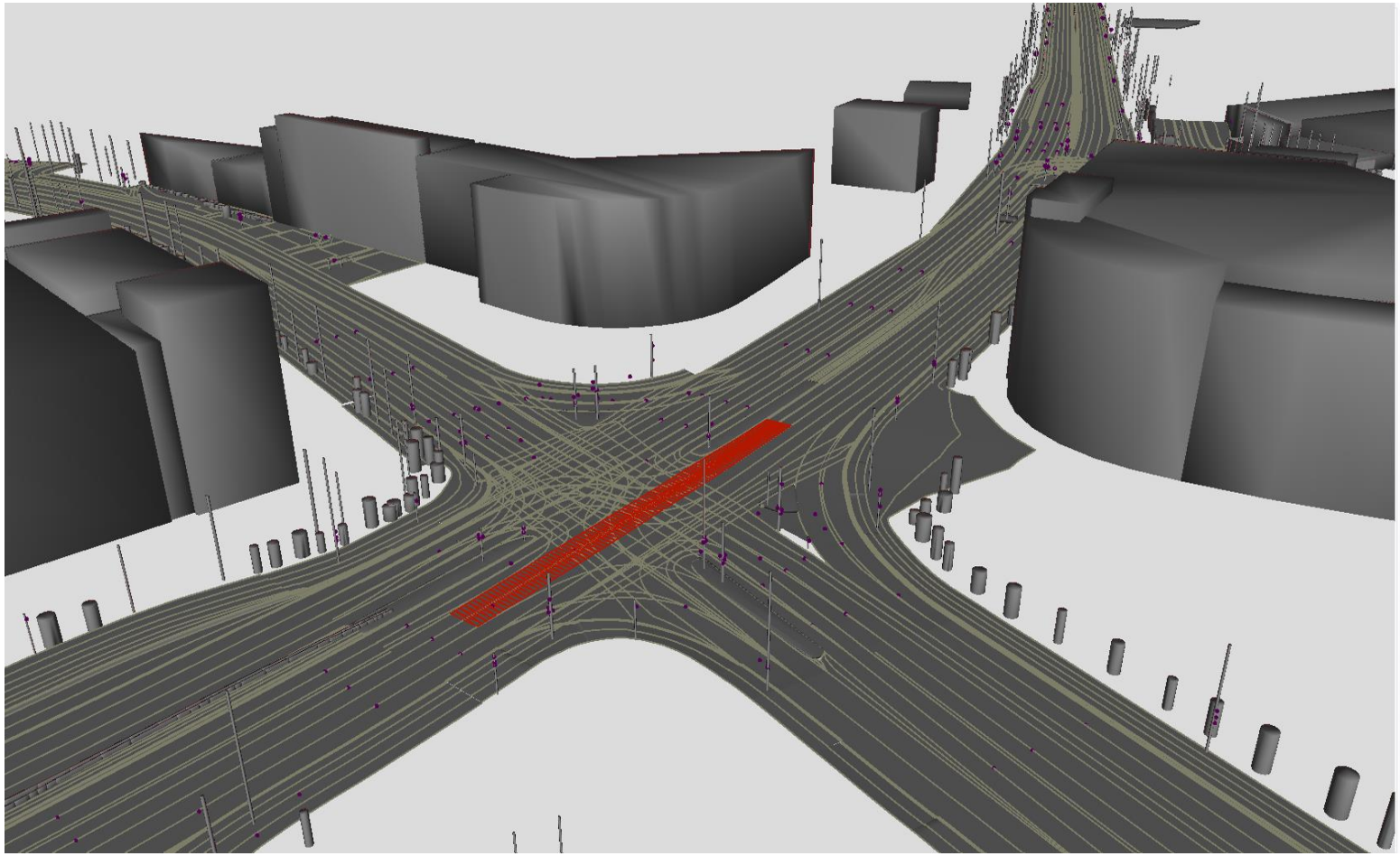
Tools for OpenDRIVE

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

Tools for OpenDRIVE
odrviewer.io, also using libOpenDRIVE



Tools for OpenDRIVE
r:trån (rtron.io), conversion to OGC CityGML 3.0



Property	Value
Feature Type	Road
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Max Extents	678866.4587420645, 5405787.700486677, 418.97760792542…
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citygml_level_of_detail{0} (encoded: UTF-16LE)	2
citygml_target_uri (encoded: UTF-16LE)	http://www.opengis.net/citygml/transportation/2.0
fme_geometry (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
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opendrive_lane_roadMark_color_4 (encoded: UTF-16LE)	STANDARD
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opendrive_lane_roadMark_material_2 (encoded: UTF-16LE)	standard
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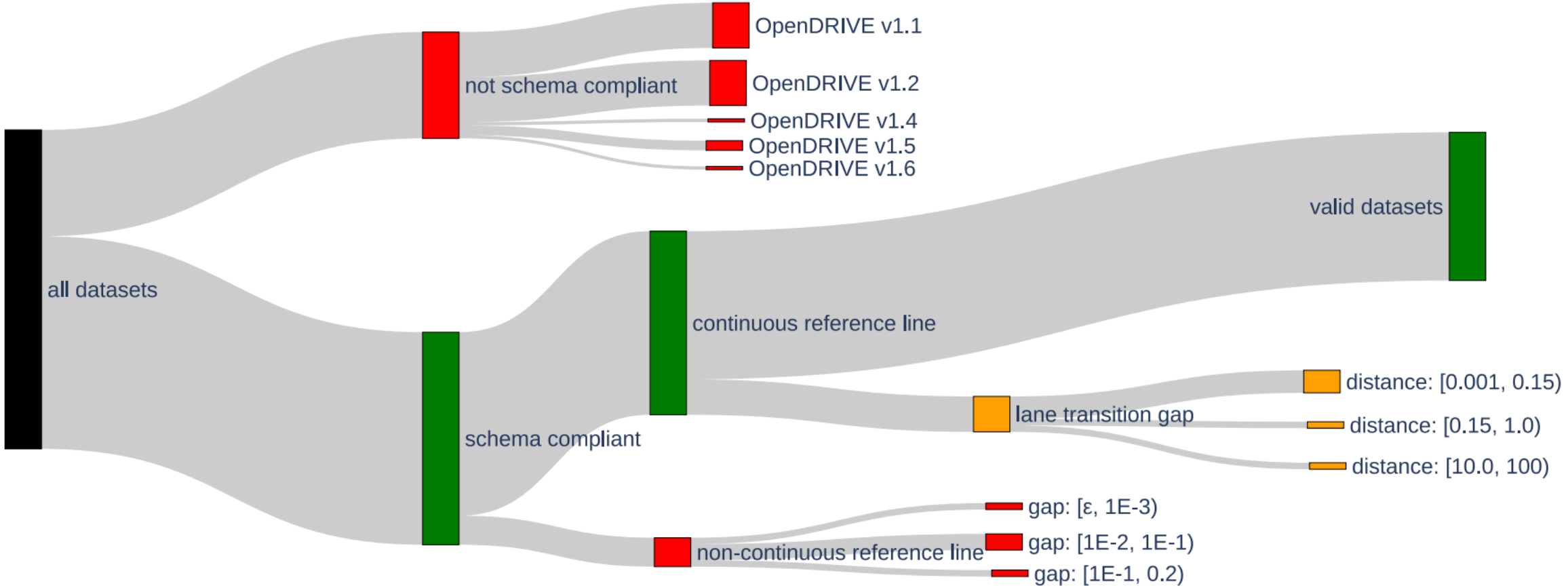
opendrive_lane_roadMark_weight_0 (encoded: UTF-16LE)	STANDARD

Features Selected: 1 of 1

DOI 10.5281/zenodo.7702313

Tools for OpenDRIVE
r:trån (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 24th 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